FALCON 4.0 ®

Realism Patch Group

Realism Patch v5.0
User's Manual

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Important Information

Falcon 4.0 Realism Patch
Version 5.0 FINAL (US and UK)
August 6, 2001

Microprose Falcon 4.0 is a flight simulation game produced by Infogrames, to simulate the Block 50 F-16C in a fictitious Korean War. Falcon 4.0 is a U.S. registered trademark of Infogrames. The last supported patch release by Infogrames is version 1.08, available at the now defunct Microprose website, http://www.falcon4.com. Prior to the dismissal of the Falcon 4 development team in December 1999, an unofficial version of the v1.08 game executable modified by the Microprose developers was tested by a team of public beta testers under iBeta LLC, a Colorado based quality assurance company. This version was released with increased multiplayer stability, and has now become the most widely used executable, known as version 1.08i2. This version may be obtained at the major Falcon 4 sites. The rights to develop the Falcon 4 game was purchased by Force 12 Studios/G2 Interactive in May 2001.

The Falcon 4.0 Realism Patch is a community-based project that endeavors to improve the gameplay of Falcon 4.0 by enhancing its realism. This Realism Patch is "unofficial," and is not maintained by Infogrames. The Falcon 4.0 Realism Patch is supplied “as-is.”

The Falcon 4.0 Realism Patch concept was begun by Executive Producer Eric “Snacko” Marlow with the support of iBeta LLC. The iBeta Realism Patch was released up to version 3.0 by iBeta. Eric and iBeta CEO Glenn “Sleepdoc” Kletzky have decided that iBeta cannot continue to provide corporate resources for further development. iBeta has ceased support of all previous versions of the Realism Patch, and has not been involved in the Realism Patch ever since.

The Realism Patch effort is carried forward by a dedicated team of flight simmers, many of who were the original members of the iBeta Realism Patch team. The Realism Patch Group (RPG) has expanded to include several new members of the F4 community who have been contributing to its development and growth, and has grown to even greater heights than its iBeta days. The members of the Realism Patch Group includes current and ex- service pilots and engineers, who brought with them many years of working experience and knowledge on military aviation. The Realism Patch effort has also expanded in scope, and is no longer a data only patch. Extensive executable changes are now made to make full use of the data changes, as well as improving weapons and AI behavior. The product that you have today is the result of close collaboration between the many members of RPG, scattered all over the world. The Realism Patch has taken more than 15,000 emails and thousands of man hours of testing, research, and development to produce.

When the RPG was the iBeta Realism Patch Team, we received permission from Hasbro Interactive (now Infogrames) to develop externally-driven changes to the Falcon 4.0 product. Permission was obtained from G2 Interactive to release this version of the Realism Patch with executable edits, and subsequent releases of the Realism Patch with only externally driven edits.

This user’s guide is organized into three parts, namely the Quick Start Guide, the User’s Guide, and Designer Notes. We suggest you read through the entire manual thoroughly. Many sections have been updated and re-written, and a lot of new material have been added. Most of your questions will be answered by the material contained within this manual, and you will also find the tips and tricks of making the most out of the Realism Patch.

USER SUPPORT

IMPORTANT NOTICE

The Realism Patch has been developed, and tested to function as design, using only the Falcon 4 version 1.08i2 executable. Falcon 4 is a very complex simulation, and the incorporation of the executable changes made in the Realism Patch into any other versions of the Falcon 4 executable **does not** imply compatibility with the Realism Patch, as the changes may not (and in many cases, do not) produce the same effects. This is true even for data edits. Unless the Realism Patch Group confirms the compatibility of the executable independently, any claims of compliance is without basis and the agreement of the Realism Patch Group, as the executable in concern has either not been tested at all, or has been tested and found not to perform as designed with the Realism Patch. The Realism Patch Group must emphasise that the product will only function as designed when used in its entirety, i.e. with the executable and data changes. The Realism Patch Group cannot and will not provide support for any other versions of the Falcon 4 executable, other than the one supplied as part of the Realism Patch. Should the user choose to install the Realism Patch over any other Falcon 4 executable, they should understand that they are doing so at their own risk, and the Realism Patch Group cannot be held responsible for any damage, data loss, or performance loss that may result. The material covered in this user's manual pertains only to the Falcon 4 executable provided as part of the Realism Patch, and do not reflect the performance of any other versions of the Falcon 4 executable.

On-line and Telephone Support:
On-line and telephone support are not offered.

Internet:
You can read the latest news and information about the Realism Patch on our World Wide Web page at **http://rpg.falcon40.com**. Questions, feedback, and ideas can be posted to official Falcon 4 forum, under the Realism Patch Group area, at **http://www.delphi.com/falcon4/start/**.

How to Get Help:
Please see the notice at the bottom of this page for support information. If you are having problems with the Realism Patch, we can best help you if you provide the following information:

- Your computer's processor and its speed.
- Total RAM installed on your computer.
- Version of DirectX and DirectX drivers.
- Video card brand and model name.
- Sound card brand and model name.
- Joystick brand and model name.
- Any error message or crash log.
- Detailed description of what you were doing when you experienced the problem, and if the problem is reproducible, the steps required to reproduce the problem.
- Any saved TE or campaign files that will cause the problem.
- Any ACMI files or screen shots that will illustrate the problem.

Other Localized Versions: If you have other localized version of Falcon 4.0 (German, Italian, etc) you may attempt to install these files, but you must install 1.08US as part of your upgrade. This may affect Falcon 4.0 adversely – if you choose to install 1.08US and the Realism Patch, you must do this at your own risk. You may attempt to install these files on a French version of Falcon 4.0. Unofficial support for French versions of Falcon 4 may be obtained at **http://www.checksix-fr.com**.

FOREWORD

Falcon 4.0 was first released in December 1998, after spending four years in development. Many bugs were resolved between the initial release of Falcon4 in December 1998 and the final official patch, version 1.08, which was released in December 1999. Falcon 4 finally became a game stable enough for meaningful play. However, the lay off of the entire Falcon 4 development team in December 1999 had effectively stopped any more official enhancement to this revolutionary flight simulation game. The efforts to improve and sustain this remarkable game was and is still being continued by a team of users from all over the world. A plethora of different patches, ranging from airplane skin textures, new cockpits, to a complete package such as the Realism Patch, have been made available after the cessation of official support by Infogrames.

The original concept of Falcon 4 as conceived by the chief designer, Gilman "Chopstick" Louie, was to simulate the experiences of a fighter pilot, by putting the player's head into the war, and not just into the plane. The genius of Falcon 4 is that the game creates a tactical environment that makes the player look inward, and develop real fighter pilot skills, in order to succeed. The ingenious design of the data files and the executable also made Falcon 4 one of the most extensible and customizable game. It is on the basis of the excellent game architecture that the Realism Patch is made possible.

In a flight simulator as complex as Falcon 4, compromises have to be made. As we developed the Realism Patch series, we have stuck faithfully to the original intent of the designers, and spared no efforts in improving the tactical environment in Falcon 4. All the changes are geared towards providing a realistic battlefield to the player, where real life tactics can be put into practice to help the player survive and succeed. While the changes may not be academically correct in the strictest sense (who cares about where a third order fit is better than a fifth order fit anyway?), the changes in the Realism Patch have been made to produce realistic effects and to simulate the intricacies of a modern air campaign.

We have improved the environment to the point where you will need to develop real fighter pilot instincts, and understand the strengths and limitations of your equipment. You will be faced with different scenarios of conflicting needs, similar to those faced by real fighter pilots. For example, you will realize the fear of not being able to positively identify targets; the limitations of electronic counter-measures; the limitations of your weapons; and the need for meticulous mission planning, amongst others.

With the release of version 5 of the Realism Patch, we have finally completed the process of modeling the full effects of electronic warfare on modern air campaign. With an integrated air defense system, stand-off jammers, and other electronic support and counter-measures, Falcon 4 with the Realism Patch is now the most complete simulation of a modern air war ever made available in the PC flight simulation industry. The physics and engineering behind every change in the Realism Patch have been thoroughly and painstakingly researched, and put together as an integrated whole.

We hope that you will enjoy the Realism Patch, as much as we have enjoyed developing and testing it. This user's manual is part of the Realism Patch experience, and complements the Realism Patch. We thank you for your interest in the Realism Patch, and wish you clear skies, calm winds, and a MiG at your twelve o'clock !

The Realism Patch Group

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I

QUICK START GUIDE

This section provides a quick overview of the changes in the latest version of the Realism Patch. You are advised to read through this section first to familiarize yourself with the changes in the Realism Patch, as well as the known issues. Highlights of previous Realism Patch releases are also included. The installation instructions for the Realism Patch may be found in the installation guide, which is a separate document.

EXECUTIVE PRODUCER'S NOTES – REALISM PATCH VERSION 5.0

The Realism Patch Group has not been working really hard since the release of Realism Patch version 4.1. More enhancements have been made, and more weapons are being added to the Realism Patch to reflect the updated ORBAT of the forces in the Korean theatre, as well as support the needs of other theatres. Realism Patch version 5.0 is the most extensive and comprehensive release of the RP series ever, and completes our quest to model the modern air battle in the highest fidelity possible.

Here are some of the highlights of RP5.0:

- *NCTR (Non Cooperative Target Recognition) has been totally revamped. You will no longer see the friendly/hostile bar, but instead, you will see the actual target ID, depending on the target aspect.*
- *The RWR has been fixed. Contacts will now be dropped after 6 seconds if the emitter fails to repaint the target. The audio tone of the emitter will also be played when the emitter actually repaints the target. You will no longer find that the emitter appearing on your RWR if you are outside its radar gimbal limits, although the RWR will wait for 6 seconds before purging an existing symbol.*
- *The RWR symbology library has been expanded and extensively modified. Additional symbols have been added to reflect the capabilities of the most modern RWR systems such as the ALR-56M. The symbol set now allows for both high and low-end RWR systems to be modeled.*
- *Dogfight mode HUD symbology has been de-cluttered. The flight path marker, pitch ladder, altitude, and airspeed scales have been removed to reflect the actual symbologies of the Block 50 HUD in dogfight mode.*
- *RPM symbology has been removed from the HUD. The actual HUD display does not show RPM on the F-16, and pilots rely on the engine RPM gauge for this information.*
- *The default bomb spacing is now 125 feet, and is the most common bomb spacing used by operational F-16 pilots. The ripple spacing is also adjusted for release altitude, just as in the actual fire control computer.*
- *The ballistics of low drag bombs, cluster bombs, and laser guided bombs have been adjusted to reflect the actual ballistics of their real world counterparts.*
- *Laser guided bombs must now be guided all the way until impact. If the LANTIRN targeting pod breaks lock prior to impact for whatever reason, the laser guided bombs will miss. The miss distance is dependent on the range at which the targeting pod breaks lock, and is higher for Paveway II bombs (GBU-10, GBU-12, GBU-28) than Paveway III bombs (GBU-24).*
- *The LANTIRN pod will now inhibit its laser designator from firing above an altitude of 25,000 feet. LGBs released above this altitude will miss even when the targeting pod is locked onto the target. This simulates the actual LANTIRN pod behavior and the limitations of its xenon lamp laser designator.*
- *The radar elevation scan volume has been fixed. In all versions of Falcon 4, the radar elevation scan volume is less than that shown on the radar cursors. This is now fixed. The radar elevation scan volume in RWS and TWS mode have also been corrected to match the actual APG-68 radar.*
- *The radar detection performance is now dependent on the target aspect. This captures the variation in the radar cross section of a target, as well as the differences in the doppler velocities in tail-on and head-on scenarios. Head-on detection ranges are higher than tail-on detection ranges.*

- *Anti-radiation missiles can now be fired at search radars.*
- *Warhead arming time delay has now been implemented for missiles. If you fire a missile inside its minimum range, the warhead will not detonate.*
- *Variable firing rates have been implemented for different guns in the Realism Patch. You will get firing rates ranging from a few hundred rounds per minute on the 23 mm AAA guns, to 6,000 rounds per minute on the M61 Vulcan cannon.*
- *Variable minimum engagement altitudes for SAMs have been implemented. The minimum altitude will no longer be 1,500 feet for all SAMs, but will vary from 50 feet AGL for MANPADS, to over 4,000 feet AGL for the high altitude SA-5.*
- *The flight formations have been adjusted to reflect actual tactical formations used in real life.*
- *The AAA Flak effectiveness is now dependent on the skills of the AAA battalion.*
- *Search radars (such as GCI and EW radar sites) will now show up on the RWR and the HTS. Destruction of these radars will have a detrimental effect on EW radar coverage, and will affect enemy GCI/AWACS capability.*
- *The GCI/AWACS environment has been completed revised in 2D and 3D. If an aircraft is detected by any component of the IADS, enemy fighters will be vectored to intercept if they are within range. Low level tactics can now be used to evade detection.*
- *The radar coverage in the planning map is now dynamic, and shows the current radar coverage. As enemy radars are destroyed, the effect on radar coverage is reflected.*
- *Threat circles can now be shown only for detected units (SAM units, AAA, and ground combat units). The threat circles will show for any unit that is capable of posing a threat to aircraft, such as tank units with ADA support.*
- *Stand-off Jammers have been implemented. As long as a package is protected by the jammer aircraft, it will jam enemy IADS assets (SAM/AAA sites, EW/GCI radars, and AWACS) and delay their detection of the package.*
- *The 2D map display now shows the details of the flights, in a pseudo AWACS mode. Together with the IADS implementation, the 2D map can now be used as an AWACS module.*
- *Destruction of enemy power stations and nuclear plants will now affect the industrial production capacity. This affects the rate of resupply in the campaign.*
- *A new communications command to request the AI wingman for weapons check has been implemented.*
- *The AI now bombs accurately. Bombing accuracy decreases with altitude, and is dependent on the skills of the AI pilots.*
- *When bombing objectives, the AI flight will automatically select the features of importance, and will no longer bomb unimportant features such as taxi signs.*
- *The AI will now release all the air-to-ground ordnance of the same type in a single pass. This reduces the frequency of multiple passes over highly defended targets. The AI will also initiate tighter turns away from the target after attacking them, to avoid entering MANPADS/AAA engagement envelopes. The AI will also dispense one flare and two chaff packets after every attack pass over the target.*
- *The AI will now expend all their air-to-ground ordnance against ground targets when task for BAI, strike, or interdiction missions, or when carrying A/G missiles, before returning home. The AI lead will also not order the wingmen to rejoin when the flight is committed to ground attack.*
- *The AI flight will no longer stay in trail formation after attacking ground targets. They will now assume the wedge formation for egress, and this improves the AI survivability on A/G missions. The AI will also follow the steerpoints and return to base after bombing.*
- *The AI will now obey the “Rejoin” command and abort its attack on ground targets immediately, and the player can reassign another target to the AI.*

- *AI SEAD strikes and SEAD escorts will prioritize radiating targets over non-radiating targets, and will no longer launch a volley of anti-radiation missiles at the same target. They will also engage targets of opportunity, and will query the loadout of each flight member to prevent repeated attacks on the same target.*
- *The ground attack altitudes for various ordnance types have been totally revamped to improve AI survivability, and their targeting effectiveness. This also brings the AI's behavior in conformance with typical doctrines. Low drag bombs are now delivered from 11,000 feet; high drag bombs are delivered from 1,000 feet; Durandals are delivered from 250 feet; air-to-ground missiles are delivered from 4,000 feet; rockets and gun strafe attacks will commence at 7,000 feet; and laser guided bombs are delivered from 13,000 feet.*
- *The AI's accuracy with rocket delivery has now been improved. AI helicopters and aircraft can now hit their targets with rockets, and the kills will be displayed on the debriefing screen after the flight.*
- *Helicopters will now fire rockets, ATGMs, and air-to-air missiles. The helicopters will also descend to the lowest possible altitude during the attack, and are capable of executing ATGM attacks from masked positions behind terrain.*
- *Airplanes will now fire rockets and score reasonably accurate hits against their targets.*
- *Helmet mounted sights have been implemented for the AI. The AI will employ the AA-11 at high off-boresight angles, and is also more capable of employing IR missiles with smaller seeker gimbal limits more intelligently.*
- *The ATO will now only tasked stealth aircraft for night operations. Aircraft that are not night capable may also be tasked for night missions only if their morale is not broken. This allows them to perform night intercepts and bombing.*
- *New airplanes have been added. The PLAAF now has the Chengdu J-7 III, and the formidable multi-role Su-30MKK figher. The DPRK forces now have the J-5, and the Russians are now equipped with the MiG-29C Fulcrum.*
- *Flight models have been adjusted. For aircraft without afterburners, engaging the afterburner will not result in an increase in engine thrust and fuel flow.*
- *New air-to-air missiles have been added. This includes the highly capable AIM-9X Sidewinder that entered low rate initial production in January 2001, as well as the fearsome Rafael Python 4, which is in service with the Israeli Air Force and several other air forces. Both missiles have been added to support other theatres.*
- *New air-to-ground weapons have been added. This includes the AGM-84E SLAM, AGM-130A, AGM-142A Have Nap, AS-17 Krypton hypersonic ARM, AS-18 stand-off missile, Mk-83 bomb, GBU-16 LGB, and the Russian ZAB-500 incendiary bomb.*
- *New SAMs have been added, including the Matra Mistral, SA-4, SA-16, and the formidable SA-10d (S-300PMU1) "Grumble" for the PLA.*
- *Helmet mounted sights are now implemented for the player. When the player flies the MiG-29A/C, Su-27, or the Su-30, the IR missiles can be slaved to the player's line-of-sight in the Padlock view, and a missile aiming reticle will be displayed.*
- *New guns have been added, and the guns are no longer shared. Guns that have been added include the 30 mm Gsh-N-30, 20 mm M39-2, 7.62 mm M134, 30 mm NR-30-3, and more. The characteristics of each gun are now modeled*.
- *New 3D models have been included. This includes the F-4E, F-4G, J-7 III, MiG-31, Su-30MKK, AGM-84E, AGM-142, AS-12, AS-17, AS-18, AIM-9P, AIM-9M, AIM-120, Chun-Ma, SA-9, PL-7, and more.*
- *The list of units for TE, and the ATO generation table is now exported to a text file for editing externally.*
- *The infamous "Nuke" bug has been fixed.*

- *The infamous "Mid-air Maverick explosion" bug has been fixed.*
- *The "aircraft taxiing to destination" bug has been fixed.*
- *The ILS localizer and glidescope deviation bug at various airfields has been fixed.*

KNOWN ISSUES WITH REALISM PATCH 5.0

- If you have created/saved missions in TE under a previous RP or v1.08US file set, they may not function properly under the most recent RP. We have found a workaround – if you must go back to 1.08US after installing the Realism Patch, you must de-install your Falcon 4.0 game completely and reinstall from the CD, re-apply the 1.08US patch, and re-apply the "i2" EXE. Similarly, if you wish to attempt to use a TE created under a previous RP then we recommend you select edit after highlighting the TE, change the mission clock by one minute (doesn't matter if you move it earlier or later), and resave the mission. These attempts to 'save' favorite TEs are not always effective. The scope and quantity of the changes made make it impossible to maintain total compatibility.

- We do not recommend using the –Gx command on your EXE command line. This may increase significantly the number of objects in the F4 world and radically increase CPU loading. You will see very significant decreases in frame rates near high activity areas (FLOT) in a campaign. When the CPU is loaded down so significantly that the frame rate drops below about 10, you will see missiles stop fusing and pass-through targets.

- The MiG-29 will now choose to carry AA-2R's for radar guided missiles in the Dogfight module. Those wishing to practice BVR in dogfight should choose the Su-27 that now carries the AA-12.

- When using Sylvain's patches and the combat autopilot your own aircraft will not fire medium range missiles if your radar is set to RWS (the default). This problem is solved by switching the radar mode to TWS.

- If you load the aircraft asymmetrically, for example with CBU-58 on one side of the wing, and CBU-87 on the opposing side of the wing, or AGM-65B on one side of the wing and AGM-65D on the other, the AI pilot will become confused, as Falcon 4 assumes a loadout that is normally symmetric. This can produce unpredicatable AI behavior, such as flying orbits over the target area without dropping its ordnance. Asymmetric loadouts are rare and hardly used in war.

- If SAM units are placed too close to buildings, this will inhibit the SAMs from firing. Falcon 4 will inhibit the SAMs from firing due to collision detection. This problem affects all SAM types, especially SA-2, SA-3, SA-5, SA-10, and the Patriot. You should move the SAM unit further away from buildings, or the city that it is defending, to prevent such problems from occurring.

- When the S-24 rocket is carried, the graphics will be that of the LAU-3/A rocket pod. All unguided rockets are placed in "containers" such as the LAU-3/A. The actual 3D model of the S-24 rocket will not be visible until the rocket is fired. This is hardcoded in the executable, and cannot be changed. All rocket pods will share the same graphics, i.e. the LAU-3/A model.

- The AI wingman will always follow the flight lead's waypoints. This is not unrealistic as in real life, the flight lead is responsible for the entire flight. If you set the DED waypoint to another waypoint that you are not flying towards, for example, you are landing at an airbase and have your waypoint set to the divert airfield, the AI wingman may land at the divert airfield instead. This is a behavior of the AI since the first release of Falcon 4.

- Due to the way Falcon 4 computes the drag of bombs (i.e physically incorrect by assuming a linear reduction), the ballistics of bombs when released at high and low altitudes may not correspond exactly to the ballistic tables supplied in this manual. Some data scatter is expected.

REALISM PATCH DESIGN PHILOSOPHY

"Hex Editing" started as a grass roots effort with players modifying the files of Falcon 4.0 to get more enjoyment from their gameplay experience. Fortunately, the designers of Falcon 4.0 created a scheme that allowed much of the inner workings of the simulation to be accessed by modifying the text and binary files that came with the game. Now, thanks to the innovative and creative discoveries made by those who explored the depths of Falcon 4.0, we have the ability to bring additional immersion to the Falcon 4.0 world.

In most cases, F4 Hex Editing started out as a way to have some fun with the weapons by making them bigger and more plentiful than Falcon allows. However it has become increasingly difficult to sort through the various modifications and collect the ones that you would like to include. For many players, "realism" is the most important thing. Having a set of files that increased realism while maintaining gameplay expanded the scope of Falcon 4.0 beyond what was initially delivered. This "realism patch" is the outcome of this philosophy.

During our modifications, we discovered many inaccuracies, oversights, and just plain wrong information in the files. Our realism patch attempts to correct many of these issues. We also wanted to increase the realism by adding objects, weapons and capabilities that would exist in the real world.

We had several guiding principles in developing this patch. They are listed as follows:

- The changes should not add any additional instability to Falcon 4.0.
- The changes must reflect "real world values" - real world values must be supported by actual military or civilian documentation.
- The changes will not adversely affect gameplay.

As we dealt more with the data files in Falcon 4.0, we uncovered errors inside the executable, and the limitations posed by the original implementation proved to be a hindrance in the quest for realism. Starting with version 4 of the Realism Patch, we have started to add new data to various records in the hex files. These additions grow functionality beyond the design of the original Falcon 4.0 data files and we have added new patch code to the game executable to take advantage this new data. We have also made numerous changes to the executable to improve the modeling of real world tactics and doctrines. The hex files are now intimately and inextricably tied to the executable modifications that we have made.

The "real world" in Falcon 4.0 terms is a hypothetical battlefield in the present or near future, which involves the US, ROK, DPRK, Chinese, and Russian forces. All modifications to the objects and capabilities of Falcon 4.0 will be made with these force capabilities in mind. Although the F-16 has additional capabilities beyond those that the USAF employs, we tended to keep to strict USAF specifications. The design of the avionics and weapons mechanization is also from the perspective of the USAF F-16, even though it is possible to fly other airplanes in the Falcon 4 world.

One of our most sacred guiding principles is to support our changes with verifiable military and civilian sources. While complete and accurate information is sometimes difficult to come by, we feel strongly that as a matter of principle all changes made in RP must be backed by verifiable real world sources. By doing this, we will avoid getting pulled into lengthy speculative debates over capabilities and performance characteristics of the items we are attempting to modify. The information sources that the RP has used included actual USAF technical manuals for the Viper, as well as correlated material from individuals who have worked on the Viper and other military aircraft. Many of the members of the RPG have served, and some are still serving, as fighter pilots and engineers in the military aerospace sector, and brought along with them a wealth of experience and knowledge on technical and doctrinal issues.

The Realism Patch Group takes a very serious stand not to use any information from military sources that has not been de-classified for public use, including unclassified information that is meant for official use only. The lives and safety of the servicemen and servicewomen in the armed forces depend on such information being protected, and we recognize the sacrifices made by them to protect our freedom and our way of life. While we want to achieve the ultimate realism in simulation, we take a very dim view of people who compromise military information and use them in gaming.

Our vision for Falcon 4 is to create the most tactically and strategically realistic F-16 simulation available. Part of that vision has always included the universal axiom of "Do No Harm." All the while there has been the tacit recognition that realistic numbers do not always produce realistic effects in the game. The process of thinking things and thorough debate has allowed us to produce truly remarkable advances in Falcon 4, including realistic missile kinematics, true-blue BVR detection, fully functional ECM, unique IR signatures for every aircraft, and literally over one hundred others changes.

More important than what these data and executable edits do is what they do *not* do. Each and every one of the data and executable changes produced catastrophic side effects in the game in their early incarnations. This taught us important lessons such as having humility in the face of code that is not fully understood, and the tenacity to look at data and executable edits from all perspectives. This approach extends beyond the sake of methodology alone, but includes detailed measurements, assessments, and everyone asking all the necessary questions such as "How does the AI handle this edit (i.e.; ECM, gimbal limits, Visual canopy restrictions, etc), "how does the campaign ATO deal with the change we have made?" and "what are the side effects other than the intended effect of the edit we have created." The principle of making sure that the edits not only work *but also work properly and without untoward effect*, has made the RP Series what it is today. The *Law of Unintended Consequences* was learned by all successful members of the RPG.

The level of testing, combined with the research required to get it there, and the axiom of not changing anything that will tilt the gameplay and balance adversely, has often increased the developmental time of each successive Realism Patch release. We deem this approach necessary for quality assurance, and it is this approach that has ensured the playability and accuracy of the Realism Patch.

REALISM PATCH VERSION 5 TEAM COMPOSITION

These are individuals who have contributed their free time and energy towards the development of the Realism Patch, for no other reward than to be able to play the end results and share it with others. The members of the team are from all over the world, spread across four continents. The list is organized according to tasks, and some names will appear more than once.

Air Combat Tactics
John “NavlAV8r” Simon
Paul Stewart
“Hoola”

Air to Ground Combat Tactics
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Jeffrey “Rhino” Babineau
Leonardo “Apollo11” Rogic

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Alex Easton
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John “NavlAV8r” Simon
“Hoola”

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Bubble Effects
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Kurt “Froglips” Giesselman

1.08i2 Executable Modifications
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Miran “Warlord” Klemenc
Sylvain Gagnon

Communications
Marco Formato
Thomas McCauley
Manfred “Schumi” Nelles

Ground Units
Jeffrey “Rhino” Babineau

Integrated Air Defense System
Leonardo “Apollo11” Rogic
John “NavlAV8r” Simon
Paul Stewart
“Hoola”

Missile Models and Electronic Warfare
Barry “Baz” Puttee
John “NavlAV8r” Simon
Paul Stewart
“Hoola”

3D Models
Christian “Ripper” Thomsen
Miran “Warlord” Klemenc
Shawn Agne

Hex Meisters
Jeffrey “Rhino” Babineau
Leonardo “Apollo11” Rogic

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Rob “Scoob” Muscoby
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James “The Silkman” Gary
Jerry “Pookie” Davis
Martin Friedrich
Martin “Mav” Vinther
Michael “Huntsman” Paddon
Manfred “Schumi” Nelles
Michael “Fangs” Spanos
Nick “Paradox” Parker

CREDITS

The EXE-meisters get a medal this round for their modifications to the Falcon 4.0 EXE. The addition of many new EXE modifications have definitively opened up F4 like is has never been opened before. Sylvain Gagnon, Marco Formato, and Miran Klemenc have been instrumental in helping us make the most out of the many of the data enhancements that form the RP. In particular, Sylvain's tireless efforts have been instrumental in making the RP perform as what it is today. The monumental efforts that the EXE-meisters put in to squash bugs and CTDs in the last hours preceding the release of Realism Patch 5 simply exceeds descriptions. We all owe them a tremendous amount of gratitude.

Thanks must to MadMax, Bengs, Duck Holiday, Paradox, Nemesis, Shawn Agne, Metal, RAD, and others not mentioned specifically here for their contributions to the F4 hex editing community. Their pioneering efforts have started the long and ardous hex editing process and brought the Falcon 4 community to where we are today.

Many thanks need to be offered to the entire Falcon 4.0 iBeta Public Sector team for their long hours and attention to detail. These have made Falcon 4.0 version 1.08US and 1.08i2 a possibility, and a stable base upon which the Realism Patch is built.

Many thanks also to Paul Stewart, who was the prime mover behind the efforts to improve the AI. His keen observations and understanding has made the AI what it is today, and he has ensured that all the changes in the Realism Patch do not cripple the AI. His tireless efforts in testing and designing the RP has cost him a painful back injury, and we wish him a speedy recovery.

Many thanks to Mark Doran and Dave "Killer" Morrison, who took time off to proof read the Realism Patch user's manual.

This patch would not be possible if it were not for the efforts of Leonardo Rogic and Jeff Babineau. They bore the brunt of labor on this version, as much work had to be done just to correct the underlying Falcon 4.0 data files to get them in shape for subsequent changes.

HIGHLIGHTS OF PREVIOUS REALISM PATCH RELEASES

RPG REALISM PATCH VERSION 4.1

Release Date: January 10, 2001

With the release of RP4.0, we discovered several issues that required a responsive set of fixes. RP4.1 addresses the problems with the AI not firing HARMs, and a vexxing "campaign consolidation bug" that existed since RP1.0. There were also small changes made to the missile models, and corrections made to the loadout of different airplanes.

- *The problem of AI not firing AGM-88 and the missing DLZ scale in the player's HUD when using AGM-88 is fixed. This is part of the RP4 Hot Fox #1.*
- *Amended squadron stores for B-1, B-52, Tu-16, Tu-95, and Il-28.*
- *"Campaign consolidation bug" fixed. Allied ground forces no longer enter into a "consolidation" loop.*
- *The movement type of several units (Naval Infantry, Chinese infantry, Spec Ops, Chinese Air Defense, and HQ units).*
- *Fixed the tail gun on the Tu-16, and removed the nose gun on the F-4G. In addition, a tail gun was added for the Tu-16.*
- *Fixed the loadout and hardpoints of the B-52, F-111, B-1B. F-4D, F-5E, F-117, F-15C, Mi-24, MiG-23, MiG-29, Su-27and Su-25.*
- *Graphical changes to the 300 gallon tank for F-14, F/A-18, F-5E, AV-8 and A-6E.*
- *Corrected the weight and blast area of Russian laser guided bombs.*
- *Made some changes to the composition of some units.*
- *Corrected the Patriot missile model. The Patriot will not not give a RWR launch warning when launched. This correction was based on information obtained from Patriot operators.*
- *Corrected the SA-5 missile and radar model. The SA-5 is now less maneuverable and less likely to do loops.*
- *Corrected the AAA gun effectiveness of the K-200AD and several other AAA guns.*
- *Minor changes to the Hellfire missile model to better reflect the missile characteristics.*
- *Corrected the AIM-54 onboard missile radar and missile model.*

RPG REALISM PATCH VERSION 4.0

Release Date: November 22, 2000

This is the most comprehensive release of the Realism Patch since version 1.0. This is also the first release of the Realism Patch under the Realism Patch Group, following the withdrawal of corporate support from iBeta LLC. Major changes have been made to the AI, and much effort have been dedicated to creating an electronic warfare environment as close to reality as possible. The Realism Patch README was also re-organized into a user's manual, and greatly expanded in its scope of coverage.

- *The AI has been revamped, with different behavior for different skill levels. The changes include distinctions in BVR and WVR tactics, different weapon selection criteria, different gunfight tactics, AI missile evasion tactics, and different sensors for different AI planes, and improved AI ground attack tactics.*

- *All radars have been adjusted to create the new electronic battlefield. Changes also include creation of different types of RWR for different airplanes, and different visual envelope.*
- *ECM now works with Sylvain Gagnon's EXE hex patch. There are also coverage zones and dead zones now. Internal jammers are implemented for some aircraft where appropriate.*
- *Rate of fire adjusted for all ground units.*
- *All the visual, radar, and RWR sensors on all aircraft have been separated out to facilitate individualization of sensors for each aircraft.*
- *New flight models included.*
- *New hit bubble changes that reflect accurate hit areas.*
- *SAMs fire properly at airbases and do not shoot into the ground. AAA and SAMs are no longer invulnerable when placed at airfields.*
- *The vehicle graphics have been fixed for the AA-11 and a new 3D model is included for AA-12.*
- *Many 3rd party EXE patches have been tested and included, such as the external fuel patch, AI patches, and ECM patch.*
- *The modeling of active radar guided missiles such as AIM-120, AA-12 and AIM-54 has been revised. The launch of these missiles no longer triggers the RWR launch warning.*
- *AAA and flak effectiveness has been revised and depends on slant range and airspeed.*
- *Revised radar cross sections for airplanes, and all airplanes have unique visual and IR signature.*
- *A new AI wingman/element command, known as "Attack Target," has been added.*
- *Two new air-to-air missiles, the PL-7 and the PL-8, have been created, and may be carried by the PRC J-7/MiG-21.*
- *Loadouts have been corrected on more aircraft, such as F-15, F-14, and F-5, MiG-21, MiG-23, MiG-29, Su-27, F-18, and F-4. The B-1 loadout changes from F4Alliance is now included.*
- *New flight models for the A-10, B-52, B-1B, C-130, F-14B, F-15C, F-15E, F-16C, F-18C, F-18D, F-4E, F-4G, F-117, MiG-29, and Il-28 are now included.*

iBeta Realism Patch Version 3.0

Release Date: July 20, 2000

- *The AAA has been readjusted. The blast radius values are still based on realistic numbers, and include references to warhead size, warhead type (flak vs. contact), cyclic rate of fire, and guidance. The new values diminish the power of the large-caliber flak guns, while still keeping the deadly nature of the smaller caliber tracer-type guns. Although the new blast values should make it easier to penetrate enemy airspace, there is still no substitute for good planning and combat tactics. Read the section of "AAA Briefing" in this document for additional intel on how to defeat the AAA threat.*
- *The ground and air-based radars have been improved to allow for more realistic detection performance.*
- *The "roles" of various aircraft have been adjusted to allow the aircraft to be tasked with more correct mission types. No longer will the A-10 be tasked to fly OCA missions against airbases!*
- *The sizes of the ground and air units have been adjusted to account for the difference in OPFOR vs. US/ROK size/strength.*
- *Separated out all of the flight model data for the aircraft – this was done to facilitate future modifications for each individual aircraft.*

- *Developed a new keyboard command file (ibeta_keystrokes.key) that contains the ability to assign keystrokes to the AUX COMMs commands and to the new CAT I/III switch.*
- *Improved the A-10's hardpoints, maximum takeoff weight, and fuel loads. A-10 flight model improvements forthcoming in a future RP version.*
- *Improved "abort/cowardice" behavior in AI in the statistical (2D) war (user selectable – not selected by default)*
- *Fixed the vehicle graphics for the 2S19 and SA-9.*
- *Tested and included many 3rd party EXE hex patches such as the GLOC patch, "Fly and Plane," BARCAP, interactive airbase relocation, CAT I/III switching, and recon window fix.*
- *Many other "minor" fixes that will improve the overall gameplay and enjoyment.*

iBETA REALISM PATCH VERSION 2.1

Release Date: May 29, 2000

With the release of RP2, we discovered several issues that required a responsive set of fixes. RP2.1 addresses the problems with the D-30 "super gun" and the inability of the Patriots to fire. We also added the capacity for helicopters to attack ground targets using air-to-ground missiles (ATGMs). RP2.1 (like RP2a) also fixes the problem of copying a duplicate set of files to the Windows/System directory.

- We discovered several issues that required a responsive set of fixes after the release of RP2. RP2.1 addresses the problems with the D-30 "super gun" and the inability of the Patriots to fire. We also added the capacity for helicopters to attack ground targets using air-to-ground missiles (ATGMs). RP2.1 (like RP2a) also fixes the problem of copying a duplicate set of files to the Windows/System directory.
- We adjusted the balance of AAA along the FLOT and in mobile AAA battalions. These changes were implemented after we managed to speak to a former USAF targeter with PACAF and Osan AFB. You will now find smaller caliber (57mm and below) around the DMZ because of the mobility required in the forward-deployed units, but you will see the larger caliber AAA (85mm and 100mm) encircling Pyongyang and other fixed strategic targets. These changes were based on a conversation with a former USAF targeter with PACAF at Osan.
- Both the AAA battalion (which contain the KS-12, S-60, M-1939, and KS-19) and the Towed AAA battalion (which contain the S-60, M-1939, ZPU-2) are available for placement in TE missions. The HART battalion, which is not available for placement in TE, now contains only the S-60 and the SA-7 as air defense protection.
- Radar guidance for some of the AAA guns is turned on. The FireCan radar controls the KS-19, KS-12, and S-60. While our tests have not shown that adding radar to the AAA increases their accuracy, you will see them on your RWR with the "A" symbol. You can target and destroy these guns with HARMs.
- The addition of large amounts of AAA is no doubt a surprise to many F4 pilots who have become complacent with the lack of a Triple-A threat. North Korea has over 5000 pieces of flak-type AAA, and although much of it is older technology, many of these pieces have fire control radar attached and are a credible threat. The large numbers of AAA guns can be a danger, you should be able to avoid much of it by proper mission planning. Make sure to fly around, over, or under known AAA sites (HART sites around the DMZ, cities, airbases, etc.). Be especially careful around large cities and other strategic targets, as this is where much of the large caliber AAA resides. You may have to run several anti-AAA sorties before attacking the targets they are protecting. A rapid change in altitude once AAA is encountered also seems to defeat their ability to track and hit you.

iBeta Realism Patch Version 2.0

Release Date: May 17, 2000

The recent illegal release of the Falcon 4.0 source code was cause for concern at iBeta. We were not sure how Hasbro Interactive would view hex editing and the Realism Patch project in light of the source code release. We have had the opportunity to clarify these issues with Hasbro Interactive, and they send not only their approval to continue the iBeta Realism Patch Project, but they fully support users developing their own hex edits that result in an increased enjoyment for their product. Given our confirmation and clarification concerning this hex-editing project, we offer these modifications to the Falcon 4.0 community with "Infogrames's blessing."

Please be aware that with the bubble changes and other EXE modifications, there is likelihood that the in-game frames-per-second (FPS) rate will be affected*. If you choose to adopt the iBeta F4 RP2 EXE, you will have the ability to NOT install the "airbase relocation fix" (a big frame rate hog), and adjust the in-game bubble, but everyone must understand that the more we turn on, the more it affects the CPU and frames per second.*

If you are using the Bubble Slider EXE fix, the recommended in-game bubble slider setting is "3." We have adjusted all bubble values to reflect the best balance of AI and FPS when "3" is used.

- *All A2A missile kinematics have been adjusted based on realistic performance characteristics - A2A engagement envelopes have been updated for realistic behavior*
- *Most SAM missile kinematics have been adjusted based on realistic performance characteristics - SAM engagement envelopes have been updated for realistic behavior*
- *Most SAMs and A2A missiles now launch at their maximum effective range; radar "pings" to the RWR also occur at ranges commensurate with their radar distances*
- *The SA-5 was given a terminal homing active radar seeker head (a la AIM-120 and AA-12). Watch for the "M" to appear in the RWR*
- *New weapons for the ROK: KSAM (Chun-ma missile) and KFIV-AD (Tracked Vulcan) are now included*
- *HN-5a MANPAD is now given in quantity to the "elite" forces of the DPRK. Russian forces now have access to the SA-14, as do some NK forces*
- *Weapon blast and damage values have been improve to allow for a more realistic missile/bomb results*
- *Ground unit order of battle (OOB) has been improved to simulate realistic grouping of weapons and equipment*
- *You can now fly any plane in TE*
- *The USAF F-16C now has realistic loadout and carry limits; some weapons were removed while some were added (don't worry – we've compromised for those who wish to still use the Mk-77 and LGBs even though these are not realistic on the block 50/52)*
- *The CBU-97 Sensor Fused Weapon has been added - this is THE tank buster cluster munitions to carry.*
- *We added the KS-19 100mm AAA gun to the HART battalion in Campaign (watch out when flying over the DMZ!). AAA bursts up to 40,000 ft! Also added the KS-12 85mm AAA (bursts may reach up to 26,000 ft), the S-60 (57mm AAA – bursts up to 16,000 ft), and the M-1939 (37mm AAA – bursts up to 8500ft) to AAA battalions that are available in TE. Created an e M-1992 tracked 37mm AAA gun for the DPRK as well as a ZPU-2 14.5mm AAA gun.*

- *Flight model limiters have been installed into AI aircraft to give them more realistic performance limits (the flight models of the AI aircraft are not individualized, but rather prevent them from behaving unrealistically).*
- *Nike Hercules, Patriot, and Hawk have now all been enabled with the correct RWR symbologies.*
- *Ground-based search radars and AWACS are now enabled and emitting*
- *Unit deaggregation distance improvements in line with the new bubble discoveries; this improves aircraft/SAM AI among other things*
- *We removed the AIM-120s from the F-14A as this is no longer a legal loadout*
- *F/A-18A has been renamed to F/A-18C*
- *An actual AIM-9m Sidewinder "growl" sound has been added – really cool!*
- *The C-130 and other prop planes now have a prop sound when viewed externally*
- *Renamed SAM launchers and SAM missiles so it will be easy to distinguish what is what in ACMI and when using labels*
- *Corrected all the Bradley variants: M2A2, M3A3, and M2A2 BCV (Bradley Command Vehicle): Now they have the proper loadouts. Created the M2A2 BSFV (Bradley Stinger Fighting Vehicle and M6 BL (Bradley Linebacker): both are mobile Stinger platforms.*
- *Created the BTR-60: a common DPRK troop transport*
- *Runways now have a repair time that is more realistic – 6-10 hours for an entire runway*

iBETA REALISM PATCH VERSION 1.0

Release Date: February 18, 2000

- *F4Gs now carry AGM-45 Shrikes and AGM-88 HARMs.*
- *Ground battles are more realistic – ground units have accurate weapons/loadouts, and are organized according to battle doctrine.*
- *Bomb blasts, penetration, armor, and damage values are now more accurate across the board.*
- *Patriot and Nike SAMs are now "awake."*
- *Formations now work properly.*
- *AWACS "Vector to" message now works.*
- *Mig-19 now has radar and AA-1s.*
- *BLU-27 (napalm) is now designated as Mk-77, which is the USAF designation.*
- *SA-7s are more realistic – they are now impact fused and not proximity fused.*
- *AA-10 series of missiles behave more realistically due to correct seeker heads.*

iBeta Team – Falcon 4.0 Realism Patch (Up to Realism Patch version 3.0)

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Executive Producer: Eric "Snacko" Marlow

Associate Producer: Leonardo "Apollo11" Rogic

AI Coordinator: Paul Stewart
Aircraft Loadout Coordinator: Lloyd “Hunter” Case and Robert "Trakdah" Borjesson
Blast and Damage Coordinators: Jeff "Rhino" Babineau and Eric “Snacko” Marlow
Bubble Mafia Coordinator: Kurt “Froglips” Giesselman
Campaign/AI Coordinator: Gary “Ranger” Perry
Command/Menus/UI Coordinator: Kurt “Froglips” Giesselman and Thomas McCauley
F-16 Flight Model Coordinator: Tomas “RIK” Eisloe and "Hoola"
Formation Coordinator: Rodrigo "Motor" Lourenco
Ground Unit Coordinator: Jeff "Rhino" Babineau and Eric “Snacko” Marlow
Missile Coordinator: "Hoola,” Paul Stewart, and John Simon
Radar/ECM Coordinator: Eric “Snacko” Marlow and Tomas “RIK” Eisloe

Hex Meisters: Leonardo "Apollo11" Rogic and Jeff "Rhino" Babineau

Documentation: Eric "Snacko" Marlow, Leonardo "Apollo11" Rogic, and Jeff "Rhino" Babineau

HISTORY OF REVISIONS AND README FILES

FileChanges.TXT – contains a list of the files that have changes as part of the F4 Realism Patch as well as the patch installation and de-installation procedures.

F4_RealismPatch_v50_User_Manual.PDF – This document

F4_RealismPatch_v50_Installation_Guide.PDF – Installation instructions for the Realism Patch.

F4_RP_Sensor_Properties.XLS – Excel spreadsheet containing sensor properties (radar, visual, RWR, IR) and vehicle signatures (IR, visual and radar cross section)

FILE DEFINITIONS

FALCON4 ACD	- AI Control (?) Data
FALCON4 CT	- Falcon 4 Class Table
FALCON4 FCD	- Feature Control (?) Data
FALCON4 FED	- Feature Entity (?) Data
FALCON4 INI	- as is
FALCON4 ICD	- IR Sensor Control Data
FALCON4 OCD	- Objective Control (?) Data
FALCON4 PD	- Point Data
FALCON4 PHD	- Point Header Data (?)
FALCON4 RCD	- Radar Control Data
FALCON4 RWD	- Radar Warning Data
FALCON4 SSD	- Squadron Stores Data
FALCON4 SWD	- Sim Weapon Data
FALCON4 UCD	- Unit Control Data
FALCON4 VCD	- Vehicle Control Data
FALCON4 VSD	- Visual Sensor Data
FALCON4 WCD	- Weapon Control Data
FALCON4 WLD	- Weapon List Data
KOREAOBJ HDR	- Object LOD and Texture Header database (?)
KOREAOBJ LOD	- Object's Level Of Detail database (?)
KOREAOBJ TEX	- Object's Textures
simdata.zip	- zip file of data for flight models, weapon sensors, etc.

3RD PARTY REALISM ADD-ONS

The RP Group has tested a series of additional Falcon 4.0 add-ons that we feel contribute to the added immersion of the Realism Patch. Listed below are additional patches that we recommend:

Paul Wilson's 1024x768 F-16C Block 50/52 cockpit –
http://msnhomepages.talkcity.com:6010/msngamingzone/crazyammo/

Skypat's and Ben Hur's F-16C Block 50/52 cockpit –
http://spower.free.fr/falcon4/addons/cockpits/ckptBS/cockpitBS.htm

Xis's F-16C Block 50/52 cockpit –
http://www.ozemail.au.com/~xis

Byoung-Hoon Moon's Korea Skyfix – can be found at the iBeta website, or in the F4Patch distribution.

If you have a 3rd party add-on for F4 and you would like the RP team to test it for possibly inclusion in our "recommended" list, please let us know.

References and Sources

There have been requests that we update the F4 Tactical Reference to go along with everything we are changing as part of this project. It may be possible to edit the entries in the Tactical Reference guide. This project is being pursued.

For those of you interested in knowing more about many of changes we are including, you should visit www.fas.org (Federation of American Scientists). This website, while having some inaccuracies, is for the most part the most convenient single-source of military information available to the general public.

The following list contains the references used during the development of the Realism Patch. This list is however not exhaustive.

1. Aerospace Encyclopedia of World Air Forces – David Willis
2. AFP 51-45: Electronic Combat Principles, September 1987, available at http://www.wpafb.af.mil/cdpc/pubs/AF/Pamplets/p0051050.pdf
3. Air Forces of the World - Christopher Chant
4. Air Forces Monthly (various issues)
5. Aviation Week and Space Technology (various issues)
6. Avionics: The Story and Technology Of Aviation Electronics, Bill Gunston, published by Patrick Stephens Limited, 1990.
7. Encyclopedia of World Military Aircraft – David Donald and Jon Lake
8. Federation of American Scientists – http://www.fas.org
9. Flight International (various issues)
10. FM 100-2-3 The Soviet Army, Troops, Organization and Equipment. US Army CGSC 101-1
11. FM101-10-1/1 Staff Officers Field Manual Organizational, Technical and Logistical Data
12. Introduction to Airborne Radar, 2nd Edition – George W. Stimson
13. Jane's – Aero-Engines
14. Jane's – Air Launched Weapons
15. Jane’s – Avionics
16. Jane's – All the World’s Aircraft
17. Jane’s – Aircraft Upgrades
18. Jane's – Armor and Artillery
19. Jane's – Land Based Air Defense
20. Jane’s – Radar and Electronic Warfare
21. Jane’s – Defense Weekly (various issues)
22. Jane’s – Missiles and Rockets (various issues)
23. Jane’s – Defense Review (various issues)
24. Jane’s – Intelligence Review (various issues)
25. Journal of Electronic Defense, http://www.jedonline.com (various issues)
26. MCIA-2630- NK-016-97 North Korea Country Handbook
27. OKB- MIG- Jay Miller, Piotr Butowski
28. OKB- Sukhoi- Jay Miller with Vladmir Yakonov, Vladmir Antonov, 6 others
29. Organizational and Tactical Reference data for the Army in the field- US- Army
30. ST 100-3 Battle Book
31. ST 100-7 OPFOR Battle Book
32. USN Electronic Warfare and Radar Engineering Handbook, http://ewhdbks.mugu.navy.mil
33. Weapons and Tactics of Soviet Army third edition- David C. Isby
34. World Air Power Journal (various issues)

PART II

USER'S GUIDE

This section contains information to guide you through the changes in the Realism Patch, as well as how to best utilize it for your maximum enjoyment. You will find information that will help you to cope with and understand the tactical changes in the F4 world.

This section is organized according to topical chapters. Each chapter is preceded by a brief introduction and overview, followed by sections elaborating on specific subjects, written by Realism Patch Group members who are experts in the particular subject. You are recommended to read the Designer's Notes if you require more information on the technical details concerning the relevant topics and subjects. The Realism Patch user's manual is designed to complement the Falcon 4 user's manual.

CHAPTER 1: FALCON 4 GAME MECHANICS

INTRODUCTION

Have you ever wondered why your wingman scored no kills even though they dropped all their ordnance apparently on target? Have you also wondered why you were still assigned with SEAD missions in campaign even though you have indicated in the campaign sliders that you want to be tasked with only BAI missions? Fret not, for the sections in this chapter will explain how you can influence the outcome of your wingman's bombing, and how you can influence your mission assignments. Understanding the mechanics of the game will allow you to influence the outcome of not just your own flight, but also the campaign.

Before we begin, lets make sure that your computer system is optimized for Falcon 4. Falcon 4 is a very CPU intensive game, and will scale very well with your CPU's horsepower. This is one of the very few games that will really stretch your computer system, how ever powerful it might be. We will discuss some of the methods to wring every bit of performance out of your PC, as well as some of the tricks of making multiplayer work.

To begin, we will need to explain the concept of bubbles. F4 is a flight simulation and battle simulation all rolled into one. To keep the CPU loading at a manageable level, combat is divided into two forms, i.e. 3D and 2D combat. The concept of bubbles is an important factor in determining the outcome of 2D and 3D combat. The section titled "*The Incomplete And Unapproved Quick Guide To Bubbles*" will provide you with a basic understanding of how bubbles work in F4. While you may find the descriptions and terminology somewhat technical, do make an effort to understand the concept, as the terminology will be used consistently throughout the User's Manual and the Designer's Notes.

With the Realism Patch, you have the ability to change the bubble slider setting in the game option. Before you starting tweaking these, you should first understand how these changes will affect gameplay, particularly the AI bombing results. With a basic understanding on the concept of bubbles, the section titled "*Bombing In The Bubble*" will explain how best to overcome the limitations posed by the bubbles on gameplay, and how you can help the AI achieve better air-to-ground kills.

Once you have busted the myth of bubbles, it is time to progress to influencing your mission assignments. The section titled "*Beyond Winning Battles: Winning The War*" will explain in detail how the campaign priority sliders interact with one another, and how you can manipulate them to achieve the mixture of missions assigned to your squadron. You will also learn about the dramatic effects of using time acceleration in the game, the effect of changing the force ratios, and the effect of changing the object densities. So read on, and discover the secrets of F4 !

MILKING THE HARDWARE

Optimizing Your System For Falcon 4
By "Hoola"

When Falcon 4 was first released in 1998, it represented the state-of-the-art for combat flight simulation. Besides simulating the F-16, Falcon 4 has an internal simulation engine built to simulate an entire war in a campaign. Such a daunting task requires a lot of computing power.

Even with processors that runs at Gigahertz speeds these days, Falcon 4 can still place considerable amount of stress on the personal computer. The beauty of the game's design lies in its ability to scale with the computing power. With the bubble slider, the action can be cranked up tremendously, to a point where a top-of-the-line personal computer with a Gigahertz processor can be brought to its knees.

This section will discuss some of the ways of optimizing your computer system for Falcon 4. Since most of us do not have an unlimited budget, optimizing our computer system will go a long way to ensure that our hardware do not become obsolete too quickly. The techniques described in this section are by no means guaranteed. You will need to experiment and test for yourselves the optimal settings for your own computer.

PROCESSOR AND GRAPHICS

If you have not noticed by now, Falcon 4 is extremely CPU-hungry. With the graphics sliders cranked up to their maximum, the game will exert an extremely high toll on the CPU. Obviously, the faster your processor, the more smoothly the game will run. If you decide to overclock your CPU and squeeze every bit of performance out of it, do keep in mind the need for cooling, as the CPU will run very hot. You should also disable any software CPU cooler, such as WinCooler[1], as these utilities halt the processor regularly, and this may have an impact on the CPU performance.

The graphics slider settings play a very important role in the game FPS. I will explain what these sliders control, and how they will affect the FPS.

Terrain Texture: This slider controls the terrain texture. The higher the setting, the greater the distance that the terrain texture is drawn. This has an impact on the memory requirement, as loading in the textures will lead to more disk swapping if your physical RAM is insufficient. This slider does not affect the gameplay, other than providing better "eye candy." If you are experiencing FPS problems, try setting this slider at a lower setting.

Terrain Texture: This slider controls the details of the terrain texture. The higher the setting, the greater the detail that the terrain texture is drawn. This has an impact on the memory requirement, as loading in the textures will lead to more disk swapping if your physical RAM is insufficient. This slider does not affect the gameplay, other than providing better "eye candy." If you are experiencing FPS problems, try setting this slider at a lower setting.

Object Detail: This slider controls the details of the objects. The higher the setting, the greater the detail that the object is drawn. As with the first two sliders, this has an impact on the memory requirement. While this slider does not affect the gameplay, the greater the object detail, the easier it will be for you to identify ground and air targets. Lowering this setting may make it slightly more difficult for you to spot ground targets from higher altitudes. If you are experiencing FPS problems, try setting this slider at a lower setting. You need to bear in mind that if you set this slider to 5 or less, the weapons that you are carrying will not be shown in the 2D cockpit view.

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[1] This software utility can be downloaded at http://www.wincooler.com

Object Density: This slider controls the number of ground objects. Although the Falcon 4 manual seems to indicate that this slider controls only the number of ground objects in a city area, this slider does more than that. The position of the slider will determine how many ground vehicles are shown in the 3D world. The composition of the ground units in the Realism Patch have been extensively researched, and correspond to their real world counterparts. Setting this slider to any position less than 6 will result in erroneous composition of ground units, and may even result in some of the ground units being deprived of their AAA vehicles. For full realism, you are advised to set this slider to 6. Do bear in mind that this slider has a big impact on game FPS. If you are facing a FPS problem, you will need to weigh the trade-off yourself, between realistic ground unit composition, and higher FPS.

Player Bubble: This slider controls the size of the bubble. For a detailed explanation of the bubble concept in Falcon 4, please refer to the next section, titled "*The Incomplete And Unapproved Quick Guide To Bubbles*." The default setting should be 3. This is the setting at which the Realism Patch is tuned to. If you increase the setting, you will improve the A/G performance of the AI jets, but reducing the 3D to 2D combat. Do bear in mind that a bubble setting of more than 3 will seriously affect FPS, but setting this to less than 3 will compromise the realism.

Vehicle Magnification: This slider controls the size of the vehicles. This has no impact on FPS.

Special Effects: This slider controls the duration and details of special effects (such as smoke and explosions). There is an impact on FPS, and the higher the slider setting, the greater the impact. This slider does nothing other than to improve the "eye candy," and if you are experiencing FPS problems, try setting it to a lower value.

Other than tweaking the graphics sliders, you can try overclocking your processor (or upgrading it). Falcon 4 will scale very nicely with faster processors. In some of the benchmarking tests that I have conducted, an increase of 20% in CPU clock speed resulted in an increase of at least 14% in FPS.

Falcon 4 is more limited by the CPU's horsepower, than the graphics card, due to all the processing that is required. If some of the benchmarking tests that I have conducted, the gain from using a Voodoo 5 card compared to using a pair of Voodoo 2 cards in SLI mode is marginal, and constitute to only less than 10% in the FPS difference. However, using a higher processor will bring about a greater difference. Since Falcon 4 is optimized for Glide, running the game in Glide mode will definitely bring about better FPS and stability, compared to running it in DirectX mode.

PHYSICAL AND VIRTUAL MEMORY

Falcon 4 is an extremely memory hungry game. This is expected, since the game is controlling every single AI entity, and running an entire war in the background. You should not expect to run Falcon 4 with an acceptable FPS on a 64 MB RAM machine. The minimum hardware specifications defined by Microprose is woefully inadequate, and it is for this reason that the Realism Patch Group has re-defined the recommended hardware specifications.

You should really run Falcon 4 on a machine with at least 128 MB of RAM. The performance of the game increases with the amount of physical RAM. With RAM prices tumbling down, this is the most effective way of improving game performance. You should increase the physical RAM first and check your FPS, before considering a CPU upgrade. You will be pleasantly surprised with the effect of running Falcon 4 on a machine with 265 MB RAM or more.

The Windows 95/98/ME environment do not handle memory very well. Windows can often gobble up 60% (in few cases even 80%) of your installed memory for the cache. If you still have free RAM, this should not be the case. If not, Windows will very probably increase the usage of virtual memory (swap file on your hard drive) instead of decreasing the disk cache by a significant amount. Using virtual memory is an extremely slow process, compared to RAM access.

In addition, Windows 9x/ME may not be able to work correctly on a system with more than 512MB of memory. The cause is a too large cache that consumes all of the addresses in the system arena, leaving no virtual memory addresses available for other functions such as creating a new virtual machine. You should tweak the disk and file cache settings, as well as the virtual memory settings, with utilities that you can obtain from most shareware sites. One such utility is Cacheman[2], a virtual memory and disk cache tuning utility. You should experiment with the settings to optimize for your specific hardware configuration. You should also consider turning on the option "Conservative Swap File Usage," to minimize the disk swapping.

You should also free up memory by closing every single task that is not essential. This includes hidden tasks that may not be displayed in the Task List. Lastly, you should try deactivating any power saving features, such as spooling down the hard drive. This may help with the performance by eliminating disk spin-up time.

One last thing concerning optimizing the memory. Every time you switch view, you will incur a small impact on the memory, as the game will load the additional textures required to display the objects. Repeated switching of views will rapidly exhaust the free memory, and increase the disk swapping activity. This is especially important for low memory systems.

DISK I/O OPTIMIZATION

If you are using a SCSI disk system, try putting the Windows Swap File on a separate physical disk (instead of placing on the disk that Windows or Falcon 4 reside on). The SCSI card's ability to queue the disk commands and the ability to disconnect while the device is busy, will help the disk I/O performance compared to an IDE disk I/O system.

Hard disk fragmentation will also have a big impact on the game performance. Falcon 4 will load a large number of textures during the game, and hard disk fragmentation will decrease the overall disk I/O performance. You should defragment your hard disk first, prior to installing Falcon 4. After all the patching and installation, you should then defragment your hard disk again. Regular defragmentation of the hard disk will maintain the performance of the game.

One important note concerns the usage of the option "Rearrange program files so my programs start faster" in the Windows Disk Defragmenter. Selection of this option can sometimes cause problems with Falcon 4, such as the game not being able to start-up, or inexplicable crashing. If you are experiencing such problems after defragmenting your hard disk, delete the Falcon 4 executable, and install a fresh copy of the executable again.

OPERATING SYSTEM

The operating system that you are running Falcon 4 on does play a part in the performance of the game. The Windows 9x/ME series of operating systems are not known for their superior memory management and stability. However, it is possible to run Falcon 4 in Windows 2000, and operating system that is much more stable, and has superior memory management as compared to Windows 9x/ME.

Many people have mentioned that Falcon 4 will run well with Windows 2000, but the compatibility patch (dated March 2001) and Service Pack 2 (SP2) needs to be installed. Although I have not tried it myself, many users have reported success in running Falcon 4 in Direct3D mode, with F4Turbo (a DirectX proxy) installed. The game will run with both DirectX 7 and DirectX 8, and users have not reported any incidences of the `devCreatesurface` errors or CTDs. Several users have reported

[2] Cacheman may be downloaded from http://www.outertech.cm.

mixed success with running Glide under Windows 2000. Some users have reportedly been able to do so by using the latest version 1.04 drivers for the Voodoo 5 card, in conjunction with DirectX 8a, the March 2001 Application Compatibility Update, and Service Pack 2 (SP2). Other users of Voodoo 3/4/5 cards have reported that the game tends to CTD upon exiting a mission (dogfight, TE, and campaign), although these users may not have been using DirectX 8, Service Pack 2 and the Voodoo 5 version 1.04 drivers.

Most if not all users have reported that Falcon 4 runs better under Windows 2000 than Windows 9x/ME. You will need to experiment on your own before you decide to switch, as Windows 2000 is not a common gaming platform, and you will also need to take into consideration if your programmable joystick is supported by Windows 2000. The robust multi-tasking, superior memory management and superior file system will definitely help the game in some ways.

CONCLUSION

The performance of Falcon 4 is very dependent on your hardware specification, as well as software settings in Windows 9x/ME/2000. Go on, tweak your computer, and have fun finding the optimal settings for your hardware, and be pleasantly surprised at the improvements that you may see !

Banishing The Ghosts Of Multi-player

Making Multi-Player Work in Falcon 4 Realism Patch
By Jeffrey "Rhino" Babineau

Introduction

We have found that multiplayer has had it's ups and down during the course of development of Falcon 4. Currently we have had great success in the Realism Patch Series, defined as 12+ players in a LAN campaign. We have also found that problems that occur in online flying are also present in LAN flying, i.e. hooking up and not seeing each other and only getting 4 guys to hook up easily. Here are some things we did to help us enjoy a really great LAN campaign event. We've found the more players you have, the more problems you will experience, but an 8-player game will be quite reliable. Many of you will notice our throwback techniques to Falcon 3 days.

Multiplayer Tricks

The fastest machine should load the campaign. This machine should also have at least 512 MB of RAM. We have a dedicated Pentium III 800 MHz to run our campaign, and this machine is not used for flying. The campaign should be running and ready for the players to jump in and fly *with no editing*. What we have had great success in mission planning, is to edit all future missions for our next flight *from the server*, and then save the game and reboot before beginning the process all over again. In short, we adopt the following procedure:

1. Enter the campaign
2. Edit the future mission
3. Save the mission
4. Exit the game, and reboot the machine
5. Begin the player entrance procedure for flying.

Each time we begin the campaign entrance routine, it goes like this:

1. The campaign is running on the fastest machine in the LAN. Players will enter the campaign one at a time. Each player will only enter the campaign when the preceding player is in the Mission Briefing UI. If a player cannot get in, he should exit Falcon 4, reboot his machine, before retrying. When all the players are in the campaign, we will proceed further.

2. Find the mission that you want to fly, i.e., the mission that you had edited previously. Typically, we will pick 4 ship missions. It is important to note that the mission time should be less than 20 minutes from the current time. If you have a flight setup that you will like to fly, and the pilot reads "unassigned," it is almost certain that the server will get the pilot assigned eventually, and then fail to pass that information to the clients. When the player at the clients try to fly, they will get an error message stating that their flight has been cancelled. This is easily avoided by entering the flight that is less than 20 minutes away from the current time.

3. Have the *first* (defined by take off time) *human* flight lead enter the selected mission. The *human* flight lead should enter the mission alone. After he has entered his game cockpit, he should then taxi off the main taxiway and *hold in place*.

4. The human flight lead should then call his entire flight of human players into the game, and as they enter the pie, the pilots should report "2 cockpit, 3 cockpit, 4 cockpit," before the flight may taxi forward for take off. *At no time should a human move while the rest of his flight joins the game. This will definitely result in the AI crashing the jet prior to the human player entering in the cockpit*. All the players need to understand how they should enter a mission, in order to eliminate AI movement while their human pilots get into their cockpits. There are times when other AI flights will appear around you. These will taxi right through you. Your only option is to

ensure that collisions are deactivated in the game setup screen. This will reduce your total points, but will keep your jet intact, and avoid any quirks with Falcon 4.

It is a good idea *never to edit a mission while it is running*. If you do, then there is a very high likelihood that the changes made will **not** get passed on to all the players. You should save the campaign after completing a mission, and have everyone save it and if the whole game crashes, reload the most recent version of the campaign.

We've also found that it is better not to enter the UI screen while other players are flying. There will be a "hiccup" that will take place, and it will almost always arrive while someone is landing or shooting. You wait in the "action view" until all the players have completed their mission.

There, that was easy!

SETTING UP A TCP/IP NETWORK

We will now go through the procedures of setting up a TCP/IP network.

1. Click on the “Start” button, and select “Settings,” and then “Control Panel.”

2. Click “Internet- select connection.”

3. For older versions of the Internet Explorer. Select "Connect to the Internet using a local area network.” The reason for selecting this is that should you connect to the internet using your modem, initiating the TCP/IP connection in Falcon 4 will result in the activation of your dial-up adapter. This will cause Falcon 4 to "hang.” Hitting the ALT-F4 key combination may cause the dial-up adapter to hang up, and then Falcon 4 may work again, but why chance it?

4. Close all the windows and return to the Control Panel.

5. Now double click on the “Network” icon.

6. Select TCP, and then select your network card. *Do not select the dial-up adapter!*

7. Select the network card properties.

8. Select the "IP address" tab.

9. Select the "Specify an IP address" option.

10. Input the IP address, 192.168.1.1. The address range of 192.168.X.XX is a non-routable IP address, and this is a standard IP address range that is commonly used for home based networks.

11. Input the subnet mask address of 255.255.255.0.

12. Input the IP address of 192.168.1.2 for the next machine, and so on, until you have configured all the machines on the network.

13. Select the "DNS configuration" tab.

14. Select the "Disable DNS" option.

15. Select the "WINS configuration" tab.

16. Select the "Disable WINS Resolution" option.

17. Select the "Advanced" tab.

18. Select the "Set this to be the default protocol" option.

19. Reboot the machine, and then enter Falcon 4.

20. Select the LAN option. Many of you have already discovered that the option for saving a new Internet connection is now the default, instead of LAN

21. Select a connection speed of T1 or better.

22. Select the "CONNECT" option, and you will be connected !

Connection Tips

There are some ideas that other players have found, that seem to make Falcon work better for games involving larger number of players:

1. Everyone should use the INTERNET option, instead of the LAN option.
2. Everyone should use the “-pf100” command line switch to start Falcon 4. This can be put into the Windows shortcut, e.g. “c:\falcon4\falcon4_108i2.exe –pf100”:
3. The server should selects the T1 connection speed but all the clients should select 33.6 kbps.

These options are supposed to help with packet management, and have worked to the advantage of some players.

Good luck with your multi-player games !

THE INCOMPLETE AND UNAPPROVED QUICK GUIDE TO BUBBLES

By Kurt "Froglips" Giesselman

As of today, all owners of Falcon 4.0 are required to go to your nearest novelty store (No, not those kinds of novelties! Get your mind out of the gutter. A kid's novelty store.) You are to purchase a bottle of soap bubble liquid and a large soap bubble wand for blowing soap bubbles. Go home, sit in front of your computer, start Falcon, enter the simulation, then open the soap bubble liquid and use your bubble wand to blow several dozen bubbles. Now sit back and look. This is what Falcon's AI is seeing. A world of bubbles moving, breaking apart into smaller bubbles, popping, touching each other, and touching you.

In Falcon, like your soap bubble experience, we can divide the world into two groups. There are bubbles that you are in contact with or have even passed inside, and there are bubbles that you have not contacted. All bubbles, in the Falcon world, have a Cluster at the exact center of the bubble. Some bubbles are in the air and are spherical, some bubbles are on the ground and appear as hemispheres. In Falcon, the soap bubbles never pop when they contact each other. So we can be in contact with and even inside dozens and dozens of bubbles at once.

The Clusters in Falcon, mentioned above, are of two types that can exist in two conditions. They are Units or Objectives. Units are Clusters that have actions associated with them. This does not always mean they move, although it often does. Aircraft, Ground Units, Naval Craft, and SAMs are all Units. Objectives are stationary and do not have an action associated with them that they could perform. Examples of Objectives are Bridges, Factories, Towns, Air Bases, and SAM Sites (note: these are not SAMs but the location of the fixed SAM emplacements).

The characteristics of these two types of Clusters aside, Falcon does not treat them any different in its managing of their bubble world. Falcon will treat them as Clusters if you are not in contact with their bubble, or Falcon will DEAGGREGATE them as Entities whenever you contact their bubble and for as long as you remain in contact or within their bubble's sphere.

In Falcon, because the default state of an object is AGGREGATED, a Cluster is initially not drawn in the Falcon world. Falcon assigns a placeholder to the location of that Cluster but does not draw or manipulate the Cluster's component parts. By parts, we mean the Cluster could be composed of four aircraft in a flight, the forty-eight members of a ground unit, or even the dozens of parts of a factory complex (like Office Buildings and Cooling Towers).

Falcon calculates all battles and damage for Clusters statistically. This means that there is no use of position for the calculation of damage to the components. Falcon calculates that a bomb from an AGGREGATED B-52 flight strikes an AGGREGATED airbase. Falcon calculates that the bomb has an 'X' chance of hitting the runway. If the 'roll of the dice' is favorable, then Falcon reports that the B-52 hit the runway and statistically calculates damage. The reason this is done is to reduce the load on the computer's CPU. If Falcon had to calculate the position of every bomb hit, every missile strike, and every bullet or shell in the simulation to determine where it hit the target, there would not be a powerful enough computer on the planet to run the full Falcon campaign. However, that is exactly what Falcon does for all Entities in its DEAGGREGATED world.

The amazing thing in Falcon is that each Cluster type, from AT-3 to ZU-23 and Airbase to Underground Factory, has a unique ACDD (Aggregated Cluster Deaggregation Distance) value found in the FALCON4.CT file. A distance from zero to the length of the theatre can be assigned to each Cluster type. When we assign a distance for DEAGGREGATION we are saying one of two things is true. At a range equal to the ACDD from the cluster, either the cluster is close enough for identification by visual means or radar or the cluster must be DEAGGREGATED to function correctly. We would not want to see airbases pop into existence five miles in front of us nor see a single blip on our radar that we were targeting suddenly become a four ship at 10 miles. Similarly, we want SAMs to 'light-up', search for us, and then fire with a measurable time period between each action. The deaggregation distance of a unit and an objective is known as the Unit Deaggregation Distance (UDD) and Object Deaggregation Distance (ODD) respectively (see the section below for a more detailed explanation).

Setting the ACDD distances requires understanding a) what the player pilot needs to maintain his immersion within the simulation and b) what the different Clusters in Falcon need to function in a realistic manner. The trade off is CPU load. As stated before, we could just make every Cluster DEAGGREGATED in Korea and save a lot of people a ton of work. No one's computer could run the program. Every time a Cluster's ACDD is increased (their bubble increases in size) we know that, on average, the CPU load will increase and (sob) our frame rates will go down. Fortunately, the enormous flexibility of Falcon's design allows us to turn up UDD or ODD value for Clusters where it is necessary for them to work properly (SAMs) and turn down UDD or ODD for Clusters where a high number adds no realism, no immersion, or value (airbases) to improve frame rates.

BUBBLE LEXICON V1.1

ACDD - The Aggregated Cluster Deaggregation Distance is the distance in feet from the Player Position (PP) or Composite Multiplayer Position (CMP) that an AGGREGATED Cluster will DEAGGREGATE into its component Vehicles (a Unit's components) or Features (an Objective's components). The ACDD variables for Units are named UDDs and for Objectives are named ODDs and can be examined and changed in their CT file using F4Browse.

Bubble - An imaginary hemispherical volume, which surrounds every Cluster or Entity in Falcon 4.0. Its diameter is determined by its ACDD and is set by their UDD and ODD found in the CT file. For ground units at least – and maybe all entities – the shape of the bubble is a hemisphere with radius equal to the UDD and height at least 60000 ft and maybe a lot more.

Bubble Combat Types - This section is a work in progress. Better insights, descriptions, and testing are welcome. Much more investigative work needs to be done with the different types of combat. There air two overall type of combat, Air to Air (missiles, SAMs or guns attacking aircraft) and Air to Ground (weapon attacks on Units {AGGREGATED, or 2D} or Entities {DEAGGREGATED, or 3D}). The type of weapon being used and the type of target being attacked are the most significant factors in all combat engagements.

Attack Category #1 - AGGREGATED vs. AGGREGATED

This attack is conducted between (AGGREGATED) Clusters. Falcon tracks the composition of any Unit or Objective Cluster when it is AGGREGATED. If combat occurs, Falcon 'rolls the dice' and calculates, based on some as yet unknown percentages, how many bombs hit the target. The calculations for damage are not positional (i.e. Falcon does not use individual Entity positions) but damage is 'awarded' against a Cluster as a whole then distributed between the components of the Unit or Objective. Falcon picks which components, of the Unit or Objective, are hit. Finally, after Falcon determines how much damage is done and whether each Unit or Objective is damaged or destroyed, Falcon 'awards' the kill to an attacker. The attacker awarded the hit is not necessarily the actual attacker that fired the weapon but one that was in the AGGREGATED Unit. If it seems like the sequence of events is peculiar then you understand it as well as anyone.

Attack Category #2 - DEAGGREGATED vs. DEAGGREGATED

This attack is conducted in the DEAGGREGATED world. All calculations are performed based on the positional data of Entities, Vehicles or Features, vs. the impact point and blast radius of the weapon being employed. Falcon must check every DEAGGREGATED entity in the game and compare its position to the weapon impact point with appropriate blast radius. If the Entity is within the blast radius then additional calculations are performed for damage and for the possibility of destruction. Changes in graphics, AI response, and position are possible.

Attack Category #3 - DEAGGREGATED vs. AGGREGATED

Falcon uses Active Targeting weapons (LGBs and Mavericks), much like the player. Active Targeting (AT) weapons are locked onto a target. Passive targeting weapons (dumb bombs, rockets, cluster munitions) are dropped at a particular ground location. They are not targeted. The success or failure of Cat3 attacks is totally controlled by the type of weapon utilized. Active Targeting weapons sometimes hit, with varying success, and passive targeting weapons always miss. This is easy to understand if we remember that Falcon never uses positional data to for AGGREGATED targets. A dumb bomb may impact the ground 10 feet or ten miles from a tank column. If the column is AGGREGATED, it is all the same to Falcon.

Subtype A – AT Weapon vs. Objective

Example is an AI aircraft with a UDD of 120,000 is attacking a bridge with a UDD of 50,000 when the PP's or CMP's ACDD is 90,000 feet to the bridge. The aircraft are DEAGGREGATED. The bridge is AGGREGATED. AI aircraft are firing AGM-65s. Falcon will award hits and sometimes divide them arbitrarily between the aircraft.

Subtype B – Passive (dumb) Weapon vs. Objective

Example is an AI aircraft with a UDD of 120,000 is attacking a bridge with a UDD of 50,000 when the PP's or CMP's ACDD is 90,000 feet to the bridge. The aircraft are DEAGGREGATED. The bridge is AGGREGATED. AI aircraft are dropping Mk.84s. There is no positional data for the bridge's Features. Falcon awards no hits against the bridge.

Subtype C – AT Weapon vs. Unit

Example is an AI aircraft with a UDD of 120,000 is attacking an armor column with a UDD of 60,000 when the PP's or CMP's ACDD is 90,000 feet to the armor column. The aircraft are DEAGGREGATED. The armor is AGGREGATED. AI aircraft are firing Mavericks. Falcon will award kills to the aircraft and sometimes divide them arbitrarily between the aircraft.

Subtype D – Passive (dumb) Weapon vs. Unit

Example is an AI aircraft with a UDD of 120,000 is attacking an armor column with a UDD of 60,000 when the PP's or CMP's ACDD is 90,000 feet to the armor column. The aircraft are DEAGGREGATED. The armor is AGGREGATED. AI aircraft are dropping Mk.84s. Falcon will not award hits against the Unit.

Attack Category #4 - AGGREGATED vs. DEAGGREGATED

Example is an aircraft with a UDD of 120,000 attacking a SAM with a UDD of 300,000 when the PP's or CMP's ACDD is 250,000 feet from the SAM (with all the entities involved arranged linearly). The SAM is DEAGGREGATED. The aircraft are AGGREGATED. Falcon determines, because the aircraft are AGGREGATED, that it will use Attack Category #2. This is what Dave 'DewDog' Wagner reported. It is a new type of attack that exists when a SAM UDD is larger than an aircraft UDD.

Units such as aircraft and ground forces have no attack AI. The weapon being employed determines when an aircraft will engage. A Unit's AI controls its movement, defensive actions, and mission actions.

<u>BubbleRebuildTime</u> - Variable in the Falcon.AII file (found in the MicroProse\Falcon4\campaign\saved folder) which determines how often (in seconds) Falcon checks the UDDs and ODDs for Clusters within 300,000 feet of the player. Default is one (1).

<u>Bubble Slider</u> - This is a multiplier for the UDD and ODD values. The multiplier for the standard

settings is listed below. Higher settings are accessible with the –g# command line switch may be calculated by following the pattern (+1 on the slider = +0.25 to the factor).

Setting	Factor
1	0.50
2	0.75
3	1.00
4	1.25
5	1.50
6	1.75
7	2.00

Cluster - Clusters are Units or Objectives that remain AGGREGATED as long as their ACDD (to the PP or CMP) is greater than the Units' or Objectives' UDD or ODD as set by their CT value. Falcon tracks them statistically, as a single item. The Cluster's component pieces, such as individual Vehicles or a structure's Features, are not tracked positionally by Falcon for damage. Falcon calculates damage to Clusters statistically. Falcon displays a Cluster's approximate location, when using far labels. A Cluster's location may shift dramatically when it is DEAGGREGATED into Entities and visible with near labels.

Cursor Bubble - A player controlled, mobile, ground DEAGGREGATION bubble, one nautical mile in diameter. The center of the Cursor Bubble is moved by the player's SOI cursors. Anything within a onenm. radius of the SOI cursor's position and on the ground is DEAGGREGATED.

Composite Multiplayer Position (CMP) - The bubble contacts of all players are shared as long as their aircraft's ACDD is less than the distance to another player's aircraft. Therefore, Falcon calculates ACDDs for each player but displays DEAGGREGATED Entities for every player within the ACDD of another player using the CMP. The CMP is a union of the bubble perimeters around players.

Deaggregated Entity - Vehicles (airborne, ground, or naval) or Objectives (man-made structures), which are fully drawn (rendered). Tank squads have individual vehicles drawn (the number of Vehicles displayed is controlled by the Object Density slider on the Falcon/Setup/Graphics page). Aircraft flights have all aircraft displayed individually visually or on radar. Objectives are displayed with all Features in place. Vehicles and Objectives may not be displayed at their maximum graphical detail. Level of detail is controlled by a yet unexplored FPRD (Feature Polygon Rendering Distance).

Feature - A structure that is part of an Objective and may be individually damaged. Features may not be selected individually as targets using Recon when viewing the Falcon map screen.

FPRD - The Feature Polygon-Rendering Distance is the Bubble Distance value found in the Feature's CT record using F4Browse. This is the distance at which the feature is POLYGON RENDERED.

Objective - Clusters that have no 'actions' associated with them. Objectives are predefined Clusters of Features (as Units are predefined Clusters of Vehicles). The key difference between Objectives and Units is the component parts of a Unit (Vehicles) require an independent AI BRAIN when they DEAGREGATE. The component parts of Objectives (Features such as taxi signs and hangers) do NOT require AI brains when they DEAGGREGATE. They may be targeted using Recon and selected when on the Falcon map or mission builder screen.

ODD - The Objective Deaggregation Distance is the distance from the player at which an Objective is DEAGGREGATED. Objectives include such Clusters as Airbases and Bridges and the value is found in the CT file with F4Browse.

SimBubbleSize - Variable in the Falcon.AII file (found in the MicroProse\Falcon4\campaign\saved folder), which determines the maximum distance that Clusters will be displayed on radar or are detectable by other sensors. Names for entities are displayed if they are within simbubblesize distance from a player or three times the entity's UDD whichever is less.

Statistical - see Cluster

UDD - The Unit Deaggregation Distance refers to the value of the 'Bubble Distance' variable of a Unit found in the CT file. This value, in feet, represents the distance from the PP (or CMP) at which an AGGREGATED Unit is DEAGGREGATED into its component parts. Interestingly DEAGGREGATION does *NOT* appear to mean that it is physically drawn as polygons. It simply means, at the point where the player's ACDD is less than the Unit's UDD, the AGGREGATE Unit is now DEAGGREGATED into its individual components such as tanks and trucks. Each of these tanks and trucks, once DEAGGREGATED, receive their own INDIVIDUAL AI brain and behave as individual entities. They no longer behave as an AGGREGATED Unit, being controlled by a single, AGGREGATED AI BRAIN. However, their polygons are *NOT YET* rendered at the UDD. Each vehicle in the Unit is actually first polygon-rendered when the VPRD (Vehicle Polygon Rendering Distance) for that Vehicle is reached.

Unit - These are predefined Clusters of Vehicles. A single, AGGREGATE AI BRAIN controls a Unit, which we call a Cluster, in Falcon. This AGGREGATE AI BRAIN can detect your aircraft and will fire at you. For example, an AGGREGATE SA5 Unit will fire a DEAGGREGATED SA5 missile at you. The missile becomes DEAGGREGATE at the moment it is fired, the Unit remains AGGREGATE until your ACDD is less than the Unit's UDD. When a Unit is DEAGGREGATED into its component Vehicles, each Vehicle acquires its own, individual AI BRAIN. We currently believe that the combat behavior of a Unit, as controlled by its AGGREGATE AI BRAIN, is distinctly different from the behavior of a DEAGGREGATED Vehicle. INDIVIDUAL AI BRAINS individually control all the DEAGGREGATED Vehicles. The difference in the behavior of an AGGREGATE Unit and a DEAGGREGATE Vehicle is still not clear, and may be very different for each Unit or Vehicle found in the game.

Vehicle - These are the individual parts of Units. Examples include SA-5 Launchers and Kraz 255 support trucks. Vehicles only exist when a Unit is DEAGGREGATED. When a Unit is DEAGGREGATED into its component Vehicles, each Vehicle is immediately tracked independently and positionally. A Vehicle is assigned an INDIVIDUAL AI BRAIN. At the moment a Unit is DEAGGREGATED into its component Vehicles, even though the above characteristics are true, that Vehicle is NOT YET polygon-rendered. That may happen later, when the player is closer. So we now make a distinction between DEAGGREGATION (which occurs first as we approach a Unit) and POLYGON-RENDERING, which occurs to the individually DEAGGREGATED vehicles as we approach to within visual distance.

VPRD - The Vehicle Polygon-Rendering Distance is the Bubble Distance value found in the Vehicle's CT record. Vehicles are the component parts of Units. When a Unit has been DEAGGREGATED into its component parts as a result of its UDD being less than the ACDD of a player, its component parts are tracked individually but may NOT be polygon-rendered. They are essentially individual but INVISIBLE vehicles until their VPRD is reached. A Vehicle in a Unit starts thinking and acting as an individual vehicle at UDD, but is actually polygon-rendered at its VPRD.

Bombing In The Bubble

Making It Work For You
By Alex Easton

Some Definitions

Let's start off with some basic definitions, in case you have skipped the previous section "*The Incomplete And Unapproved Quick Guide To Bubbles*." The old way of thinking about the bubble is that you are surrounded by a volume of space that extends out to the bubble setting. Inside this volume, flights, battalions, towns, etc. are DEAGGREGATED into their individual components, whereas outside it they are AGGREGATED into a single entity - the entire battalion (for example). The bubble for air units (19 miles), ground units (about 4 miles) and objectives like towns (variable) were all different in the original Falcon4.

Then it was discovered that each type of unit can be given a different bubble size - for example, bombers can have a different bubble size from fighters. This made the old way of thinking VERY cumbersome, so a new way of discussing it evolved.

In the new way, each unit-type (a T-90 battalion, say) now has a specific bubble size and the unit is deaggregated by YOU flying into ITS bubble. Each entity is now surrounded by a volume of space where your presence inside it causes the entity to deaggregate.

The "bubble size" for these entities are called the **U**nit **D**eaggregation **D**istance (or the *UDD*) when referring to ground or air units and the **O**bjective **D**eaggregation **D**istance (or *ODD*) when referring to fixed objects like towns, airbases, factories, bridges, etc. It is the optimum setting of these UDDs and ODDs that is one of the elements of the Realism Patch (version 2 and beyond).

You can also cause ground units to deaggregate when you are at a range greater than the UDD for the entity by placing the radar cursor or the TD box of the Maverick or LGB on them. When (say) the radar cursor is within about a mile of the battalion, *SECONDARY DEAGGREGATION* occurs, but the battalion will re-aggregate if the cursor is moved away and the player is more than the UDD from the battalion.

First let us review some of the background.

CAT-3 combat is defined in the air-to-ground situation as deaggregated aircraft attacking aggregated ground units. In other words, the aircraft are "inside your air bubble" and the ground units are "outside your ground bubble." Or, to put it the new way, you are within the UDD of the aircraft but outside the UDD of the battalion.

To summarize the effects of CAT-3 combat, as they are relevant for the player :

Mavericks CAN score hits against the AGGREGATED battalion, and when they do they are likely to score multiple kills per missile - normally in clumps of 5 for the D and B mavericks and in clumps of 3 for the G-maverick. However, the percentage of hits seems to reduce as the number of mavericks launched (i.e. CPU loading) increases.

Bombs that deaggregated aircraft (such as your aircraft) drop on aggregated ground units **NEVER** hit.

This is CAT-3 combat (A-G).

It is therefore NECESSARY that in using bombs, the CAT-3 condition is eliminated - i.e. that the unit remains deaggregated at least when the bombs strike. We also submit for realism's sake that it should also be eliminated as far as possible in using Mavericks, although this is less critical. The purpose of this section is to indicate ways in which the player can apply a little technique to achieve this.

THE IDEAL

The ultimate aim of the project is to allow the player to fly completely naturally, employing techniques that he/she might employ in the real world, without having to pay **ANY** attention to bubble issues.

Ideally, the ground bubble (UDD's for ground units) should be the same as the air bubble (UDD's for air units). This would eliminate completely CAT-3 combat for **ALL** aircraft. We are unfortunately a long way away from being able to do this because of the massive hit on frame rate this would entail. However, the RP group recommend that the ODD for objects such as factories be made the same as the UDD for the aircraft. This eliminates CAT-3 conditions for strategic bombing.

More realistically, a UDD for ground units of 12 miles would ensure CAT-3 conditions are eliminated for the player, and would be a rarity for the wingmen (but not other AI flights). However, the setting for the ground unit UDD will necessarily be a compromise between frame rate, the realistic capabilities of the GMT sub-mode of the radar, and the hit on frame rate. Arguments can be made for any reasonable value, but after much debate the RP Group has decided to recommend a setting of 6 miles for this parameter.

ORIGINAL DEFAULT SETTINGS FOR THE UDDS AND ODDS

The default setting for the UDD for the ground units is 4nm.. This is really too small and gives rise to problems in many situation. These problems have always been there, but have been masked by other bugs or wrongly diagnosed in the past but the past few months have been very productive in isolating and solving problems with the sim. Here are a number of situations, which pertain only to the player and not the wingmen.

a) CCIP bombing from a shallow dive, release about 8000ft.

This is OK. The battalion is deaggregated when the bombs are released, and the bombs aren't in flight long enough to permit the player to get far enough away before the bombs strike. The battalion therefore remains deaggregated the whole time.

b) CCRP level bombing from 12000ft at 450 KIAS

This is just about OK. The battalion is deaggregated by the cursors as the bombs are released, and, as the player has approached within the battalion's UDD, remains deaggregated **UNLESS** the player pulls away as fast as possible immediately after the bombs are released. There is then a good chance that the units will aggregate before the bombs strike.

c) CCRP level bombing from 18000 ft at 450 KIAS

This is problematic. This techniques is often used by players when attacking a stationary battalion as it gives immunity from AAA and IR SAMs, and a good stand-off distance to counter the SA-8/SA-15. However, at 450 knots, the bombs are in the air for about 30 seconds, easily enough time for the payer to get well away from the battalion before the bombs strike if she/he pulls away. The battalion will therefore aggregate and **NO KILLS WILL BE SCORED**.

d) Dive toss bombing.

This technique is usually used to enable the player to get back above 12000 feet as quickly as possible, in which case the player will continue to approach the battalion and it will remain deaggregated. However, if it is used from higher up and the player uses it to get as far away as possible from the battalion as quickly as possible, it is likely that the battalion will aggregate. This is similar to (c) above.

It is clear why many of us were missing with bombs in the past, and indeed why it is that our wingmen were very variable in scoring with cluster bombs/napalm. Their success was VERY dependent on what YOU were doing - i.e. if you had deaggregated the battalion by flying close to it, using the AG radar cursor or the Maverick screen. With the old "bubble setting" of 4nm., it was common to miss these conditions.

RECOMMENDED SETTINGS FOR UDDS AND ODDS

The first thing to say here is that CAT-3 will NEVER be a problem with the new settings when bombing **OBJECTIVES** such as factories, bridges, etc. - the ODD for these entities are 30 miles, the same as for aircraft, which eliminates completely this problem since BOTH aircraft and objectives are deaggregated.

Secondly, bombing fixed SAM sites, such as the SA-2 again should never be a problem as the UDDs for these battalions are set at the range of the SAM plus 10%. This was to ensure correct operation of the missiles, but has the added effect of essentially removing CAT-3 combat for the player, and making it much more unlikely for the wingmen - even using HARMs.

A "realistic ideal" for the ground unit UDD is 7.5 miles as, except in very extreme conditions, this would have eliminated CAT-3 for the player. But considerations regarding frame-rates and the use of an un-hacked exe dictated a lower setting. However, the setting of 6 miles for the ground UDD is still a huge improvement. Let's take the situations above.

a) CCIP bombing from a shallow dive, release about 8000 feet

Even less of a problem! It should be possible to bomb from 12,000 feet in a 25 degree dive at 500 knots and still keep the units deaggregated until the bombs strike, whatever you do after the bombs have gone. In a dive-bombing profile, the bombs are in the air for a shorter time and the release point is closer to the target so there is less time to get out of the bubble.

b) CCRP level bombing from 12,000 feet at 450 KIAS

Except when the player makes EXTREME efforts to get as far as possible from the battalion as quickly as possible, this should be OK. The only exception we can think of is when launched against by a SA-8 just after the bombs are released. Dumping stores with a deep slice away from the battalion on full AB with a 30 degree dive to pick up speed will aggregate the battalion just before the bombs strike, but any other situation is OK. We suggest the following:

- Drop the bombs and then turn to beam the battalion dropping chaff (just in case) and then orbit the battalion, keeping it within 6 miles from you.
- Turn away from the battalion and, as soon as it is on your six, reverse the turn to beam it just in case of a SA-8 launch.
- Keep flying towards the battalion for about 2 seconds. Then do what you like!

c) CCRP level bombing from 18,000 feet at 450 KIAS

If you try to get away from the battalion as soon as the bombs have gone, you will probably aggregate it before the bombs strike. We suggest something similar to the previous situation:

- Drop the bombs and then turn to beam the battalion dropping chaff (just in case) and then orbit the battalion, keeping it within 6 miles from you.

- Turn away from the battalion and, as soon as it is on your six, reverse the turn to beam it just in case of a SA-8 launch.
- Keep flying towards the battalion for about 5 seconds, in level flight to avoid MANPADS. Then do what you like!

Bear in mind that attacking fixed SAM batteries is not a problem, and that the technique is only really realistic when attacking stationary troops or armor. It does, however, give virtual immunity to any air defense system carried by combat units in the Realism Patch.

d) Dive toss bombing.

This is easier than in the default settings as you are MUCH more likely to be attacking a deaggregated battalion when the bombs are released. Again, using this technique simply to get back up to 12,000 feet is still OK. But to use it to get visual targeting with the greatest stand-off distance, allowing you to pull away from the battalion, still has it's problems. If you are going to pull away after release, we suggest you immediately turn to BEAM the battalion, and then orbit it at a distance of less than 6 miles. Having said that, it is still very difficult to aggregate the battalion before the bombs strike because of the nose-high attitude of the aircraft as the bombs are released.

The Wingmen

The ideal here is to keep the battalion deaggregated during the times when your wingmen are making bombing runs. You can do this with the Maverick screen, the AG radar cursor or by keeping within 6 miles of the battalion. Again, fixed SAM battalions and Objectives (like bridges) are not a problem.

The increase in the ground UDD to 6 miles makes it MUCH easier to do this. Added to the fact that the bubble seems to be a CYLINDER rather than a SPHERE allows you to fly high in the vicinity of the battalion without having to close the horizontal distance.

Six miles is a reasonable distance to orbit the battalion at 15000ft before rolling in for a CCIP dive-bomb attack. But if you want to pull away 10 miles before turning back for a medium altitude level CCRP, attack you should consider the following two tips. Either:

- Co-ordinate your wingmen by recalling them so that they don't attack when you are outside the battalion's UDD. When you turn back, assign them their targets just before you start your run and after YOUR bombs have been released, orbit the battalion at a range of just under 6 miles until THEY have completed their runs. Again, this is a recognized technique - see Zambo's article again on Co-operative AG techniques (reference at end of article).
- Time your egress before turning back for your run so that they have just finished their run and their bombs have struck.

Having said that, the increase in UDD to 6 miles means that the battalion is aggregated for less time, so the problem of your wingmen bombing dirt in CAT-3 combat is reduced anyway.

Mavericks

Normally, players make the run launching as many Mavericks as they can before getting too close and then they pull off. So CAT-3 isn't too much or a problem here as you end up within 6 miles of the battalion as the last Maverick is launched. The exception is when a player launches a single (or maybe two) Maverick at maximum range and then pulls away. When the angle off the nose of the battalion exceeds the gimbal limit for the Maverick seeker head - or if you have just fired your last Maverick - the battalion will aggregate unless you are within 6 miles of the battalion. To eliminate CAT-3 combat, we suggest one of the following:

- Only launch the last Maverick when within 6 miles of the battalion.
- Use slave mode in firing the last Maverick if fired from long range.

- Maintain a radar lock (or keep the ground-stabilized TD box) on the battalion until the Maverick has struck. You can do this by only pulling far enough round so that the battalion is still on the radar screen.

Likewise, it is an idea to assign your wingman a target on initial approach from a range of about 10 miles and drop behind him, maybe pulling off to the side to give lateral separation, either keeping the battalion deaggregated using the AG radar or your own Maverick screen. Keep the lock until all his Mavericks have hit.

Other AI Flights

You have a lot less flexibility here, but there are still some things you can do to help them out.

- Just as for your wingmen, you can keep close enough to their target to keep it deaggregated. It is an idea to maybe attack a battalion that is close to the one they are attacking and to loiter between the two battalions
- One technique commonly used in the F4 world is to follow them in about 4 miles behind, keeping the battalion deaggregated using the Maverick screen. When a SAM launch is seen on the Maverick screen, the launcher can be targeted with a Maverick. This is a very good way of thinning the SA-13s or the SA-8/SA-15s.

Enemy Flights

There will be some small differences here , say when Su-25s or Hinds are attacking a friendly battalion in your vicinity, especially with cluster bombs. It is now more worth while to waste them if you can!

But the big difference will be in enemy bombers attacking fixed installations like bridges or even airbases. You really have to be much more careful in flying CAPs as they will now be able to destroy targets within a 30 miles radius of your plane. It is certainly now more worth while, even when returning from a strike mission, to take out these Tupolevs that you used to ignore, especially if they are heading towards YOUR base!

And remember that allied SAM batteries now have a much greater UDD that makes them more effective at longer ranges, but also makes them more vulnerable. They can protect you better, but you may have to do more to look after them in turn.

In testing these methods, the success of our bombing and that of the wingmen has significantly improved. But you may use different methods. So be skeptical and don't take it as the final word, but instead think of it as something to consider in refining your AG techniques. We would be very pleased to hear of anything we have got wrong as this will help us ALL understand better what is going on and how to work within the limits of the game.

BEYOND WINNING BATTLES: WINNING THE WAR

Understanding The Falcon 4 Campaign
By Leonardo "Apollo11" Rogic

FALCON 4 "CAMPAIGN PRIORITIES"

The Campaign Priorities button allows the player to influence the type of missions created for the player's squadron's ATO. This section explains the functions of the campaign priority sliders, and how you can best use them to influence the mission assignments.

Campaign Sliders Explained

The list of "Target Types" in "Priorities" is as follows:

- *Aircraft*
- *Air Fields*
- *Air Defenses*
- *Radar*
- *Army*
- *CCC*
- *Infrastructure*
- *Logistics*
- *War Production*
- *Naval Bases*
- *Armored Units*
- *Infantry Units*
- *Artillery Units*
- *Support Units*
- *Naval Units*

The list of "Mission Types" in "Priorities" is as follows:

- *OCA*
- *SAM Suppression*
- *Interdiction*
- *CAS*
- *Strategic Strike*
- *Anti Ship*
- *DCA*
- *Reconnaissance*

For each mission type, it is paired to specific target types as follows:

OCA

If *OCA* is selected as "Mission Type" and there are no *Aircraft* or *Air Fields* or *Radar* selected in "Target Types," the Campaign ATO generator will schedule:

- OCA strikes (against army bases that house helicopter units)
- OCA strikes (against airstrips)
- OCA strikes (against highway airstrips)

If A*ircraft* or *Air Fields* or *Radar* are selected then the Campaign ATO generator will schedule:

- Sweeps (against airborne targets)

- OCA strikes (against army bases that house helicopter units)
- OCA strikes (against radar sites - rare)
- OCA strikes (against airbases)
- OCA strikes (against airstrips)
- OCA strikes (against highway airstrips)

Note: Airfield strikes can only be generated *Air Fields* are present as a target type, and both *OCA* and *Strategic Strike* are also selected as "Mission Types."

SAM Suppression

If *SAM Suppression* is selected as "Mission Type" and there are no *Air Defenses* selected in "Target Types," the Campaign ATO generator will not schedule any mission.

If *Air Defenses* is selected then the Campaign ATO generator will schedule:

- SEAD strikes (against SAM/AAA units)

Interdiction

If *Interdiction* is selected as "Mission Type" and there are no *Air Defenses*, or *Armored Units*, or *Infantry Units*, or *Artillery Units*, or *Support Units* or *War Productions* selected in "Target Types," the Campaign ATO generator will not schedule any mission.

If *Air Defenses* or *Armored Units* or *Infantry Units* or *Artillery Units* or *Support Units* or *War Productions* are selected then the Campaign ATO generator will schedule:

- Interdiction missions (against SAM/AAA units)
- Interdiction missions (against Armored/Infantry/Artillery/Support units)
- BAI missions against (against Armored/Infantry/Artillery/Support units)
- Interdiction missions (against industry)

Note: Strikes against industrial targets will only be generated if *War Productions* are present as a target type, and both *Interdiction* and *Strategic Strike* are selected as "Mission Types."

CAS

If *CAS* is selected as "Mission Type" and there are no *Armored Units* or *Infantry Units* or *Artillery Units* or *Support Units* selected in "Target Types," the Campaign ATO generator will not schedule any mission.

If *Armored Units* or *Infantry Units* or *Artillery Units* or *Support Units* are selected then the Campaign ATO generator will schedule:

- CAS missions (against Armored/Infantry/Artillery/Support units)

Strategic Strike

If *Strategic Strike* is selected as "Mission Type" and there are no *Air Fields* or *Army* or *CCC* or *Infrastructure* or *Logistics* or *War Productions* or *Naval Bases* selected in "Target Types," the Campaign ATO generator will not schedule any mission.

If *Air Fields* or *Army* or *CCC* or *Infrastructure* or *Logistics* or *War Productions* or *Naval bases* are selected, then the Campaign ATO generator will schedule:

- Strike/Deep Strike/Bombing missions (against airbases)
- Strike/Deep Strike/Bombing missions (against army HQ's - rare)
- Strike/Deep Strike/Bombing missions (against CCC - rare)
- Strike/Deep Strike/Bombing missions (against bridges)
- Strike/Deep Strike/Bombing missions (against depots - rare)
- Strike/Deep Strike/Bombing missions (against industry)
- Strike/Deep Strike/Bombing missions (against naval bases - rare)
- Strike/Deep Strike/Bombing missions (against airbases)

Note: Airfield strikes can only be generated *Air Fields* are present as a target type, and both *OCA* and *Strategic Strike* are also selected as "Mission Types."

Anti Ship

If *Anti Ship* is selected as "Mission Type" and there are no *Naval Units* selected in "Target Types" the Campaign ATO generator will not schedule any mission.

If *Naval Units* is selected then the Campaign ATO generator will schedule:

- Anti Ship missions (against ships - rare)

DCA

There is no need to specify "Target Type" for DCA. When selected the Campaign ATO generator will automatically schedule:

- CAP missions (against airborne targets)
- Intercept missions (against airborne targets - rare)

Reconnaissance

There is no need to select any "Target Type" for Reconnaissance. When selected the Campaign ATO generator will automatically schedule:

- Reconnaissance missions

What you need to understand about the interactions of the sliders and mission types are as follows:

#1 The player can only influence "package type missions"

The list of "Mission Types" in "Campaign Priorities" is as follows:
- OCA
- SAM Suppression
- Interdiction
- CAS
- Strategic Strike
- Anti Ship

- DCA
- Reconnaissance

The player only has influence on package type missions (i.e. the main mission on which the package builds upon) and does not have any influence on the sub-package flights.

Therefore, even if you disable "SAM Suppression" in "Mission Types" but still have "Strategic Strike" enabled you will get strike packages that still include "SEAD Escort" flights. The only thing you will not get is "SEAD Strikes" as "Mission Type.”

#2 Package interconnection

Although in "Strategic Strike" or "OCA Strike" packages (for example), there are no "SEAD Strike" and "Sweep" flights - they do EXIST!

The F4 Campaign ATO generator will create those "SEAD Strike" and "Sweep" flights - but as SEPARATE PACKAGES.

In order to have "Sweep" missions, you will need to set "OCA" as the mission type and "Aircraft" as the target type. Similarly, to have "SEAD Strikes,” you will need to have "SAM Suppression" selected as mission type and "Air Defenses" selected as target type.

Here is a quick summary of the undesirable things resulting from this approach to ATO scheduling by the F4 Campaign ATO generator.

a) TOT (Time On Target) problem:

A combination of "Sweep" package, "SEAD Strike" package, and "OCA Strike" package will all share the same TOT.

This is obviously undesirable since "SEAD Strike" and "Sweep" packages will have to have the TOT set to several minutes earlier than that of the “OCA Strike” package to clear up the path for the strikers. You will have to manually adjust the TOT for each package to de-conflict them, and ensure that the main strike package is free from any ground or airborne threats.

b) "Campaign Priorities":

Be VERY careful with the setting up of these preferences. If you mess up the combination of target type and mission type, you will get strange package assignments, such as deep penetration packages without "Sweep" and "SEAD Strike" packages as escorts. This is the surest way of ensuring that the F4 Campaign ATO generator generates suicidal missions.

#3 PAKs

Note that the selection of PAKs also play a big role in the generation of missions. This is important because in some PAKs, some targets may or may not exist at that moment in time (you can task the F4 Campaign ATO generator such that certain PAKs are NOT targeted at all).

Examples:

#1

OCA	= 100%
SAM Suppression	= 0%
Interdiction	= 0%
CAS	= 0%
Strategic Strike	= 0%
Anti Ship	= 0%
DCA	= 0%
Reconnaissance	= 0%
	= 100

100/100 = 1 => each percentage point in "Mission Types" carry 1% of all missions scheduled.

All missions that the F4 Campaign ATO generator schedules will be OCA. In other words, all the missions scheduled will be OCA flights at the exclusion of other missions.

#2

OCA	= 100%
SAM Suppression	= 0%
Interdiction	= 0%
CAS	= 0%
Strategic Strike	= 0%
Anti Ship	= 0%
DCA	= 100%
Reconnaissance	= 0%
	= 200

100/200 = 0.5 => each percentage point in "Mission Types" carry 0.5% of all missions scheduled.

All missions that the F4 Campaign ATO generator schedules will be OCA and DCA. In other words, there will be an even split of OCA and DCA missions scheduled at the exclusion of all other missions..

#3

OCA	= 100%
SAM Suppression	= 0%
Interdiction	= 0%
CAS	= 50%
Strategic Strike	= 0%
Anti Ship	= 0%
DCA	= 100%
Reconnaissance	= 0%
	= 250

100/250 = 0.4 => each percentage point in "Mission Types" carry 0.4% of all missions scheduled.

All the missions that the F4 Campaign ATO generator will schedule will be OCA, DCA and CAS. The missions will be split between 40% of OCA, 40% DCA, and 20% of CAS flights.

CAMPAIGN "FORCE RATIOS" SLIDERS

The Campaign Force Ratio sliders allows the player to influence the power of the enemy in the campaign. This is done by varying the number of vehicles in the enemy units. The maximum number of vehicle slots (the number of vehicle in one entry can be a maximum of 3) is 16 (0-15) in a unit.

The principle of the "Force Ratios" sliders is very simple indeed:

	Harder Gameplay (MIN)		(MIDDLE)		Easier Gameplay (MAX)
Player - used vehicle slots	0-7	0-9	0-11	0-13	0-15
Player - number of vehicle slots	(8)	(10)	(12)	(14)	(16)
Enemy - used vehicle slots	0-15	0-13	0-11	0-9	0-7
Enemy - number of vehicle slots	(16)	(14)	(12)	(10)	(8)

Note 1: The enemy side is always at the "Left" regardless of the flag shown. It is important to know this when you are flying for DPRK/China/Russia.

Note 2: Some slider settings can't be obtained so you have to move slide one notch left/right and re-enter Campaign "Force Ratios Slider in order to achieve desired settings.

We recommend that the "Force Ratios" sliders in campaign be left in the middle position for RP. This is the only setting where realistic (real world) orbat for ground and air units are attained.

OBJECT DENSITY SLIDER

Another factor that influences the number of ground vehicles is the "Object Density" slider (in the Setup menu under the "Graphics" option). Understanding how the "Object Density" slider works will help you understand how F4 handles ground units, and how it will eventually affect combat.

#1 - "Object Density Slider" effectively turns OFF the vehicles inside a unit from 3D combat. They simply do not exist in our 3D flying world and they can't be engaged, nor engage us or other AI vehicles (air/land/sea).

#2 - When visible vehicles in unit are destroyed the previously invisible vehicles replace the destroyed vehicles in our 3D flying world. The replacement will occur only after the unit has been allowed to reaggregate, and is deaggregated again.

#3 - The "Object Density Slider" selects the percentage of vehicles inside a unit that will be shown in the 3D world. This number may or may not be "rounded up" with the vehicle slot (i.e. some vehicle slots hold 3 vehicles, but depending on the "Object Density Slider" setting, only 1 or 2 vehicles may be selected).

#4 - The "Object Density Slider" percentage varies a lot and I cannot decipher exact formula - but on the whole, it looks like triangle.

Please note that maximum number of vehicles per unit is 48 (16 vehicle slots x 3). Below is example of generic unit that has 48 (16x3) vehicles in it:

Vehicle Slot #	**Density Slider Setting**					
	1	**2**	**3**	**4**	**5**	**6**
0	3	3	3	3	3	3
1	3	3	3	3	3	3
2		1 *	3	3	3	3
3			3	3	3	3
4			3	3	3	3
5				3	3	3
6				3	3	3
7					3	3
8					3	3
9					3	3
10					3	3
11						3
12						3
13						3
14						3
15						3
Total Vehicles	6	7	15	21	33	48

* Where each vehicle slot may have up to three vehicles, each of which is present in the 3D world except for the slot marked with the asterisk where less than 3 vehicles appear in the 3D world.

#5 There is special variable known as the "Rad Vcl" in the unit window (you can see this using the "F4Browse" utility). This variable holds the number of radar vehicle slots. This is necessary because F4 must have fully functional units even at the lowest "Density Slider" setting. This is to ensure that regardless of the position of the “Object Density” slider, radar equipped units such as SAM units will always be equipped with radar vehicles. In other words, SAM unit is placed in a high numbered vehicle slot, F4 overrides the otherwise triangular "shape" of the used slots (see #4 above) and uses the vehicle slot marked by "Rad Vcl" even at "Density Slider" = 1.

Below is example of "Nike Hercules ADS" unit in the Realism Patch (Rad Vcl=9):

Vehicle Slot #	**Density Slider Setting**					
	1	**2**	**3**	**4**	**5**	**6**
0. Nike ADS x 1	1	1	1	1	1	1
1. Nike ADS x 1	1	1	1	1	1	1
2. Nike ADS x 1	1	1	1	1	1	1
3. Nike ADS x 1		1	1	1	1	1
4. Nike ADS x 1			1	1	1	1
5. Nike ADS x 1				1	1	1
6. Fuel Truck x 1					1	1
7. Jeep x 3					3	3
8. M977 x 2					1 *	2
9. Nike Radar x 1					1	1
Total Vehicles	4	5	6	7	12	13

The maximum number of vehicles per slot is determined by the ORBAT of the unit (up to a maximum of 3 vehicles per slot). For example, if the maximum number of vehicle is 2, then the maximum number of vehicles will be visible if the object density slider is set to 6, and and the number of visible vehicle decrements by 1 for every decrement in the object density slider setting.

Conclusion

In order to get the orbat of all ground/sea units composition correct (i.e. as they are designed to be) the "Object Density Slider" must be set at 6.

We know that this is hard blow for many users who manipulate the "Object Density" slider to improve the game FPS but this is how things are... sorry folks ...

TIME ACCELERATION IN TE AND CAMPAIGN

In the design of the Realism Patch, we noticed that time acceleration plays a very, very BIG role in how the 2D statistical fight is resolved in TE and campaign.

Note: There are essentially 2 kinds of combat in F4. Combat done in our 3D world and the 2D statistical fight (when you just observe unit symbols moving on the mission map).

Our conclusions are quite shocking:

Even with a Pentium III-600 MHz and 256 MB of RAM, we found that accelerated time higher than 16x (32 seems to be the "border") produces errant results.

The AI actions are EXTREMELY limited at such high time acceleration multipliers, and the AI was unable to hit anything.

Try this for yourself in a simple TE or with any of the campaigns. Watch the statistical fight in the map view with time acceleration of 16x or less and observe how the AI begins to score hits in missions and how the targets are damaged/destroyed. This is simply not happening with time acceleration of 32x and 64x.

Therefore it is our strong recommendation not to run campaigns or TE at time acceleration in excess of 16x.

CHAPTER 2: MISSION PLANNING

INTRODUCTION

You are all keyed up to go, having just received your ATO and mission frag order. However, arrayed against you is the entire gauntlet of enemy air defenses. Will you survive it? Will you complete the mission successfully, or will you be forced to abort just to save your own skin?

The foundation of success for any mission is laid in the mission planning stage. This is where you analyze the threats that you may face, and plan your threat reaction accordingly. Many of the threats may be avoided totally through proper flight route planning. Even the formation that you use will affect the survivability of each flight member as you transit through the target area. The section titled "*Knowing Your Enemy*" will help you analyze the threats that you will face, and equip you with the knowledge to plan your flight route accordingly to avoid detection or engagement. We will discuss threat reaction and evasion in the next chapter, but you will need the concepts that you have learned in threat analysis.

Figure 1: Detailed mission planning and a thorough pre-flight briefing is essential to the success of any combat mission. (Picture credit of USAF)

Even with the best laid plans, the AAA threat still needs to be respected, as even a ground troop with a rifle can pose a threat to you. Be sure you get the latest intelligence update on the AAA threat from the section titled "*The AAA Menace*."

Before you start filing the flight plan, you will need to arm yourselves. A fighter aircraft without weapons is no better than a passenger airliner. War is won by conquering forces on the ground, and while air combat is sexy and exciting, mud moving will still be required to win the day. The section titled "*Hell, Fire And Brimstone From Above*" will discuss the various surface attack armament options at your disposal. Be sure to identify your target types, and understand the effects of your weapons against these target types. Using the wrong weapon even when it is delivered bang on the target probably won't bring about the desired destruction.

Lastly, we will get to the meat of the flight planning. For ground pounder, weapon delivery profile will need to be planned and the target study will need to be conducted. The section titled "*The Art And Science Of Moving Mud*" will you through the process of target study, flight route planning, and weapon delivery planning. Adequate planning is half the battle won, so make sure that you cover all angles during the planning phase, and leave no stone unturned.

KNOWING YOUR ENEMY

Threat Analysis in Realism Patch
By "Hoola"

ANALYZING THE AIRBORNE THREAT

The first concern that you should pay attention to is the threat of enemy interceptors. This will determine the ingress routes and profile that you should adopt. We will take you through a systematic way of analyzing the capabilities of interceptor types. The analysis will make extensive use of the data presented in the Excel spreadsheet "F4_RP_Sensor_Properties.XLS," included in the distribution of this user's manual.

Avoiding Hostile Interceptor Radar Detection

The onboard radar of the interceptors will be the first sensor that will allow them to detect your presence. If you can avoid detection on their radar, you will deny them the ability to shoot at you with radar guided missiles, or even deny them the awareness of your presence.

1. Firstly, determine the radar range of the hostile aircraft in the sheet labeled "Radars." This range is given in feet.

2. Determine your own aircraft radar cross section in the sheet labeled "RCS."

3. Multiply the radar range of the hostile aircraft by your own aircraft RCS, and divide the result by 6076. This will give the range in nautical miles at which the hostile aircraft will detect you in a look up situation, assuming that you are not employing ECM and not beaming the radar.

4. Next, multiply the detection range by the look-down multiplier for the hostile radar (you can obtain this from the sheet "Radars"). This will result in the look down detection range of the hostile aircraft against you.

The radars will be in the look down mode when detecting targets that are 2.5° or more below the horizon. For example, at a 15nm. range, the hostile radar will be looking down at the target amongst the ground clutter return if the target is at an altitude of more than 4,000 feet below the hostile radar. Hence, if the hostile radar has a look-up performance of 15nm. and a look-down performance of 10nm., you can plan your flight route to within 10nm. of the hostile interceptor as long as you maintain an ingress altitude of at least 4,000 feet below the interceptor. If you intend to ingress at a higher altitude, you will then need to plan your flight route such that it is more than 15nm. from the hostile interceptors to avoid detection.

For more technical details on the mechanization of radar detection in F4, please refer to the sub-section titled "*The Electronic Battlefield*" in the Designer's Notes.

Avoiding Hostile Interceptor RWR Detection

You will be operating your radar during ingress to sweep the skies for bandits. This leaves an electronic trace for the bandit's RWR to detect (if the bandit is so equipped, which not all of them are), especially if you decide to lock up on the bandit to obtain an NCTR identification. However, not all RWRs are created equal, and they have different sensitivities. What you need to realize is that you will be highlighting your position to the orbiting bandit whenever you ping it. To determine if the bandit's RWR can detect your radar emissions, you will need to do the following:

1. Firstly, determine the basic radar range of your own radar in the sheet labeled "Radars." This range is given in feet.

2. Determine the bandit's RWR sensitivity in the sheet labeled "RWR."

3. Multiply the radar range of your own radar by the bandit's RWR sensitivity, and divide the result by 6076. This will give the range in nautical miles at which the bandit's RWR will detect your radar emissions.

4. Determine the elevation coverage of the bandit's RWR. If you are outside the elevation coverage and lock-up the bandit with your radar, it will also not detect you.

You now know the passive RWR detection capabilities of the enemy interceptors. This will help to determine if you should lock on any target appearing on your radar display. If you lock on outside its RWR detection range, you will be able to obtain an NCTR identification without the bandit knowing. If you lock-up the bandit inside its RWR detection range, then you've just stirred a hornet's nest and invited him to join you for some air combat fun.

Avoiding Hostile Interceptor Visual Detection

While you can deny radar or passive ESM detection of your presence, the one thing that you cannot deny is the Mark I eyeball on the enemy interceptors. Denying a radar lock will deny a BVR shot opportunity for the enemy, but once the enemy has detected you visually, there is little you can do to prevent a visual knife fight. Depending on what airplane you are flying, the enemy will be able to acquire you visually at different range, that are skill dependent.

1. Firstly, determine the basic visual acquisition range of the enemy AI in the sheet labeled "Visual Sensors." This range is given in feet.

2. Then, determine the visual signature of your own airplane in the sheet labeled "Visual Signature."

3. The visual acquisition range of your airplane by the various AI skill levels are given in the sheet labeled "Visual Signature." For example, an F-16 will be visually detected by a Recruit AI at a range of 2.58nm., and 5.58nm. by an Ace AI.

4. If you wish to compute the visual acquisition range on your own, you will need to multiply the visual acquisition range by the visual signature, and then finally by the AI skill multiplier (see the section titled "*Open Heart Surgery On Artificial Intelligence*" in the Designer's Notes). This will give the AI visual acquisition range in feet.

You will find that even though you can successfully deny a MiG-19 radar and passive ESM detection at a range of 5nm., by flying at low altitudes and avoiding painting the MiG-19, you will not be able to escape its visual detection if the MiG-19 pilot has a skill rating of Ace.

You will also need to be concerned about contrail altitude and engine smoke signature. Remember to check the contrail altitude before you takeoff, and avoid flying at this altitude and above, as contrails will increase your visual signature by four times.

If you are flying an airplane with smoky engines such as the MiG-29, you will also need to be aware that the smoke trail will increase your visual signature. As such, remaining in MIL thrust may increase your visual signature. The appropriate throttle setting will depend on the aircraft type.

Threat Capabilities

An important factor in mission planning is understanding the abilities of the enemy interceptors to engage you. You will need to know which of the enemy's air defense aircraft are capable of Beyond Visual Range (BVR) engagements, and which aren't. These are summarized in Table 1 below:

Aircraft	IR WVR Missiles	Semi-Active Radar WVR	IR BVR Missiles	Semi-Active Radar BVR	Active Radar BVR
F-4	AIM-9			AIM-7	
F-5	AIM-9				
F-14	AIM-9			AIM-7	AIM-54
F-15	AIM-9			AIM-7	AIM-120
F-16	AIM-9				AIM-120
F-18	AIM-9			AIM-7	AIM-120
F-22	AIM-9				AIM-120
MiG-19 / J-6	AA-2	AA-2			
MiG-21	AA-2	AA-2			
MiG-23	AA-8		AA-7	AA-7	
MiG-25	AA-8		AA-6, AA-7	AA-6, AA-7	
MiG-29	AA-8, AA-11			AA-10	
MiG-31	AA-8		AA-6	AA-9	
Su-27	AA-8, AA-11		AA-10	AA-10	AA-12
Su-30	AA-8, AA-11		AA-10	AA-10	AA-12
J-5	AA-2				
J-7	PL-7, PL-8				

Table 1 : Air-to-Air Missile Capabilities of Fighters in Falcon 4 (Korean Theatre)

You should read the intelligence reports on what kind of threats are present in the target area, and familiarize yourselves with their capabilities. We will discuss more about weapon capabilities in the later sections of this user's manual, how best to employ them, and how best to counter them. For a start, knowing what kind of threats you will be facing will allow you to prepare yourself mentally. For example, you will only need to defeat the hostile aircraft's radar in order to foil a semi-active radar homing (SARH) missile shot, but you will need to contend with both the hostile aircraft's radar as well as the missile's onboard radar when defending against an active radar guided missile. You will also need to be aware that some BVR missiles are guided by infra-red radiation, and you will not be warned of a missile launch. More on weapon capabilities later.

You should also review the self defense ability of the aircraft that you will face, and whether they are equipped with countermeasure dispensing systems (CMDS) or internal/external jammers. You can find the details in the "F4_RP_Sensor_Properties.XLS" Excel spreadsheet included with the distribution of this user's manual, under the sheet labeled "Jammer and CMDS."

ANALYZING THE GROUND BASED THREAT

The next concern that you should pay attention to is the threat of enemy ground based air defenses. This is less complicated than planning against airborne interceptors, as the ground based air defenses are not as mobile, if not static. The analysis will again make extensive use of the data presented in the Excel spreadsheet the "F4_RP_Sensor_Properties.XLS" included with this user's manual.

Avoiding SAM engagements

Surface-to-Air guided missile radars have tremendous detection ranges. They will usually detect your presence from distances way beyond their effective firing range. You may find that it may not be possible at all to plan your flight route around the SAM sites to avoid detection. What you will need to do is to avoid getting shot at. This will also help you decide if you should carry a jammer, in the event that you are unable to plan a flight route to avoid an engagement, as well as how you should approach the SAM site if you are tasked with a SEAD mission.

1. Firstly, determine radar range of the SAM in the sheet labeled “Radars.” This range is given in feet.

2. Determine your own aircraft radar cross section in the sheet labeled “RCS.”

3. Multiply the radar range of the SAM radar by your own aircraft RCS, and divide the result by 6076. This will give the range in nautical miles at which the SAM radar will detect you in a look up situation, assuming that you are not employing ECM and not beaming the radar.

4. Next, multiply the detection range by the “beam distance” multiplier. This will give you the distance at which a beaming maneuver will succeed in defeating a radar track on you.

5. Multiply the radar detection range by the “ECM De-sensitization” multiplier. This will give you the distance at which your onboard ECM equipment will succeed in defeating a radar track on you.

Missile	Guidance	Max Effective Altitude (feet)	Min Effective Altitude (feet)	Engagement Range (nm)	Mobility Type
Patriot	TVM	80,000	500	50	Static
Nike	Command	70,000	4,512	45	Static
I-HAWK	SARH	50,000	700	13	Static
Daewoo Chun-Ma	Command Line-of-Sight with FLIR	10,000	200	5	Mobile SHORAD
Mistral	IR with IRCCM	10,000	50	2.5	MANPADS organic to non ADA units
Stinger	IR with IRCCM	12,000	50	3	MANPADS organic to non ADA units
SA-2	Command	70,000	1,200	13	Static
SA-3	Command	48,000	5,000	12	Static
SA-4	Command	80,000	1,500	20	Mobile
SA-5	Command with terminal active radar homing	80,000	6,000	45	Static
SA-6	Command	40,000	800	10	Mobile
SA-7	IR with no IRCCM	7,000	200	2	MANPADS organic to non ADA units
SA-8	Command	30,000	300	5	Mobile SHORAD
SA-9	IR with no IRCCM	14,000	300	3	Mobile SHORAD
SA-10	TVM	90,000	500	50	Static and mobile deployment
SA-13	IR with IRCCM	12,000	300	3	Mobile SHORAD
SA-14	IR with no IRCCM	14,000	200	2	MANPADS organic to non ADA units
SA-15	Command	15,000	150	5	Mobile SHORAD
SA-16	IR with no IRCCM	12,000	50	2.5	MANPADS organic to non ADA units
SA-19	Command	10,000	100	4	Mobile SHORAD

Table 2 : Surface-to-Air Missiles In Falcon 4 (Korean Theatre)

An unguided SAM is a harmless SAM, so as long as you can prevent it from gaining a radar lock on you, you will prevent a guided launch on you. Now bear in mind the usage of Electronic Countermeasures (ECM) requires some finesse, but more on this later. You will also need to be aware of any IR SAM threats that you will be facing. These will be problematic and will be encountered in large numbers if you intend to fly at low level. You best approach is to consciously avoid overflying enemy troops as they may be equipped with organic air defenses, and intentionally avoid flying at altitudes below 15,000 feet.

Radar guided SAMs are easy to counter by getting SEAD escorts that can target the SAM radars from stand-off distances using weapons such as the AGM-88 HARM, but IR SAMs do not require a radar lock to launch. IR SAM launch will also not trigger the RWR launch warning, and this means that you will need your wingman to warn you, or spot the launch visually yourself.

There will usually be a mix of radar guided SAMs and IR guided SAMs, with the IR SAMs mainly belonging to the SHORAD (Short Range Air Defense) type. Table 2 on the preceding page will list the pertinent information required for mission planning purposes, such as maximum effective altitude, engagement range, etc.

Figure 2: Careful route planning will help you avoid most of the enemy ADA threats. (Picture credit of USAF)

As you can see from the table in the preceding page, to avoid the SHORAD threat, you will need to operate above an altitude 15,000 feet. This will however put you in the heart of the envelope for radar and command guided SAMs. With active defense suppression, you may be able to destroy most of the static air defense sites, but certainly, the threat of SHORAD remains tangible as many of these SAMs are organic to the ground combat and HQ units.

You will have to decide as part of your mission planning process the minimum safe altitude. This has to be determine even if you are tasked with a sweep or escort mission, as it is often easy to descend below the minimum safe altitude into SHORAD envelope. The low altitude warning function on the DED is handy for setting reminders to yourself, as it is easy to forget about the SHORAD threat when you are in the midst of air combat.

The presence of SHORAD will also affect your weapon delivery profile. You will need to decide as part of your mission planning process if you should adopt a medium or high level CCRP bombing profile to stay above the SHORAD envelope, or if you should switch to the visual CCIP profile. In the latter profile, you will obviously have to deliver your ordnance in a dive. The dive and the subsequent recovery may result in you entering SHORAD engagement envelope. The questions that you will have to ask yourself will be:

1. What kind of dive profile should you be using? A steeper dive will mean better weapon accuracy, but will result in a faster rate of descent that may bring you even deeper into the SHORAD engagement envelope.

2. How should you approach your target? Should you be making the bombing run out of the sun, in which case you will prevent IR missiles from acquiring you easily, or should to perform a low level pop-up profile? If you decide on a pop-up profile, what are the possible threats to you as you climb from your low level ingress route to acquire your target and initiate the run-in?

3. Should you use your countermeasures pre-emptively? If you are facing an IR missile threat, should you be dispensing flares at a regular interval as you perform your bombing run, in case somebody sneaks a missile that you failed to notice up your tailpipe?
4. Is your onboard ECM useful against the SHORAD threat such as SA-8 and SA-15? Should you turn on the ECM as you begin to roll into the target, and take the risk of highlighting your position to other hostile interceptors in the vicinity, or should you wait till the threat launches at you?

You should also decide on the ingress route and altitude? Most SAMs have a minimum engagement altitude, often at 1,000 feet or more. Adopting a very low level ingress altitude will help you avoid detection from SAM sites, and leave precious little reaction time for the enemy ground troops to fire MANPADS at you, especially if your ingress speed is high. Of course, a big part of your consideration should be the anti-aircraft artillery, which we will be discussing next.

The Anti-Aircraft Artillery (AAA) Threat

The AAA threat comes from dedicated AAA units equipped with anti-aircraft guns (such as the HART sites), AAA vehicles attached to combat and HQ units (such as the ZSU-23-4), and the ground troops' automatic rifles and machine guns. The range at which these guns can engage you varies, and there really isn't much you can do about the small caliber guns since they are everywhere, except to fly at higher altitudes (about 15,000 feet and above) to avoid getting shot at.

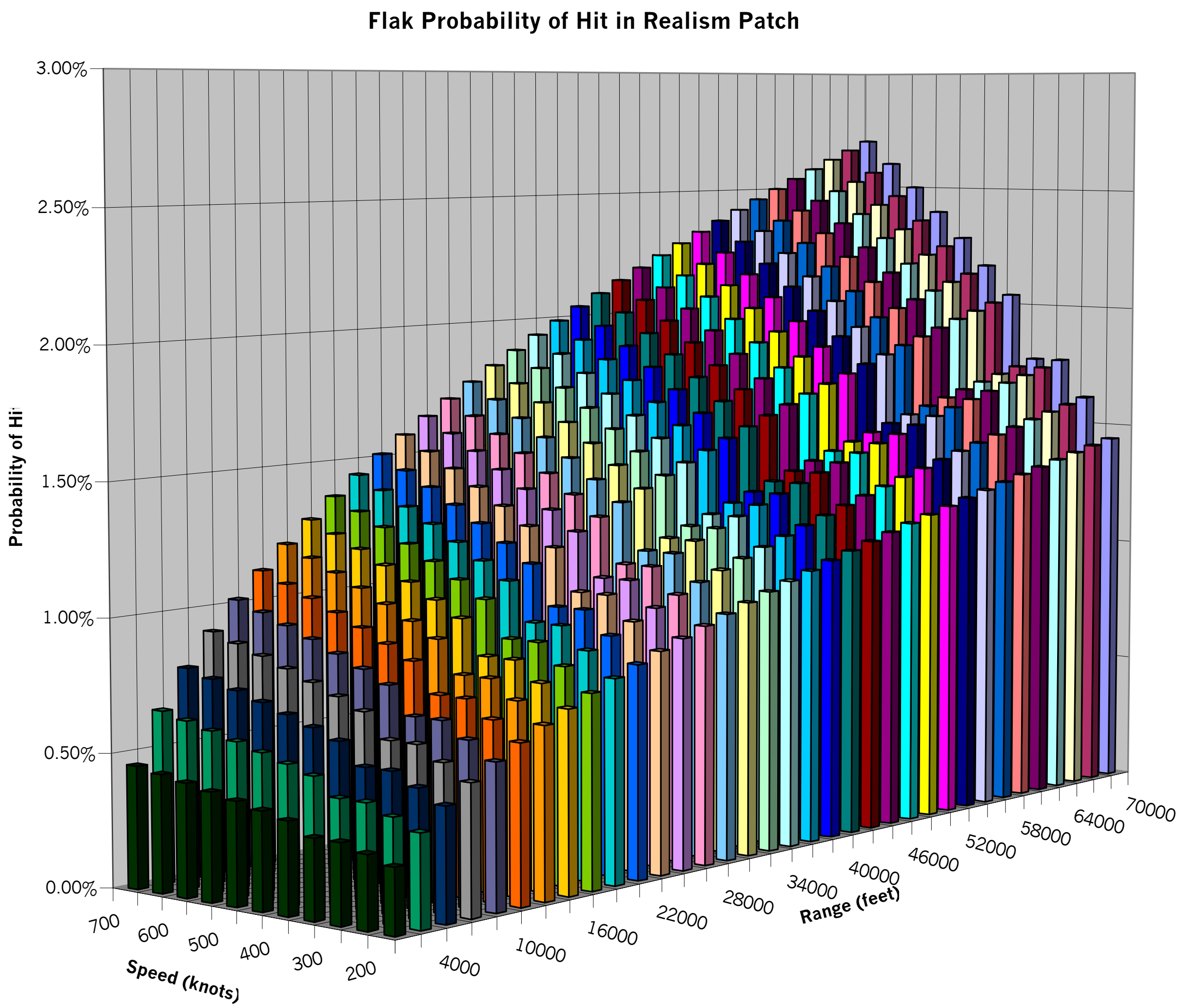

Figure 3: Flak Effectiveness in Realism Patch

The large caliber guns are usually sited at fixed locations, and are part of dedicated AAA battalions. These are often radar equipped and easy to locate on the intel map. Even if you manage to knock out the radar with SEAD strikes, there is nothing you can do to prevent barrage fire as the guns can be optically aimed.

What you can do as part of the mission planning process is to plan your flight route away from the dedicated AAA sites and battalions. You should assume a worst case engagement range of about 8nm., and as long as you stay outside an 8nm. radius from such sites and units, they should not be able to engage you.

Your target may also be defended by AAA batteries, which may mean that a visual CCIP attack will bring you smack into an AAA barrage. You will need to examine your target carefully as part of your mission planning process, to determine if any of such threats are present. Alternate weapon delivery profiles such as DTOS or medium level CCRP may help you stay outside the AAA envelope, though you may need to plan SEAD escorts armed with cluster bombs to suppress the AAA defenses first before initiating your attack.

The low level AAA threat is an obvious concern. While flying at low level will help you avoid detection from enemy fighters and SAM sites, there really isn't any good defense against AAA, as even an M-16 or AK-47 rifle squad can shoot at you and score hits. To make matters worse, you cannot detect these threats easily as they do not light up the RWR, and often, the only indication of the presence of such threats is when you start seeing tracer rounds flying up towards you, or when you hear the rounds hitting you. You may be forced to ingress and fly at a higher altitude, which will bring you into the engagement range of large caliber AAA.

Figure 3 on the preceding page shows the probability of being engaged and hit by larger caliber AAA guns (the 85 mm KS-12 and 100 mm KS-19) equipping DPRK AAA units. These are radar directed flak guns that fire proximity fused shells. You can see that the probability of kill decreases with increasing altitude and airspeed. If you really need to fly into the engagement envelope of such AAA batteries, this chart will help you plan your ingress altitude and speeds. Remember, knocking out an AAA radar or jamming it does not prevent it from firing as the guns can be optically aimed, but knocking out or jamming the radar of SAM sites will stop them from shooting.

The chart above clearly shows that the effectiveness of AAA fire decreases from 1.25% at a ground speed of 200 knots and a slant range of 2,000 feet, to less than 0.11% at 700 knots with a slant range of 70,000 feet. For any combination of your altitude and ground range, you can always determine the slant range to the AAA battery, and compute the gun Pk as follows (the random number is a value between 0 and 1):

AAA Hit Probability = Random Number * 40 / 32767 * ((Slant Range * Ground Speed/100000)$^{0.5}$)

We will leave the detailed coverage of the AAA threat for the next section, "*The AAA Menace*."

ROUTE PLANNING

After you have analyzed the threats arrayed against you, you should begin to plan your ingress and egress routes. The 2D theatre map shows all the ground and air units that have been detected by your intelligence and IADS assets, as well as the fixed assets belonging to the enemy, such as air bases and radar stations.

You should display the locations of all fighter aircraft flights, AWACS, radar sites, C^3I facilities, air bases, and air defense units (AAA/SAM battalions, and HART sites), and then select the option to display high and low altitude radar coverage. Begin by examining the map, and determine if there are any blind spots that are not covered by the enemy's radar sites. You will find that the enemy is able to cover a very extensive area for high and medium altitude targets, and it will be almost impossible to find a gap in the radar coverage at the start of the war. However, you should be able to find some gaps in the low altitude radar coverage. These gaps will allow you to sneak into the enemy's airspace without being detected.

Once you have identified gaps in the radar coverage, begin by planning your ingress and egress flight routes. Make sure that your flight route does not take you over any enemy early warning radar sites, airbases, or SAM/AAA units, as these form part of the enemy's integrated air defense system (IADS), and once you have been detected by them, enemy fighters will be vectored towards you.

During the start of an air campaign, you may find that the only way you can sneak into the enemy's airspace undetected is to fly at low altitudes (below 500 feet AGL), and exploit the radar blind spots. As you wage the air war and destroy the enemy's C^3 facilities such as airbases and radar sites, you will create more gaps in the low and high altitude radar coverage. Destruction of SAM sites and air defense units will also degrade the enemy's ability to detect you. Low level tactics will become extremely important at the start, and this will expose you to a considerable amount of MANPADS threat. As the air war progresses, you can expect to operate using medium level tactics once the enemy's IADS has been degraded.

It is thus important to begin by systematically destroying the enemy's air defense assets, as this will reduce the ability for the enemy to guide fighters. By blinding the enemy's fighters and forcing them to rely on their own onboard sensors to detect targets, you will give your strike aircraft a better chance of entering the enemy's airspace without having to contend with airborne threats. This reduces the chance of them aborting their primary strike mission, and increases the overall effectiveness of the air-to-ground campaign.

CONCLUSION

With the knowledge of threat analysis, you will be put in a better position to assess the threats arrayed against you, and plan your flight route and weapon delivery profile to minimize your exposure to such risks. This will also help you determine the true capabilities of the threats arrayed against you. While this sounds like a tedious exercise in arithmetic, we strongly urge you to develop the habit of proper mission planning. Many a times, you will need to intervene to manually plan the flight so as to improve the survivability of your packages. Remember, proper mission planning is half the success of any mission!

THE AAA MENACE

Intelligence Briefing on DPRK Anti-Aircraft Artillery Threat
By Alex Easton

PREAMBLE

The purpose of this briefing is to fully acquaint all pilots and mission-planners to the capabilities of the DPRK AAA and to suggest techniques to minimize the threat.

The AAA is a serious threat that cannot be taken lightly. While you can reduce this threat with appropriate planning, you will probably never be able to fully eliminate it. I don't have to tell you that the randomness of AAA means that even with the best planning and execution in the world, there will be times when you have to enter the engagement zone of these weapons and the "chance" factor comes into play. But here's how to load the dice in your favor.

THE THREAT

The main threat is from the DPRK AAA battery. It normally possesses four KS-19 single-barreled 100 mm FLAK AAA guns with a normal maximum engagement altitude of about 45,000 ft and a maximum horizontal engagement distance of about 7.5nm.. This is a radar guided gun with excellent accuracy as regards the altitude of the target. Accuracy in azimuth is less pronounced with the net effect of spreading burst distribution widely in the horizontal in front of the aircraft. This makes jinking in the horizontal to counter the threat less effective; jinking in the vertical plane will be more effective.

Figure 4: S-60 AAA guns

ECM and chaff are a lot less effective with these guns compared to SAMs, as the guns can be aimed optically even when you deny the AAA fire control radar a valid target lock-on. However, its use of radar does make the gun vulnerable to HARM missiles launched within the correct parameters.

The battery also has four KS-12 85 mm single barreled FLAK guns with a maximum engagement altitude of 20,000 ft and a maximum horizontal range of about 3.5nm.. The same considerations apply to this gun.

The battery normally carries six medium-altitude radar guided 57 mm S-60 FLAK guns. These have a maximum altitude of 15,000 ft and fire horizontally to 2.5nm.

Completing the complement of FLAK guns are six optically-guided M-1939, a single-barreled 37 mm gun with a high rate of fire. Normally this gun will only fire up to 12,000 ft, but can engage out to about 2nm..

The battery is supplemented by six 14.5 mm double barreled ZPU-2 tracer-type guns. These are dangerous below 6,000 ft and can fire right down to ground level. Although of short range, they can be VERY dangerous against low-flying aircraft and must be treated with respect. Despite not having radar-guidance, they are accurate and difficult to spot. Of course, they cannot be attacked with the HARM missile.

The battalion is expected to be equipped with a number of ZIL-135 trucks and maybe a BMP command vehicle, which carries the SA-14 missile.

In addition, the DPRK has in its OOB a towed AAA battery. This unit contains S-60 and M-1939 guns, and therefore lacks the range and altitude of the AAA battery. Nevertheless, it is still dangerous. Its complement of guns is completed by a number of short-range ZPU-2 pieces.

How do we translate such intelligence into our mission planning and the techniques to be employed against sites protected by these units?

ENROUTE TO THE TARGET

These units are quite common in the theatre and it is likely that your flight path on a deep-strike mission will take you close to at least one of them. Here are some indications on how to plan such missions.

1) Avoid them when you can. The KS-19 can engage out to 7.5nm., so plan the mission to pass them with a minimum separation of 8nm.. If you are in combat spread formation, close it up to avoid the possibility of the outside planes entering the engagement zone of the guns.

2) If you must overfly the battery, do so as quickly as you can. The radar-guided guns are less accurate in engaging targets at high speeds, and you will spend less time in the engagement zone by flying faster.

3) Best altitudes when flying close to the battery (but not over it) are over 20,000 ft where ONLY the KS-19s will engage, or UNDER 2,000 ft where the flak guns will not fire. But if flying low, do not overfly the battery directly or you will be engaged by the ZPU-2s. The best low-level altitude is below 1,500 ft, which is below the low-level limit of the radar SAMs, but make sure you do not fly near a town, or any site that may have a combat or AD unit stationed there. Also avoid, where possible, roads which may have combat battalions moving along them.

4) The DPRK has modified the guns so they can fire on the move. If you encounter the battery moving along a road, EXPECT them to engage you if within range.

5) If you ARE caught in the engagement zone of the guns, jinking in the VERTICAL plane is more effective than jinking in the horizontal plane as good altitude discrimination but poor accuracy in azimuth results in a burst distribution that is wide in the level plane but thin in terms of altitude. If your wingman is being targeted by the guns and INSISTS, like any good wingman, in maintaining formation, then YOU jink to make him maneuver as well.

6) Don't rely on chaff or ECM - they are ineffective against these weapons.

7) If you are engaged by a battery that had previously gone undetected, then either pull up above 20,000 ft or drop below 10,000 ft and head away from the battery. In the former case, this will eliminate all the guns other than the KS-19, and in the latter, the horizontal range of ALL the guns is somewhat lower below 10,000ft.

Having said all that, it is a good strategy to punch a hole in the defenses around the FLOT and then to direct deep strike missions through the gap. This worked for the Israelis during the Yom Kippur war- and it'll work again if pre-strike intelligence is good enough.

There will be times when, despite all the best planning, you find yourself in the heart of the engagement zone for the battery. Have a game plan up your sleeve for this eventuality and keep a constant eye using the A/G radar on the positions of surrounding units to help you decide your plan of action - going low or high.

ATTACKING THE TARGET

First of all, I'd like to say that there is NO good substitute for preparing the way for a strike mission by degrading the battery by SEAD and Interdiction missions beforehand. If possible, arrange such flights to precede the strike package to reduce the risk.

HARM attacks

The best approach is just below 10,000ft. At this altitude, the radar WILL switch on, but the KS-19 will not engage beyond about 5nm. horizontally. You should be able to pick a target, lock-on and launch well before entering the engagement zone at this altitude. But be sure you have your egress direction worked out or you may accidentally overfly another unit.

Maverick attacks

Approaching from under 2,000 ft altitude will get you safely to a very close range to the battery, but don't go too near or the ZPU-2s will engage. The best approach is to fly under 1,500 ft as this protects you from radar guided SAMs, but check on the A/G radar for any other units in the vicinity. Egress at the same altitude, but look on the A/G radar for undetected enemy units on your flight path. You can climb up to less than 10,000 ft when you are more than 5nm. from the battery.

High-level bombing

Don't!

Medium-level bombing

Use a fast, level CCRP approach at just under 10,000 ft altitude. The flat, fast approach will throw the bombs far enough so that you only enter the engagement zone of the guns for a short time. As a guide, a level ingress at 9,000 ft altitude and carrying 2 Mk-84s on full MIL thrust will do the trick.

On release, pull away from the target at a vector that you have verified beforehand is safe, but don't climb above 10,000 ft until you are more than 5nm. from the target. Dive-toss is not recommended as it may put you into the higher-altitude band, where the guns can engage further out.

Low-level bombing

We cannot recommend this technique unless the ZPU-2s have been significantly degraded. But if they have, you can ingress and egress at less than 1,500 ft in relative safety. Watch out for small arms AAA and the SA-14 though. Note that if you are carrying CBUs, you will need to climb above the burst height before you release your ordnance.

If you must use this technique without degrading the low-level AAA first, do so as fast as possible and as low as possible. Start jinking as soon as the bombs are released and dispense flares all the way to decoy any SHORAD IR missiles launched at you. Make sure your jet is returned to CAT-I as soon as the bombs have gone and keep under your egress altitude under 1,500ft until you are at least 5nm. away from the battery. This is a VERY risky technique at the best of times and should only be employed when necessary.

DISPERSAL PATTERN FOR THE BATTERY

The battery takes up a number of different formations, depending on the type of site they are stationed at and whether they are moving or stationary. Make sure you check the recon screens before take-off to identify their positions more closely.

At civilian sites - towns, villages, etc
They are generally arranged in line-abreast formation.

In transit
The battery will move from site to site in a column formation.

Airbase
All the units will be dispersed around the edges of the base. The ZPUs will be dispersed around the base and will be placed to defend against anti-runway bombing runs down the length of the runway

Other military sites
These will be dispersed around the outskirts of the site

Figure 5: 2S6M Tunguska firing its twin 30 mm anti-aircraft cannons. This is a serious threat to low level attackers.

AAA In Combat And Support Units

Many combat and support units have dedicated AAA vehicles accompanying them in addition to the small-arms AAA you will find from APCs, tanks etc. The most serious threats are :

ZSU-57-2 : The ZSU-57-2 is a double barreled 57 mm flak gun similar in performance to the S-60, but a little less capable as it does not employ radar guidance.

ZSU-23-4 : The ZSU-23-4 Shilka is very dangerous indeed below 7,000ft. It is a 4-barrelled 23mm tracer-type gun with radar guidance. Avoid it if you can.

ZU-23 : Lastly the ZU-23 is a double-barreled 23mm tracer-type gun similar in performance to the ZSU-23-4 but less lethal because of its lack of radar guidance and the smaller number of barrels (only two barrels).

There will also be a variety of short-range small arms fire from assault rifles, APCs and tanks.

Jinking Against Tracer Type AAA

Once again, the best way of surviving tracer-type AAA is to avoid it if possible. If you must fly low and may encounter low-level AAA, it is essential to keep your speed as high as possible - low and slow is a lethal combination.

If you are caught at low-levels in the heart of a Shilka's envelop, jinking can help if you have prior warning. How you jink depends on where the fire is coming from. If it is from the side, it is better to use out-of-plane maneuvers. A turn purely in the horizontal will still put you through the line of fire of the shells and if the burst is long enough, you will still get hit. Be careful to avoid climbing above 1,500ft if there are radar SAMs around as this is their normal low-altitude cut-off. If the shells are coming from behind or below, a horizontal jink will get you out of the line of the shot - once again, a straight pull up will pull you through the line of fire and if the burst is long enough, you will get hit.

Often, you will be targeted by AAA from different directions, or you are taking prophylactic measures against suspected AAA. In such cases, use both the vertical and horizontal plane maneuvers. If you have the altitude, a barrel roll is not a bad tactic to use. Whatever the situation is, flying the jet unloaded for more that 2 seconds is dangerous.

To conclude, the AAA is a serious threat that must be factored into planning and execution of missions. I hope this briefing will help you out there. Good luck!

Colonel *** (name deleted for security reasons)***
Intelligence Section

Hell, Fire And Brimstone From Above

Air-to-Ground Weapon Selection
By "Hoola"

The sole purpose of airpower is to deliver ordnance onto enemy targets. Weapon selection plays an important role in ensuring that assigned targets are destroyed. An inappropriately selected weapon may not have the appropriate fire power to destroy the targets that you are tasked against. This section will discuss the characteristics of the air-to-ground weapons available to you in the Realism Patch. We will save the discussion on air-to-air missiles for the next chapter.

Unguided Bombs

Mk-82, Mk-84, FAB-250 and FAB-1000 Low Drag General Purpose High Explosive Bombs

There should be plenty of these ordnance in your squadron stores. These bombs are effective against a large variety of targets such as buildings, bridges, fortifications and soft skinned targets. They can create considerable damage to most targets if they manage to hit the target. The problem is with the delivery mode, which is usually CCIP/DTOS/CCRP. These delivery modes do not provide sufficient precision. The damage that will result from these bombs is mainly blast and shock, and the bombs do not have a lot of armor penetration power. When used against armored targets, these bombs will usually only destroy targets in the vicinity of the impact, as the armored targets are better protected against the blast and shock wave.

Do not expect to destroy many armored vehicles (usually only 3 – 4 vehicles at most) even with the 2,000lb. Mk-84 and FAB-1000 bomb. An impact point of 25 feet or more from the armored vehicle will usually only result in damage, especially for smaller bombs such as the Mk-82 and FAB-250, though larger bombs will destroy armored vehicles up to about 50 feet away from the impact point.

Figure 6: Mk-82LDGP bombs awaiting to be loaded on B-52 bomber. (Picture credit of USAF)

When used against troops in the open or soft skinned vehicles, these bombs can be surprisingly effective with the capability of destroying targets within 100 feet (for Mk-82 and FAB-250) to 200 feet (for Mk-84 and FAB-1000). A large bomb such as the Mk-84 will also destroy a building if a direct hit is scored.

Figure 7: Russian FAB-500 bombs loaded on Su-24

You are advised not to use these bombs if you require precision strike capabilities, such as when you are targeting bridges and small bunkers. These bombs are not penetrator type of weapons, and will be less effective at destroying runways as they explode on impact and do not result in the heaving of the runway surfaces. This makes runway repair easier compared to dedicated runway cratering ordnance such as the BLU-107 Durandal or the JP233. Do not use these bombs if you intend to deliver them low level, as you may not be able to escape the frag pattern during detonation. The Mk-82 and FAB-250 bombs weight 500lb. each, and the FAB-1000 and Mk-84 bombs weights 2,000lb. each.

BSU-49/B, BSU-50/B, FAB-250 HDGP, FAB-1000 HDGP High Drag General Purpose High Explosive Bombs

Figure 8: F-111F releasing BSU-49/B AIR bombs

These are high drag bombs designed for low level delivery. The bombs consist of the same warhead as the Mk-82, Mk-84, and FAB series low drag bombs, but the low drag tail kit is replaced with a retarder system. When released, the retarder system deploys a parachute and slows down the bomb rapidly, allowing the aircraft to escape the fragmentation pattern during detonation.

The BSU-49/B and FAB-250 bombs weigh approximately 550lb., and the BSU-50/B and FAB-1000 bombs weigh approximately 2,100lb.

BLU-109 High Explosive Penetrator Bomb

This is a 2,000lb. class unguided penetrator bomb, designed to destroy fortified structures and bunkers. This bomb is designed to penetrate thick concrete fortified structures before exploding inside. The explosive content is lower due to the thicker steel casing. As such, the bomb is a lot less effective when used against troops or armored concentration as the blast effect is much lower compared to the Mk-82/84 bombs. You should only select this bomb if you are targeting fortified structures of large size, as the delivery mode is CCRP/DTOS/CCIP and precision impact cannot be achieved.

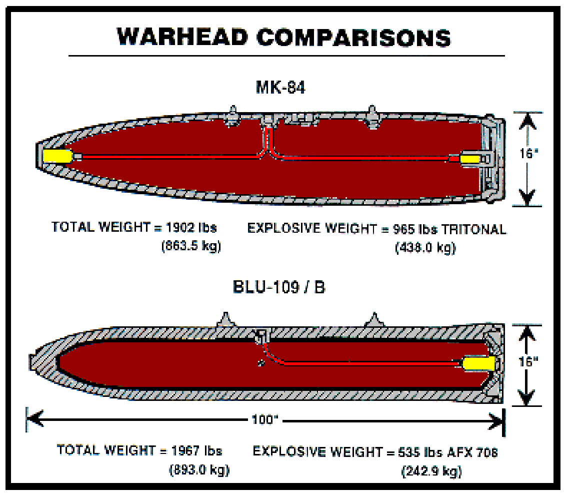

Figure 9: Comparison of BLU-109/B with Mk-84

Mk-77 Napalm Bomb

Figure 10: Mk-77 napalm bomb loaded on USMC A-6 Intruders.

These 750lb. napalm bombs have a flame and incendiary effect, but no blast effect. They are designed to break apart upon impact, and splash the impact area with incendiary gel. Napalm bombs can be highly effective in close air support missions, as their effects can interrupt enemy operations without endangering friendly forces due to the localized damage that they cause (there is no blast and shock wave). They are also effective against supplies stored in light wooden structures or wooden containers.

However, despite the spectacular display of fireworks, the damage caused by napalm bombs is less than that caused by conventional high explosive bombs. Near misses will seldom cause damage to vehicles, and troops may be trained against the effects of a napalm attack. There is little penetration ability, and as such, these bombs are effective only when used against soft skinned vehicles and troops in the open. You can read more about the technicalities of napalm bombs in the section titled "*Blast and Damage Models*" in the designer's notes.

ZAB-500 Incendiary Bomb

The ZAB-500 incendiary bomb has a canister shaped body, with an ogival nose and a four-fin drum tail unit similar to that used on many Russian conventional bombs. The bomb has a weight of 520 kg. The bomb has a flame and incendiary effect, and the bomb body will break apart on impact and splash the impact area with incendiary gel.

Figure 11: ZAB-500 incendiary bombs awaiting to be loaded on Russian Su-25 during the Chechnya conflict.

As with the Mk-77 napalm bomb, the damage caused by incendiary bombs is limited compared to conventional high explosive bombs. The ZAB-500 is best used against infantry and soft skinned vehicles. This bomb is widely used by many ex-Warsaw Pact countries, as well as the DPRK. It has now been withdrawn from service with the Russian Air Force, and replaced with the more effective and powerful ODAB-500 Fuel Air Explosive bomb. The FAE bomb will envelop the target area with a mist of fuel, which is then detonated. The blast and incendiary effects of FAE bombs are far more deadly against armored targets compared to the incendiary bombs.

BLU-107 Runway Cratering Bomb

This is a dedicated 407lb. runway attack bomb, designed for low level delivery. The bomb is normally released in low level high speed flight, and upon release, deploys a parachute to decelerate the bomb. The moment the bomb reaches an inclination angle of 30 degrees, the parachute is jettisoned and the booster motor fires. This drives the warhead into the runway concrete, where it detonates and heaves the concrete. The resultant crater is several meters in length and 2 to 3 meters deep, and surrounded by a large area where the slabs have been raised and cracked.

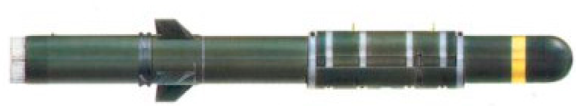

Figure 12: BLU-107/B Durandal Runway Cratering Bomb

To repair the runway, the repair team will need to cut away the heaved slabs before filling in. This process slows down the repair, compared to normal bombs, as normal HE bombs will only result in a crater without heaving the concrete. You should only use this bomb if you intend to attack runways.

CBU-52B/B, CBU-58A/B, CBU-87, Mk-20D, RPK-250, RPK-500, PTK-250 Unguided Cluster Bombs

Cluster bombs are designed to attack area targets such as armored columns, troop concentrations, aircraft parking on dispersal sites, etc. The different bombs are packaged with different sub-munitions. CBU-52, CBU-58, PTK-250, RPK-250 and RPK-500 cluster bombs are equipped with high explosive fragmentation sub-munitions, with incendiary contents. These cluster bombs are good for anti-material and anti-personnel purposes, and are ideal for attacking troop concentrations and soft skinned unprotected vehicles. The CBU-58 has a greater incendiary effect compared to the CBU-52. Similarly the RPK-500 has a better

Figure 13: Mk-20 Rockeye Cluster Bomb

incendiary effect against soft skinned vehicles when compared to the RPK-250. These cluster bombs are not as effective against hard targets as the Mk-20 or CBU-87.

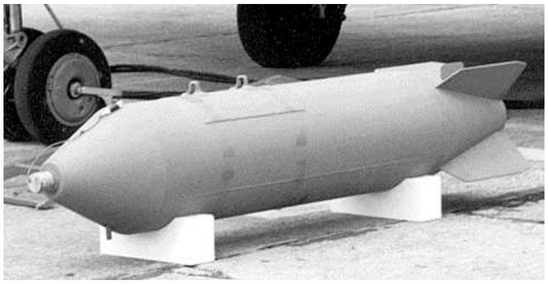

Figure 14: Russian RPK-500 Cluster Bomb

The Mk-20 Rockeye is a dedicated anti-armor cluster bomb filled with 247 Mk-118 bomblets. The bomblet contains a shaped charge which is ideal for use against hard targets such as tanks, gun emplacements, and armored personnel carriers. These bomblets are also highly effective against parked aircraft and other soft skin targets. If you are tasked against armored targets, you should load up with the Mk-20 in preference to the CBU-52/58 weapons. The Rockeye is however not as effective as the CBU-87/B as the HEAT only bomblets lack the fire starting capability of the CBU-87/B's bomblets. The Russian equivalent of the Mk-20 is the PTK-250 cluster bomb. Each PTK-250 cluster bomb dispenser is equipped with 30 PTAB-2.5 anti-armor bomblets. The dispersion pattern is not as extensive as the Mk-20 though, due to the lower bomblet count.

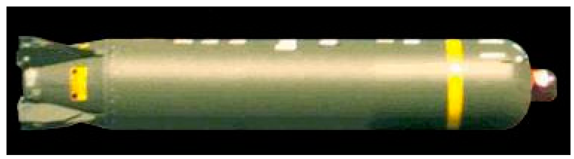

Figure 15: CBU-87/B CEM

The CBU-87/B Combined Effects Munition (CEM) is a multi-purpose cluster bomb loaded with 202 BLU-97/B sub-munitions. The BLU-97/B sub-munition is designed with a shaped charge to penetrate armor, a fragmentation body for anti-personnel and anti-material effects, and a zirconium incendiary ring to start fires. This makes the CBU-87/B an ideal all purpose weapon for use against hard and soft targets. The CBU-87/B is a cluster bomb of choice compared to the other CBUs due to its versatility.

The CBU-52 weighs 675lb., and both the CBU-87 and the CBU-58 cluster bombs weigh 940lb., while the Mk-20 weighs approximately 470lb. The RPK-250 and PTK-250 cluster bombs weigh approximately 500lb. each, while the RPK-500 weighs 1,153lb.

Figure 16: Deployment of CBU-97/B against armored targets

CBU-97 SFW Cluster Bomb

The CBU-97/B Sensor Fused Weapon (SFW) is a cluster bomb filled with 10 BLU-108/B bomblets. The bomblet is a cylindrical body containing four skeet projectiles, each equipped with stabilizing parachute and rocket motor. The skeet warhead consist of a shaped charge with an IR seeker to detect the presence of armor targets. The skeet warhead then fires a shaped charge at a selected aim point on the top side of the target. Generally, you can expect up to 4 T-72 type targets to be destroyed per SFW on a single pass, though you are advised to release them singly to avoid overlapping the damage pattern. You can read about the CBU-97 in greater detail in the section titled "*Arming The Birds of Prey*," which is found in the designer's notes. The CBU-97/B weighs approximately 1,000lb.

GUIDED BOMBS

GBU-24B/B and GBU-28/B Penetration Laser Guided Bombs

These are penetration bombs equipped with the LGB guidance kits. The GBU-24B/B is equipped with the BLU-109/B hard target penetrator bomb, while the GBU-28/B is equipped with the a penetrator warhead modified from an 8" artillery barrel. Both bombs are designed to attack hardened targets such as underground command bunkers and hardened aircraft shelters. The GBU-24B/B is a 2,000lb. class weapon, while the GBU-28/B tips the scale at approximately 4,700lb., with the F-111 being the only aircraft that can carry it.

Figure 17: GBU-24B/B Paveway III LGB

GBU-12B/B, GBU-10C/B, KAB-500L, and KAB-1500L Laser Guided General Purpose Bombs

Figure 18: Russian KAB-500L LGB

These laser guided bombs are equipped with the same warhead as the Mk-82, Mk-84, FAB-250 and FAB-1000 general purpose bombs. The warhead is mated to a tail kit and a front laser seeking guidance section.

Being laser guided bombs, you will need to carry a laser target designator pod such as the LANTIRN targeting pod to designate the target. The blast and shock wave effect of these bombs are the same as the unguided HE bombs. Being precision strike weapons, these bombs are ideal against targets such as buildings, runway intersections, bunkers, and general infrastructure, or even individual vehicles, especially if your concern is to minimize collateral damage. The GBU-12B/B and GBU-10C/B weigh approximately 600lb. And 2,050lb. Respectively, while the KAB-500L and KAB-1500L weigh approximately 1,000lb. And 3,000lb. Respectively.

GBU-15 Glide Bomb

The GBU-15 is a TV/IIR guided glide bomb that can be carried by the F-111 and F-15E aircraft. The bomb consist of a Mk-84 warhead married to a TV/IIR seeker and a tail unit. The bomb is controlled by a datalink pod carried on the launch aircraft. This bomb has a glide range of up to 15nm. when released from high altitude, and 5nm. when released from low altitude. It has to be manually flown into the target by the weapon system officer on the launch aircraft. The advantage of this weapon is the stand-off attack range, which allows the strike aircraft to hit the target with the same precision as laser guided bombs, but from a greater distance away, usually outside the air defense engagement ranges. This is a weapon of choice if you need to attack heavily defended targets.

Figure 19: GBU-15 TV Guided Glide Bomb. (Picture credit of USAF)

Air-to-Surface Missiles

AGM-65B, AGM-65D and AGM-65G Maverick

Figure 20: AGM-65 in flight. (Picture credit of USN)

The Maverick missile is a subsonic surface attack missile. Both AGM-65B and AGM-65D are armed with a 125lb. shaped charge warhead that is ideal for attacking tanks, vehicles, and small fortifications such as gun emplacements and SAM launchers/radars. AGM-65G is equipped with a 300lb. HE penetrator fragmentation warhead, designed to penetrate hardened targets, and is ideal for attacking buildings, infrastructure, bridges, and small ships.

The B version has a TV guidance unit, and as such, is only useful in daylight conditions. Due to the lower magnification of the seeker, the TV seeker can only lock onto small targets such as tanks inside of 6 – 8nm.. The TV seeker can however be confused by battlefield smoke and atmospheric haze. The D and G versions are equipped with an imaging infra-red seeker, and are useful for all weather operations including night operations. The IIR seeker on the D and G versions of the Maverick has higher magnification, and is capable of locking onto targets from a range of 8 – 10nm..

The AGM-65B is ideal for daylight operations, and you should reserve the AGM-65D for night missions. Both missiles are ideal for attacking tanks and SAM sites, as they give a greater stand-off range compared to laser guided bombs, and may allow you to shoot at the SAM site from outside their engagement range. The AGM-65G should be reserved for attacking hardened targets and larger vehicles such as ships, and should not be wasted on attacking tanks. The AGM-65B and D versions weigh approximately 470lb., and the AGM-65G version weighs approximately 670lb. due to the heavier warhead.

AGM-84E SLAM

The AGM-84E Stand-Off Land Attack Missile (SLAM) is a modification of the AGM-84 Harpoon anti-ship missile. The missile is equipped with a turbofan engine, a 500lb. HE warhead, a datalink section, and an IIR seeker from the AGM-65D. The missile is guided inertially throughout, until the terminal phase, when the IIR seeker is turned on. The FLIR picture is transmitted back to the launch aircraft through the datalink. The pilot can then select the aim point and lock onto the target.

Figure 21: AGM-84E SLAM (Picture credit of Boeing)

The missile weighs about 1,280lb., and has a range of about 25 – 45nm., depending on the launch altitude. This is a USN only weapon, and can be carried by the F/A-18 aircraft. As with the GBU-15 glide bomb, this weapon allows the launch aircraft to attack the target from great stand-off distances, remaining out of reach of the enemy air defenses, yet retaining the precision strike capabilities of laser guided munitions.

Figure 22: AGM-130A on F-15E Strike Eagle. (Picture credit of USAF)

AGM-130A

The AGM-130A is a modification of the GBU-15 modular glide bomb. The missile is created by strapping a rocket motor onto the GBU-15 bomb, and weighs almost 2,900lb. The purpose of this missile is to extend the stand-off range of the basic GBU-15 glide bomb, to about 25nm. when released from an altitude of 25,000 feet, and about 8nm. when released from low altitudes. This missile can only be carried by the F-15E, F-111, and F-4E (South Korea).

This missile is useful against infrastructure type of targets, such as control towers, communication towers, etc. You should only use this missile if you intend to have a precision strike capability, and need to strike at heavily defended targets. The high cost of this missile means that you will not have many of these, and if the defenses are not too heavy, you should always use the cheaper LGBs instead.

AGM-142A Raptor (Have Nap)

The AGM-142A Raptor (formerly known as the Have Nap) is a stand-off air-to-ground missile manufactured by the Rafael Armement Authority of Israel. This missile weighs over 2,900lb., and has a 800lb. HE blast/fragmentation warhead. The missile has a range in excess of 40nm. when launched from an altitude of 25,000 feet, reducing to just over 15nm. when launched from low altitudes. The missile is guided by inertial guidance throughout most of its flight, and has an IIR seeker (similar to that of the Maverick missile) for terminal guidance. The seeker image is transmitted back to the launch aircraft, and the pilot/WSO will steer the missile towards the target through a datalink. This missile can be carried by the B-52 bombers (up to four missiles may be carried), and the ROK air force has procured 116 of these missiles to equip their F-4Es with a stand-off strike capability.

Figure 23: AGM-142A loaded on B-52H. (Picture credit of USAF)

The large warhead and long range of this missile makes it a suitable weapon for attacking heavily defended targets, such as nuclear reactors and C^3I facilities. However, the high cost of the missile (approaching US$1 million apiece) means that you will not have many of these missiles available.

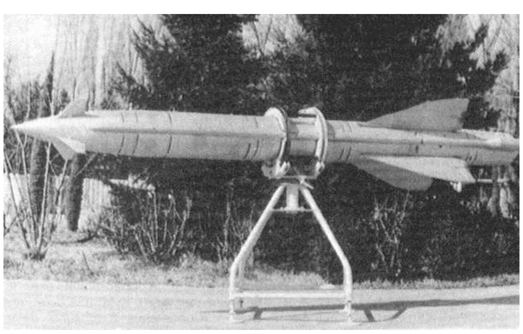

Figure 24: AS-7 (Kh-23 GROM) Kerry ASM

AS-7 (Kh-23) Kerry

This is a short range, command guided missile that was developed from the AA-1 air-to-air missile, and is known to the Russians as the Kh-23. The missile is equipped with a 240lb. warhead and the missile weighs 640lb. Guidance is via a command link and the pilot has to manually line up the missile with the target and steer it with a joystick. This severely restricts the stand-off range of the missile, and makes the firing aircraft very vulnerable to SHORAD threats. The missile range is approximately 3nm., and it can be used to attack vehicles and hardened targets such as gun emplacements. The AS-7 missile can be carried by MiG-23, MiG-27, Su-17 and Su-25 aircraft, and has been exported to North Korea, and you will often see Su-25s launching them over the FLOT.

AS-10 (Kh-25) Karen

This is a second generation tactical short range surface attack missile that can be carried on the Su-17, Su-24, Su-25 and MiG-27 aircraft, and is known to the Russians as the Kh-25. The missile can be radio command guided or laser guided, and weighs approximately 660lb. The warhead is only 200lb., and the missile can be fired from up to about 10nm. range, depending on the launch altitude. As with the AS-7, this missile can be used to target vehicles and hardened targets, though the small warhead means that the effect against large buildings will be limited. The slightly longer range will allow the attacking aircraft to minimize the exposure to SHORAD threats. This missile was never exported to North Korea.

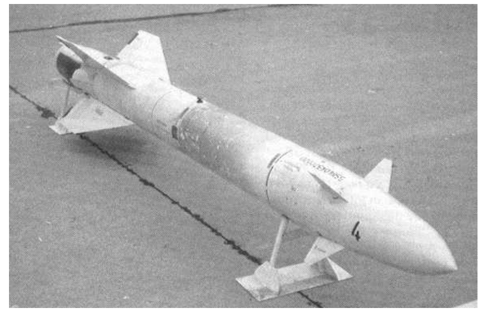

Figure 25: AS-10 (Kh-25) Karen command guided ASM

AS-14 (Kh-29) Kedge

Figure 26: AS-14 (Kh-29) Kedge ASM

This is a third generation tactical medium range surface attack missile known to the Russians as Kh-29T/L. The missile can be carried on the Mirage F1, Su-17, Su-24, Su-25, MiG-27, and later models of the MiG-29 aircraft. The missile is guided by a TV seeker mounted in the nose, and tips the scale at 1,450lb. The large warhead weighing almost 700lb. means that this missile packs a greater punch that the earlier AS-7 and AS-10 missiles, and is effective against buildings, hardened shelters, bridges, runways, and ships. The missile has a range in excess of 15nm. when launched from high altitude, and has been exported to ex-Warsaw Pact countries as well as Iraq.

AS-18 (Kh-59M Ovod-M) Kazoo

The AS-18 Kazoo (also known to the Russians as the Kh-59M, or the X-59M for the export version) is a derivative of the AS-13 (Kh-59) “Kingbolt” missile. This missile can be carried on the MiG-27, Su-24, and Su-25 aircraft. The missile has four narrow swept and clipped delta fins at the nose, and a turbojet engine fitted under the missile body. The launch weight of the missile is 2,050lb. Mid-course guidance is inertial, with command updates. The missile has a TV seeker in the nose, and transmits the imagery back to the launch aircraft during the terminal phase. This allows the pilot to steer to missile to the impact point. The large 700lb. HE/blast penetration warhead packs a greater punch than the AS-7 and AS-10 missiles, and is effective against buildings, hardened shelters, runways, ships, and other C^3I facilities. This missile has a range in excess of 50nm. when launched from high altitudes, and a range approaching 22nm. when launched from low altitudes.

Figure 27: AS-18 (Kh-29M Ovod-M) Kazoo

ANTI RADIATION MISSILES

Figure 28: AGM-45 Shrike (Picture credit of USAF)

AGM-45 Shrike

The Shrike missile is modification of the basic AIM-7 airframe into an anti-radiation missile. The missile weighs 390lb., and is equipped with a 145lb. HE fragmentation warhead for blast effect. Guidance is by passive radar homing, and the missile can be equipped with a variety of homing heads tuned to different narrow frequency bands. This missile is largely obsolete due to its lack of programmability, slow speed, and limited range of only 7nm.. Employment of the missile will often require the launch aircraft to enter the engagement range of the SAMs. You are better off using the Shrike against mobile air defenses such as SA-8, SA-15, SA-19, and ZSU-23-4, as these ADA assets have shorter engagement ranges of less than 6nm.. If you intend to attack SAM sites such as Patriots, I-HAWK and SA-2, you are better off using the AGM-88 HARM.

AGM-88 HARM

The HARM missile is a second generation anti-radiation missile developed from the AGM-45 Shrike. The HARM is equipped with a broad band antenna, and the guidance processor software is reprogrammable. The warhead is a 145lb. HE fragmentation type, with tungsten cubes to enhance the fragmentation effect. The HARM operates by homing on the emissions from hostile radars, which may be detected by the AN/ASQ-213 HARM Targeting System (HTS), carried on the right intake station of the F-16.

Figure 29: AGM-88 HARM (Picture credit of USAF)

The HARM missile can reach up to 12nm. when launched from low altitudes, and beyond 20nm. when launched from higher altitudes. The missile will accelerate and climb once launched, and then perform a terminal dive onto the target. The seeker sensitivity extends to slightly behind the missile, though when fired as such, the missile will lose a tremendous amount of energy to fly the attack course. This is the missile of choice if you need to attack SAM sites with considerable reach, though you will still need to fly into the lethal range of Patriot and SA-5 if you intend to attack them. This missile is also ideal for attacking GCI and EW (Early Warning) radar sites as part of a co-ordinated effort to degrade the enemy's C^3 facilities.

AS-11 (Kh-58) Kilter

Figure 30: AS-11 (Kh-28) Kilter Anti-Radiation Missile

The AS-11 missile is a third generation Russian anti-radiation missile developed in the early 1970's to complement the AS-9, and comes with the Russian designation Kh-58. This missile was designed to attack ground and shipborne radars, and weighs 1,400lb. The HE fragmentation warhead weighs 330lb. This missile has a tremendous speed, and a range in excess of 30nm. when launched from medium altitude. The AS-11 can be carried by the Su-17, Su-24, as well as the MiG-27 aircraft. The missile is still in service with the Russian air force, and was reported to be in service with the North Korean air force. If you are tasked to defend key radar installations, be sure to position your CAP route at a distance far enough from the radar site, such that you can intercept the enemy before the radar installation enters the firing range this missile. With the exception of the Patriot, all other SAM sites will be within the reach of this missile, while the launching aircraft remains out of range of the SAM.

AS-12 (Kh-25MP) Kegler

The AS-12 missile is a second generation Russian anti-radiation missile developed in the early 1970's to replace the AS-9. The Russian designation for this missile is Kh-25MP. This missile was designed to be launched from low altitudes to improve the survivability of the launch aircraft. The missile weighs 700lb., and is equipped with a 200lb. warhead. The AS-12 missile is a close cousin of the AS-10 missile, and can be carried on the MiG-27, Su-17, Su-24, and Tu-22M. The low altitude range of the missile is about 14nm., increasing to nearly 20nm. when launched from medium altitude. This missile is in service with the Russian air force and ex Warsaw Pact countries, but was never exported to North Korea or other Arab countries other than Syria.

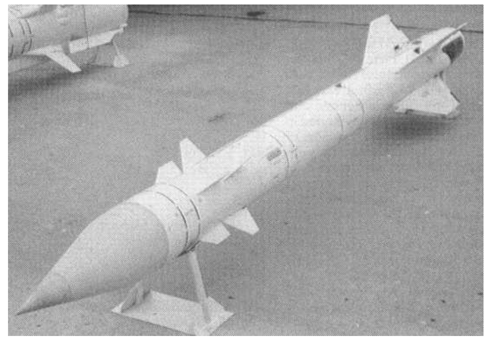

Figure 31: AS-12 (Kh-27) Kegler ARM

AS-17 (Kh-31P) Krypton

Figure 32: AS-17 (Kh-31P) Krypton ARM

The AS-17 (Kh-31P) Krypton missile was first unveiled at the 1991 Dubai Air Show. Development of the missile began in the 1970's, as a follow-on to the AS-12 missile. The key development objective were to improve the AS-12 performance, and to counter the MIM-104 Patriot as well as the AN/SPY-1 Aegis phased array radar systems. This missile is powered by a solid fuel boost motor, and four ramjet sustainer motors mounted on the outside of the missile body. The booster motor accelerates the missile to Mach 1.8, and the sustainer motors then take over and accelerate the missile to a cruise speed of Mach 3.0. The missile will climb sharply immediately after launch, and the terminal attack profile is a very steep high speed dive, making it very difficult to counter. This gives the missile an effective range of over 50nm. when launched from high altitudes, with a low altitude range of more than 25nm.. The missile weighs approximately 1,350lb., and the warhead weighs 195lb. The basic missile airframe was also developed into the MA-31 supersonic target. The US Navy purchased several units of the MA-31 for ship defense training in 1994, and the missile reportedly managed to evade all the ship defense systems during trials. This missile is the only OPFOR missile capable of targeting the Patriot air defense batteries close to the edge of the Patriot engagement envelope, and allows the attacker to shoot and turn away without entering the inner engagement envelope of the Patriot battery. The missile can be carried by the MiG-27, Su-24, and the PRC Su-30MKK aircraft, and poses a serious threat that is very difficult to counter.

<u>UNGUIDED ROCKETS</u>

LAU-3/A 2.75" FFAR

The LAU-3/A is a 19 round launcher for the 2.75" FFAR (Folding Fin Aerial Rocket). The 2.75" FFAR is a simple steel tube filled with rocket propellant and a small warhead, and is designed to be fired singly or ripple fired.

The ballistics of the rockets varies a lot due to the inherent design, so the hit pattern will result in considerable dispersion. These rockets are excellent for close air support purposes, especially against soft skin vehicles and troops, but you should not expect much damage from them as they need to score a direct hit in order to destroy a vehicle. Normally, a maximum of 2 to 3 vehicles may be destroyed for one 19-round salvo. If you expect to face considerable SHORAD threat, you are advised not to use rockets, as you will need to descend to fairly low level (approximately 2,000 feet or less) in order to be accurate. The slant range of 8,000 feet is also a handicap as this will force the attacker to overfly the SHORAD threat after releasing the rockets.

If you are flying FAC missions, rockets are handy for marking targets. A single shot will often serve to highlight the position of the target for the CAS airplanes to follow-up with their attack. This is also a good way of giving a target location unambiguously, without having too much radio chatter.

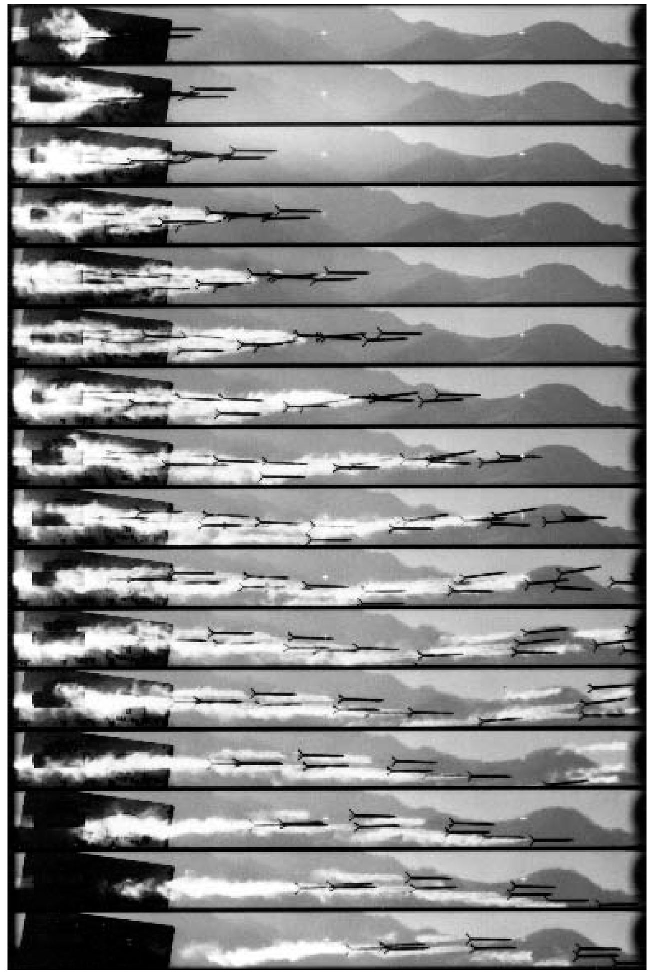

Figure 33: High speed time lapse photography of the ripple firing of the 2.75" "Mighty Mouse" Folding Fin Aerial Rockets. (Picture credit of USN)

Figure 34: UB-32-57 rocket pod loaded on Mi-17 helicopter.

UB-19-57, UB-32-57, S-24

These are Russian aerial rockets of different caliber and warhead sizes. As with the American 2.75" FFAR, these rockets do not have a long range, and will require the attacker to fly close to the target before launching. The dispersion pattern is also large, hence further decreasing the accuracy of single shots. Your best approach is to ripple fire all the rockets in the pod to increase the probability of hitting a specific target. The UB-19-57 and UB-32-57 are 19-round and 32-round 57 mm rocket launchers, firing the S-5 rockets. The S-24 is a heavy 125 mm calibre rocket designed to destroy targets such as bridges and buildings, and is carried singly on each pylon.

WEAPON SELECTION

The weapon that you should select will obviously depend on the target type, and the type of air defenses that you will face. If you anticipate extensive SHORAD threat or if your target is equipped with organic MANPADS, you may wish to switch to using medium level delivery of cluster bombs to maximize the kill area. Missiles such as the Maverick are good for their stand-off distances, and allow you to target individual vehicles and gun emplacements without straying into SHORAD envelope.

You are not constrained to having the same weapons loaded on all aircraft in your flight. A mixed loading is sometimes a better approach. For example, if your flight is targeted against a SAM site, only one or two of the flight members need to be equipped with HARM, as one accurate shot is enough to knock out the SAM site. The remaining flight members may be armed with cluster bombs to destroy the launchers, after the SAM site has been rendered ineffective by destroying the radar.

Figure 35: Serbian T-55 caught in the cross hairs of the LANTIRN targeting pod moments before the LGB impact during Operation Allied Force. The LANTIRN targeting pod allows precision strikes to be carried out from medium level altitudes, above the engagement altitude of SHORAD threats. (Picture credit of NATO)

Stand-off weapons will allow you to target infrastructure that is heavily defended, without the strikers having to run the gauntlet of air defenses. Missiles like AGM-130 and AGM-84E SLAM are good for such purposes, and allow the strikers to attack from safe distances. You may be able to cut down on the support flights within the package (such as SEAD escorts and escorts) if the strikers have the ability to hit from afar. However, you will not have many of these weapons available due to their high costs, so you will need to ensure that these weapons are reserved for use against high value targets.

Bear in mind that the weapons that you select will often dictate your tactics. An extremely low level attack makes cluster bombs a bad choice, for example, as the cluster bombs may not have sufficient altitude to disperse the sub-munitions. Similarly, a low level CCRP delivery profile will make low drag general purpose bombs a bad choice, as you may not be able to fly clear of the fragmentation pattern in time. Choosing an anti-radiation missile of insufficient range may also force you to fly into the lethal engagement range of the SAM site before you are able to launch the missile.

Take your time to consider the different weapon characteristics, and plan your attack carefully. You will be able to maximize your kills while staying safe from the enemy's air defenses. Always bear in mind that your mission is to destroy the target without getting creamed yourself, and preferably without the enemy being able to take a shot at you.

THE ART AND SCIENCE OF MOVING MUD

Air-to-Surface Attack Planning
By "Hoola"

INTRODUCTION

An important part of pre-flight mission planning is the attack planning. This involves detailed study of the target's characteristics, local geography, air defenses, etc., as well as selection of the attack profile. While the computerized bombing system of the Viper will automatically compute the weapon release parameters, it will help you perform better if you are able to anticipate what is to happen during the bombing run. Half the success of any attack mission lies in the planning process, and if a mission is well planned, it will remove many uncertainties during your final attack run-in, and leave you with more mental capacity to handle other tasks, such as looking out for threats.

There are several attack profiles available. We will discuss the merits and disadvantages of each of them, and step you through the planning of the release parameters. This section may be very boring and academic, but you must remember that good planning is essential to the success of any mission. You should develop the discipline of planning your mission thoroughly, and maximize the damage that you can bring about to the enemy. For additional information on air-to-ground attack planning and tactics, a good reference source is the *USAF Multi-Command Handbook 11-F16, Volume 5, F-16 Combat Aircraft Fundamentals*, available at http://www.fas.org/man/dod-101/sys/ac/docs/16v5.pdf.

TARGET STUDY

The sole purpose of any surface attack mission is to deliver the ordnance onto the intended target. You should make use of the "Recon" feature in the mission planning screen to help you visualize the target and its local geography. Your considerations should include at least the following:

Figure 36: Satellite imagery of the Pristina fuel depot in Serbia, prior to its destruction by NATO jets during Operation Allied Force. Detailed target study is an integral part of strike mission planning. (Picture credit of NATO)

1. What is the target's elevation? There is no easy way of estimating this in Falcon 4, and you will need to guess the approximate altitude based on the local geography. This will determine your minimum release altitude, especially if you are attacking with cluster bombs. For example, if the target is at an elevation of 1,000 feet, and you have set the cluster bomb to burst at 1,500 feet, then it will only burst at an altitude of 500 feet AGL, since the cluster bomb burst height is barometric and not AGL. The target elevation will also affect whether you will enter any SHORAD envelope during the release and the dive pull-out. For example, if the target is at an elevation of 1,000 feet, and is defended by SAMs with an effective altitude of 10,000 feet, you will enter the effective envelope of the air defenses when you are at a barometric altitude of 11,000 feet.

2. Is the target situated on flat ground or on a hill? If it is the former, then you are not limited in your choice of attack heading. If it is the former, then your choice of attack heading is limited to the side of the hill that the target is sited on. For example, if the target is on the

eastern slope of a hill, then you can only attack it by flying on a westerly heading, since the target will be masked if you attack on an easterly heading.

3. How are the targets distributed? If you are attacking a column or formation of vehicles, what is the heading that they are travelling along? You may want to attack the column along its direction of travel, rather than perpendicular to it, so as to maximize the bomb fall pattern on the targets. If you are attacking a SAM site, how are the launchers distributed? Where is the fire control radar located? How will the GM and GMT radar picture look like from your attack heading? Will you be able to locate your primary target easily on radar? What is the bomb release interval that you will need to select in order to maximize the target coverage?

4. How does the target area look from your attack altitude and heading? You should adjust the controls on the "Recon" (viewing angle as well as the zoom controls), and study the target in detail.

5. Where are the air defenses located? Are you facing IR SAMs? If so, you may want to plan your attack axis such that the sun is behind you. This prevents a head-on shot against you during your attack run-in. Which direction should you turn after releasing the ordnance? This will depend on the location of the air defenses, and you will certainly not want to turn towards an AAA site during your egress.

6. What is the weather over the target area? Where is the cloud base? If the cloud base is low, you may not be able to use LGBs from medium level altitudes. You will also have to descend below the cloud base to use any electro-optical weapons, or if you want to bomb visually. What is the wind direction? Will the smoke and debris from your wingman or package member's bombs be blown over the target, such that it will be obscured by the time you attack it?

Giving considerations to all of the above factors will help you determine the attack profile that you should use, and the attack axis. It will also familiarize you with the way the target will look like during the attack. With these information available, you will then be able to plan the route, and place the waypoints as well as initial point (IP) and action point.

ROUTE PLANNING AND DE-CONFLICTION

All the detailed target study will go to waste if you plan your flight route haphazardly. Route planning is an important activity, as not only does it help you avoid known threats, it will also help get you to your target on time. The default flight route given by the ATO generator may not necessarily be the best, although it is a good starting point.

Now that you have studied the target in detail, and have decided your attack axis, as well as ingress and egress directions, you can start altering the flight plan to suit your needs. You should alter the location of the initial point (IP), such that you will be flying along the attack axis once you have passed the IP. This may not be true if you decide to conduct an off-set pop-up attack, but more on that later. The steerpoint after the target should also be placed such that it is in the direction at which you will egress after bombing the target. You should also take the opportunity to fix the TOT (Time Over Target). Do not be overly concerned about the altitude and the airspeed at the target and the IP at this point in time, as you will still need to make some fine adjustments after you have done your detailed attack profile planning. As long as these are not way off the mark, you can leave them alone.

You can then adjust the remaining steerpoints (and add/delete if necessary), keeping your route away from known threats, such as SAM sites, ground units, AAA sites, and CAPs. This is where the threat analysis will pay off (see the section titled "*Knowing Your Enemy*"). With the knowledge of the capabilities of the threats arrayed against you, you should be able to plan your flight route to avoid most if not all of them. Be sure that you study the mission planning map carefully, and identify the locations of the ground as well as air units along your entire flight route. Note that the situation may change once you are airborne, and the “fog of war” may not provide a complete picture of the battlefield at the time of mission planning.

If you are flying in a multi-player mission, or as part of a multi-package strike mission, you will also need to consider de-conflicting the TOT for different members of the flight, and different packages. The airspace over the target can become congested if every flight member is to arrive at the same time, and the risk of mid-air collision increases tremendously under such circumstances.

You should also consider the minimum interval between the TOT of various members of the same flight, if they are bombing the same target. This is especially important if you are using a low level weapon delivery profile. The minimum interval between flight members should allow for the flight time of the ordnance. For example, if the bombs require a flight time of 10 seconds between release to impact, then, for a start, the TOT between each aircraft should be spaced at least 10 seconds apart. This will be increased by the time required for the bomb fragments from the resulting explosion to descend back to the ground, and a rule of thumb to use is to add approximately 15 to 20 seconds. For this example, the minimum TOT spacing between each aircraft should be at least 25 to 30 seconds to allow for this.

The last thing to consider is planning a different attack axis for each member of the flight. This ensures that the target is attacked from multiple directions, and adds an element of surprise to the air defenses. This is very useful especially if you are attacking SAM sites, as it allows you to overwhelm the SAM site since the SAM battery will not be able to engage any targets outside its sensor’s azimuth coverage. If the SAM battery targets a specific flight member, the remaining flight member can attack it from a different direction, and can often remain undetected and unmolested during the attack run-in.

ORDNANCE CONSIDERATIONS

The type of ordnance that you are carrying will determine the feasibility of the delivery profile, as well as the placement of the initial point and action point. The planning considerations for the various ordnance types are as follows:

Safe Escape

The minimum release altitude for ordnance is determined by fuse arming requirements (which is not modeled in Falcon 4), and the safe escape requirement. The latter allows the aircraft to escape from the fragmentation pattern of its own bombs, so as to avoid being damaged by the explosion. The safe escape minimum release altitude is dependent on the release profile, as well as the escape maneuver. For planning purposes, typical safe escape minimum release altitudes (MRA) for low drag bombs and various escape maneuvers are given in Table 3 through Table 5. For high drag bombs, as long as you release them at an altitude of at least 300 feet, you should not be concerned about safe escape.

The escape maneuvers are as follows:

i. For level release, a constant speed, no-turn profile. The time duration to maintain the profile is 3 seconds more than the time-of-flight (TOF) of the bombs. For example, if the TOF for a level release is 6 seconds, then the escape maneuver is a level constant speed maneuver of 9 seconds in duration. This is known as the **Level Constant Speed, No-Turn** maneuver.

ii. For a dive release, the escape maneuver is to initiate a 5g pull-up after releasing the bombs, and maintaining 5g until the aircraft pitch attitude reaches 20°. The g is reduced gradually to 1g as the aircraft achieves a 30° climb. This is known as the **5g Climb** maneuver.

Note that the minimum release altitudes given in this manual pertain only to Falcon 4 Realism Patch. They should not be construed as representative of actual ordnance, and neither should they be used for actual ordnance release.

500lb. (250 kg) Low Drag General Purpose HE Bomb		
Release TAS (kts)	**MRA (ft)**	**Bomb TOF (sec)**
450	850	7.0
500	750	6.5
550	650	6.0
600	550	5.5
2000lb. (1000 kg) Low Drag General Purpose HE Bomb		
Release TAS (kts)	**MRA (ft)**	**Bomb TOF (sec)**
450	1450	9.5
500	1350	9.0
550	1200	8.5
600	1000	7.5

Table 3: Minimum Release Altitude, Level Constant Speed No-Turn Escape Maneuver

500lb. (250 kg) Low Drag General Purpose HE Bomb			
Dive Angle (deg)	**Release TAS (kts)**	**MRA (ft)**	**Bomb TOF (sec)**
0	450	350	4.5
	500	300	4.0
	550	270	3.7
	600	260	3.5
10	450	870	4.2
	500	900	4.0
	550	900	3.8
	600	870	3.5
20	450	1400	4.3
	500	1500	4.2
	550	1550	4.0
	600	1530	3.7
30	450	1900	4.3
	500	2050	4.2
	550	2200	4.0
	600	2200	3.9
40	450	2400	4.3
	500	2600	4.2
	550	2700	4.1
	600	2900	4.0
50	450	2750	4.3
	500	3000	4.2
	550	3250	4.2
	600	3500	4.2

Table 4: Minimum Release Altitude, 500lb. HE bomb, 5g Climb Escape Maneuver

2000lb. (1000 kg) General Purpose HE Bomb			
Dive Angle (deg)	Release TAS (kts)	MRA (ft)	Bomb TOF (sec)
0	450	410	4.9
	500	390	4.7
	550	390	4.6
	600	380	4.5
10	450	1050	4.8
	500	1080	4.7
	550	1150	4.6
	600	1200	4.5
20	450	1650	4.8
	500	1750	4.8
	550	1850	4.6
	600	1950	4.6
30	450	2200	4.8
	500	2400	4.8
	550	2550	4.7
	600	2700	4.6
40	450	2750	4.8
	500	3000	4.8
	550	3150	4.7
	600	3400	4.6
50	450	3250	4.9
	500	3500	4.8
	550	3700	4.7
	600	4050	4.8

Table 5: Minimum Release Altitude, 2,000lb. HE bomb, 5g Climb Escape Maneuver

Cluster Bomb Splash Pattern

Cluster Bomb Type	Cluster Bomb Pattern Diameter (feet) for Various Burst Height									
	BA 300	BA 500	BA 700	BA 900	BA 1200	BA 1500	BA 1800	BA 2200	BA 2600	BA 3000
CBU-52B/B	696	898	1063	1205	1391	1556	1704	1884	2048	2200
CBU-58A/B	885	1143	1353	1534	1771	1980	2169	2398	2607	2800
CBU-87	632	816	966	1095	1265	1414	1549	1713	1862	2000
CBU-97	632	816	966	1095	1265	1414	1549	1713	1862	2000
Mk-20D	506	653	773	876	1012	1131	1239	1370	1490	1600
PTK-250	569	735	869	986	1138	1273	1394	1541	1676	1800
RPK-250	474	612	725	822	949	1061	1162	1285	1396	1500
RPK-500	885	1143	1353	1534	1771	1980	2169	2398	2607	2800

Table 6: Falcon 4 Cluster Bomb Pattern Diameter for Various CBU Burst Height

When deploying cluster bombs, an important consideration is the splash pattern, or "footprint" of the bomblets. You can change the area covered by the bomblets by altering the inter-bomb spacing, and altering the burst height, in the Stores Management System (SMS). For planning purposes, typical cluster bomb pattern diameter for various burst height are given in Table 6.

Note that the release dive angle does not affect the pattern diameter significantly, and will generally vary the pattern diameter by about ±15%. You can approximate the pattern diameter by taking the cosine of the dive angle multiplied by the pattern diameter in a level release.

DIVE RECOVERY CONSIDERATIONS

If you are delivering the ordnance in a dive, you will need to consider the altitude lost during the dive pull-out. This will prevent you from adopting a dive profile that will lead to excessive altitude loss during pull-out. The consequence of excessive altitude loss is obvious, as you will either stray into SHORAD envelope or stay in SHORAD envelope for a longer time, or, in the worst case, you will auger into the ground during the dive recovery.

The approximate altitude loss during pull-out for various airspeeds, and altitudes, for 3g and 5g pullouts, are given in Table 7. This is on assumption of the following flight parameters:

i. IDLE thrust at the commencement of pullout
ii. Immediate pullout initiation after ordnance release
iii. Wings level
iv. Maximum g onset rate
v. Full speedbrakes at the commencement of pullout

3g Dive Pullout			5g Dive Pullout		
Calibrated Airspeed (KCAS)	Initial Dive Angle (deg)	Altitude Loss (feet)	Calibrated Airspeed (KCAS)	Initial Dive Angle (deg)	Altitude Loss (feet)
300	15	400	300	15	150
	30	1100		30	800
	45	2200		45	1400
350	15	450	350	15	200
	30	1300		30	800
	45	2700		45	1600
400	15	500	400	15	350
	30	1400		30	950
	45	3200		45	1850
450	15	600	450	15	400
	30	1800		30	1100
	45	3800		45	2200
500	15	700	500	15	500
	30	2100		30	1300
	45	4200		45	2450
550	15	800	550	15	600
	30	2400		30	1400
	45	4800		45	2800

Table 7: Approximate Altitude Loss For 3g and 5g Pullout During Dive Recovery

To determine the approximate altitude loss during dive recovery, you can interpolate between the different airspeeds and dive angles. The exact altitude loss will be dependent on the initial altitude, due to slightly different air densities, but the variation between an initial altitude of 5,000 feet and 15,000 feet is small, and for can be ignored for all intent and purposes of gameplay.

WEAPON BALLISTICS

The final piece of information that you will need for mission planning is the weapon ballistics. Knowing how far the weapon will fly upon release will help you decide on the delivery profile. It is useless going through all the planning for a loft delivery in hope of staying out of the SHORAD engagement envelope, if the bomb cannot fly out to the required range.

Weapon ballistics depends on a number of factors. Although the trajectory of the ordnance is simple kinematics, the slight differences in drag between each ordnance type will introduce small differences. For the purpose of gameplay, these differences are small, and within 5 to 10% of one another. Since Falcon 4 does not have any provisions for manual bombing and ballistics, you should simply let the fire control compute take care of all the bombing solutions. Knowledge of weapon ballistics is helpful for initial mission planning, for no other reason than to highlight to you that you may not be able to stay out of the target's air defense engagement zones whichever delivery profile you choose.

You can compute the weapon ballistics using simple kinematics equations. The approximate bomb range and time-of-fall (TOF) for all weapons are given in Table 8 for level release, Table 9 and Table 10 for dive release, and Table 11 for loft toss release, for your convenience. The data given pertain to low drag bombs of all tonnage, as well as laser guided bombs and cluster bombs. Ballistics of high drag bombs are not presented here, since you will need to overfly the target anyway.

Level Release							
Release Altitude (ft)	**Release TAS (kts)**	**Bomb Range (ft)**	**Time of Fall (sec)**	**Release Altitude (ft)**	**Release TAS (kts)**	**Bomb Range (ft)**	**Time of Fall (sec)**
500	400	3500	5.3	1000	400	4950	7.6
	450	3850	5.3		450	5500	7.6
	500	4300	5.3		500	6100	7.6
	550	4700	5.3		550	6700	7.6
2000	400	7000	11.0	4000	400	9900	15.8
	450	7900	11.0		450	11050	15.9
	500	8700	11.1		500	12200	15.9
	550	9400	11.1		550	13200	16.0
5000	400	11100	17.8	10000	400	15500	25.6
	450	12300	17.9		450	17200	25.7
	500	13500	17.9		500	18900	25.8
	550	14700	18.0		550	20500	25.9
15000	400	18800	31.7	20000	400	21700	37.0
	450	20900	31.8		450	24100	37.1
	500	22900	32.0		500	26400	37.3
	550	24900	32.2		550	28600	37.5

Table 8: Weapon Ballistics for Low Drag Bombs, CBUs, and LGBs in Level Delivery

10° Dive				15° Dive			
Release Altitude (ft)	Release TAS (kts)	Bomb Range (ft)	Time of Fall (sec)	Release Altitude (ft)	Release TAS (kts)	Bomb Range (ft)	Time of Fall (sec)
1200	400	3600	5.6	1500	400	3500	5.7
	450	3900	5.4		450	3700	5.3
	500	4100	5.2		500	3900	5.0
	550	4300	5.0		550	4100	4.8
1500	400	4200	6.6	2000	400	4300	7.0
	450	4500	6.3		450	4600	6.6
	500	4800	6.0		500	4900	6.3
	550	5100	5.8		550	5100	6.0
2000	400	5100	8.0	4000	400	6900	11.4
	450	5500	7.8		450	7500	11.0
	500	5900	7.5		500	8000	10.7
	550	6300	7.3		550	8500	10.3
4000	400	7900	12.7	5000	400	8000	13.3
	450	8600	12.4		450	8700	12.8
	500	9300	12.1		500	9300	12.5
	550	9800	11.8		550	9800	12.2

Table 9: Weapon Ballistics for Low Drag Bombs, CBUs, and LGBs in 10° and 15° Dive Delivery

30° Dive				45° Dive			
Release Altitude (ft)	Release TAS (kts)	Bomb Range (ft)	Time of Fall (sec)	Release Altitude (ft)	Release TAS (kts)	Bomb Range (ft)	Time of Fall (sec)
3000	400	3800	6.8	4000	400	3200	7.0
	450	4000	6.3		450	3300	6.5
	500	4100	5.9		500	3350	6.0
	550	4300	5.6		550	3400	5.6
4000	400	4800	8.6	5000	400	3700	8.4
	450	5000	8.0		450	3900	7.8
	500	5200	7.6		500	4100	7.3
	550	5400	7.2		550	4200	6.9
5000	400	5600	10.2	6000	400	4400	9.8
	450	6000	9.7		450	4600	9.1
	500	6200	9.2		500	4700	5.6
	550	6500	8.7		550	4900	8.0
6000	400	6400	11.8	8000	400	5500	12.4
	450	6800	11.2		450	5800	11.5
	500	7200	10.6		500	6000	11.0
	550	7500	10.0		550	6200	10.5
8000	400	7800	14.6	10000	400	6500	14.8
	450	8400	14.0		450	6800	14.0
	500	8900	13.4		500	7100	13.5
	550	9300	12.8		550	7400	12.5

Table 10: Weapon Ballistics for Low Drag Bombs, CBUs, and LGBs in 30° and 45° Dive Delivery

45° Loft Toss							
Approach Alt Above Target (ft)	**Approach TAS (knots)**	**Release Angle (deg)**	**Release Attitude (deg)**	**Release Altitude (ft)**	**Time Pull-Up to Release (sec)**	**Range Pull-Up to Impact (ft)**	**Time Release to Impact (sec)**
200	500	45	48	2900	8.5	32100	43.5
	550	45	48	3400	9.0	35900	46.5
	600	45	48	3700	9.5	38200	47.5
500	500	45	48	3200	8.5	32500	44.5
	550	45	48	3700	9.0	36100	47.0
	600	45	48	4000	9.5	38500	48.0
1000	500	45	48	3700	8.5	32600	45.0
	550	45	48	4200	9.0	36500	47.5
	600	45	48	4500	9.5	38800	49.0

Table 11: Weapon Ballistics for Low Drag Bombs, CBUs, and LGBs in Loft Toss Delivery

True Airspeed to Calibrated Airspeed Conversion (20° Centigrade)							
True Airspeed (kts)	**Altitude (feet)**	**Calibrated Airspeed (kts)**	**True Mach Number**	**True Airspeed (kts)**	**Altitude (feet)**	**Calibrated Airspeed (kts)**	**True Mach Number**
300	0	300	0.45	350	0	350	0.53
	2000	289			2000	339	
	4000	280			4000	326	
	6000	269			6000	319	
	8000	260			8000	308	
	10000	247			10000	292	
400	0	400	0.60	450	0	450	0.68
	2000	385			2000	435	
	4000	372			4000	423	
	6000	360			6000	410	
	8000	350			8000	394	
	10000	334			10000	376	
500	0	500	0.75	550	0	550	0.84
	2000	480			2000	523	
	4000	467			4000	515	
	6000	450			6000	500	
	8000	435			8000	482	
	10000	417			10000	464	
600	0	585	0.89	650	0	647	0.98
	2000	568			2000	631	
	4000	550			4000	612	
	6000	532			6000	593	
	8000	515			8000	523	
	10000	498			10000	550	

Table 12: Airspeed Conversion Table (Approximate)

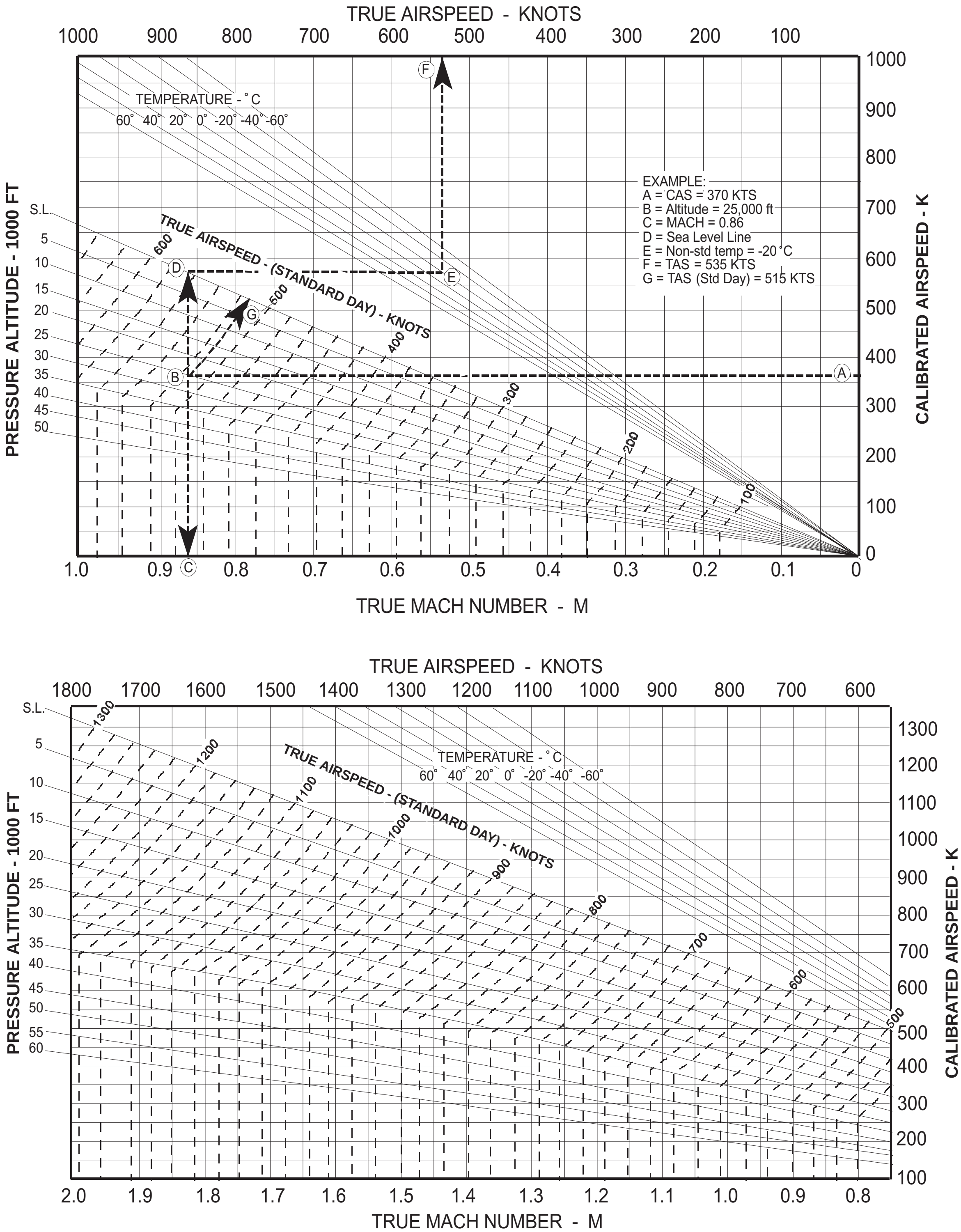

Figure 37: True Airspeed-Calibrated Airspeed-Mach-Altitude Lookup Chart

LEVEL BOMB MISSION PLANNING

The level delivery profile consists of level approach to the target, weapon release, and a level escape. You may use either the CCRP or CCIP mode of release with a level delivery profile. At the point of weapon release, the target may be under the nose of the aircraft, and impossible to sight with the pipper. The level release profile is illustrated in Figure 38. The steps to plan a level release are as follows. Unless otherwise stated, the measurement unit for speed is in knots (nautical miles per hour); the measurement unit for length (range, and altitude) is in feet; and the measurement unit for angular displacement is in degrees.

1. Select approach course to target.

2. Determine target elevation MSL.

3. Select release altitude AGL.

4. Determine minimum release altitude for safe escape (see Table 3). If this is greater than item 3, then increase item 3 until it is at least equal to item 4.

5. Determine release altitude MSL. This should be equal to item 3 plus item 2.

6. Select release true airspeed.

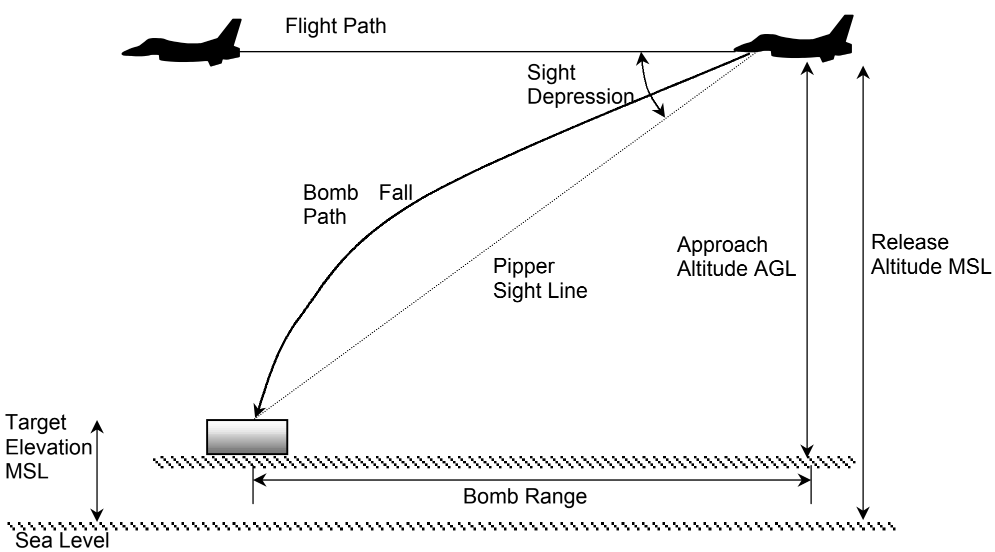

Figure 38: Level Bombing Profile

7. Determine bomb range in feet (see Table 8).

8. Determine release calibrated airspeed in knots (see Table 12, or Figure 37).

9. Determine approximate sight depression in milliradians, as follows:

$$\textit{Sight Depression} = 3.14159/180 \times \tan^{-1}(\textit{item 3 / item 7})$$

If the sight depression is less than 260mrad, then the target is visible in the HUD at the point of weapon release. If the sight depression is greater than 260mrad, the target is not visible in the HUD at the point of release, and if you are using CCIP mode, you should be expecting to see the CCIP delay cue. In this case, you are better off using CCRP mode instead.

10. If you are using cluster bombs, determine the cluster bomb splash pattern as follows:

    a. Select burst height (feet) and determine corresponding pattern diameter (feet) for the weapon of interest (see Table 6).
    b. Select release mode (single or paired)
    c. Select ripple quantity
    d. Select bomb spacing
    e. Determine total cluster bomb coverage area as follows:

Width of cluster bomb pattern = Item 10a (this is the same for single and paired release)

Length of cluster bomb pattern = Item 10a + ({No. of bombs – 1} × bomb spacing)

11. If you are using low or high drag bombs, determine the bomb stick length as follows:

    a. Select release mode (single or paired)
    b. Select ripple quantity
    c. Select bomb spacing
    d. Determine stick length as follows:

Stick Length = ({No. of bombs – 1} × bomb spacing)

By going through the above planning process, you can determine the best bombing mode to use, as well as pre-plan your release parameters such as cluster bomb burst height, ripple count, and ripple interval.

If you are using the level bombing profile at low level, the target is likely to remain visible during weapon release, provided the ordnance is not a high drag bomb or a BLU-107. At medium or high altitudes, the sight depression required is such that the target will not be visible during weapon release. If you are employing high drag bombs, you are advised to use the CCRP mode in a level profile, as the target will not be visible during weapon release.

Example of Level Release of Cluster Bombs

You are tasked to attack a tank column with 6 CBU-58A/B cluster bombs, and there are no constraints on release parameters. The tank column is in a single file formation with a total length of 5,000 feet, and is traveling in the direction of 040. Target elevation is at sea level.

1.	Approach Course To Target	**040 deg**
2.	Target Elevation MSL	**0 feet**
3.	Release Altitude AGL	**2000 feet**
4.	Minimum Release Altitude for Safe Escape	**None for cluster bomb**
5.	Release Altitude MSL	**2000 feet**
6.	Release True Airspeed	**450 knots**

7. Bomb Range **7900 feet**

8. Release Calibrated Airspeed **435 knots**

9. Approximate Sight Depression **247mrad**

10. Cluster Bomb Parameters
    a. Burst Height **1500 feet**
    b. Release Mode **Single**
    c. Bomb Spacing **175 feet**
    d. Ripple Quantity **6**
    e. Cluster Bomb Coverage Area **Width 1980 feet, Length 2855 feet**

With a release TAS of 450 knots (435 KCAS) at 2,000 feet, and a run-in heading of 040, it is possible to cover half of the tank column with cluster bombs if the bombs are selected to burst at 1,500 feet, and released singly with a ripple count of 6. The tank column is also expected to be just inside the HUD during release, and it may be possible to use CCIP mode for this profile, though it is more advisable to use CCRP mode.

DIVE BOMB MISSION PLANNING

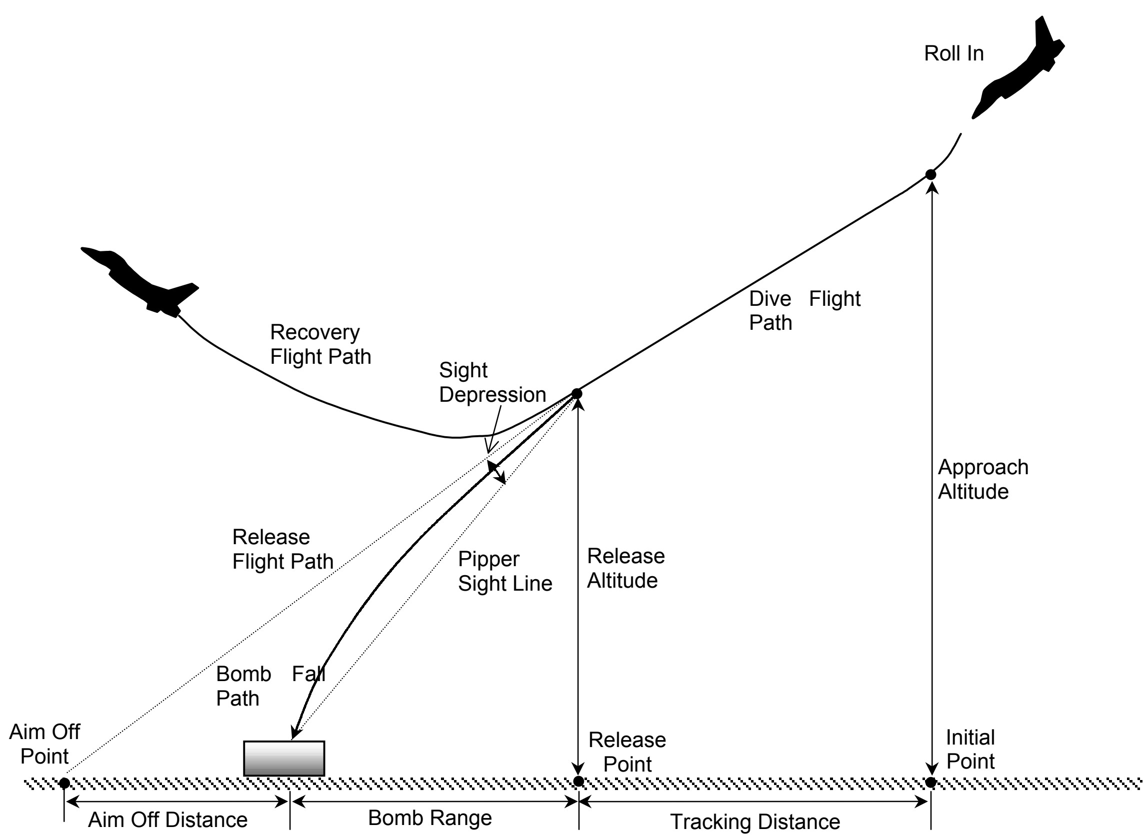

Figure 39: Dive Delivery Profile

The dive delivery profile consist of a roll into the dive over the IP (Initial Point), dive approach to the target, weapon release, and a 4g pull-out in 2 seconds. This profile may be used for dive bombing, rocket attack, or strafing. The proper dive flight path is attained by rolling into the dive at the proper altitude over the IP, and aiming the flight path marker at the aim off point. Following weapon release, a 4g pullout escape maneuver is performed. The dive delivery profile is illustrated in Figure 39. The planning steps are as follows. Unless otherwise stated, the measurement unit for speed is in knots (nautical miles per hour); the measurement unit for length (range, and altitude) is in feet; and the measurement unit for angular displacement is in degrees.

1. Select approach course to target.

2. Determine target elevation MSL.

3. Select approach altitude AGL.

4. Determine approach altitude MSL (item 3 plus item 2).

5. Select release/approach true airspeed.

6. Select release dive angle.

7. Determine minimum release altitude for safe escape (see Table 4 for 500lb. HE bomb, and Table 5 for 2,000lb. HE bomb).

8. Select release altitude AGL. This should be greater than item 7 to ensure that you do not get hit by the bomb fragments, and item 10 to ensure that you do not auger into the ground during dive recovery.

9. Determine release calibrated airspeed (see Table 12, or Figure 37) based on release altitude MSL.

10. Determine altitude lost during dive recovery (see Table 7).

11. Determine bomb range (see Table 9 and Table 10).

12. Determine sight depression angle (in radians) from flight path:

    $$\textit{Sight Depression} = 3.14159/180 \times \{ \textit{Dive Angle} - \tan^{-1}(\textit{item 3 / item 11}) \}$$

If the sight depression is less than 260mrad, then the target is visible in the HUD at the point of weapon release. If the sight depression is greater than 260mrad, the target is not visible in the HUD at the point of release, and if you are using CCIP mode, you should be expecting to see the CCIP delay cue. Strictly speaking, the total sight depression should also include the aircraft AOA. This is inherently variable and dependent on the weight at the point of release. Since Falcon 4 does not have any provisions for manual bombing, and the fire control computer takes care of the bombing solution, the AOA may be ignored, and the sight depression computed here can taken as a guide to the final sight picture during the bomb run.

13. Determine aim off distance:

    Aim Off Distance = (Release Altitude AGL / tan (Dive Angle)) – Bomb Range (item 11)

14. Determine Initial Point Distance:

Initial Point Distance = Approach Altitude AGL (item 3) / tan (Dive Angle) – Aim Off Distance (item 13)

15. Determine Tracking Distance:

Tracking Distance = Initial Point Distance (item 14) – Bomb Range (item 11)

16. Determine ground speed during dive, assuming zero winds:

Ground Speed = True Airspeed × cos (Dive Angle)

17. Determine tracking time:

Tracking Time (sec) = Tracking Distance / (Ground Speed × 1.69)

18. Determine altitude lost during tracking:

Tracking Altitude Loss = (True Airspeed × 1.69) × sin (Dive Angle) × Tracking Time

19. If you are using cluster bombs, determine the cluster bomb splash pattern as follows:

    a. Select burst height (feet) and determine corresponding pattern diameter (feet) for the release TAS (see Table 6).
    b. Select release mode (single or paired)
    c. Select ripple quantity
    d. Select bomb spacing
    e. Determine total cluster bomb coverage area as follows:

Width of cluster bomb pattern = Item 10a (this is the same for single and paired release)

Length of cluster bomb pattern = Item 10a + ({No. of bombs – 1} × bomb spacing)

20. If you are using low or high drag bombs, determine the bomb stick length as follows:

    a. Select release mode (single or paired)
    b. Select ripple quantity
    c. Select bomb spacing
    d. Determine stick length as follows:

Stick Length = ({No. of bombs – 1} × bomb spacing)

Example of Dive Bombing with Low Drag Bombs

You are tasked to attack a building with dimensions of 250 feet by 50 feet, with 6 Mk-82 low drag bombs, and there are no constraints on release parameters. The building is defended by a battalion of infantry armed with SA-7 missiles. The building's length is aligned along a magnetic heading of 090, and the building consist of a single story, and its elevation is at sea level. The time of the attack is 0800 hours.

1.	Approach Course To Target	**270 deg to attack out of the sun**
2.	Target Elevation MSL	**0 feet**
3.	Approach Altitude AGL	**12000 feet**

4.	Approach Altitude MSL	**12000 feet**
5.	Release True Airspeed	**450 knots**
6.	Release Dive Angle	**30 degrees**
7.	Minimum Release Altitude for Safe Escape	**1900 feet**
8.	Release Altitude AGL	**8000 feet**
9.	Release Calibrated Airspeed	**394 knots**
10.	Altitude Lost During Dive Recovery	**950 feet (approximately) for 5g pullout**
11.	Bomb Range	**8400 feet**
12.	Approximate Sight Depression	**237mrad**
13.	Aim Off Distance	**5456 feet**
14.	Initial Point Distance	**15329 feet**
15.	Tracking Distance	**6929 feet**
16.	Ground Speed During Dive	**390 knots**
17.	Tracking Time	**10.5 seconds**
18.	Tracking Altitude Loss	**3998 feet**
19.	Mk-82 Low Drag Bomb Parameters	
	a. Release Mode	**Single**
	b. Bomb Spacing	**75 feet**
	c. Ripple Quantity	**6**
	d. Stick Length	**375 feet**

For this particular profile, the dive is entered at 12,000 feet altitude, and bomb release is at 8,000 feet altitude. The flight path marker should be placed approximately 5,400 feet long of the target, and the target will remain visible during the bomb run. This makes both CCIP and CCRP modes usable. The total tracking time of 10.5 seconds should give you ample opportunity to fine tune your aim point during the run-in.

The minimum altitude reached during the 5g pullout is 7,050 feet, which just puts you outside the SA-7 envelope (maximum SA-7 engagement altitude is 7,000 feet). The stick length is 375 feet, and the target will be struck by 3 of the bombs.

LOFT BOMB MISSION PLANNING

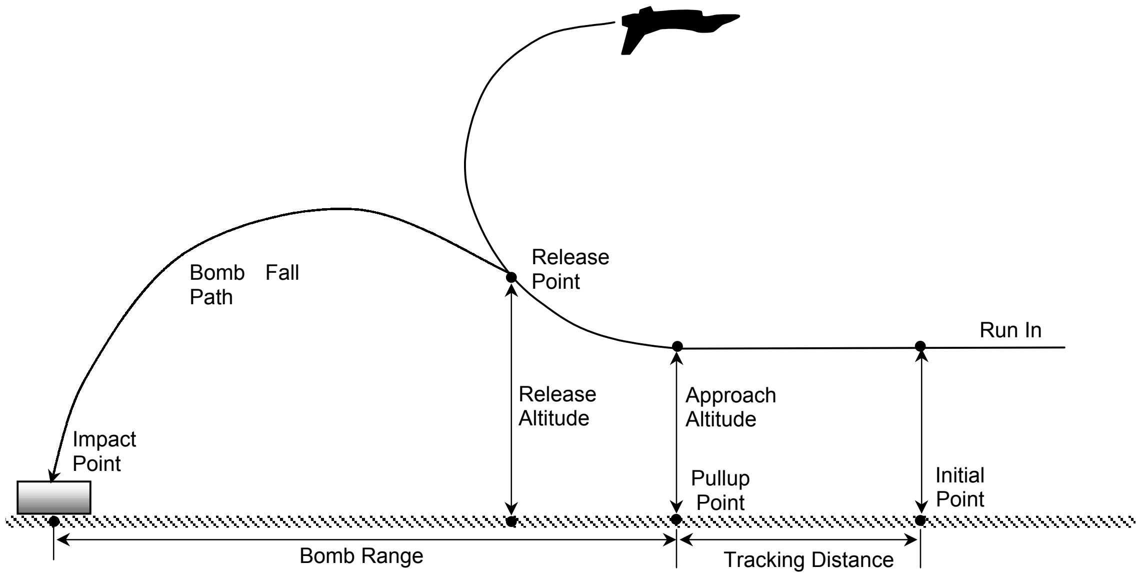

Figure 40: Loft Delivery Profile

The loft delivery profile consists of a low level approach, a 4g pull-up, weapon release, and a wing-over escape maneuver. Due to the long ranges from pull-up to target in loft bombing, the target may not be visible at the pull-up initiation point. In order to initiate the pull-up at the proper time, an initial point of known distance and travel time to the pull-up point is needed. You should note that loft bombing will work only properly at low altitudes. At medium or high altitudes above 10,000 feet, it may not be possible for the fire control computer to arrive at a solution for bomb release, even in real life.

The dive delivery profile is illustrated in Figure 40. The planning steps are as follows. Unless otherwise stated, the measurement unit for speed is in knots (nautical miles per hour); the measurement unit for length (range, and altitude) is in feet; and the measurement unit for angular displacement is in degrees.

1. Select approach course to target.

2. Determine target elevation MSL.

3. Select IP (Initial Point) location and determine range from IP to target.

4. Select approach altitude AGL.

5. Determine approach altitude MSL (item 4 plus item 2).

6. Select release/approach true airspeed.

7. Select release loft angle. For maximum range, use 45° loft angle.

8. Determine release altitude AGL (see Table 11 for 45° loft toss profile).

9. Determine release altitude MSL (item 8 plus item 2)

10. Determine time from pull-up to weapon release (see Table 11 for 45° loft toss profile).

11. Determine aircraft attitude during weapon release (see Table 11 for 45° loft toss profile).

12. Determine range between pull-up point and impact (see Table 11 for 45° loft toss profile).

13. Determine release calibrated airspeed (see Table 12, or Figure 37) based on release altitude MSL.

14. Determine tracking distance (range between IP and pull-up point)

15. Determine ground speed. Assuming zero winds, this is the same as the true airspeed.

16. Determine tracking time (time to fly from IP to pull-up point):

    Tracking Time (sec) = Tracking Distance / (Ground Speed × 1.69)

Example of Loft Bombing with Low Drag Bombs

You are tasked to attack a POL storage facility, defended by an anti-aircraft battalion equipped with the SA-8 surface-to-air missiles. The SA-8 engagement range is approximately 5nm., and the SAM battalion is located 2,000 feet to the north of the POL facility. There are no constraints to the attack profile, and you are armed with a pair of Mk-84 low drag bombs.

1.	Approach Course To Target	**180 deg to maximize the range to the SA-8 battalion located at the north.**
2.	Target Elevation MSL	**0 feet**
3.	Initial Point Location (Range to Target)	**48608 feet, or 8nm.**
4.	Approach Altitude AGL	**500 feet**
5.	Approach Altitude MSL	**500 feet**
6.	Release True Airspeed	**500 knots**
7.	Release Loft Angle	**45 degrees**
8.	Release Altitude AGL	**3200 feet**
9.	Release Altitude MSL	**3200 feet**
10.	Time Between Pull-up To Weapon Release	**8.5 seconds**
11.	Aircraft Attitude During Release	**48 degrees**
12.	Bomb Range (Range from Pull-up to Target)	**32500 feet**
13.	Release Calibrated Airspeed	**475 knots (approximately)**
14.	Tracking Distance	**16108 feet, or 2.65nm.**
15.	Ground Speed	**500 knots assuming zero winds**

16. Tracking Time **19.09 seconds**

For this attack profile, the 4g pull-up is initiated approximately 19.1 seconds after passing over the IP, with weapon release achieved when the aircraft pitch attitude is at 48°. The bomb range is 5.35nm.. As the SA-8 is located 2,000 feet further north, the range between the pull-up point and the SAM battalion is approximately 5.7nm.. It is thus possible to enter the SA-8 engagement range during the pull-up. If you execute a rapid wing-over after weapon release, the exposure to the SAM battalion may be reduced, and you will most likely not be engaged.

POP-UP ATTACK PLANNING

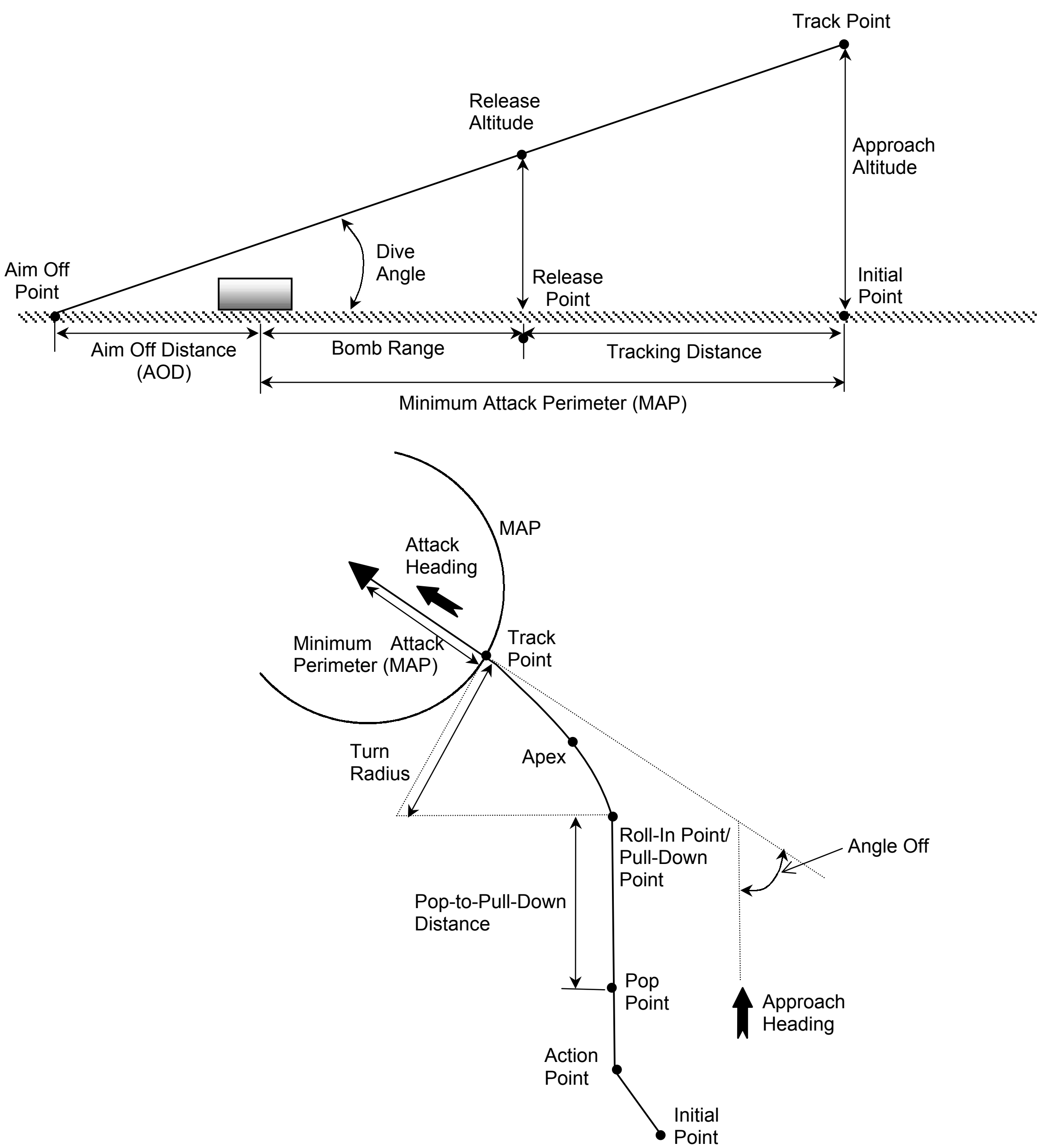

Figure 41: Pop-Up Attack Planning Parameters

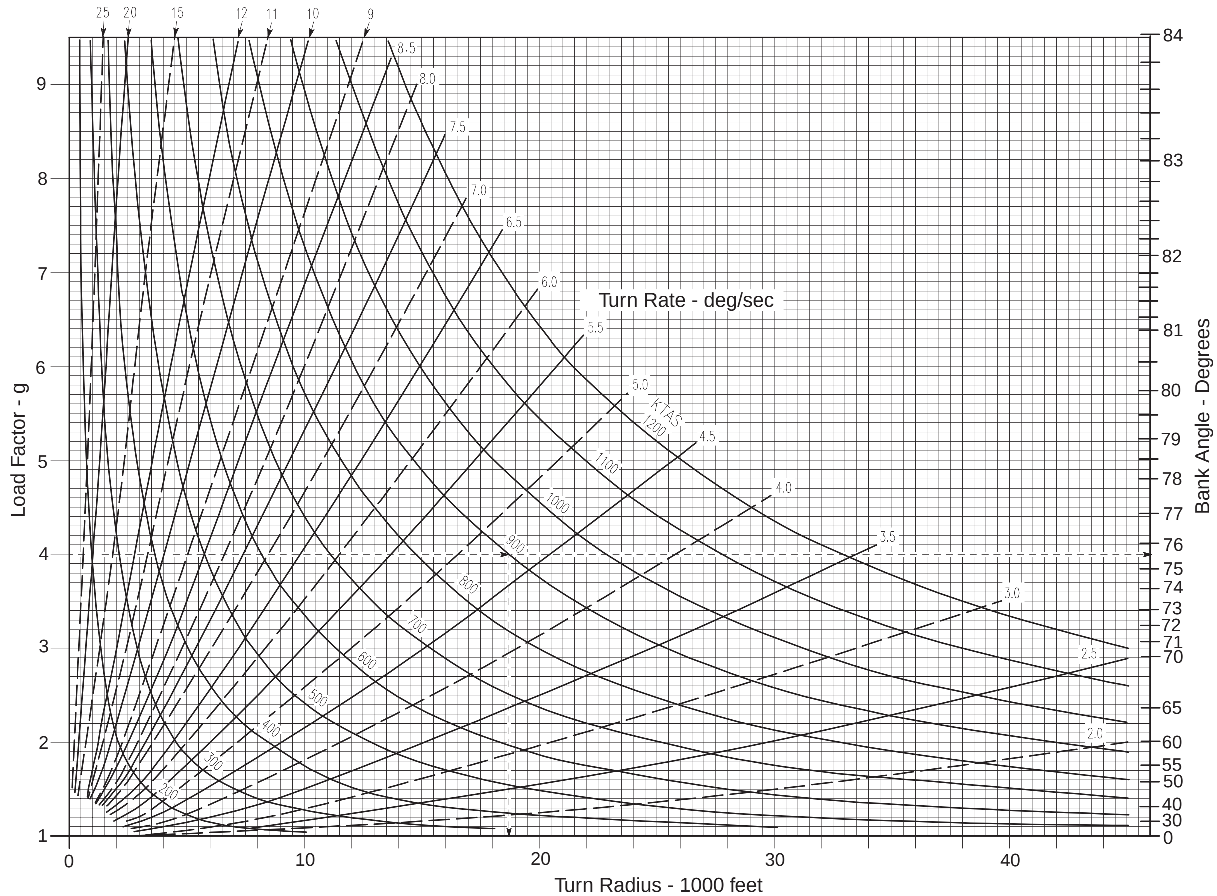

Figure 42: Turn radius and turn rate as a function of load factor and true airspeed

When you are facing a sophisticated and integrated SAM/AAA environment, or the weather is such that the cloud base is low, you may need to consider a low level ingress profile and a pop-up attack. Although such tactics will likely place you in SAM/AAA engagement envelopes, when executed properly, it can provide an element of surprise to improve your survivability.

Pop-up attack planning begins after you have completed your delivery planning (see the previous sub-sections). During the execution of the pop-up attack, it is important to align yourself on the proper target attack heading, and acquire the target in time. Due to the highly dynamic nature of the maneuver, you will not have much time to decide if you have achieved the right parameters. As such, you should immediately abort the attack if you are faced with parameters that you do not recognize. As a guideline, a pop-up attack should be aborted if any of the following conditions arise:

- Dive angle exceeding planned by more than 5°
- Airspeed decreasing below 350 KCAS, or 300 KCAS if you are above 10,000 ft AGL.

The pop-up attack geometry and parameters are shown in Figure 41. The pop-up definitions are as follows:

- Approach Heading – The heading flown during wings-level pull-up and climb.
- Attack Heading – The heading flown during the wings level attack. This is also known as the attack axis.
- Angle-Off – The difference between approach and attack heading.
- Direct Pop-up – Angle-off of less than 15°.

- Offset Pop-up – Angle-off between 15° and 90°.
- Indirect Pop-up – Angle-off greater than 90°.
- Initial Point (IP) – The point where the final leg to the target commences. You should set this to a unique and easily identifiable point, about 10 to 20nm. away from the target.
- Action Point – The point from the target where you take an offset for an offset or indirect pop-up attack. The action point is typically placed between the initial point and the pop point.
- Pop Point – The point at which the pop-up attack is initiated. You will also initiate the climb at this point.
- Climb Angle – The angle of climb to be achieved during the initiation of pop-up.
- Pop-to-Pull-Down Distance – Distance from the pop point to the pull-down point. This distance can be computed.
- Pull-Down Point (PDP) – The point at which you will transition from climbing to the diving portion of the pop-up profile.
- Dive Angle – The selected dive angle for weapon delivery.
- Apex – The highest altitude reached during the pop-up delivery.
- Minimum Attack Perimeter (MAP) – This is defined as the sum of the distance covered by target tracking, and the bomb range.
- Tracking – The portion of the weapon delivery profile dedicated to fine tuning the aircraft sighting system with the target.
- Tracking Time – The time required for target tracking. This is usually the time taken from roll out to weapon release.
- Horizontal Tracking Distance – The distance traveled across the ground during tracking time.
- Vertical Tracking Distance – The vertical distance between tracking altitude and release altitude.

Pop-Up Maneuver

During a pop-up maneuver, the approach course is usually selected such that the angle-off varies with the required climb angle to permit the pilot to acquire the target as soon as possible and maintain visual contact until the completion of weapons delivery. For steeper climbs, the angle-off requirements will increase.

The pop-up is executed over a pre-planned pop point, with a minimum airspeed of at least 450 KCAS. If you have a radar lock on the target, the locator line will give you a good indication of your angle off. At the initiation of the pop-up, select the desired power to minimize the loss of airspeed (either MIL or AB), and then execute a 3 – 4g wings-level pull-up to the desired climb angle. Depending on the threats, they may detect you once you execute this maneuver, so it may be prudent to dispense chaff and flares, or to activate your ECM system. You should expect the target to become visible just slightly off to the planned roll-in direction. It is also important for you to maintain the planned climb angle and monitor the altitude gained.

Once you have arrived at the pre-planned pull-down altitude, execute an unloaded roll in the direction of the target, and then perform a 3 – 5g pull-down to intercept the pre-planned dive angle. You should practice the pull-down maneuver to determine the bank angle that you need to establish before executing the pull-down. At this point in time, you should be making slight course adjustments to compensate for minor errors as well as unexpected winds. The apex altitude will usually be achieved halfway through the pull-down maneuver.

Pop-Up Attack Options

There are several options available to you if you decide to execute a pop-up attack. These are all dependent on your ordnance load, and the threat that you are up against.

Low Angle High Drag Bombing (LAHD): This delivery profile is designed for delivery of high drag bombs. The dive angle is usually between 10° to 15°. The approach is normally planned to be made with an angle-off of 15° to 30°, at a speed of at least 450 KCAS. At the pop point, a 3 – 4g pull-up is initiated, to achieve a climb angle that is usually 5° more than the desired dive angle (for example, if the desired dive angle is 10°, then the desired climb angle is about 15°). At the pre-planned pull-down point, the aircraft is rolled towards the target and the nose pulled down to roll out. The delivery profile will usually allow 3 – 5 seconds of tracking time, so the margins for error at very tight. If you are bombing with CCIP, you should plan to roll out with the target approximately one third down between the flight path marker and the CCIP pipper. The flight path marker should ideally be close to if not exactly on the aim-off point.

Low Angle Low Drag Bombing (LALD): This delivery profile is designed for delivery of low drag bombs, and as such, safe escape and fuse arming requirements become important. The planned angle-off is usually twice the climb angle (for example, if the desired climb angle is 30°, then the angle-off should be about 60°). The pop-up profile is the same as LAHD, but you should expect the apex altitude to be much higher than LAHD. If you are bombing with CCIP, you should plan to roll out with the target approximately halfway down between the flight path marker and the CCIP pipper.

High Altitude Dive Bombing (HADB): This delivery profile is designed for high angle (between 30° to 45° dive angle) delivery of low drag bombs in a high threat environment. If you are heavily loaded, this form of delivery may not be suitable as you may not be able to achieve the required parameters. The approach is normally made at a higher speed of 500 KCAS or more, with an action point placed 4 to 5nm. away from the target. Once over the action point, a check turn of 20° to 30° is made to obtain the required offset. You may also choose to take the offset directly at the IP if the IP is placed close to the target. At the desired pop-point, a 4g pull-up is initiated to achieve the planned climb angle (usually dive angle plus 15°) in full AB. You should try to acquire the target as soon as possible, and keep a look-out for the altitude as the pull-down altitude will be achieved very quickly. You will be almost inverted at the apex during the pull-down, so plan to give yourself at least 5 seconds of tracking time since it will be tricky to achieve the appropriate aiming parameters during pull-down. For CCIP bombing, you should plan to roll out with the target approximately one third down between the flight path marker and the CCIP pipper. The flight path marker should ideally be close to if not exactly on the aim-off point.

Visual Level Delivery (VLD): This delivery profile is usually flown using CCIP, and if the threat precludes a steep dive, or the cloud base is too low and will hinder visual acquisition of the target during a steep dive. The dive angle is usually between 0° to 5°, and if a 5° dive profile is selected, a 10° climb is initiated at the pull-up point. You should initiate the pull-down or bunt over just 500 feet short of the apex altitude, and pay attention to the minimum release altitude for safe escape and ground avoidance.

Deciding on Low or High Altitude Bombing

One of the most important considerations for the selection of the bombing profile is the altitude at which the bombing will be carried out. This is a tradeoff between bombing accuracy and threat avoidance. When you are low down in the weeds, the apparent target size will be larger. This makes it easier for pipper placement if you are bombing in CCIP mode, and may be more accurate than bombing in CCRP mode.

As bombing altitude decreases, bombing accuracy increases. Higher release altitudes introduce more uncertainties into the bombing solution, such as temperature differences, varying wind gradients, etc. Bombinb accuracy at 5,000 feet is typically double that at 10,000 feet. For point targets, higher release altitudes make it a lot more difficult to put an unguided bomb onto the target accurately, though this may be less of a problem for area weapons such as CBUs.

The down side of low altitude bombing is the exposure of your strike aircraft to the enemy's SHORAD systems. You will be taking greater risks of being hit by enemy AAA fire, or IR SAMs. For some ordnance such as the BLU-107, you do not have much choice other than to use low altitude bombing profile. While you can increase the bombing accuracy by using precision bombs such as LGBs, these bombs are more expensive, and you will not have many of them. You will need to weigh the increased accuracy of low altitude bombing against the threats, and strike a balance that will allow you to achieve your mission objectives.

Pop-Up Planning

The planning procedures for a pop-up attack are as follows. Unless otherwise stated, the measurement unit for speed is in knots (nautical miles per hour); the measurement unit for length (range, and altitude) is in feet; and the measurement unit for angular displacement is in degrees.

1. Select the delivery profile to use (LALD, LAHD, HADB, etc).

2. Determine the following bombing parameters:

    a. Axis of attack
    b. Dive angle
    c. Release altitude
    d. Bomb range
    e. Aim-off distance
    f. Track point altitude
    g. Tracking distance
    h. Approach altitude

3. Determine the Minimum Attack Perimeter (MAP):

    Minimum Attack Perimeter = Bomb Range + Horizontal Tracking Distance

4. Select the roll-in g, i.e. the load factor that you will want to attain during the roll-in to the target.

5. Determine the turn radius:

    $$\textit{Turn Radius} = (\textit{True Airspeed} \times 1.69)^2 / (32.2 \times \textit{Aircraft g})$$

where aircraft g is the g that you will see in the cockpit during the roll-in to the attack heading. You can also estimate the turn radius using Figure 42.

6. Select the climb angle:

    Climb Angle = Dive Angle + 5° (for 5° through 15° deliveries)
    Dive Angle + 10° (for 20° and higher angle deliveries)

7. Determine angle-off:

    $$\textit{Angle-Off} = \textit{Climb Angle} \times 2$$

8. Determine apex altitude:

    $$\textit{Apex Altitude} = \textit{Track Point Altitude} + (\textit{Dive Angle} \times 50)$$

9. Determine pull-down altitude:

Pull-Down Altitude = Apex Altitude – (Climb Angle × 50) for a 3 to 3.5g roll-in
= Apex Altitude – (Climb Angle × 37.5) for a 4.5 to 5g roll-in

10. Determine Pop-to-Pull-Down Distance:

Pop-to-Pull-Down Distance = (Apex Altitude × 60) / Climb Angle

11. Determine roll-in point (horizontal range to target, in feet), by constructing a scaled drawing of the various parameters, as shown in Figure 41. You can measure the range between the roll-in point to the target from the scaled drawing.

12. Determine the range between the pull-up point and the target, by constructing a scaled drawing of the various parameters, as shown in Figure 41. You can measure the range between the pop-up point to the target from the scaled drawing.

ATTACKING WITH LASER GUIDED BOMBS

Laser guided bombs (LGBs) such as the American GBU-10, GBU-12, GBU-24 and the Russian KAB-500L and KAB-1500L are designed for attacking point targets. Laser guided bomb delivery requires some pre-flight planning to execute correctly, and requires the pilot to understand the limitations of the laser target designator. This sub-section will discuss the delivery of LGBs from the perspective of the F-16 pilot using the LANTIRN targeting pod.

The LANTIRN targeting pod has a FLIR camera, and a laser target designator. The laser target designator is correlated to the boresight of the FLIR camera, and the laser will fire at the aim point of the FLIR camera. The firing of the laser is automatic, and occurs at the point of LGB release. The laser is fired at the target, and the reflections form a cone that will seem to emanate from the target. The diameter of the cone increases with increasing range away from the target. This is known as the "laser basket." The seeker mounted on the nose of every laser guided bomb will search for the laser spot and the "basket," and will steer the bomb into the "basket." As the bomb closes in on the target, the diameter of the "basket" decreases, and the guidance of the bomb becomes increasingly more precise due to this. The bomb increases its frequency of control movements in order to keep the seeker centered on the "basket." This continues until the point of impact, when the diameter of the "basket" shrinks to just a few feet.

The laser designator must remain firing throughout the flight of the LGB. This ensures that the target is continuously illuminated with the laser energy, so that the LGB seeker can guide. As long as the LANTIRN targeting pod remains locked onto the target, the laser will continue firing. If the lock is broken for whatever reasons (either due to the pilot manually breaking the lock, or the pod reaching its gimbal limits), the laser will cease firing, and the LGB will go ballistic.

You should be aware of the total flight time of the LGB for the delivery profile that you have chosen. The flight time may be obtained from Table 8 through Table 11. For the entire duration of the LGB's flight, you will need to ensure that you do not break the targeting pod's lock prematurely, and fly a profile that will prevent the targeting pod reaching its gimbal limits. This limits the amount of maneuvering you can perform, and should you be engaged by enemy SAMs during the LGB delivery, the lock will most likely be broken by your maneuvering, and the LGB will miss. The increased accuracy comes with the price of increased vulnerability to enemy air defenses due to the predictable profile that you will be flying.

Targeting Pod Operating Limitations

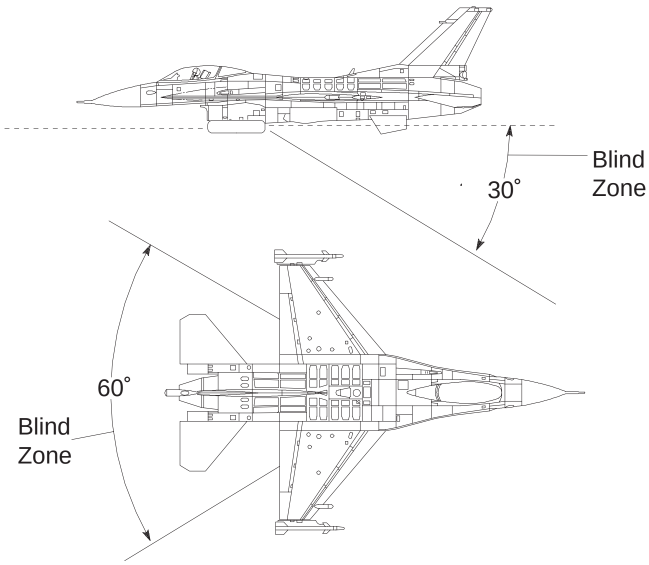

Figure 43: LANTIRN Targetint Pod Blind Zones (Gimbal Limits of Tracking Head Assembly)

The LANTIRN targeting pod's tracking head assembly consists of a FLIR camera, as well as a laser target designator. The blind zones of the LANTIRN targeting pod's tracking head assembly are shown in Figure 43. This is the physical gimbal stop on the tracker head assembly. The tracker head will not be able to look into the blind zones. Even in areas that are outside the blind zone, the pod will still not be able to see through to the target at certain combinations of tracker head azimuth and elevation displacements, because aircraft parts such as fuselage and external fuel tanks will get into the way.

The laser target designator is correlated to the boresight of the FLIR camera. Combat lasers are not eye-safe, and can potentially cause permanent eye damage and blindness. If the laser is fired into the aircraft structure, the reflections off the aircraft may blind the pilot, or the pilots of neighbouring aircraft. The combination of tracking head azimuth and elevation displacements that will result in the FLIR camera looking at the aircraft structure is programmed into the targeting pod. When the targeting pod detects that it is looking into the aircraft, the pod inhibits its laser from firing. The combination of elevation and azimuth displacement of the tracking head assembly that will result in the laser being inhibited from firing is known as the "Laser Masking Zone." Hence, even though the tracking head assembly can rotate such that the FLIR camera

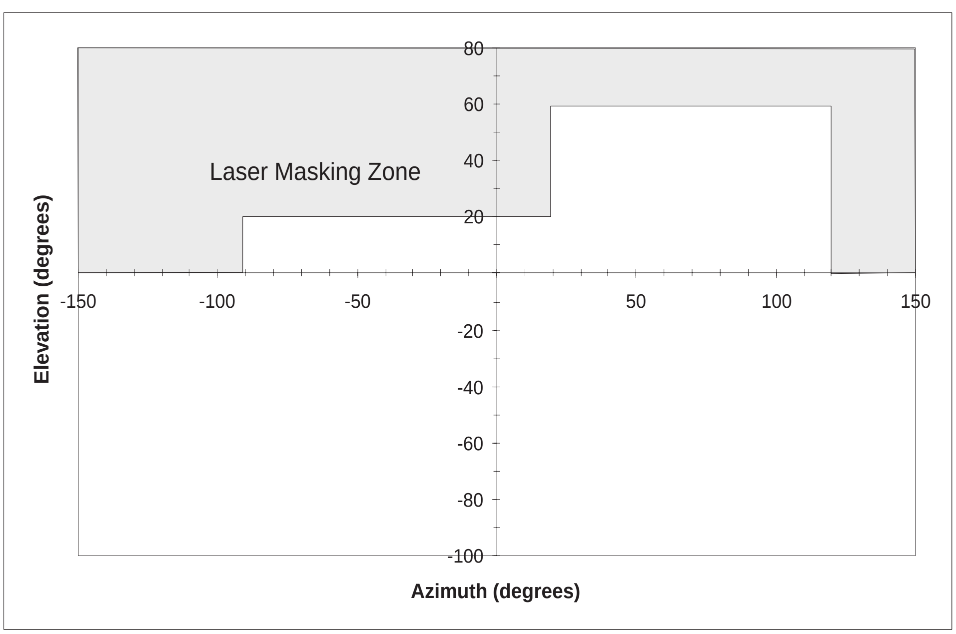

Figure 44: Falcon 4 LANTIRN Targeting Pod Laser Masking Zone (Simplified)

can look at the aircraft itself, the targeting pod will still not fire the laser. The laser masking zone that is implemented in the Realism Patch is shown in Figure 44. The datum point of (0,0) refers to the boresight of the aircraft. An elevation of –90° means that the pod is looking vertically downwards, and vice versa. An azimuth of –90° means that the pod is looking at the left side of the aircraft, and vice versa. You should always make sure that the target remains outside the laser masking zone throughout the entire duration of the LGB's flight, to ensure that the laser is firing.

The laser target designator consists of a flashing xenon lamp that will pulse at a high frequency to produce the laser. At barometric altitudes above 25,000 feet, the air density is much lower. The rarefied air around the xenon lamp may ionise during the flashing of the lamp, and cause electrical arcing through the internals of the targeting pod. This will damage the targeting pod. The laser target designator is automatically inhibited from firing the laser when you are flying above a barometric altitude of 25,000 feet. You should bear in mind that you will still be able to lock onto a target with the targeting pod, and release the LGB. However, the laser will not fire, and the LGB will miss. Hence, you should always descend below the altitude of 25,000 feet for LGB deliveries. The altitude restriction of the targeting pod is a major constraint, as it places you within the engagement envelope of medium range SAMs such as SA-6 and SA-15, as well as large calibre flak guns. This is one of the problems experienced during Operation Allied Force in Kosovo, where NATO forces had to deliver the LGBs from lower altitudes than desired. Newer targeting pods that are undergoing development and entering initial low rate production will replace the xenon lamp laser with a diode pump laser, and the altitude limit is raised to 40,000 feet. You will not have the luxury of using such systems as yet.

You should also note that smoke will dissipate the laser and cause back scatter. This will prevent proper reflection of the laser, and may result in the LGB missing even though the targeting pod appears locked onto the target. Should you be tasked to attack a target with multiple LGBs, make sure that the smoke and debris from the earlier LGBs are blown away from the target first, before releasing the next LGB.

Differences Between Laser Guided Bombs

Most of the laser guided bombs in service today belong to the second generation of LGBs. This includes the American Paveway II series (GBU-10. GBU-12, and GBU-28), as well as Russian KAB series (KAB-500L and KAB-1500L) of laser guided bombs. The only third generation LGB available in Falcon 4 is the American GBU-24 Paveway III.

Second generation LGBs use a guidance logic more commonly known as the "bang-bang" logic. The seeker unit will always generate guidance commands that will result in full deflection of its control fins. The bomb will nose over and overshoot the intended flight path, after which the seeker will reverse the guidance commands and cause the control fins to deflect to the maximum opposite direction. This will again cause the bomb to overshoot its intended flight path. The actual flight path will resemble a snake, with the bomb overshooting during each guidance correction cycle.

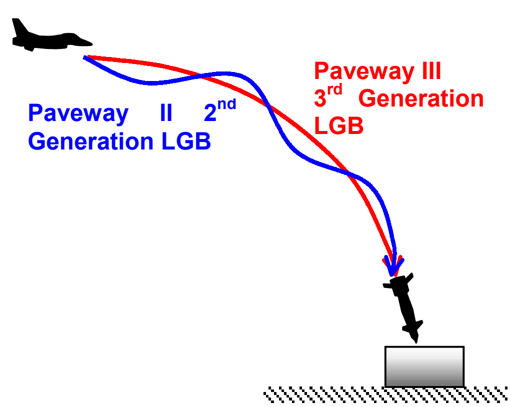

Figure 45: Flight path differences between second and third generation laser guided bombs

Third generation LGB seekers will generate guidance commands that result in the correct proportional control fin deflections required to keep the bomb on the intended flight path, keeping deviations from that path to a minimum. The guidance unit will not oversteer the bomb, unlike the second generation LGBs.

While there is not much difference between the flight path of both second and third generation LGBs, the trajectory of third generation LGBs is more efficient. There is also a difference in the miss distance in the event that the LGB loses lock prior to impact (be it due to the targeting pod breaking lock, or other causes). The control system on the LGB is irreversible. When the LGB seeker loses lock on the laser spot, the control fins will stay at their last known deflection angle. For second generation LGBs, this is at the maximum deflection on either sides of the control servo actuator. For third generation LGBs, due to the incremental guidance commands, the fins are unlikely to be at their maximum deflection angles. Hence, a second generation LGB will grossly oversteer, and either overshoot or undershoot the target by a considerable distance. Third generation LGBs will overshoot or undershoot much less (about 1/3 that of second generation LGBs in Falcon 4).

The difference in miss distance is important. For a third generation LGB, should the lock be broken just prior to impact, the LGB may still impact at a distance that is sufficiently close to destroy or damage the target. The second generation LGB will most likely miss by a huge distance even when the lock is broken just prior to impact, and will likely not even damage the target.

Flight Path Considerations

One of the most important factor in the delivery of LGBs is the flight path of the aircraft throughout the entire duration of the bomb flight time. You will need to ensure that your flight path and aircraft maneuvers do not cause the laser target designator to break lock, so that you can provide target illumination to your LGB up till its impact on the target. You should draw a scaled drawing of your flight path from bomb release up to bomb impact, and then resolve the geometry to determine if your flight path will lead to the laser target designator's limits being exceeded, or the laser being masked.

ATTACKING WITH STAND-OFF WEAPONS

Stand-off weapons such as the AGM-130 and the AGM-142 allows you to attack heavily defended targets from ranges well outside those of the air defenses. As such, you will not need to be concerned about terrain masking and shielding your approach from the enemy air defenses. The attack involves flight to the release point, launch of the weapon, egress from the target area and then the return flight to home base.

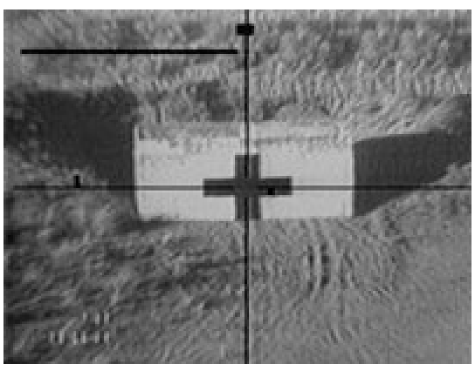

Figure 46: AGM-142 seeker video of its target moments before impact. (Picture credit of Lockheed Martin Missiles and Fire Control)

When planning for stand-off weapon release profiles, you must be aware of the characteristics of such weapons. You will only be able to optimize the range of the weapon if you deliver the weapon from medium to high altitudes. A low level delivery profile will severely curtail the range of such weapons, and you will need to fly closer to the target in order to release your weapon. In addition, you will increase the chances of the weapon ploughing into intervening terrain during its flight to the target.

The most important part of the planning is altitude at the release point. You will need to study the topography between the release point and the target to look for any high ground such as hills. If you are releasing the weapon from altitudes below 5,000 feet, the risk of the weapon ploughing into high ground is increased considerably. You should then release the weapon at higher altitudes. You should also plan the location of the release point properly. This usually corresponds to the IP (initial point), and you should place the IP at a range that will allow you to employ the weapon with a high chance that the weapon will reach its target, yet far enough from the enemy air defenses such that you will not need to concern yourself with them.

As a guideline, you should place the IP at a distance approximately equal to 80% of the weapon's effective range when launched at the desired altitude. If the launch altitude is lower, then the IP has to be closer, and vice versa.

EGRESS AND ABORT PLAN

Once you have delivered your weapons, it is time to get away from the target and its air defenses. The egress plan must be a simple as possible, and the priorities for egress are as follows:

1. Leave the target area
2. Get away from threats
3. Regain formation mutual support

The egress route should be planned such that it is relatively free of enemy defenses. It is possible for the formation to split up during the attack, due to the need to de-conflict the various flight members, and possibly due to threat reactions. As such, there is a possibility of flight members losing mutual support and needing to provide their own threat lookout. Selecting an egress route that is relatively free of threats will minimize the possibility of any unsupported flight member being shot down. This will also give an opportunity to initiate a re-attack, if necessary. If the attack involves lofting of weapons, you will need to make sure that you de-conflict your flight path with that of the lofted weapons, as collision with your own weapons will not do you any good.

For two-ship egress, you should ideally egress in line abreast formation, to provide mutual support. Four ship egress should maintain at least element integrity, with visual mutual support. If the egress route is over mountainous terrain, then the terrain provides for ample opportunity to mask your flight from enemy defenses, and a trail formation egress may be more suitable.

You should also consider an abort plan for the attack. In the event that the target is too heavily defended, or the weather is too poor, it may be more prudent to conserve your forces and attack it another day, when the conditions are more favorable. The possible reasons for aborting an attack are as follows:

1. Poor weather, such that the pre-planned delivery profile (and any alternate delivery profiles) cannot be executed properly without undue risks.
2. Target acquisition problems.
3. Unacceptable target defenses.
4. Low fuel.
5. Battle damage

THREAT REACTION

You will need to pre-plan and brief the reactions to any expected threats that may become active during ingress and egress to the target area. When you are on an air-to-ground mission, even if you detect any enemy aircraft, you should exercise discipline to stay on your mission and not chase after the enemy, unless they are a threat to you. This applies whether you are ingressing to the target, or egressing after delivering your weapons. Getting yourself shot down due to your eagerness to get some air-to-air kills will be a bad way to start and end a bombing mission. In general, you should draw up a listing of criteria, under which you will consider engaging the enemy airplanes:

1. Any enemy airplane faster than 300 KCAS and at high aspect inside of 40nm. from you.
2. Any low aspect target between 10 to 20nm. out within 30° of your nose.
3. Any low aspect target inside 10nm..
4. Any enemy airplane called by AWACS or visually spotted inside 5nm..

In summary, do not mess with any enemy fighter who is not messing with you while you are on an air-to-ground mission. Concentrate on the mission, and you will stay out of trouble if you do not go looking for trouble.

THUNDER AND LIGHTNING

Waging the Air Campaign in the Realism Patch
By "Hoola"

INTRODUCTION

We have been discussing tactical matters so far. While it is important that you survive your combat missions, and get home alive, you need to understand a little about the air war at the strategic level. Many battles can be won, but a war can still be lost anyway. The Air Tasking Order (ATO) engine in Falcon 4 is not very smart, and you will need to assist it in the selection of targets, so that the air war is also taken care of at the strategic level. This section is written to give a brief introduction of planning an air campaign, and is tailored to the Falcon 4 environment. I do not claim to know the tenets of an air war: that is best left to professionals. One of the best books available on the art of waging an air campaign is "*The Air Campaign*," authored by John A Warden III (revised edition published in 1998, ISBN 1583481001). This section is also useful for TE designers who design complex tactical engagements. You can systematically plan your air campaign to destroy piece-by-piece the enemy's air defenses.

DISMANTLING THE INTEGRATED AIR DEFENSE SYSTEM

One of the key features in the Falcon 4 Realism Patch is the presence of an integrated air defense system (IADS) and network. With such a network, the enemy is capable of detecting the presence of your forces, and vector interceptors or command SAM batteries to engage them. From a force protection point of view, it is important for you to reduce the enemy's integrated air defense network into various isolated components. You will need to divide your enemy so that you can rule over him. You should make sure that you understand how the IADS environment function in the Realism Patch. A detailed description of the IADS implementation in the Realism Patch can be found in the section titled "*Ground Control Intercept, Integrated Air Defense System, And AWACS in Falcon 4*" in the Designer's Notes.

The Opening Move

The functional state of the enemy IADS will determine the tactics that you can use. At the beginning of the campaign, the enemy air defenses will be largely intact. Your strike aircraft will be forced to run the gauntlet of enemy interceptors and SAM/AAA batteries. Since the enemy's GCI/EW radar network is functional, you may want to consider using low level NOE (Nap of the Earth) tactics during the opening moments of the air war. Such tactics allow your strike packages to enter the enemy's airspace, while minimizing the chances of the enemy detecting them.

However, this will expose your strike packages to a considerable amount of low level SHORAD threats. You should target the enemy's EW/GCI radar network early in the air campaign, so that you can create gaps in the enemy's radar coverage. While your ground forces may be in need of air support, you need to bear in mind that the presence of enemy interceptors and combat air patrols will seriously disrupt your ability to conduct BAI/CAS missions effectively. You should plan to destroy the enemy's GCI ability early in the campaign, as well as destroy enemy airbases and disrupt his ability to conduct air operations against you.

The emphasis in the early part of an air campaign should be to establish air dominance over the battlefield. This means that you should actively seek out and destroy airbases and EW/GCI radars. You should also actively sweep the skies for enemy interceptors and combat air patrols, as these will present problems when you need to shift the emphasis of the air war towards ground support. Destruction of airbases will ground the enemy's interceptors, and the two pronged approach of destroying enemy fighters that are flying, while preventing others from taking off, is the most effective way of ensuring that your own strike packages remain unmolested by enemy fighters.

SEAD Rollback and Destruction of the Enemy IADS

One of the most important components in a strike package is the SEAD escort. Dedicated SEAD strikes will also contribute to the survivability of the strike packages by destroying the SAMs and early warning radar (EWR) assets. The IADS consists of early warning radar stations at dedicated radar sites, air bases, SAM sites, and air defense units, as well as AWACS. All these assets are linked together to give the complete GCI (Ground Controlled Intercept) environment.

The threat to strike packages exists in the form of the enemy SAMs/AAA, as well as enemy fighters. SEAD strikes and SEAD escorts will usually be tasked to destroy radar SAM sites, as well as radar sites. Make full use of the anti-radiation missiles that are available to you, and use them wisely to destroy the fixed SAM sites as well as EW radars, instead of wasting them on mobile SAM vehicles. The destruction of the enemy's radar SAM sites will neutralize the ground based medium/long range threats, and limit the ground threats to SHORAD SAMs, which are largely ineffective against targets flying above 10,000 feet in altitude.

Figure 47: Russian "Long Talk" GCI radars. Destruction of such radars will compromise the IADS of the enemy.

All enemy fighters in the Falcon 4 world operate as an integral part of the IADS. The destruction of the enemy's EW radar stations, airbase radars, and SAM radars, will interrupt and create holes in the enemy's radar coverage over the battlefield. The holes created allow strike packages to fly into the enemy's airspace relatively unmolested, and without the fear of being intercepted by GCI directed enemy fighters.

By denying AWACS/GCI support to the enemy, air-to-air engagements against enemy fighters will degenerate to localized aerial engagements, instead of a co-ordinated aerial battle. For example, the enemy's MiG-21 may be vectored to intercept low flying strike aircraft in a GCI/AWACS environment even though the MiG-21's own radar cannot detect the strikers. This can and will happen as long as the strike aircraft are detected by **any** radar in the enemy's GCI/AWACS network. If the enemy's GCI/AWACS network is disrupted, the MiG-21s will need to detect the low flying aircraft with their own onboard radar, which is not capable of look-down operations. This will allow the strike aircraft to sneak into the enemy's airspace without being intercepted.

You should plan systematically to dismantle the enemy's IADS network through SEAD strikes and SEAD escorts, as well as dedicated strikes against the enemy's EW radar stations and airbase radars. This will seriously compromise the enemy's ability to wage a co-ordinated air war against you, and you will be able to limit the enemy's fighters to localized aerial engagements, where you can exploit the advantages of your own fighters advanced avionics. This is best illustrated by Operation Desert Storm in 1991, as well as Operation Allied Force in 1999. The IADS networks of the Iraqis and the Serbians were systematically destroyed by the Allied forces within the first week of both conflicts, and thereafter, the Allied fighters had a free reign over the skies of Iraq/Kuwait and Kosovo.

As part of your mission planning process, you should always examine the enemy's low and high altitude radar coverage for gaps. It is also important to examine the low and high altitude threats (by toggling on the threat circles). The campaign map will show the threat circles for every detected unit that is capable of engaging your aircraft, and this includes SAM, AAA, as well as other combat units. Learn to exploit these gaps in GCI/AWACS coverage, and use these as transit routes for your own fighters to use. You will minimize the risks to you own forces by not exposing them to the enemy's air defenses and fighters. As you wage the air war, and systematically destroy the enemy's IADS, you will find more gaps in the GCI/AWACS coverage, and this will give you more freedom in planning your future air operations.

You should also make full use of any stand-off jammers that may be at your disposal. Stand-off jammers are invaluable in providing protection to your strike packages, when the SAM and fighter threats have not already been neutralized. SOJs are “soft kill” options available to you as part of a SEAD rollback campaign. The most effective SEAD campaign will combine the “soft kill” options such as SOJs, and “hard kill” options such as SEAD strikers equipped with anti-radiation missiles.

One important factor that you should know about an IADS is the level of integration between all the EW/GCI and SAM radars. This is a key feature of all modern IADS (and is modeled in the Realism Patch). The radar coverages of EW/GCI radars and SAM radars overlap. If the radar coverage of a radar is covered by another radar in the IADS network, the radar will shut down and rely on other radars in the IADS network for detection and target information. These SAM sites are still capable of engaging enemy aircraft. When SAM and EW/GCI radars have been destroyed, the “dormant” radars will become active to fill in the gaps in the radar coverage. You will thus need to maintain the pressure for at least the first few days of the war, to ensure that you have crippled the enemy IADS structure.

You can influence the ATO generator by changing the campaign priority sliders (for a detailed description of the functions of the sliders, please refer to the section titled “*Beyond Winning Battles: Winning The War*”). Your primary target types should be aircraft, air fields, air defenses, radar, and CCC facilities. You should also concentrate on OCA, SEAD, and interdiction missions. This will ensure that the campaign engine allocates a greater proportion of missions dedicated to destroy the enemy IADS.

Low and /Medium High Altitude Tactics

As you begin to gain air superiority, you should move away from low level tactics, and begin to shift your operations to medium level altitudes. Low level tactics are extremely dangerous, as the low level SHORAD threats cannot be eradicated effectively in the SEAD rollback. Every ground troop will be able to shoot at your strike airplanes, and the SHORAD threat cannot be dismissed lightly.

As you gain air dominance and destroy the SAM and fighter threats, you will have a free reign over the skies. Medium level tactics (above 10,000 to 15,000 feet altitude) will put your own strike aircraft out of the range of most if not all the MANPADS and SHORAD threats. The SHORAD threat accounts for more combat loss during Operation Desert Storm, as compared to enemy SAM/AAA batteries and fighters.

One of the disadvantages of adopting medium level tactics is the difficulty in identifying targets, and the reduced accuracy when delivering dumb bombs. You will have to trade off between force protection, and targeting accuracy. If the SHORAD threat is dense, then it may not be worth pursuing the higher targeting accuracy at the expense of your own pilots.

Target Selection

Target selection is an extremely important aspect of an air campaign. In the Falcon 4 world, you have control over the targets for your strike packages. You should ensure that you maximize the destruction capacity of your strike packages by ensuring that they do not all target the same objective (such as the control tower). You should also assign targets to individual strike aircraft to ensure that the key objectives are destroyed (such as runways, control towers, radar sites, etc).

Shifting The Emphasis

However many EW/GCI radars, SAM sites, and enemy fighters you destroy, this will never help to win the war. Wars are won and lost on the ground. The destruction of the enemy’s IADS will serve to provide a conducive and less hostile environment for you to conduct BAI/CAS operations in support of the ground combat units. The political aspect of an air campaign is not modeled in Falcon 4. As such, it will be rather pointless for you to target political and infrastructure targets.

Airlift missions are generated in Falcon 4 to provide supplies needed to fuel the war effort. Each successfully airlift mission gives the team a total of 20 supply points, 2 fuel points, and 2 replacement points. Factories and refineries produce supplies and fuel to sustain the war effort. The production capacity of each factory and refinery varies, and decreases as they are damaged [3]. The factories and refineries require power supply to function, and the destruction of power and nuclear plants will prevent them from functioning. Destruction of the enemy's war production and logistics infrastructure will hamper his ability to wage war against you.

You should provide adequate air support for ground units that are involved in combat with enemy units. Your fighter assets are essentially flying bomb trucks once you have achieved air superiority. You should also dedicate a portion of your fighters for interdiction missions, i.e. to destroy enemy ground units that have yet to enter the war (such as strategic reserves).

You should strike a balance between apportioning part of your air assets to strategic strikes, and part of your assets to support the ground forces. It is useless to attack only strategic targets, as the enemy ground units may be over-running your frontline. Similarly, it is a futile exercise to attack the ground units when their supply lines are intact. As you move into this phase of the air war, you should shift your emphasis towards targeting infantry, armor, artillery, and support units, as well as infrastructure, logistics, war production, and CCC facilities. You should also adjust your mission priorities, so that the campaign engine will generate a greater proportion of interdiction, CAS, and strategic strikes.

Ordnance Allocation and Conservation

One of the most important functions for a war planner is ordnance allocation and conservation. Weapons will run out during a war, and effective usage management will ensure that you do not run out of weapons before the next resupply.

You have a wide variety of different weapons at your disposal. Each of these weapons has been optimized for a different target. You should ensure that your fighters are loaded with the appropriate weapon for its mission. You should also know the amount of weapons available to you, and monitor their usage. For example, if you do not anticipate any serious air threats, you should conserve weapons such as AIM-120 and AIM-9M, and equip your fighters with the less capable AIM-9P instead. You will thus save the more capable air-to-air missiles for a time when the air-to-air threat is more ominous.

You should also conserve your stocks of precision guided weapons. While laser guided bombs and Mavericks are highly accurate, you will not have many of them. You should learn to equip your strike packages with various weapon fits, for example, equipping the lead with Mavericks and the wingman with cluster bombs. This gives you more flexibility in target selection, especially on BAI/CAS missions. Effective ordnance management will help prevent your squadrons from running out of certain weapons when you need them most.

Force Protection

While you are waging war on the enemy's IADS, you will need to protect your own assets. You depend on your GCI/EW radar sites, SAM battalions, and AWACS, to provide you with the air picture. The air picture is only as complete as your assets are, and as your own IADS assets are destroyed, you will find that the air picture becomes less complete, and uncertainty increases.

You should understand the threat posed by your enemy, such as his ability to conduct SEAD operations, etc. Place your CAPs and interceptors at locations that will allow them to intercept enemy airplanes flying at low altitudes, and make sure that the HAVCAPs and BARCAPs are positioned

[3] The production capacity of factories and refineries are given in the objective data file, FALCON4.OCD. The data field is labeled "Data", and this corresponds to the number of supply or fuel points that the facility is capable of producing over a 24 hour period, if it is 100% functional.

sufficiently forward of your IADS assets (such as EW/GCI radars and AWACS), so that the enemy cannot engage these assets from stand-off ranges. For example, the AS-17 anti-radiation missile has a typical range of 50nm.. You should place your CAP flights at least 50 to 60nm. ahead of your EW/GCI radars and SAM batteries, so that the enemy fighters equipped with this missile will be intercepted before they can launch their missiles.

Your fighters are most effective when they function as part of your IADS. By placing your interceptors and CAPs where you have radar coverage, you will give them a better change of success as your IADS assets can vector them to the threats. You should also consider placing some fighters to plug the blind zones of your EW/GCI/AWACS radar network.

CONCLUSION

Adjustments of the campaign priority sliders will allow you to exert an influence over the war. You should adjust the target and mission priorities of each squadron individually, as the campaign progresses. It is a good idea to save the campaign periodically, and then reenter the campaign under a different squadron to adjust the priorities. Although this is a tedious process, it allows you to influence the ATO engine and tailor your air campaign depending on how the war progresses. A thorough understanding of functions of the campaign sliders is essential for you to use them effectively.

The effectiveness of any air war is not just dependent on good piloting skills. Effective management of your assets will multiply the effective combat power. A systematic way of waging the air war will help you achieve your war objective in a progressive and systematic fashion, and increase the options available to you for conducting air operations. Effective logistics management will also ensure that you are able to sustain the tempo of your own operations, and bring pressure to bear on your enemy around the clock. You will be surprised at the results if you take an active interest in management of the air war in the Realism Patch.

CHAPTER 3: TACTICS AND WEAPON EMPLOYMENT

INTRODUCTION

Now that we have covered the basics of mission planning, it is time for some action. All the planning and considerations will go to waste if the tactics do not match up. We will not cover the basics such as intercept tactics and basic fighter maneuvers. These are best described in the Falcon 4 user's manual, and other books dedicated to such topics. The tactics covered here are limited to missile employment, missile evasion, and sensor employment.

Figure 48: Kitting up and getting ready for the flight. (Picture credit of USAF)

The section titled "*Conquering The Virtual Skies*" will give you a quick overview of the changes made in the Realism Patch, and some of the considerations that we have taken into account. It you are impatient and do not want to read about the details, this is the section to read to familiarize yourself with the new air war environment compared to the stock Falcon 4 1.08US. We will then plough into the nitty gritty of tactics and weapon employment.

Sensor management is the most important factor in maintaining your situational awareness. Your onboard sensors include your own Mark I eyeball, the radar, and the RWR. All these sensors will supply information to you, which you will need to interpret and understand, and form your own mental picture on what is going on around you. We will discuss this in detail in the section titled "*Managing Electrons*." This is where you will learn the differences between each radar mode, and what the RWR is trying to tell you. You will also learn about the intricacies of using jammers, and emission control (EMCON) discipline. We have also compiled a number of frequently asked questions, and provided the answers to these common questions.

Figure 49: F-16C from the 36th FS taking off from Osan AB, South Korea. (Picture credit of USAF)

We will then discuss in detail all the air-to-air weapons available in Falcon 4. You will be briefed on the employment considerations, and the tactics to evade and counter them. Knowing your weapon's characteristics will enable you to employ them more effectively, and knowing the weapon characteristics of your enemy will allow you to counter them more effectively. Read all that you need to know about air-to-air weapons in the section titled "*The Pointed End Of the Sword*." In case you do not have the patience to wade through the detailed briefing, we have also compiled a number of frequently asked questions at the end of this section.

Lastly, we will discuss how not to play nice with the enemy in "*Chivalry Is Dead*," and how to manage your AI wingman in "*Mothering The AI*." We will discuss in some detail the tactical considerations of fighting F-pole and A-pole combat, and infra-red countermeasure tactics as well as fighting off-boresight missiles. If you want to survive, you will need to be able to destroy the enemy before they destroy you. You will also learn the various tricks of helping your AI wingman survive their missions.

Read on, have fun, and we wish you clear skies and tail winds!

CONQUERING THE VIRTUAL SKIES

Overview Of The Air War in Realism Patch
By Paul Stewart

REALISM PATCH CONSIDERATIONS

The Realism Patch represents literally thousands of man-hours of research and editing by hardcore simulation fans. The goal was principally to enhance the simulation by creating a more realistic and thus tactically dynamic environment than had existed in the original and unfinished Falcon 4.0, whose development was discontinued by Infogrames in December of 1999.

Every single change included in the patch, from the concrete (ammunition and weapons modeling) to the abstract (AI "awareness" zones) was performed with the principal goal of realism in mind. In almost every instance, each change can be traced to specific, referenced sources including Jane's Information group, World Air Power Journal, the United States Naval Institute, and well-researched books written by military aviators (Yefim Gordon, others). In addition, the missile modeling was done in strong collaboration with former military pilots and enlisted men, and engineers with experience in these fields, participating in the Realism Patch development.

Many, many things have been addressed, though clearly more remains to be done. Though the goal is to achieve realism, care was also taken to utilize only publicly available and unclassified data.

When you enter F4 enhanced with the Realism Patch, you will find the tactical environment of F4 is considerably changed. In some situations, you will find flying in F4 more survivable than 1.08US, but in others you will find it more lethal. The goal of this short piece is to provide a description of some of the general changes that you will experience, and some information that players may need to survive and succeed in this more realistic environment.

THE AIR-TO-AIR ENVIRONMENT - MISSILES

The tactical nature of the air-to-air aspect of the simulation is perhaps most changed. Many modern missiles such as the AMRAAM, Archer, and AIM-9 are very lethal when employed properly, while others such as the venerable AA-2 Atoll and the AA-7 APEX are less maneuverable and lethal than before. No matter what missile you employ, a single shot will no longer guarantee a single kill. Much will depend on altitude, target aspect, closure rate and line-of-sight (LOS) rate.

Most players will notice the change to the AMRAAM right away. In the default F4, the AMRAAM is nearly 100% capable of hitting and killing any target at any aspect and airspeed out to a range of about 45-50nm. While published estimates of the AMRAAMs maximum range do vary from 20 to 45nm, these are typically *kinematic* or even *ballistic* ranges at high altitude and high closure rates against non-maneuvering targets. While the AMRAAM is capable of *reaching* 45nm, its energy state at that stage is so low that the Pk of the missile is very poor.

You may have heard of the concept of the "no escape zone," which is a dynamic zone in front of the launching aircraft in which no target will escape from the missile. This means that the missile will reach the target no matter what evasive maneuvers or escape tactics the target makes. Whether the missile hits or is "spoofed" at the end game is another question, but generally the Pk in the "no escape zone" is relatively high.

For the AMRAAM, you will find a "no escape zone" to be about 6-10nm in a tail-on chase or about 15-17nm for a head-on shot. At longer ranges, the missile may still hit and kill but the Pk of the missile will be lower owing to the reduced airspeed and consequently reduced maneuverability. The AI of the defending pilot will also be a critical factor. Cadet and Rookie pilots exhibit fairly poor BVR defense tactics, whereas Veteran and Ace AI shows some very sophisticated "out-range then beam" tactics and multiple out-of-plane jinks to force the AIM-120 to lose energy. An Ace MiG-29 can be seen in Dogfight mode to occasionally spoof the AIM-120 in this way.

For all missiles, the player will also note that head-on high closure rate targets are no longer a "sure kill," and all A/A missiles now have a minimum range for firing. This affects the BVR missiles particularly, and it is no longer wise to employ AMRAAM and expect it to perform like the AIM-9 in a dogfight scenario. For IR missiles, the effect of sun and ground IR clutter is similarly modeled, and players have to exercise caution when employing missiles such as the AIM-9P and AA-2 to ensure that the missiles are fired away from ground clutter and the sun.

In terms of DPRK, Chinese, and Russian missiles, you will find that the AA-11 (R-73) Archer is bar none your most lethal threat, followed close behind by the new and frightening AA-12 (R-77) Adder Active-Radar-Homing missile developed by the Vympel corporation. In real life, the AA-12 has been ordered by the Chinese air force for its SU-27s (Malaysia and India placed orders also). You will see AA-12s in very limited quantities when the Chinese enter the war. A call-out of "Adder Inbound" or "Archer Inbound" is a most serious and dangerous threat.

In contrast to these lethal threats, other missiles will offer a more variable level of threat depending on the missile type and the range at which it is launched. The AA-10 series (AA-10A, B and C) are a respectable threat but can often (but not necessarily always) be defeated with good evasion tactics and decoys. The older, 1970's-era Soviet missiles (and earlier) such as the AA-1 Alkali, AA-2 and AA-7 series and AA-8 are more spoofable, with or without decoys. The IR and radar guided versions of the MiG-25 dedicated AA-6 missiles are also modeled, with their tremendous speed, as well as the frightening ability of the MiG-25 to launch the AA-6 IR missile from beyond visual range, without any RWR warning.

The net-effect of the more realistic missile parameters in F4 is that air-to-air engagements will be far less predictable and much more dynamic. No longer will both sides instantly obliterate each other with 1 to 1 exchanges of god-like super missiles with seemingly limitless kinetic energy and physics-defying maneuverability. In general, you will find that most weapons are no longer "golden bb's" in that they must be properly employed to obtain a reasonable Pk. Employment ranges have been reduced somewhat, especially at lower altitudes. Do not expect these repaired weapons to retain the energy and maneuver capacity of any previous F4 weapons. It will behoove the shooter to maneuver to the heart of the firing envelope or risk seriously degrading missile Pk.

As missile gimbals are now realistically modeled, the shooter will also need to be aware of engagement geometry so as not to result in the missile exceeding its gimbal limits during launch. These stands in stark contrast to the original F4, where missiles could be launched considerably off-boresight and still achieve hits. Missile minimum range is now modeled to some extent.

Even the blast radius of each warhead has been altered to realistic values. In the default F4, the blast radius of most A2A missile was a whopping 225 feet. This blast radius is more appropriate for a medium-to-large sized SAM and can hardly be considered accurate for most air-to-air missiles. In the real world, the AIM-9M's and AA-11 Archer's blast radii are estimated to be between 30 and 40 feet. The AIM-120 blast radius is somewhere above 55 feet. The blast radius edits also mean that all missiles and SAMS will have to get closer to the target before detonating. Since the performance of most modern missiles is most crucial during the end-game, the realistic blast radii will allow the player to experience the difference between a near-miss and a proximity hit, rather than having all missiles, no matter how maneuverable or how poor, simply detonate 200 feet away and destroy your aircraft.

Tactically, you will see differences in each A/A missile's ability to track its target. Some missiles will be easier to out maneuver, while others such as the AA-11 will have the ability to maintain track and re-engage the target if the first hit opportunity is not successful. The ability to turn into the missile and cause it to break lock will also depend on the tracking ability of each missile, your aspect, airspeed, and LOS rate across the missile's FOV. Similarly, the effectiveness of counter measures will vary, and will depend on timing the employment of such counter measures properly.

AIR WAR TACTICAL CHANGES

In the original F4, most air-to-ground sorties were wasted (both Allied and Enemy –see Bubble and abstract combat definitions) because ground entities were not deaggregated except for very near the player aircraft. However, since the bubble slider is now functional, this allows for an even greater expansion of the air and ground bubble. Aborts are drastically decreased and CAS, STRIKE and BAI missions performed by AI aircraft are far more successful on both sides when "inside the bubble."

The aircraft and long-range SAMs are now more aggressive on both sides (allied and enemy). This effect is primarily due to an increase in “awareness” zones of aircraft and SAMs, as well as improved AI sensor usage.

Figure 50: Direct hit on the target ! This is the desired end result of every bombing mission. (Picture credit of USN)

SAMS now require a more realistic detect and track time prior to actual missile launch. This allows for greater HARM opportunities. There is also no need to keep the HTS cursor locked on the SAM site to deaggregate it in order for HARMs to engage effectively.

AIR WAR STRATEGIC CHANGES

Rapid Runway Repair efforts are now based upon real-world data (based on Iraqi Gulf War repair times, Arab-Israeli repair times, and consultation with an expert on Rapid Runway Repair at Arizona State University). Individual runway sections now take 3-4 hours to repair, resulting in total runway repair times of up to 12-16 hours depending on runway size and the extent of damage.

THE SURFACE-TO-AIR ENVIRONMENT

DPRK (and Allied) air defense systems will be both more and less lethal than the original 1.08US, depending on the defensive system encountered. Unquestionably the most immediate and salient change is the much greater frequency and range of AAA guns. North Korea possesses a great quantity and a *wide* array of AAA in its arsenal, from low altitude 30mm AAA to extremely high altitude 100mm AAA guns. The higher-caliber AAA guns have practical engagement altitudes of between 24,000 and 45,000 feet AGL. Combined with low (ZSU-23-4) and medium-altitude AAA, it is possible for the DPRK to pose an AAA threat from as low as 1,000 feet to as high as almost 45,000 feet. The KS-19 100mm AAA gun and the KS-12 85mm AAA gun near the FLOT at the DPRK HART sites will make this clear fairly quickly. Below 1,000 feet there is now the danger of encountering small arms fire (AK-47s) and MANPADS on both foot soldiers and soldiers in select vehicles. As always, it is best to fly above AAA unless there are many high-altitude SAMs. If forced to fly through AAA, it is best to enter and exit its envelope quickly, and where possible alter course to throw off the enemy's firing solution.

SAMS are more numerous and varied than in the original F4, especially if and when Russia enters the war. Many SAMS that belong to the DPRK and the Combined Forces were lying dormant in the F4 code, whereas a few (such as the Chun-Ma) were added to F4 because they are actually in the DPRK or ROK inventory. In general, older Soviet-era SAMS such as the SA-2, 3, 5, and 6 have far greater envelopes (altitude and horizontal ranges) and are capable of engaging at longer ranges rather than waiting until the last possible moment.

At the same time, however, the maneuverability of these SAMs is now based upon well researched kinematic and performance data from a professional aeronautical engineer. This means that although the SAMS are more numerous and longer-legged, they are also more easily spoofed. By far the most dangerous SAMS are the low to low-medium altitude Russian SAM systems such as the 2S6 SA-19 launcher and the SA-14. Some of these systems have the capability of engaging air targets as high as 9-14,000 feet. All this information again points to the necessity of being wary as one enters the low altitude arena. When you play with the Realism Patch, you will understand far better why it was that many aircraft were not allowed below 15,000 ft in the Kosovo Conflict. For medium and high altitude SAMs, you will also notice a distinct minimum range and altitude where the SAM can be fired at you, and it will not have the ability to maneuver quickly enough for a kill. This allows the shooter to employ tactics to close in to bomb at lower altitudes and out turn the missile during SEAD strikes, the same tactics the Israelis employed against the SA-2, SA-3, and SA-6 SAM sites during the Yom Kippur War.

RUNWAY REPAIR

Runway repair times in F4 have always varied from one extreme to the other. In the original Falcon 4.0, runways were repaired at an unrealistic rate (in as little as 20 minutes) following even massive cratering damage. Runway repair times were later disabled completely in 1.08US (a bug that the developers later planned to fix before the project was discontinued), and then set arbitrarily at 12 hours per section by MPS in the waning days of the Microprose F4 labs.

However, none of these repair times had a specific basis in any historical records. Research investigating runway repair times during the Gulf War [1] and the Arab-Israeli Wars [2] was conducted. In addition, information about the North Korean’s capabilities was gathered through consultation with an expert [3] in Rapid Runway Repair (at the Performance Based Studies Research Group (PBSRG) at Arizona State University). All three sources of information have revealed that, in real life situations, entire runways can be restored to at least operational status in 4-12 hours depending on the amount of damage. The North Koreans may take as long as 12 hours to repair a runway that has been cratered continually by multiple BLU-107 Durandals across its longitudinal axis [3]. This is possible because organized airfield-repair teams are typically supplied with fast-setting concrete and other critical materials that are pre-positioned very close to the runways.

For example, "Runways are attractive targets for enemy aircraft to take out. A bomb is dropped on a runway, which creates a large crater putting the runway out of commission. If aircraft can't get off the ground then they can't fight. Rapid runway repair is a long, tedious process that is vital to success on the battlefield and in the skies. The main focus in airfield repair is the Minimum Operating Strip (MOS), which the United States doctrinally defines as 15 by 1,525 meters for fighter aircraft and 26 by 2,134 meters for cargo aircraft.

Coalition attacks on runways complicated Iraqi airbase operations, but there is little evidence that they hampered sortie rates. Iraqi runways were reportedly repaired in as little as four to six hours [1]. Under ideal conditions with a motivated crew, the rapid runway repair task would take a minimum of about four hours. If reasonable allowances are made for the cold weather impacts on both the soldiers and equipment used for a snowy, windy 20°F day, the time is increased to about seven hours. In the Arab-Israeli war of October 1973, Arab repair teams typically restored damaged runways in nine to twelve hours. [2]" [FAS.org].

1. *Air Attack Short of Goal; Hussein's Force Intact, Defense Aides Say Privately," Newsday, 24 January 1991, 5*

2. *V. K. Babich, Aviation in Local Wars (Moscow: Voyenizdat Publishing House, 1988), in Joint Publications Research Service (JPRS) Report--Soviet Union, JPRS-UMA-89-010-L, 2 October 1990, 51.*

3. *Communication: Dean T. Kashiwagi, Ph.D., P.E. Assistant Professor Director of the Performance Based Studies Research Group (PBSRG) at Arizona State University.*

Runways in Falcon 4.0 have two or three "sections" each. With the Realism Patch, each runway *section* now takes approximately 3-4 hours to repair. This repair time, in addition to the time it takes for Engineering Battalions to begin repair operations, results in a total of about 12 hours of repair time for medium (3 sections) runway. Unfortunately Falcon 4 does not model the ability of air forces to use alternate highway strips, long taxiways and selected roads in the even that primary airbase runways are destroyed.

This is in contrast to 1.08US and 1.08i2, where runway repair times required an unrealistic 2-3 days or more before sorties could be regenerated. Note that the runway repair times, in Falcon 4.0 and in real life, are not based upon the time it takes to achieve *pristine* runway conditions, but rather the average time needed to achieve *operable* conditions. Former Soviet and Eastern-Bloc aircraft, with their stronger gear and ability to ingest more debris, are better suited to taking off on rough runways. An unfortunate thing, which cannot be modeled currently in F4, is the ability of aircraft to use alternate highway strips, long taxiways, and selected roads if or when the runways are destroyed.

AIR TO AIR CHANGES IN REALISM PATCH

Figure 51: MiG-23ML firing a SARH AA-7 missile

In the original F4, all IR Air-to-Air missiles used the same flight model and one of two IR seeker heads. This has been corrected. Now all IR A/A missiles have their own unique seeker, with accurately modeled FOV, gimbal limits, sensitivity (range), and susceptibility to clutter/sun and decoys (Infra Red Counter-Counter Measures). Each seeker is based upon real-world data as far as possible, from publicly available sources.

In the original F4, weapons had virtually no drag once fired and highly exaggerated maneuver capability, gimbal limits, LOS rates and warheads. This has been corrected. AA missile flight envelopes, blast radius, ranges, maneuverability, thrust, speed and decoy susceptibility are now based on publicly available real-world data for each missile (i.e. AA-11 “Archer” still deadly, whereas the venerable AA-2 Atoll is a poor performer). All missiles also now have realistic HUD cues for missile launch zones, and the effect of altitude on missile range and performance is now modeled, with missile range and maneuverability increasing with altitude.

Changes include:

- AA-1 radar guided missile now functioning properly on the MiG-19 and is no longer a “killer” missile.
- AA-2 Atoll missile now more accurately resembles the AIM-9B missile with rear aspect capabilities and limited dogfight maneuverability.
- AA-2R radar-guided Atoll now functional on the MiG-21, MiG-23 and MiG-29.
- AA-6 “Silent but deadly” BVR, command guided/terminal IR homing missile now loaded on the MiG-25 Foxbat. The RWR will not sound when the missile is fired from BVR.
- AA-6R radar guided missile now loaded on the MiG-25, replacing AA-7R. This missile is unique to the MiG-25.

- AA7-R APEX now functional on the MiG-23 Flogger.

- AA-7t IR APEX now functional on the MiG-23 Flogger.

- AA-10C now realistically modeled as a SARH missile. You will no longer get the "M" symbol on the RWR. The missile also lofts slightly now compared to before.

- AA-11 Archer now has thrust-vectoring capability with expanded seeker gimbal limits and IRCCM capabilities. The AI will also fire the AA-11 at high off-boresight angles.

- AA-12 Adder ("AMRAAMSKI") added to Chinese SU-27 Inventory. It's an active missile similar to the AMRAAM with a RWR symbol of "M."

- AIM-7 Sparrows no longer loaded on F-16s. The APG-68 doesn't have the capability to guide the Sparrow.

- AIM-120 no longer behaves like a FMRAAM (Future Medium Range Air-to-Air Missile). "No Escape" zone roughly 15nm at high aspect, with Pk still viable but decreasing at longer ranges.

- AIM-9P now modeled more closely as a rear aspect missile and can no longer be slaved to the full radar gimbal limits.

- AIM-9M now has realistic seeker gimbal limits and maneuverability, and can no longer hit head-on targets from within gun range.

- Ammunition levels and damage for all A2A guns are now accurate.

- The MiG-29 now flies with AA-10 series missiles on the inboard pylons only, as is the case with the actual MiG-29.

- MiG-29 loadout probabilities altered to increase tasking of MiG-29 for the Air-to-Air role instead of air-to-ground.

SAM AND AAA CHANGES IN REALISM PATCH

In the original F4, all IR SAMS used a similar flight model and one of two IR seeker heads. This has been corrected. Now all IR SAM missiles have their own unique seeker, with accurately modeled FOV, gimbal limits, sensitivity (range), and susceptibility to ground clutter and decoys.

Figure 52: North Korean SA-5 missiles on display during a military parade in Pyongyang

Each seeker is based upon real-world data. The kinematics of each missile are also tailored according to publicly available real world data, with unique and corresponding maneuverability, engagement range, and altitude.

In the original F4, most control-guided SAMs (both allied and enemy) had extremely exaggerated blast radii, lead pursuit angles and maneuverability. Missile flight envelopes, blast radii, ranges, maneuverability, thrust, speed and decoy susceptibility are now based on real-world data for each missile. The radar SAMs now ping first before launching, and give ample warning through the RWR prior to launch, giving time for evasive actions. The kinematics against closing and retreating targets are realistic now.

Changes Include:

- HAWKs, Patriots, SA-2s, SA-3s, SA-5s, and SA-6s now have much greater engagement altitudes, but are less maneuverable. The missiles will also fly out to higher altitudes, corresponding to their real world counterparts.

- SA-5 now has realistic terminal active seeker, and realistic Pk against fighter sized targets

- The SA-7 is now much less maneuverable and effective. Real world data indicate the poor performance of this missile. The sun or ground IR clutter can now decoy the missile easily.

- SA-8 range now reduced and is more susceptible to chaff

- SA-13 now included in the sim

- SA-14 now included in the sim

- SA-15 now included in the sim

- SA-19 now included in the sim

- The Stinger now far more maneuverable and effective, and now rejects flares more consistently.

- The Patriot made more effective based upon real-world performance, with increased energy and engagement range

- Chun-Ma, an indigenous ROK, low-altitude command guided SAM now in ROK inventory

- North Korea's wide array of 25 to 100mm AAA capabilities now modeled much more realistically. KS-12 85mm AAA reaches a maximum engagement altitude of 24,000-27,000 feet, and the KS-19 100m AAA gun, which is deployed around the DMZ, can reach altitudes in excess of 40,000 feet.

- ZSU-57-2 AAA now reaches realistic engagement ranges of 13,000-15,000 feet.

- DPRK M-1992 37mm AAA now in Mechanized battalions with engagement ranges of -8,500 feet

- 2S6 Tunguska now carries realistic SA19 missile launcher system in addition to 30mm AAA capability with engagement ranges of 8,000 – 10,000 feet for the missile.

- Low altitude small-arms fire now modeled

- Range of ZSU-23-4 Shilka adjusted based upon actual performance data

PROBLEMS WITH MISSING MISSILES

An issue that arose with the first Realism Patch was that many users reported that their missile Pk were extremely low, even though the original Realism Patch did not, in fact, contain any of the new missile modifications except the blast radius edits. We have now determined that there is indeed a missile “pass-through” bug that can occur during period of very heavy CPU demand and high activity levels in the sim (very low frame rates). The “pass-through” bug simply refers to the fact that some A2A missiles will literally “pass through” the target and fail to detonate. This problem occurs because the Falcon 4.0 program must continually “poll” each missile and perform collision detection. When many missiles and objects are in the air at once, it takes longer for the F4 program to “strobe through” or “cycle through” all the missile and objects. When the missile is very fast and the blast radius is small, the target may pass in and out of the blast radius too quickly for the CPU to detect the collision. This problem did not exist in the original F4 because all the missile blast radii were unusually huge, thereby allowing even slow CPUs enough time to detect a collision even under the most CPU-intensive circumstances.

To address this problem in F4, the actual blast radii in the sim are slightly higher than they are in real life to compensate, though far less than they were in the 1.08US default. In addition, the problem is only occurring with regularity for users with slower CPUs and/or users who set the bubble and object densities to very high levels. Because it is caused by intensive CPU demand, it most regularly occurs over the FLOT, and rarely if ever occurs away from the FLOT. If you are experiencing what appears to be an unreasonably low Pk, and the missiles appear to be passing through the target or missing by a distance less than the blast radius (typically 30-60 feet) without detonating, the following should fix the problem:

1. Turn down the bubble
2. Turn down object density. You should bear in mind that a setting of less than 6 will not result in realistic composition of ground units, and many ground units will not perform properly (see the section titled “*Beyond Winning Battles: Winning The War*” in chapter 1).
3. Get a faster CPU

All three of these strategies should work. The final option would be to either uninstall the Realism Patch or go back to 1.08i2 until you get a faster processor. Option #1 and #2 should be sufficient, however. We recommend a bubble setting of “3” as a starting point if your bubble slider is enabled. Generally speaking, as frame rate falls below 10, the probability of missile pass-through grows. There is really no permanent solution to this, since with the bubble slider and –g switch, anyone can set it high enough to cause these problems.

AIRCRAFT AI

In general, the intercept AI of fighter aircraft has been enhanced in the sim beyond the rather myopic F4 default (see section titled “*Open Heart Surgery On Artificial Intelligence*”). In Falcon 4.0, the ability of any AI aircraft to detect you is unfortunately limited not just by its radar, but by the WEZ cues on the HUD which indicate the maximum engagement range of the missiles that it is carrying, or 10nm, whichever is larger. Falcon 4.0 AI aircraft can "see" you only if you have fallen into their weapons envelope. Because MiG-19s and MiG-21s all carry only short-range IR homing missiles, they cannot literally perceive or respond to threat outside of 10nm (save defensive maneuvers against missiles).

However, many missiles in the original F4 had unrealistically small WEZ cues associated with them. Thus, paradoxically, the missiles themselves were overpowered while the WEZ cues were undersized. This has been corrected. WEZ cues in the HUD now match the true kinematic envelopes of each missile. This results not only in correct weapons envelope feedback to the player and/or launcher aircraft, it has also expanded the "awareness zones" of many aircraft, permitting them to detect and respond to other aircraft outside of 10nm far more often than before. The AI changes have also totally revolutionized the AI, and as a result, the aircraft AI is now more intelligent and aggressive.

The net effect of this is that many times you will encounter enemy (and friendly) AI that is no longer “flying blind.” They will pick you up on radar and run an intercept on you, and will react to your presence when your radar spikes their RWR. This creates a far more realistic tactical situation, and requires you to be much more "on your guard."

ILLUSORY "WALL OF MIGS"

Many players of F4 have complained about the "Wall of MiGs" that they feel they have to get through to reach their target. While it is true that there are a large number of aircraft in Falcon 4.0 (allied and enemy), most players see this "wall" because they use labels and see scores and scores of "red" aircraft, each one looking like a potential threat. Labels may actually make it *harder* for people to concentrate on their mission and fly F4. Players see these aircraft everywhere, and tend to go after MiG-21s and such when they get within 15 miles, because they figure that distance is unsafe. And the more they see, the more they feel threatened and compelled to engage. Suddenly, your senses are flooded with potential dangers and it's hard to focus because so many things are distracting you and causing you to worry. Prioritization becomes difficult because you are looking at labels instead of your radar and RWR.

This hyper-defensive posture can be counter-productive especially when you realize that the vast majority of those aircraft are not after you. Most of them are on Strike, SEAD, CAS, BAI, or other non-AA missions. Aircraft on these sorts of missions will only attack you if you attack them, or if you fly within 2nm of the forward hemisphere of their aircraft. Leave them alone and they will leave you alone. Of those aircraft that are tasked with AA mission, you will only be "seen" if you fall inside their "engagement zones." For MiG-19 and MiG-21, these have a 10nm radius around the MiG. Don't get that close. For MiG-23s, 29s and SU-27s, they are potential danger since their engagement zones may be anywhere form 12-30nm radius depending on your altitude. Take this information into account and pay attention to AWACS and your RWR. And turn off the labels too (use the force, Luke). You'll live longer. Once you can start prioritizing your threats and ignoring non-threats you will find the skies a lot less crowded than you have perceived them to be!

MANAGING ELECTRONS

Sensor and Electronic Warfare Management in Realism Patch
By "Hoola"

THE ELECTRONIC ENVIRONMENT IN REALISM PATCH

With Sylvain Gagnon's and Marco Formato's assistance in the executable patches, and the data changes, we have created a totally new experience in electronic warfare in Falcon 4. You will find that in order to survive the battlefield environment, you will need to understand how best to employ your onboard electronic sensors, and how best to defeat the different radar types that you will encounter in the battlefield of Falcon 4.

All the different radars in the Falcon 4 universe have been given separate characteristics. We have made distinction between pulse and pulse doppler radars, pulse doppler radars with pulse capabilities, and radars of varying ability to resist electronic counter measures. You will also find differences in radar performance when looking down, and the varying ability of radars to maintain track when you are beaming them.

For example, with the MiG-21, the radar is not capable of detecting targets in the ground clutter. As such, if you are able to remain outside the MiG's visual envelope, you can now slip past it undetected. Beaming will also not work against this aircraft as the radar is a pulse type and does not rely on doppler returns to filter out targets. Comparatively, the MiG-29 radar is capable of looking down, but is handicapped in detection range. If you have detected the MiG-29 in the RWR, and you are flying in the weeds, knowing its characteristics will allow you to know if the MiG-29 has detected you, and allow you to take action before this happens.

The biggest change that has occurred is in electronic countermeasures. There are now considerations of coverage zones, and electronic signature caused by the ECM system. Use it properly and you will be able to deter a successful tracking missile launch against you. Use it improperly and you will lose its effect, or worse still, attract unwanted attention to yourself.

Implicitly, it also means that you will now need to employ a variety of tactics to avoid detection and foil a tracking radar missile shot. To best defeat an airborne radar, you will need to fly low, and beam or employ ECM against it. If you decide to beam the radar, you will lose ECM coverage. Do you then use ECM against ground threats, and beam against airborne threats? You will need to make considerations such as these to best utilize the defensive measures at your disposal. In order to survive, you will have to take the time to understand the threats, and how best to counter them defensively.

You will also find changes in the way NCTR works. You will now need to use a combination of RWR, radar, and AWACS to identify a target and its intentions. The pucker factor will now be higher in air combat, and it is important for you to really understand the characteristics and capabilities of every airborne threat, as you will need every bit of this knowledge to identify the target.

Enjoy the changes in the electronic landscape of Falcon 4, and welcome to the brave new world of electronic warfare. The maxim is "Understand your electronic threats and you will survive!"

RADAR MANAGEMENT

The sensor with the greatest reach is your own onboard radar. We will discuss the characteristics of various radars and radar modes, to give you a better understanding of how best to employ your own radar and exploit the unique characteristics of each radar mode.

Pulse Radars

Pulse radars detect targets by detecting the raw returns from the radar's own transmissions, and displays everything. This is akin to operating a pulse doppler radar in the ground mapping mode. The upside of this approach is that it makes the radar impervious to beaming, as there is no doppler filter to screen out slow moving targets. The downside of this is that the radar is incapable of detecting targets in look-down situations, as the ground clutter return will often mask out the true target return.

Pulse radars also have difficulty distinguishing chaff from the target return, and as such, are not prone to being decoyed by chaff. Interpretation of the radar picture requires a lot more skills, as the radar picture is displayed in raw video format, and will display even rain clouds or birds under some circumstances. The examples of pulse radars are the APG-159 in the F-5E, the Saphir RP-21 on the MiG-21PF, and the radar on the MiG-19.

If you are operating such a radar, you will need to exploit the ability of the radar to retain target lock even when the target beams you. However, your ability to detect targets are negligible in a look-down scenario. You are best served by maintaining a low altitude and search for targets in look-up scenarios. Once targets are detected, close in for your kill.

Pulse Doppler Radars

These radars rely on a doppler filter, and detect targets based on their doppler frequency. The filter screens out target doppler returns below a set threshold (sometimes known as the Moving Target Reject, or MTR). This will prevent slow moving vehicles such as trains and cars, as well as ground clutter, from showing up on the radar screen. This confers the radar the ability to look-down into ground clutter and search for targets, though the performance is much poorer compared to look-up performance (often about 2/3 of the look-up performance).

Pulse doppler radars have a high resistance to chaff as they base target detection on velocities. Chaff decelerates rapidly after being dispensed, and this is easily detected by virtue of the design of pulse doppler radars. The downside is that the pulse doppler radar is susceptible to beaming, which will lower the perceived closing velocity to a level below the doppler threshold.

Some pulse doppler radars such as the AWG-9 on the F-14 and the APG-71 on the F-15, have pulse and pulsed doppler modes. This allows the radar to switch to pulse mode when tracking a target performing a beaming maneuver, yet at the same time retaining the ability to look-down into clutter.

RWS (Range While Search) Mode

The RWS mode on the radar is a good compromise between rapid scan rate and target detection. The radar operates in a medium PRF mode to obtain a good trade off between detection range and range discrimination. Targets detected is displayed almost instantaneously, as no track processing are done. Coupled with a rapid scan rate and large scan area, the RWS mode is optimized for rapid target detection over a large scan area.

You can bug a target in RWS and maintain track on it, while searching for other targets in the SAM sub-mode. The detection ability of the radar is not degraded at all if all that you are interested in is one single tracked target while searching for other possible targets. The target track for the bugged target in RWS is also updated more frequently compared to other search modes. This should be the radar mode of choice, due to its rapid scan rate and good target detection ability.

TWS (Track While Scan) Mode

The TWS mode on the radar is a compromise of large scan area and target tracking performance. The radar operates in a medium PRF mode with a smaller scan area than RWS. Targets detected are not displayed immediately, as the radar needs to process the track file first. This makes TWS a poor mode to detect targets rapidly if you need to do so, though once detected, you can have data for multiple target tracks compared to track information for only one target in RWS.

The downside of TWS is the additional processing required to maintain track files on all the targets detected. This leads to increased processing and a lower update frequency for all the track files. Target tracks may appear jumpy at times due to the lower frequency of radar update frames, and as the radar processor's attention is split over all the targets, TWS does not retain track as well as a bugged target in RWS. This is a compromise of being able to maintain track information on multiple targets.

Implicitly, it also means that it is easier for a target to beam a radar in TWS mode and break its lock compared to RWS mode. The anomaly with TWS mode is that even when a target has exited the radar gimbal or scan limits, track processing will still take place for the next 8 seconds, even when the target has flown behind the radar. This feature of track extrapolation allows the target track to be retained if the target returns to the radar scan volume within the 8 second timeframe, but carries with it the penalty of degrading overall radar track retention capabilities due to the additional processing.

If you need to be able to maintain track information on multiple targets, this is the radar mode to use. Otherwise, you are better off with the RWS mode that offers faster target detection at a slightly greater range (approximately 10%), plus better track stability and retention for a bugged target.

VS (Velocity Search) Mode

The VS mode is a dedicated high PRF mode designed to detect targets with high closure speeds. The high PRF waveform confers VS mode a greater detection range, at the expense of range resolution. Bugging a target in VS mode will result in the radar going into single target track (STT). The advantages of VS mode are the increased detection range (about 20%) over RWS mode, and better ability to detect small, fast targets.

The increased detection range will yield more reaction time especially in look-down scenarios. Once you have identified the greatest threat, bugging the threat will transit into STT mode to obtain the fine range, angular, and velocity measurements.

VS mode is ideal if you are tasked for sweep missions or CAP missions. The longer detection range will identify any incursions from further out, allowing you to take action faster, and the one step transition to STT is invaluable as you do not have to double designate like in RWS to transit into STT.

Single Target Track (STT) Mode

This radar mode concentrates all the radar's attention on the single target of interest. The track data is updated very frequently as the antenna is trained solely on the target. This results in excellent track quality, and makes it more difficult for the target to break the STT lock through beaming or ECM, as the radar processing power is dedicated to maintaining the STT lock. Radar ECCM performance is also enhanced in the STT mode.

Target track quality comes at the expense of scan volume and search ability. You should use the STT mode if the target is maneuvering violently, as the radar is better able to retain track update. When firing active radar guided missiles, STT mode will also provide higher quality of target information for the inflight datalink update of the missile, to further improve the Pk compared to firing in RWS bugged target mode.

Non Cooperative Target Recognition (NCTR)

NCTR is a radar processing technique used to identify a radar contact. This function is available in both STT and TWS modes. Due to the way the RWS and VS modes process data, NCTR will not be available in these modes.

For a detailed description of the NCTR technology and its implementation in the Realism Patch, please refer to the sub-section "*Revamping Non-Cooperative Target Recognition (NCTR) In Realism Patch*" in the Designer's Notes. NCTR works by analysing the jet engine modulation (JEM) characteristics of the target. The air intakes and engines of each airplane type are unique, and the combination of the engine and air intakes will give a characteristic radar signature. All these can be analyzed and programmed into a RCS characteristics library, and loaded into the radar processor. The radar compares the returns that it sees with the library, and guesses the target ID based on how well it matches its library. As the identification criteria is very much based on the radar returns of the engine compressor and the air intakes, NCTR does not work when the engines cannot be seen from the radar's persective. For NCTR to work, it must fulfill both of the following criteria:

i. You are within ±25° off the target's nose in azimuth
ii. Your altitude difference is such that you are within ±25° of the target's nose in elevation

You should also not expect the radar to be able to distinguish between sub-variants of the same airplane, such as a MiG-29 Fulcrum-A and a MiG-29 Fulcrum-C, and between an F-15E and F-15C. This is due to the fact that NCTR relies primarily on anaysis of the engine/intake radar returns.

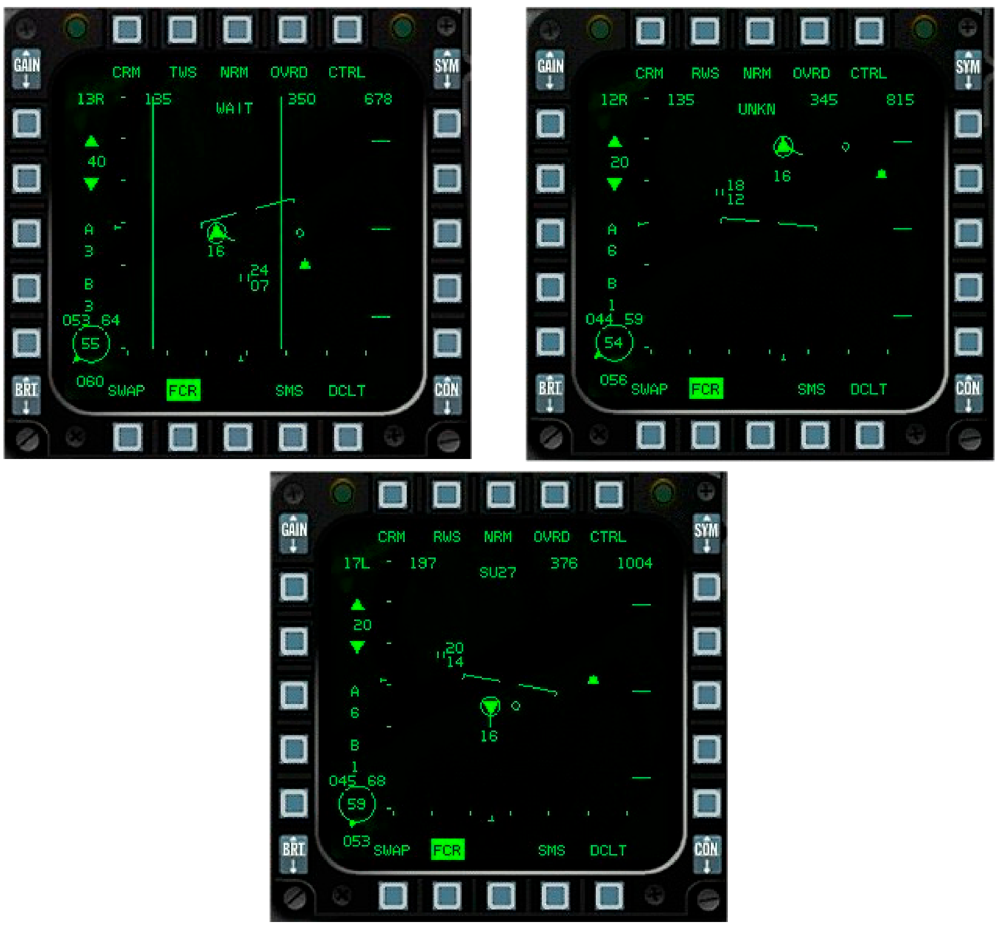

Figure 53: NCTR display in Realism Patch. The top left MFD shows the mnemonic "WAIT," indicating that NCTR processing is in progress. The top right MFD shows the mnemonic "UNKN" once NCTR processing is completed but the ownship is not within a ±25° cone centered on the target's nose. The radar contact cannot be identified. In the bottom MFD, the target is now pointed directly at the radar, allowing it to be identified as an Su-27.

When you lock-up on a target in STT mode, or bug a contact in TWS mode, the radar will attempt to identify the target ID. While the radar is processing the data, you will see the mnemonics “WAIT.” If the radar signal returns are strong enough for identification purposes, but you are not within ±25° in elevation and azimuth off the target’s nose, you should see the mnemonics “UNKN,” indicating that the radar is not able to determine the target ID. When you are within ±25° in elevation and azimuth off the target’s nose, the “UNKN” mnemonic is replaced by the target’s ID (see Figure 53).

The NCTR ID of each airplane in Falcon 4 Realism Patch can be found in the spreadsheet titled “F4_RP_Sensor_Properties.XLS,” under the worksheet titled “NCTR.” You will also find the range and conditions at which the NCTR ID can be obtained by the APG-68 radar in STT mode. For TWS mode, the NCTR ID will be obtained at approximately 70% of the STT range.

You will need to use all the means at your disposal to identify the target. As NCTR is not capable of telling you the intention of the radar contact, you will have to use the RWR (if the target is painting you) to identify it, as well as enlist the help of AWACS. You will find that for small targets, AWACS may be able to determine if the radar contact is hostile or friendly at ranges much further than the NCTR identification distance. For airplanes such as the MiG-29A and MiG-29C, you will have to analyze its characteristics, as the NCTR ID will be identical. The pucker factor will be higher, especially when you are facing a fast closing small target.

Radar Performance Under Various Conditions

The detection performance of a radar system is dependent on many factors, such as look-down situations, target aspect, etc. The radar cross section of a target varies with its aspect angle. For pulse doppler radars, this is complicated by the different doppler velocities at different target aspect angles. Tail-on targets are more difficult to detect due to the lower doppler velocities, and the smaller radar cross section, compared to head-on targets. For a detailed description of this topic, please refer to the sub-section “*Varying Radar Performance With Target Aspect In Realism Patch*” in the Designer’s Notes.

Typically, you can expect detection ranges to be reduced by 25% in tail-on situations, as compared to head-on situations. Detection range will be in between head-on and tail-on scenarios for targets in the beam. If you are using a pulse doppler radar, you will need to be concerned about the target disappearing into the doppler notch when it beams you. Look-down situations will present an even more challenging scenario to the radar, as the ground clutter will need to be filtered out, even for pulse doppler radars. You can also expect a reduction in look-down detection ranges for pulse doppler radars

RWR MANAGEMENT

The RWR is the only passive ESM equipment available onboard modern fighters. It is important that you understand the limitations of your RWR, and how information is presented by the RWR.

RWR Basics

RWRs are not all born equal. The early RWRs use crystal video receivers of limited sensitivity, while later RWRs use narrow and scanning wide band superheterodyne receivers with greater sensitivity. RWR are simple RF receivers designed to receive RF signals, analyze them rapidly, and if possible classify and recognize the emitter. They are normally comprise of receiving antennae (usually 4 or more), a processor, and a display system to display to the pilot the threats detected.

When the antenna receives an RF signal, it first processes the RF signal and reduces it to a raw video signal of the pulse pattern, and then the processor will analyze the signal and classify it according to the pulse width, frequency, pulse repetition interval (PRI), antenna scan, and direction of arrival (DOA). Once these are done, it will compare the characteristics against a pre-determined look-up table (also known as the threat library), and depending on how it matches against the threat library, it will output an audio tone and display the appropriate symbologies on the RWR display. The direction of arrival is determined vis-à-vis the relative signal strength received by the various antennae covering different quadrants.

The reception antennae are usually either tuned to a specific frequency band, or use a super heterodyne receiver that is tuned to scan rapidly across the frequency band of interest to detect RF signals. As such, the gain for the antennae are seldom as high as that of radars, and as such, RWR may not be able to detect the threat RF emissions even though the threat emitter has detected the target. This is modeled by giving the RWR a lower antenna gain. For example, a MiG-29 RWR will only detect the F-16 radar at a range of about 26nm., while the F-16 radar can detect the MiG-29 at a range of 38nm. in a look up situation.

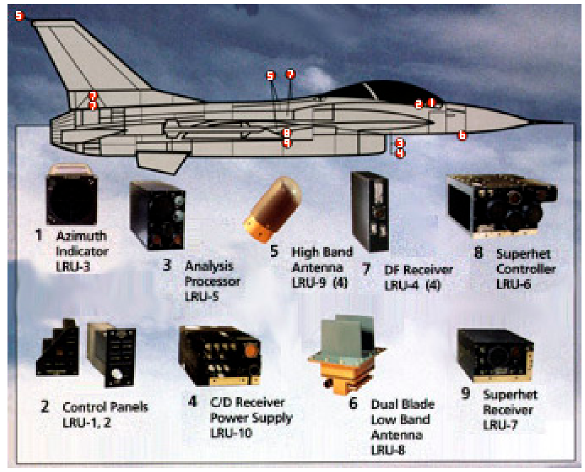

Figure 54: ALR-56M RWR Components

Also, RWRs do not provide full spherical coverage in elevation, though full coverage is obtained for azimuth. Most RWR antenna are designed for a reception coverage of ±45°. This forms a cone centered around the RWR antenna boresight. Western RWRs have an elevation coverage of ±45°, while Eastern Bloc systems have an elevation coverage of ±30°. Hence, if you lock-up a target outside the elevation coverage, it will still not trigger a spike on the target's RWR. Similarly, if you lock-up a target outside its RWR sensitivity range, it will also not detect your radar lock.

RWR recognizes radar emissions, not friends or foes. It makes its best guess as to what radar it has detected, and in a dense electromagnetic environment, this is often not simple. An RWR can only recognize a signal that it is programmed to recognize, and it makes no distinction as to whether the radar detected is friendly or hostile. This is a function left for the NCTR mode on the radar.

RWR Data Interpretation

The RWR will assign a symbol to the emitter detected, transmit an appropriate audio tone, and display the symbol at an appropriate location on the RWR display. The symbol location will correspond to the azimuth location of the emitter, but not the actual range.

RWR cannot determine actual emitter range. It senses only the signal strength of the emitter. For a emitter of low power, its symbol may be displayed on the outer RWR ring while an emitter of higher power will be displayed inside the inner ring, even though the low power emitter is physically closer.

All RWRs have threat libraries and lethal range information based on emitter power output. The RWR is programmed to display the threat symbol inside the inner ring when the signal detected exceeds a lethal threshold. This is designed such that the symbol will breach the inner RWR ring when you are about to enter the engagement range of the emitter (SAM or aircraft).

You should pay careful attention to the RWR display, especially any symbol that is displayed close to the inner threat ring or inside the inner threat ring. With SAMs and AAA, this allows you to fly around these threats and avoid getting engaged by them, by flying a ground track that does not result in the RWR symbols of these threats breaching the inner threat ring.

You should also make full use of the RWR LOW and HANDOFF facilities. The LOW function allows you to screen out high altitude threats and assign more priority to low altitude threats. This also changes the RWR gain for the low altitude threats. For example, you may be able to fly within 1nm. of a low altitude AAA gun with 3nm. range by flying above 15,000 feet, and not have the RWR symbol breach the inner ring, as the AAA gun cannot engage you. However, with the LOW function enabled, the RWR symbol will breach the inner ring at 3nm., to warn you of its ability to engage you when you are low in the weeds.

The HANDOFF function will step the RWR diamond through all the emitters detected by the RWR, in increasing order of threat priority. The RWR will automatically re-select the highest priority contact 12 seconds after you have last depressed the HANDOFF button. The RWR prioritises its contacts as follows:

1. The contact is inside the inner RWR ring, and has achieved radar lock-on.
2. The contact is outside the inner RWR ring, and has achieved radar lock-on.
3. The contact is inside the inner RWR ring, but has not achieved radar lock-on and is in search mode.
4. The contact is outside the inner RWR ring, but has not achieved radar lock-on and is in search mode.

The MODE function will also reduce the overall RWR activity to manageable levels. You should make full use of these to display only the most critical threats. The deluge of RWR information can easily task saturate you, and makes it easier to miss the critical warning or audio tone.

The RWR will also maintain track files of the emitters that it detects. Each time a new emitter is detected, the RWR will open a track file after identifying it. As long as the emitter continues to paint the RWR, the track file will remain active, and the symbol will continue to display on the RWR display. The emitter's audio tone will also be heard each time that the emitter paints the RWR. However, the RWR will not retain the track file indefinitely, and will purge it from its memory if the emitter fails to paint the RWR at least once every 6 seconds. For example, if a bandit goes head-on at you, you should see its RWR symbol and hear the audio tone as you remain in its radar coverage. Once the bandit flies pass you and you exit its radar coverage, the audio tone will cease, but you will continue to see its RWR symbology for up to 6 seconds, and the symbol will then disappear, unless the points its radar at you again within this time interval.

RWR Symbol Assignment

With the expansion of the RWR symbology library in the Realism Patch, the symbologies have been totally revised. The symbologies used are given in Table 13. You need to bear in mind that the RWR distinguishes radars and not aircraft types. As with all systems, there are inherent inaccuracies, especially in a dense electromagnetic environment. The characteristics of some radars are also very similar to one another (such as the radar on the MiG-29 and the Su-27/30), so it may not be possible for the RWR to distinguish between the different aircraft. Such uncertainties are modeled in the Realism Patch. You will notice that some radars have been assigned with generic RWR symbols (typically for attack aircraft and bombers). These airplanes are typically not a threat to most fighters, and precise identification is often not required from a threat assessment point of view.

RWR Symbol	Radar Type	Threat Type
Advanced Plane	Advanced Plane in Falcon 4 1.08US	Symbol superceded and no longer used in Realism Patch.
Old Plane	Old Plane in Falcon 4 1.08US	Symbol superceded and no longer used in Realism Patch.
2	Fan Song missile control radar	SA-2 surface-to-air-missile battery
3	Low Blow missile control radar	SA-3 surface-to-air-missile battery
4	Pat Hand missile control radar	SA-4 surface-to air-missile battery
5	Square Pair missile control radar	SA-5 surface-to air-missile site

RWR Symbol	Radar Type	Threat Type
10	Flap Lid missile guidance and tracking radar	SA-10 surface-to-air missile battery
6	Straight Flush missile control radar	SA-6 surface-to air-missile battery
8	Land Roll missile control radar	SA-8 surface-to air-missile vehicle
13	Snap Shot ranging radar	SA-13 surface-to-air missile vehicle
15	Tor missile guidance and tracking radar	SA-15 surface-to-air missile vehicle
A	Low band air defense AAA radar, typical of the Firecan fire director radar	S-60, KS-12, and KS-19 AAA sites Daewoo K-200 Air Defense vehicle
A with one dot below	Mid band air defense AAA radar, typical of the Gun Dish tracking radar	ZSU-23-4 air defense vehicle
A with two dots below	High band air defense radar, typical of the Hot Shot tracking radar.	2S6M Tunguska air defense vehicle 35 mm Oerlikon AA battery
C	Daewoo Pegasus fire control radar	Daewoo Chun-Ma air defense missile vehicle
H	I-HAWK High Power Illuminator	I-HAWK surface-to-air missile battery
P	AN/MPQ-53	Patriot PAC-2 surface-to-air missile battery
P with a dot below	Ground based pulse doppler radar	Unidentified ground based pulse doppler radar. Most probably for fire control purposes.
P with a slash down the middle	Ground based pulse radar	Unidentified ground based pulse radar. Most probably search radar or obsolete fire control radar.
M	Missile acquisition radar	Active guided missiles such as AIM-120, AIM-54, AA-12, and SA-5.
N	Nike Hercules missile control radar	Nike Hercules surface-to-air missile site
S	Generic RWR symbol assigned to radars with characteristics typical of ground based search radars	Ground based search radars
U	Unknown radar type, ground emitter. The RWR is not able to determine the radar characteristics.	Unknown ground based threat radar that is not present in the RWR programming library.
Ship	Naval radars	All naval vessels
Inverted V with a 4 below	AN/APG-120 pulse doppler fire control radar	F-4E fighter
Inverted V with a 5 below	AN/APQ-159 pulse ranging radar	F-5E fighter
Inverted V with a 14 below	AWG-9 or AN/APG-71 pulse doppler fire control radar	F-14B fighter
Inverted V with a 15 below	AN/APG-70 pulse doppler fire control radar	F-15C and F-15E fighter
Inverted V with a 16 below	AN/APG-68 pulse doppler fire control radar	F-16C fighter
Inverted V with a 18 below	AN/APG-73 pulse doppler fire control radar	F-18C, F-18D, and F-18E fighter
Inverted V with a 21 below	RP-21M or RP-22 Sapfir (or equivalent) pulse ranging radar	MiG-21, J-7 fighter
Inverted V with a 23 below	SP-23L High Lark pulse doppler fire control radar	MiG-23ML fighter
Inverted V with a 25 below	Smerch-A pulse doppler fire control radar	MiG-25 fighter
Inverted V with a 29 below	Slotback pulse doppler fire control radar. Radars include N-010RLPK-27, N-019	MiG-29, Su-27, and Su-30 fighter
Inverted V with a 31 below	S-800 Zaslon pulse doppler fire control radar	MiG-31
Inverted V with an A below	Generic symbol assigned to fire control radars equipping ground attack aircraft	Ground attack aircraft assigned with generic RWR symbol

RWR Symbol	Radar Type	Threat Type
Inverted V with a B below	Generic symbol assigned to fire control radars equipping bombers	Bombers assigned with generic RWR symbol, such as B-1 and B-52 fire control radars.
Inverted V with a P below	Unidentified airborne pulse radar	Unidentified aircraft equipped with pulse radar
Inverted V with a PD below	Unidentified airborne pulse doppler radar	Unidentified aircraft equipped with pulse doppler radar
Inverted V with a S below	Generic symbol assigned to radars with characteristics typical of airborne search radars	Airborne search radars, typically AWACS

Table 13: Realism Patch Radar Warning Receiver Symbology Assignment

RWR Audio Interpretation and Launch Warning

The RWR is programmed to issue a missile launch warning to the pilot, by sounding a launch warning audio tone as well as lighting up the launch warning light on the left canopy brow. To understand how this works, we need to discuss how the radar and missiles work.

For a radar in RWS, VS and TWS modes, the radar sweeps the sky in a regular fashion. The radar antenna is not focussed exclusively on any particular target. As far as the target RWR is concerned, it will only sound the regular chirps whenever the radar energy paints it. When the radar transits to STT mode, it's antenna is focussed at the target and the refresh and repaint rates intensifies. This results in the RWR tone for the emitter transiting from a regular periodic chirp to a constant chirp. When this happens, this is an indication that somebody now takes a very serious interest in your well being.

Normal radar transmission is in discrete pulses. This is the case for pulse and pulse doppler radars, regardless of radar modes (RWS, TWS, VS, or STT). When a missile is launched, depending on the type of missile launched, the radar may need to switch modes to support the missile in flight.

A semi-active radar homing (SARH) missile (such as the AIM-7 and AA-10) relies on the parent aircraft to provide the required target illumination, and homes onto the reflected energy from the target. The missile requires the radar to transmit in a particular waveform, known as continuous wave (CW), in order to guide. Instead of discrete pulses, the radar will have to transmit a waveform resembling a sine wave series. When the RWR detects the changing of the hostile radar transmission pulse-form to this CW pulse-form, this is an indication to it that a SARH missile has been launched at you. The RWR will then light up the launch warning light and sound the launch warning tone.

For an IR guided missile, the radar does not need to provide any support to guide the missile, except in the initial target cueing prior to launch. As such, the RWR will not be able to detect the missile launch. However, due to the short range, the enemy will usually lock you up in STT, and you will be able to detect from the change in the RWR chirp that you have been locked onto.

As for active radar homing (ARH) missiles such as AIM-120 and AA-12, this gets hairy. ARH missiles are guided in inertial mode throughout most of its flight. During this phase, the launch aircraft only needs to provide periodic update of the target location through a datalink to the missile. As such, ARH missiles can be fired even in RWS, TWS, or STT mode, as long as the target is bugged. You will not be able to decipher through the RWR tone if the enemy has fired or not, since the missile can well be fired in RWS bugged target mode. Because there is no change in the radar pulse-form and transmission characteristics, the RWR cannot detect the launch, and will not sound out a launch warning even when the missile is fired.

Once the ARH missile arrives over the target area, it will turn on its onboard radar and begin to search for the target. The active missile onboard radar are usually in the I/J band, with transmission characteristics similar to that of a typical fighter pulse doppler radar. As such, the RWR tone will sound exactly like a fighter will (of course with its own distinctive chirp). While it is searching, you will only hear a periodic chirp as it sweeps its radar beam across the search volume. Once it has locked onto you, the RWR tone will change to a regular chirp similar to an STT lock. Again, as the transmission is similar to a normal STT, i.e. discrete pulses and not CW, the RWR launch warning will not be triggered. Hence, you will never know that a missile is launched at you until the missile symbol shows up on the RWR, and you hear the chirp. We will deal with tactics on countering such threats later.

As for command guided missiles (usually SAMs), the RWR can distinguish the unique electronic signature of missile control radars. When the command signals are detected, it is an indication that the command guidance unit of the SAM radar has been activated to provide missile control. Since these missile control radars are turned on only to control a launched missile, the RWR will also interpret this as a launch, and will sound the launch warning tone and light the launch warning light.

For TVM (Track-Via-Missile) guided missiles, such as the Patriot and the SA-10 "Grumble," this gets really hairy. The guidance radar is capable of providing missile guidance when it is operating in the search and track mode, and the radar characteristics will not change even when a missile is airborne. The guidance radar's uplink transmissions to the missile will also resemble normal radar transmissions, and will not appear to the RWR as something out of the ordinary (unlike command guidance signals). As such, there is no way you can determine from the RWR signature, if a missile has been launched at you. The radar will appear in search mode, and you may possibly see it track you, but you will never know if the SAM battery has fired. The only way to know that a missile is inbound is to spot the launch and the missile, as the missile will not appear on the RWR since it is not transmitting any RF energy itself. This alone makes TVM guided missiles an even more serious threat that ARM missiles, and you will really need to develop your scan tactics and be on your guard whenever you detect a Patriot or SA-10 SAM battery on your RWR.

The RWR launch warning tone will sound at an interval of 15 seconds as long as the missile that has been launched at you is still guiding. If an additional missile has been launched at you, the launch warning tone will sound again.

ELECTRONIC COUNTERMEASURE MANAGEMENT

ECM management is a big part of ensuring a successful and safe mission. Self protection ECM systems normally carried on fighters and bombers are designed to break radar locks, and deny the hostile fire control system a firing solution.

ECM Coverage

As ECM systems have transmitting and receiving antennas, there are coverage zones. ECM is all about power management, and the jammer's power will be concentrated within the coverage zones to maximize its effectiveness. The ECM coverage zones, for podded systems such as the ALQ-131 and the Russian Sorbstiya, and internal jammer systems, are defined as shown in Figure 55 for both azimuth and elevation coverage.

The full effect of ECM jamming power is concentrated within 30° in azimuth on each side of the airplane. Jamming power reduces exponentially beyond 30°, till it becomes totally ineffective at 60° and beyond.

For elevation coverage, the full jamming power is concentrated in an arc extending from 5° above the aircraft horizontal datum, to 20° below the aircraft datum. Jamming power decreases exponentially from 5° above the horizontal plane to 15° above the horizontal plane, and from 20° below the datum plane to 30° below the datum plane. At elevation above 15° and below 30° from the aircraft datum horizontal plane, the jammer is totally ineffective.

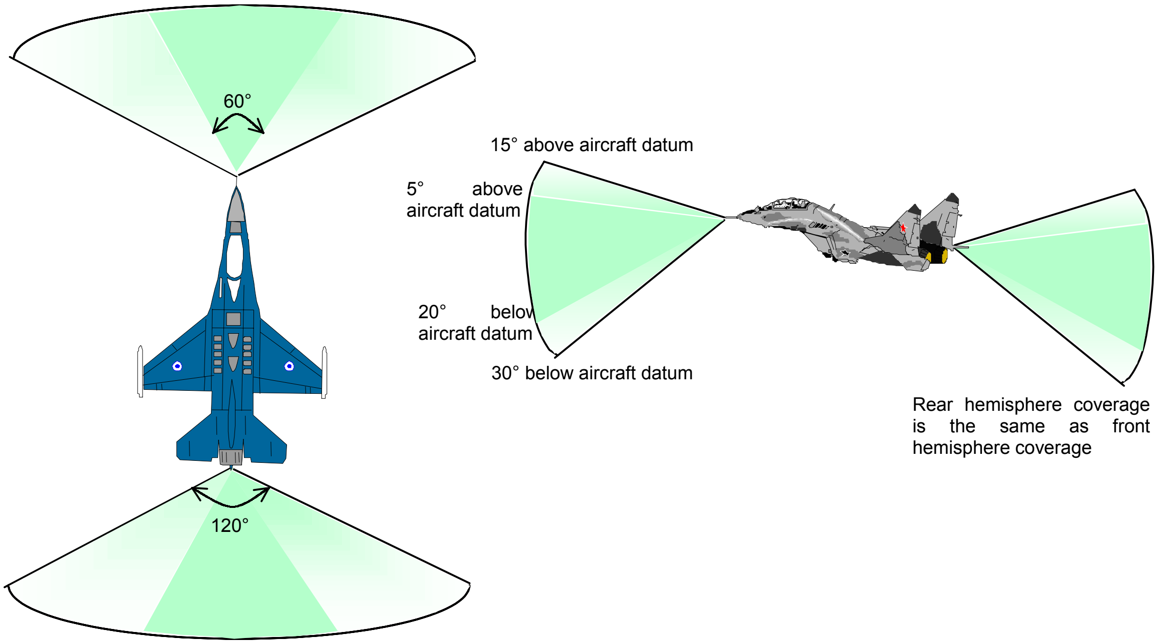

Figure 55: Elevation and Azimuth Coverage of ECM

Employment Considerations

To obtain full ECM protection, the threat emitter must be within the angular and elevation coverage where the jamming power is concentrated. Once outside, jamming effectiveness decreases rapidly. If you decide to beam the threat emitter, the jammer will lose its effectiveness, as the emitter will exit the ECM coverage arcs and fall into the dead zones.

You will need to decide if it is more effective to beam the threat or to employ ECM against it. This is where your pre-mission planning threat analysis will be useful. Remember, jamming is all about power. If the jammer has enough power, it will prevent a lock-on by the threat emitter. As the aircraft closes in on the emitter, there will come a point when the target's skin return is sufficiently strong for the threat emitter to lock onto despite the jamming. This is commonly termed as the threat emitter "burning through" the jammer. What you need to know is this range at which this "burn through" will occur.

1. First, determine the threat emitter's radar range from the "F4_RP_Sensor_Properties.XLS" spreadsheet. The data is presented in the "Radar" sheet.

2. Determine your ownship radar cross section in the "RCS" sheet.

3. Determine the range at which the hostile emitter can detect you by multiplying the radar range of the hostile emitter with your ownship RCS. Then, divide it by 6076. This is the look-up range in nautical miles.

4. Determine the look-down range by multiplying the look-up range with the hostile emitter's "Look-down multiplier," available in the "Radar" sheet.
5. Multiply the look-up and look-down range by the "ECM Desensitization" multiplier of the hostile emitter. This will give the burn-through range of the hostile emitter to your own ship in look-up and look-down situations.

As you can see, you may not be able to prevent a firing solution if the hostile radar can burn through at a range beyond its weapons' reach (such as the Su-27, which can burn through before you can enter its missile range). You will need to consider the burn through distances for each threat that you intend to employ ECM against, and determine if ECM is effective in denying the enemy a shot at you, and the range at which the enemy can engage you under jamming conditions.

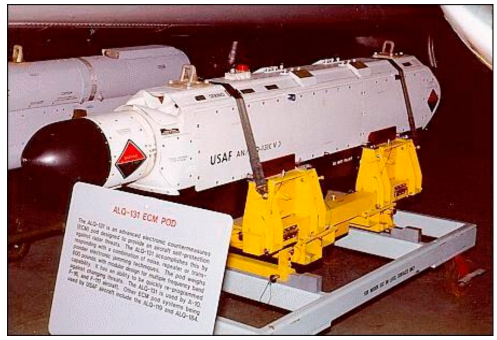

Figure 56: ALQ-131 Self Protection Jammer

Your tactics will need to be adjusted accordingly. For example, you may be able to deny a MiG-29 an AA-10 shot by using jammers against it, but the same tactic cannot be used on the Su-27, as the Su-27 will burn through before you enter its weapon engagement range, due to the raw power of its radar. You will have to examine and explore alternative tactics to deny the Su-27 a guided shot at you. In this case, beaming or notching may be a better tactic to use by exploiting the doppler notch on the Su-27 radar.

One important consideration is the signature that will result from jammer usage. While you can deny a valid radar lock, you certainly cannot hide the signature of the jammer. The jamming signal will often either snow out the enemy's radar display at the angular location of the jammer, or trip the ECCM features on the enemy's radar. While jammers can prevent a radar from obtaining critical tracking information such as range and velocities, angular tracking information is more difficult to deny. This will end up attracting attention of enemy fighters, as they can deduce an angular location is sufficient for them to vector towards your general direction even though they cannot obtain a radar lock on you. Indiscriminate use of ECM can result in you attracting all the unwanted attention like bees to honey. You will need to use ECM sparingly and only when required, to protect yourself and foil a missile shot. Leaving it turned on all the time is a sure way of asking for trouble.

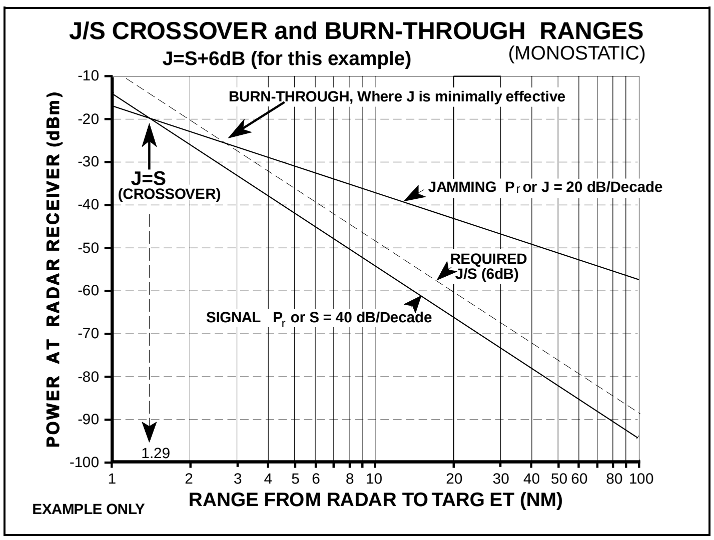

Figure 57: Example of the Relationship between Jamming Power and Burn-Through Ranges (Figure credit of USN Electronic Warfare and Radar Handbook)

You must also be aware of the home-on-jam (HOJ) capabilities of active radar guided air-to-air missiles such as the AIM-120, AIM-54 and AA-12. Activating your jammer in the presence of such missiles will of course degrade the acquisition performance of the radars onboard these missiles. However, these missiles will deactivate their onboard radars and switch to the passive HOJ mode, and home in on the jamming source. Though HOJ does not provide a very good fire control solution for the missile end game, it is sufficient to allow the missile to home and get closer to within the burn-through range of its onboard radar. You are often better off not using your jammer against such missiles once they have gone active.

The guidelines to remember about your ECM coverage are as follows:

1. The HUD field of view is approximately 20 degrees in azimuth. From your vantage point in the seat, the main jamming energy will be concentrated from the left to the right edge of the

cockpit brow. Any emitter that you see inside this arc will be jammed to full effect. The effect of jamming outside these arcs are hard to determine due to the exponential falloff.

2. From your HUD pitch ladder, the main jamming energy is concentrated between the HUD bore cross (which is at 5° above the datum horizontal plane), extending to 25° downwards. For example, if the bore cross is at the 5° pitch ladder mark, then the lower bound of the jamming energy is at the –20° pitch ladder mark. Any target inside this coverage will receive the full effect of the jamming.

As such, if you are flying against SAM sites or interceptors, this provides a quick gauge to whether the threat that you are jamming is receiving the full effect of the jammer.

EMISSION CONTROL (EMCON)

Emission Control (EMCON) plays a big part in modern warfare. This ranges from controlling precisely what frequencies are allowed to be transmitted from the radar (which is not a game function, unfortunately), to silencing all the transmitting devices on the aircraft when required (such as turning off jammers and radars). You cannot be unaware of the presence of ESM sensors onboard C^3 platforms such as the A-50 Mainstay, E-3 Sentry, and E-2C Hawkeye AWACS aircraft. These aircraft can passively detect your radar and jammer emissions from further than you can detect them.

You can also prevent enemy detection by turning off your radars and sneak up on them from behind for an ambush. This is particularly useful for sneaking up on aircraft with bad rearward visibility, and firing an uncaged IR missile at them while sneaking up to them undetected can often prevent timely dispensation of flares and decoys. You should try such tactics if you are armed with IR missiles with no IRCCM and the target is equipped with flare dispensers, else the missile will always be decoyed by the flare.

EMCON discipline is especially important for jammer usage. You and your wingman should exercise discipline and restraint in using jammers, and once the intended effect is achieved, de-activate it to avoid unwanted attention. Failure to do so may result in you hitting the silk.

TARGET IDENTIFICATION

The biggest problem in all modern warfare is positive airborne target identification. All targets may be identified either through EID (Electronic Identification) methods, or by the VID (Visual Identification) method. The latter will require you to fly to a range sufficiently close to the target, such that you can visually identify its aircraft type and hopefully, intentions. This should always be your last resort and you should use whatever means available to you to identify targets well before they enter into your visual range.

The types of EID methods available to you include NCTR, RWR, as well as AWACS. The USAF Vipers are not equipped with IFF interrogators, so this is not an option for you. You should always try to use more than one method of identifying the target, as it is very easy to mis-identify a target.

If the target is at high aspect angles, then identification is a lot easier, as you will be able to use NCTR to identify it. If the target has a radar and is painting you, then you can also confirm the target's identity from its RWR signature. AWACS will also be able to help you by declaring if the target is hostile or friendly. If you have locked up on a friendly target, you should expect to hear a "Buddy Spike" call, but this may not always happen. If the target is at a low aspect angle, then identifying it becomes more problematic, as NCTR and RWR will be useless. In this case, your best option is to query AWACS, or to lock up the target on STT and see if you hear a "Buddy Spike" call.

You may often need to query AWACS more than once before you get a confirmed answer. However, AWACS can be wrong, and it is not unheard of for AWACS to mis-identify targets in real life. One such example is quoted below:

> *During the first night of Operation Desert Storm, Captain Gentner Drummond from the 1st TFW was orbiting outside Baghdad on MIGCAP, when he was vectored to a high speed, low level bandit ingressing towards Saudi Arabia. The contact was not egressing along the pre-determined egress routes for friendly aircraft, and one of the ROEs was to engage any aircraft that is not egressing along the prescribed routes. The IFF interrogation drew no response, and he was unable to identify the target through NCTR. AWACS, however, ordered him to shoot, and confirmed that the target was hostile.*
>
> *The F-15 pilot was doubtful, and although he knew that AWACS probably had Rivet Joint data to confirm that the target was hostile, he decided to close in for a VID, just to be sure. He executed a stern conversion, and pulled up next to a Saudi Tornado egressing after a deep strike.*

You will always need to bear in mind that AWACS (and Rivet Joint, an ELINT asset) can be wrong. It is a fallacy to wish for a complete air picture in an all out war. Even in a limited war, things can often go terribly wrong. Mis-identification of the target can often lead to a wrongful shoot-down, as evident in the UH-60 Blackhawk shoot-down by a pair of F-15C over Kurdistan, during the aftermath of Operation Desert Storm. In this case, both the F-15s and AWACS mis-identified the low flying targets, and the F-15s even mis-identified the targets as Mi-24 Hinds during a VID fly-pass. This fog of war is replicated in Falcon 4, as it is not unheard of for targets to be declared as hostile, and yet they turned out to be friendlies.

FREQUENTLY ASKED QUESTIONS ON RADARS, JAMMERS, AND RWR

We have collated a series of common questions on radars, jammers and RWR for your convenience. You will find that some of the materials and answers presented in the FAQ are repetitive of materials and concepts presented earlier in this section. This section is designed to be a quick reference to provide information in bite size chunks, specific to your questions. We hope that you will find them useful.

Should you require more details on the electronic warfare mechanization in the Realism Patch, or just want to know about the design considerations, plus refer to the section titled "*The Electronic Battlefield*" in the Designer's notes.

Why can't I detect any targets below me when I am flying the MiG-21 or F-5E?

These aircraft are equipped with pulse radars. Pulse radars display only the raw radar video return, and in a look down situation, the ground reflects a large part of the radar's return. This will mask out the target return, and as such, pulse radars are unable to detect targets in a look down situation.

Why does the target disappear when the it goes perpendicular to me, and also why does the radar lose the lock under such situations?

This will only happen with pulse doppler radars. For a description of the different radar types and modes, refer to the earlier sub-section titled "*Radar Management*." The pulse doppler radar is equipped with a doppler filter that will filter out targets with velocities lower than the filter threshold. Pulse doppler radars rely on the doppler shift on the target's return to detect its presence. When the target goes perpendicular to the radar, the doppler shift decreases towards zero. When this decreases to a value corresponding to the minimum velocity threshold in the doppler filter (also called the doppler notch), the radar no longer regards it as a legitimate target and drops the lock and track.

Why isn't there an IFF in the game?

For the simple reason that USAF F-16C/D do not carry IFF interrogators. USAF F-16s (other than the F-16A ADF version) carry only IFF transponders to respond to IFF interrogations, but cannot interrogate others. IFF interrogators are carried on F-16s operated by other countries, such as the F-16A MLU, Turkish and Greek Block 50 F-16C/D, and Taiwanese Block 20 F-16A/B. The USAF Block 50 jets are not slated to be retrofitted with IFF interrogators until post 2003, under the Common Configuration Upgrade Program.

The associated fallacy is that IFF identifies friends and foes. This is wrong. IFF will identify only friends and unknowns. If the IFF codes match the target will be recognized as friendly. If the transponder codes do not match, it is either that the transponder being interrogated is set wrongly, not operating, or transmitting the wrong code. In all of these instances, the identity cannot be determined, and the IFF displays the target as unknown. The target could well be a friendly with a faulty IFF transponder, as much as it could be a hostile. Of course, the rules of engagement can be made such that an unknown IFF return can be assumed to be hostile. In this case, technically speaking, the IFF still cannot identify the target as a threat. It is just that the ROE specify that unidentified targets are to be treated as threats.

We understand that instead of using IFF interrogation (which will give away the location of the interrogator), USAF is more reliant on using NCTR for target identification, and a positive identification on NCTR is sufficient to initiate a missile engagement. This is far more reliable than IFF as the target is positively identified. IFF is not able to provide positive identification of all targets, as a failure in the IFF transponder on friendly aircraft will not allow it to be identified as friendly to its own side. This was one of the contributing factors that led to the shoot-down of two US Army UH-60 over Kurdistan, Iraq, by a pair of USAF F-15C enforcing the no-fly zone during the aftermath of the 1991 Gulf War.

How do I find out whether the target can detect me on its RWR when I am painting it?

The RWR system in the original F4 was a common system for all vehicles, and offered 360° spherical coverage, with 100% detection at 100% of the emitter ranges. From RP4 onwards, different RWRs have been created, with different coverage zones and different sensitivities (including creation of ESM systems). To find out the range at which the target can detect your own radar, look up the RWR type used by the target from the RP documentation (the sheet named "RWR" in the Excel spreadsheet "F4_RP_Sensor_Properties.XLS," included in the distribution of this user's manual). This spreadsheet shows the RWR gain, and coverage zones.

To find out your own radar range, look up the same documentation under the "Radar" sheet for the radar properties of your own ship. This is given in feet. Dividing this by 6076 will give you the nominal detection range. Multiplying this again by the RWR gain will give you the detectable range for the target's RWR system.

Do RWRs recognize friendlies and foes?

This is the biggest fallacy of all. RWRs cannot and do not recognize foes and friends. All that an RWR does is to detect the emitter, classify it by referencing the threat library, output a relevant audio tone, and display the pre-determined symbol. The RWR will recognize emitter type, but cannot make the distinction between friends and foes. If the opponents are flying the same aircraft as the friendlies, the RWR will not be able to distinguish them. The RWRs in the Realism Patch are designed as such.

RWR can make mistakes in real life, and much of its accuracy in determining the emitter type is dependent on how well the threat library is programmed (i.e. how good the intelligence and ELINT information are), and how sophisticated the emitter is with its ECCM mode. Frequency agility and varying stagger/jitter will often make identifying the emitter type more difficult in real life.

The RWR symbologies are not accurate !

The default Microprose RWR symbologies are by and large correct for the older RWR in the ALR-56C and ALR-69 class, albeit with some minor inaccuracies. MPS was more correct than everyone else gave them credit for, as far as the USAF RWR symbology implementation is concerned. With newer RWRs (such as ALR-56M and the ALR-67) and that have more processing and memory capacity, the RWRs are also capable of generating and displaying a greater variety of symbols. The Realism Patch has reflected this and updated the RWR implementation to reflect the latest generation of digital RWRs. RWR symbologies are hardwired in the executable, and are not editable without hex edits.

The revised RWR symbologies provide much better situational awareness, but cannot provide 100% target identification certainty, as RWR accuracy depends on the quality of the software programming, which is in turn dependent on quality intelligence information on the threat radar's operating characteristics. Some radars such as the N-019ME "Slotback" on the MiG-29, and the N-001 "Slotback" on the Su-27/30, have very similar electromagnetic characteristics, and is very difficult if not impossible to distinguish. Older pulse radars such as the radars equipping the MiG-19/J-5 have characteristics that are generic to most pulse radars, and this also makes it difficult to identify accurately. Even with the expanded memory capacity on the latest RWRs, the size of the threat library of newer emitters are often very large, and low priority threats such as the MiG-19 are not given much attention, and are sometimes left out of the threat library to make space for newer threats. This will also add to emitter identification difficulties. Such constraints are modeled in the Realism Patch RWR implementation.

Can RWR be programmed such that friendlies are always outside the inner ring?

As mentioned before, RWRs do not recognize friends and foes. If you program an emitter to remain outside the inner ring, then if the opponent has the same emitter, it is similarly affected. RWRs determine where the symbols are placed by determining the signal strength it receives. It then looks up a pre-determined signal strength table to determine where to display the symbol. At some point in time, the signal strength will become strong enough such that it will breach the inner threat ring, be it a friendly emitter or a hostile emitter, so programming the RWR such that friendly emitters will never breach the inner ring is not a possibility in real life.

The Realism Patch radars and RWR are adjusted such that the emitters will breach the inner threat ring when you are about to enter their effective engagement range. As such, for emitters outside the inner threat ring, they are not in a position to engage you, while emitters inside the inner threat ring will pose a danger to you as you are inside their engagement range. For aircraft, this range is set at the range of their typical BVR weapon.

Is the jammer working properly? Why does it appear that it is working intermittently?

The jammer effects have been revamped totally with effect from Realism Patch version 4. Microprose coded F4 with a spherical ECM coverage. As long as ECM is activated, it is effective and assumes total coverage. However, ECM systems have coverage areas, and within the antenna beamwidth, its ability to direct jamming power also depends on the angular displacement of the threat radar off from the jammer antenna boresight.

With Realism Patch, jammers have been given an effective coverage area of ±60° in azimuth (measured from the aircraft centerline), and an effective elevation coverage of +15° (up) to –30° (down). Within this angular and elevation coverage, the full effects of ECM are obtained within an azimuth of ±30°, and an elevation from +5° to –20°. Between azimuth of 30° and 60°, and elevation of +5° and +15° as well as –20° to –30°, the effect of ECM decreases logarithmically with an exponent of 0.5. Hence, in order to obtain the full effects of ECM coverage, it is necessary to ensure that the threat emitter is within the effective coverage cone. If you decide to beam a radar, you will lose ECM coverage.

Why do I not get any launch warning from the RWR when AIM-120, AIM-54 and AA-12 are launched at me?

The RWR missile launch warning is triggered by the detection of missile guidance transmissions from the launching platform. These transmissions are only made for SARH and command guided missiles. Active radar homing missiles do not require the transmission of any guidance signals, and at most only require a periodic datalink update on the target's location throughout missile flight. This is however optional, but desirable to improve missile Pk through flight path optimization.

Semi-active radar homing (SARH) missiles rely on continuous wave (CW) radar illumination to guide. The launching aircraft has to activate a CW illuminator (CWI) to "paint" the target, and the SARH missile will guide on the reflected CW energy. This CW waveform is a continuous sinusoidal waveform, unlike normal pulse or pulse doppler transmissions, and can be very easily distinguished. Whenever SARH missiles are launched, the CWI is turned on automatically, and this will trigger the launch warning light and audio tone on the RWR.

For command guided missiles (such as SA-2, SA-3, and SA-8), the command guidance transmissions from the missile guidance radar can be easily detected and distinguished from the normal search and track radar transmission. Detection of the command guidance transmission will similarly trigger the RWR launch warning.

Conversely, when ARH missiles are launched, the radar does not need to provide target illumination. In terms of radar transmission, it is still as per normal for the particular radar operating mode. Since there is no change in the radar pulse-form received by the RWR, it will not trigger the launch warning. When the missile turns autonomous, the transmission from the monopulse seeker also resembles that of a normal airborne radar in the I/J band, as the RF waveforms are pulse doppler signals. This will similarly not trigger the RWR launch warning. As such, the only time the RWR will know that an ARH missile is launched is when the missile goes autonomous, and the missile symbology appears on the RWR display.

The Pointed End Of the Sword

Air-to-Air Weapon Employment and Missile Generalities
By "Hoola"

Preamble

Other than rearranging the local geography of the battlefield, the other purpose for the existence of fighter aircraft is to destroy other fighter aircraft. In the good old days of bi-planes, pilots would shoot at one another with pistols. Today, pilots have at their disposal missiles of various ranges, and combat can often be resolved from beyond visual range.

This section will discuss missile and gun employment considerations, as well as the tactics that you can employ to counter them. We will discuss in more detail the characteristics of the missiles, and how to tailor the tactics to suit. This is written not just with the F-16 in mind, but for any airplane now that you can fly almost every airplane in the Falcon 4 world.

You are advised to read the section titled "*Missiles Galore*" in the designer's notes for background information on how missiles work, and how the missiles in Realism Patch are designed.

WVR IR Missiles

Tail Chasers – AIM-9P Sidewinder and AA-2D (R-13M) Atoll

Figure 58: AIM-9P Sidewinder. (Picture credit of USAF)

These missiles lack the seeker sensitivity to detect the IR signature of targets in the frontal aspect, although there may be some exceptions to this, especially if the target is in afterburner. Generally, when the target is at MIL power or below, you should not expect to obtain a seeker tone until 1nm. or closer in the frontal aspect. This may increase to about 1.5nm. if the target is in maximum AB. This limits the missiles to rear aspect engagements only.

These missiles are also handicapped in background IR clutter rejection. In look-down situations at low altitudes, it may sometimes not be possible to obtain a good IR lock against targets in MIL power or below due to the IR clutter from the ground. Similarly, the missiles are easily decoyed by the sun, and you will need to exercise care in ensuring that the target is well clear of the sun when you fire the missiles. The design of the guidance is such that the end-game for both missiles will usually end up as a tail-chase.

Due to the limited tracking rate of the missiles, you will need to be very careful with your positioning prior to firing them. The AA-2, especially, is not a good dogfight missile as it is based on the obsolete AIM-9B. Firing in a turn exceeding 4g will sometimes result in ballistic shots as the missile either gimbals out or the target line of sight (LOS) rate exceeds the tracking ability. The low tracking rate of 12.5°/sec means that you will need to unload your jet first and position within a 40° cone behind the target before firing, to maximize missile probability of hit. Beam shots will seldom succeed due to the high LOS rate during end-game.

The AIM-9P modeled in the Realism Patch is the AIM-9P-3 variant. This version was widely exported, and can be considered a dogfight missile. The tracking rate is increased over the AA-2 to cope better with maneuvering targets. Firing in a turn exceeding 5 – 6g may sometimes result in the missile tracking rate being exceeded even though the target is within the HUD field of view. The missile has slightly better maneuvering potential compared to the AA-2 due to the longer burning motor.

For both missiles, you should strive to shoot only when the target is within 1.5 – 2nm. range tail-on (reduced to 1 – 1.5nm. for the AA-2), and centered within the HUD field of view. The missile pursuit trajectory is a tail-chase, and at ranges exceeding 2nm., the missile will often not have the energy to prosecute a maneuvering target. The importance of shooting within a 40° cone at the rear of the target cannot be over-emphasized, as this will improve the chances of obtaining a hit.

Figure 59: From the left, AA-8 (R-60M), AA-2C (R-3R) and AA-2D (R-13M)

Both missiles lack any IRCCM features, and are very susceptible to flares. Release of flares will most definitely defeat the missiles. As such, these missiles are close to useless against modern fighters, as most modern fighters are equipped with flare dispensers. They are still useful against the bulk of the DPRK forces though, or against Western transport airplanes, as these are seldom if ever equipped with CMDS (countermeasures dispensing system).

If you anticipate encountering only MiG-19, MiG-21, MiG-23, and MiG-25, the AIM-9P is a good choice to carry, as these aircraft are not equipped with CMDS. The DPRK is especially disadvantaged since most Western aircraft including helicopters are equipped with CMDS. As part of your mission planning, you should review the aircraft that you are likely to face over the battlefield, and whether they are equipped with self defense systems (see earlier section titled "*Knowing Your Enemy*" in chapter 2).

In the event that you are out of chaff/flare cartridges, or you are flying an aircraft not equipped with CMDS, a hard 7 – 8g turn into the missile can often defeat it, as this will often generate sufficient LOS rate to cause the missile to break lock. Breaking lock is easier if the missile is fired at more than 30° angle-off-tail, as the high LOS rates are easier to generate.

Russia's Short Stick – AA-8 (R-60M) Aphid

The AA-8 is a cruel joke by the Russian missile industry, and just slightly better than the AA-2 that it replaces. This missile has an extremely short range due to its small size and small motor, and the seeker suffers from low tracking rate and poor sensitivity.

The missile seeker has a higher sensitivity than rear aspect missiles, but not by much. Front aspect target acquisition is possible, but very often, the IR lock is obtained very close to the minimum range of the missile. When fired under most front quarter engagement geometry, if the target speed is high, the missile will seldom be able to maintain track on the target due to LOS rate exceedance. To maximize missile probability of hit, you should strive to shoot from nowhere forward of the target's 2 o'clock and 10 o'clock position. You should also shoot only when the slant range is 1.5nm. or less, as the rocket motor does not give the missile a lot of energy to maneuver and chase after a target. The intercept path is however more optimal than AA-2 and AIM-9P, and end game will seldom end up as a tail-chase.

This missile is equipped with some degree of IRCCM, but can be decoyed by a rapid dispensation of 3 – 4 flares. Failing this, a hard turn into the missile will often defeat it, though this is more difficult to achieve compared to the AA-2.

As with the AA-2 and AIM-9P, you should strive to keep the target within your HUD field of view when using this missile, and minimize any target movement across the HUD. Again, due to the low tracking rate, when firing the missile in a high g turn exceeding 6 – 7g, there is a possibility of the missile going ballistic due to gimballing out or exceeding LOS tracking rate.

The Lethal Sidewinder – AIM-9M Sidewinder

This is the frontline missile for US and Allied air forces currently, and will stay so until the mid 2000's pending the completion of the development of the evolutionary AIM-9X. The AIM-9M missile is a much improved dogfight missile compared to the AIM-9P, with increased seeker sensitivity and improved rocket motor. The longer burning rocket motor gives the missile longer legs compared to the AIM-9P, and extends the useful range out to about 2 – 2.5nm., depending on altitude.

Figure 60: AIM-9M Sidewinder. (Picture credit of USAF)

The maneuverability of the missile is increased by easily 50% over the AIM-9P, with increased seeker LOS tracking rate. This makes the missile a much better performer in the dogfight arena. This gives the pilot greater leeway with missile employment, as the chances of the missile going ballistic when fired are reduced when firing under high g conditions. The higher tracking rate means that you can still achieve good success when firing at targets just outside the HUD field of view, up to about 20° off boresight.

You should expect a good seeker tone up to 3nm. in the forward quarter for targets in MIL power. Rear quarter IR acquisition range can often exceed visual acquisition range for MIL power and above. When firing from the front quarter, you should strive to shoot when the target is beyond 2nm. away, as line of sight rate increases rapidly at closer ranges, and the LOS crossing rate may exceed missile tracking rate or the maneuvering ability. If the target employs IRCM tactics and throttles back the power, seeker tone may be attained only when you are very close to or inside the minimum range (Rmin).

The seeker has excellent ground clutter rejection capabilities, and is a lot less prone to being decoyed by the sun. This missile is equipped with IRCCM capabilities, and is extremely resistant to flares, though a rapid dispense of 6 – 8 flares within 2 – 3 seconds may result in missile decoy, depending on the target throttle setting, target aspect, and range. You should however not count on the effectiveness of flares.

The missile is considerably more maneuverable than the AIM-9P. Coupled with the higher tracking rate, it is more difficult to defeat the missile even with a hard turn of 7 – 8g into it, especially when the missile is fired at close range. When fired beyond 2nm., if the target executes an immediate high speed hard turn to put the missile at the beam to drag it out, and then executes am 8 – 9g turn into the missile during end game, it may be possible to defeat the missile kinematically. Such a maneuver forces the missile to fly at higher angle of attack, thus bleeding energy at a higher rate.

When fired at high aspect angles in the frontal sector, a hard turn across the missile can sometimes break the missile lock due to LOS rate exceedance. The success rate increases as the firing range decreases. Strive to maintain a high speed in excess of 450 knots at all times to maximize your ability to turn and defeat the missile.

Evolution of the Heat Seeker – AIM-9X Sidewinder

After years of neglecting the development of highly agile WVR missiles, and finding themselves lagging badly behind the Russians, Europeans, and Israelis, the USAF finally began developing an equivalent of the Python 4, ASRAMM, and AA-11. Instead of choosing a totally new design, the USAF elected to award the missile development contract to Hughes (which merged with Raytheon later on), to develop an updated Sidewinder missile known as the AIM-9X. The AIM-9X was ordered into initial low rate production (LRIP) in February 2001, and will see service on the USAF F-15C and USN F-18 in 2003. It is expected to see service on the USAF F-16s from 2005 onwards.

Figure 61: The Raytheon AIM-9X Missile

The AIM-9X combines the AIM-9M's Mk-36 motor, target detector, and warhead, with a brand new guidance and control section, and adds thrust vectoring control vanes at the exhaust end of the motor. The seeker is based on focal plane array (FPA) technology, instead of the traditional reticle scan technology. This requires a digital guidance control section, and a digital autopilot system. The FPA seeker has a very high degree of IRCCM, since it does not sense thermal energy, but instead, sees the target as an image. This gives the seeker a tremendous advantage in an environment where the target is employing IRCCM, and the acquisition range exceeds that of all other IR seekers. The AIM-9X seeker is able to lock onto targets at ranges close to BVR, giving the pilot the first shoot opportunity.

Figure 62: AIM-9X FPA seeker image of an F-18 target and its engine exhaust plume. (Picture credit of USN)

The new missile airframe has much lower drag than the AIM-9M, and as a result, the missile range and speed are increased. With the thrust vectoring controls, it gives the missile a tremendous amount of close-in agility, although this will only be effective before motor burnout. The only disadvantage of the AIM-9X is its small motor, which does not give it the ability to chase after a target should it miss during the first hit opportunity.

The AIM-9X can be fired at off-boresight angles of up to about 65°, although its range performance is considerably reduced. The sensitive seeker is able to acquire head-on targets are ranges up to 4nm. away, and the missile has the energy to reach out and destroy targets at such ranges.

The high tracking rate and wide seeker gimbal limit of 90° means that it is extremely difficult if not impossible for a defending fighter to break the missile's lock. The good flare rejection capabilities of the missile means that it is very difficult, if not impossible, to defeat the missile with flares.

When fighting an opponent armed with the AIM-9X, you have to be very wary of its off-boresight capability. While you can utilize IRCM tactics to minimize your ownship IR signature you need to bear in mind that the AIM-9X can lock onto you at a range exceeding that of all other IR missiles, and the opponent will always be in a position to shoot at you first. Your best defending tactic is to engage the enemy from BVR, and avoid closing in at all.

The Israeli Connection – Python 4

Touted by many as one of the best, if not the best air-to-air WVR missile in the world, the Python 4 was developed by the Rafael Armament Authority in Israel, in respond of an IDF/AF requirement to counter the threat posed by the Russian AA-11 Archer. The missile has an extremely wide seeker gimbal limit of 90°, and can be propelled to an extremely high speed. This missile has a turn capability of up to 70g, and is capable of turning through 180° and initiating a tail chase in pursuit of its target.

The Python 4 has a large and long burning motor, and relies on its extremely sophisticated aerodynamics to achieve its agility. It does not rely on any thrust vectoring controls, and as such, retains its maneuverability throughout its flight, even long after missile motor burnout. The seeker has an extremely high degree of sensitivity, with an excellent IRCCM capability, second only to the AIM-

9X. The very high tracking rate ensures that it is almost impossible for the target to generate LOS rates high enough to break the seeker's lock.

Figure 63: Rafael Python 4 missiles loaded on IDF/AF F-16

The Python 4 can be fired at off-boresight angles of up to 65 – 70° without losing track. The missile can be fired at tail-on targets of up to 3nm. away at off boresight angles of more than 40°, with a very high chance of hitting them. Even if the missile fails to intercept the target during the first pass, it has sufficient energy to initiate a go around maneuver and chase down the target from its rear.

The flare rejection capabilities of this missile is extremely high, although it may be possible to decoy the missile if you dispense flares at a very high rate just when it is launched. This is however not guaranteed.

The unique capabilities of this missile means that it is extremely difficult if not impossible to evade it once it has been launched. Its minimum launch range is even less than the AIM-9X. This is one of the most fearsome missiles in the world today, and entered Israeli service in the early 1990's. It was reportedly sold to Chile for use on its F-5 fighters, and to Argentina for use on its Mirage III fighters. The Python 4 can be carried by the IDF/AF F-15s and F-16s, and is currently being marketed to the USAF ANG for use on the older Block 30 F-16.

The First of the Off-Boresight Missiles – AA-11 (R-73M1) Archer

This missile is undoubtedly the first IR WVR missile that has an off-boresight targeting capability. The missile has a tremendous acceleration capability and can be propelled to higher speeds than the AIM-9M, and the maneuvering capability is much higher than all the other missiles in F4, except the AIM-9X and Python 4. This missile is equipped with a large rocket motor with thrust vectoring controls (TVC), giving it a phenomenal ability to turn in excess of 50g.

Figure 64: AA-11 (R-73M1) Archer

The missile seeker has a very high degree of sensitivity, with excellent flare discrimination ability. The most important factor is the wide seeker gimbal limit of 67° and extremely high tracking rate (far in excess of that for the AIM-9M). When married to a large motor equipped with TVC, this gives the missile a high off-boresight targeting ability.

The missile can be fired at up to 45° off-boresight without losing track, though its range performance is considerably reduced when firing beyond 25° off-boresight. Within 25° off-boresight, the missile can be fired against tail-on targets at up to 2 – 3nm. range with a good chance of hitting them. When firing at off-boresight angles exceeding 25°, the missile have sufficient energy to prosecute targets out to 1.5 – 2nm. Obviously the range performance decreases as off-boresight angle increases.

The high tracking rate and large gimbal angle means that it is a lot more difficult for the missile to gimbal out, and more difficult for a defending fighter to generate LOS tracking rates that exceeds the missile's tracking ability. You should be able to fire the missile with confidence that it will track, even in a 7 – 8g turn.

The missile's flare rejection ability is good, but slightly degraded compared to the AIM-9M in a look-down situation into ground IR clutter. Still, the difference is small and not noticeable. Rapid dispense of 6 – 8 flares within an interval of 2 – 3 seconds may result in the missile being decoyed, but as with the AIM-9M, this is heavily dependent on the target's throttle setting, aspect, and range.

When fighting an opponent armed with the AA-11, you have to be very wary of its off-boresight capability. You should employ IRCM tactics to minimize your ownship IR signature (this will be discussed later). Should you choose to merge with an AA-11 armed opponent, you should strive to force a two-circle fight as this will put both fighters on an even keel after one turn. It is not advisable to enter into a one-circle fight with the opponent, as he has the ability to shoot across the turn circle, before you are in a position to take a front quarter shot. As far as possible, if you are aware that the opponent is armed with AA-11, your best tactic is to eliminate the threat from BVR and not allow it to transit into a WVR fight.

Chinese Clones – PL-7 and PL-8

Figure 65: PL-7 (Magic I clone)

The PL-7 missile is a PRC clone of the Matra Magic I missile, while the PL-8 is a PRC clone of the Israeli Python 3 missile. The PL-7 is a rear aspect only missile with no IRCCM. However, the double canard layout coupled with a high impulse rocket motor confers the missile a maneuvering capability close to that of the AIM-9M. The tracking rate of the PL-7 seeker is not as high as the AIM-9M, and is closer to that of the AIM-9P, which makes it a missile of performance midway between the AIM-9P and AIM-9M.

The PL-7 can be effectively employed up to 2nm. in the tail-on aspect, though the lower tracking rate means that the same firing considerations for the AIM-9P have to be honored. You should strive to shoot when you are turning less than 5g, to minimize LOS rate, though once fired, the missile's high maneuverability means that it is more difficult to escape kinematically. However, due to the lack of IRCCM, flares are very effective against the PL-7. This missile is a reasonable dogfight weapon, and can be a serious threat in close quarters if you are out of flares.

Figure 66: PL-8 (Python 3 clone)

The PL-8 is equipped with a large high impulse rocket motor that gives it a tremendous acceleration. This missile relies on pure power to run down the target, and is effective out to 2 – 2.5nm. in the tail-on aspect. The seeker has a very high sensitivity that is just slightly shy of the AIM-9M, though the IRCCM ability is marginal. The seeker performance is very much similar to the AIM-9L, with both missiles being relatively susceptible to flares. The flip side of the PL-8 seeker is that it is more susceptible to ground clutter and sun reflections than the AIM-9M is due to its poor background IR clutter rejection ability.

You should be able to acquire an IR tone against MIL power targets out to 3nm. in the head-on aspect, and this gives the missile an all aspect capability. Seeker tracking rates and missile maneuverability are similar to that of the AIM-9M, though the missile has higher drag and bleeds off energy faster than the AIM-9M, when it is forced into high g maneuvers.

In terms of employment considerations, the PL-8 is similar to the AIM-9M, though you should exercise caution in look-down situations into ground clutter, and refrain from shooting when the target is silhouetted against the sun. The tremendous speed of the missile leaves the target very little time to employ flares, especially if you fire it at a close range of 1.5nm. or less. You should be wary of this missile, as it can be extremely effective in capable hands, more so when you are out of flares. The PRC J-7 III and J-8 aircraft are capable of carrying this missile. As the J-7 III resembles the MiG-21, you should be aware that the J-7 III is capable of carrying PL-7 and PL-8, which are more capable than the AA-2 on the MiG-21. To be safe, you should always assume that the MiG-21 that you have seen is the J-7 III, and tailor your tactics to defend against PL-7 and PL-8 attacks.

BVR IR MISSILES

The Grand Old Dame – AA-7 (R-24T) Apex

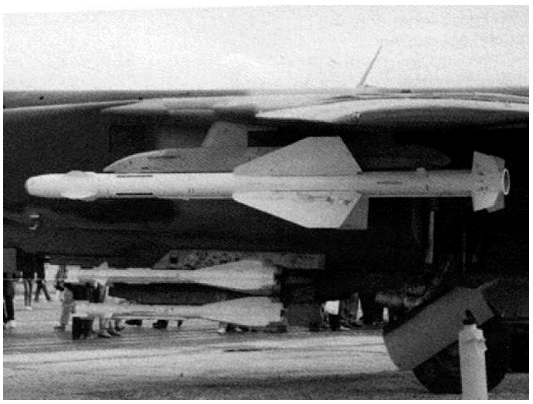

Figure 67: IR version of the AA-7 (R-24T) missile loaded on MiG-23

It is actually a misnomer to consider the AA-7 missile a BVR IR missile. This missile was designed with an IR seeker of limited sensitivity, married to a large motor to allow it to run-down receding targets. The seeker, though of all aspect capability, is limited in its sensitivity, and lacks IRCCM. This makes the missile extremely susceptible to flares.

Rear aspect sensitivity of the missile is reasonably good. You can expect a tone in the tail-on aspect out to 6nm. in MIL power. With a large rocket motor, this missile has the legs to reach up to 4 – 5nm. against a high speed receding target. The missile is limited in maneuverability, and not much of a dogfight missile. This makes it quite useless in the front quarter aspect, though the missile really comes into its own when fired in a tail-chase profile against receding targets. Compared to missiles such as AA-11 and AIM-9M, the AA-7 has the ability to reach out further.

Defense against the missile is easy with flares. The low seeker LOS tracking rate and limited maneuverability means that a hard turn into the missile can often defeat it. When employing this missile, you should strive to limit the engagement to rear quarter to improve the probability of hit, as front quarter shots will be less successful. Firing the missile at a low load factor of 3 – 4g should improve the tracking ability.

Hypersonic Heat Seeker – AA-6 (R-46TD) Acrid

This is a true blue BVR IR missile. The missile has a tremendous speed, and can reach up to Mach 5 at high altitudes. The missile has a datalink receiver, and is guided through the datalink in the initial flight phase. The IR seeker will actively search for the target according to the datalinked target location. This means that the missile can be fired from BVR, and will close in at a tremendous speed compared to other missiles. You will not get any warning on the RWR, so you will have to be very wary if a MiG-25 or a MiG-31 is detected on your RWR.

Figure 68: IR version of the AA-6 (R-46TD) missile

The missile seeker sensitivity is limited and the performance is close to that of the AA-7, though the missile has some degree of IRCCM. Dispensing 3 – 4 flares within a 2 seconds interval should decoy the missile. Maneuverability of the missile is limited though, and this missile relies on its sheer speed to run down the target. The missile was designed to intercept the XB-70 Valkyrie supersonic bomber, and is a poor dogfight missile. If you can manage to spot it in time, a hard turn into it will usually defeat the missile as it will usually not be able to generate the turn rate required to complete the intercept.

With regards to missile employment, this missile is best fired from BVR to reduce the chances of the launch being visually detected. The missile can reach out to 15nm. or more head-on at medium altitude, and can be fired at up to 8nm. against a receding target. Such tactics are good against unsuspecting targets, and is especially useful against bombers, tankers and AEW aircraft.

The Latest Incarnation of IR BVR Missiles – AA-10B (R-27T) Alamo

As with the AA-7, it is a misnomer to consider the AA-10B a BVR IR missile. Unlike the AA-6, this missile has no datalink capability, and is designed to run down high speed targets such as the F-111 in a tail-chase scenario.

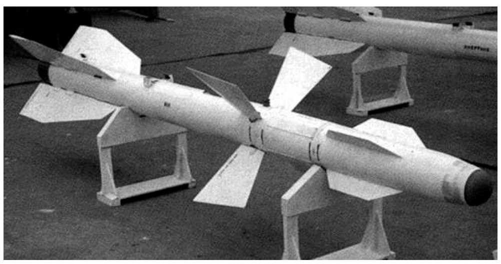

Figure 69: AA-10B (R-27T) Alamo

The missile seeker has good sensitivity, and you can acquire an IR lock against MIL power targets out to 3nm. head-on and 9nm. tail-on. However, the IRCCM and background rejection capabilities are not quite as good as the AA-11, and are mid-way between the AA-8 and AA-11. Rapid dispensation of 4 – 5 flares in 1 – 2 seconds can usually decoy the missile.

Although the missile seeker tracking rate is higher than the AA-8, the missile is not designed as a dogfight weapon. The missile can generate up to 25g at burnout, but bleeds off energy very rapidly when it maneuvers. This also means that front quarter shots against fighters, unless taken from 2.5nm. and beyond, have little chance of success as the missile will need considerable maneuverability to complete the intercept. You are better off firing it against receding high-speed targets and allowing the missile to run down the target from behind.

When defending against this missile, take note that it can be fired from more than 6nm. in the tail-on aspect. This will not trigger the RWR launch warning, and the missile has enough energy to run down the target. Unless you are already at a very high speed in excess of 550 knots, there is very little chance of you being able to out-run the missile. You should strive to take a zig zag course and force the missile to follow. Doing so will rapidly deplete the missile's energy, especially after its motor has burnt out. You can alternatively change your altitude rapidly by diving at high speed, forcing the missile to fly into the denser low altitude air (thus increasing drag and bleeding the missile of its energy), and then zoom climb when the missile gets closer. This again forces the missile to climb and bleed off even more energy. Rapid power reduction and sudden aspect changes (by beaming the missile or turning to face the missile) can also break the missile's IR lock by reducing your own IR signature drastically, although you will need to execute these techniques while the missile is still far away.

In terms of employment considerations, you will give the missile a higher success rate by taking rear quarter shots. LOS considerations are less crucial when firing from afar, so this will seldom factor into your calculations. The missile has sufficient energy to prosecute a receding target when fired from about 5nm. astern at low altitude, and 7 – 8nm. astern at medium or high altitude.

SEMI-ACTIVE RADAR HOMING MISSILES

The Faithful Workhorse – AIM-7M Sparrow

The AIM-7 had been the frontline BVR missile for the US and Allied forces since the early 1960's, and last saw combat service in the 1991 Gulf War, when it was credited with a majority of the A/A kills.

Historically, the performance of this missile has not been good, having been credited with less than 30% Pk even in its latest incarnation.

The AIM-7M missile uses a high impulse rocket motor to propel it to a very high speed within a few seconds of free flight (in excess of Mach 4 at high altitude). It then spends the rest of its time coasting towards the target. The missile is equipped with an inverse monopulse seeker to home onto the CW illumination signal from the launch aircraft.

Figure 70: AIM-7M being fired from F-15C. (Picture credit of USAF)

The missile is not very maneuverable, but can still generate up to 30g at motor burnout. Due to its drag, the missile will decelerate fairly rapidly upon motor burnout. You should strive to maximize its range by accelerating to as high a speed as possible prior to firing. The difference between firing the missile at 300 knots and 600 knots can mean a range difference of up to 3 – 4nm..

The missile has a maximum range of up to 18nm. when fired at high altitude against high speed head-on targets. At lower altitudes, this is shrunk considerably, and to assure good success, you will may have to fire under 10nm. head-on. Tail-on range is between 3 – 5nm. at low level, increasing to 7 – 9nm. at high altitude.

As with all SARH missiles, you will need to support the missile by maintaining your STT lock on the target throughout the entire missile flight till impact. As such, you will need to fly a course that prevents the target from beaming you. If the target initiates a beaming maneuver, you will also need to turn in the direction of the target to reduce the angle off tail. This will prevent the target from entering your doppler notch. You should not be expecting a hit rate of more than 40% at best, based on historical data.

Your best defense against an AIM-7 shot is to break the shooter's radar lock. This can be achieved through chaff, ECM, or beaming the host radar. The latter can be achieved easily by maintaining the RWR symbol of the launching aircraft at the 3 or 9 o'clock position. If you are unable to break the radar lock, you will need to defeat the missile kinematically. This is not as difficult as it sounds considering that the missile maneuverability is low, and a well timed 6 – 7g break into the missile can generate sufficient problems for the missile.

The WVR Missile – AA-2C (R-3R) Atoll

This is a SARH version of the heat seeking AA-2D missile's. Kinematically and in terms of seeker tracking rate, it is similar to its IR sister, the AA-2D. The heart of the envelope is within 1.5nm. from the rear quarter, and up to 3nm. in the front quarter.

As the missile maneuverability is low, it is not difficult to out-turn the missile at end game. Chaff works very effectively against this missile, as the MiG-21 RP-21 radar is a pulse-only unit. Given that the launch of this missile will trigger an RWR launch warning, it gives ample opportunity for the target to employ countermeasures.

This missile should not be much of a threat, as the host aircraft is not capable of look-down and shoot-down operations. As long as you remain amongst the ground clutter, you can deny the threat a shot at you with this weapon.

Arming The MiG-23 – AA-7 (R-24R) Apex

Figure 71: AA-7 (R-24R) Apex loaded on MiG-23

This is one of the first Russian missiles that has a look-down shoot-down capability. The missile has a lower range than the AIM-7M. The small control fins, compared to the AIM-7, means that the AA-7 has an even lower maneuverability compared to the AIM-7. This missile is generally considered to be in the same performance class as the AIM-7E.

The missile can be fired at up to 15nm. head-on against high speed targets at high altitude, reducing to about 10nm. at medium or low altitude. Tail-on effective range decreases to 6nm. at high altitude and 4 – 5nm. at low altitude. The missile loses energy very rapidly after motor burnout, and the target can often out-run the missile at low altitude if it maintains sufficiently high speed. Minor sideways course alterations and reversals will force the missile to lose even more energy.

The peak velocity of the missile is only about 1,500 knots indicated. This gives the missile a lot less energy to prosecute maneuvering targets. Kinematically, the missile can be quite easily defeated with a high speed 6g turn into it. You can improve the chances of a successful intercept by firing at closer ranges, but a hit rate of 20% should be considered good, taking into account the appalling performance of the missile over the Bekaa Valley when used by the Syrians against the Israelis.

Valkyrie Killer – AA-6 (R-46RD) Acrid

As with the IR version of the AA-6, this missile was designed to intercept high altitude bombers such as the defunct XB-70 Valkyrie, and the SR-71 Blackbird. The missile is extremely useful when used against AWACS and bombers, especially in a high speed slashing attack. You should refrain from using this missile against fighters of considerable maneuverability, as the missile is limited in its ability to turn, and loses too much energy when made to do so.

The phenomenally high speed of this missile reduces the reaction time for the target. Out-running the missile is often impossible, though you can certainly fly a course that forces the missile to keep turning and losing energy.

One of the ways of using this missile is to target high value assets such as AWACS and JSTARS, by flying towards the target at a high speed. This increases the effective missile range, and may allow you to shoot from out to 20nm. at high altitude. This will sometimes put you outside the engagement range of CAP flights protecting the high value asset.

Remember that when you face this threat, your reaction time is much shorter. The tremendous acceleration of the MiG-25 and the MiG-31 means that it can often out range the AIM-7 equipped fighters. Though this missile is rather aged, it can still be a serious threat in competent hands.

The Fourth Generation – AA-10A and AA-10C (R-27R and R-27RE) Alamo

The AA-10A is a missile of the same class as the AIM-7M. In terms of range, this missile is just shy of the AIM-7M, and is slightly out-ranged in a F-pole fight. However, the missile is more maneuverable than the AIM-7M, and slightly more difficult to defeat kinematically.

The AA-10C is a different animal, as it packs a large rocket motor. This missile easily out-ranges the AIM-7M, and can be fired at head-on targets up to 25 – 30nm. away at medium altitude, and 10 – 12nm. tail-on. However, maneuverability is lower than the AA-10A due to its larger size and higher weight, but this is more than compensated for by the larger motor and higher speed.

The AA-10C is carried only on the Su-27, and this is a considerable threat even for AIM-120 shooters, as the missile out-ranges even the AIM-120. The more powerful Su-27 radar means that it is more difficult to use ECM to defeat this missile, and you will need to use a combination of chaff and maneuvering to defeat it. The long range and high speed of this missile means that you will always need to fight defensively when encountering Su-27s. Trading shots with a Su-27 is not advisable, as the AA-10C can be fired at longer range than the AIM-120, and is likely to arrive at the target before the opponent's AIM-120 turns active.

Figure 72: AA-10A (R-27R) Alamo

The Longest Reach of The Bear – AA-9 (R-33) Amos

Figure 73: AA-9 (R-33) Amos

The AA-9 is a missile in the same range class as the AIM-54. This missile was designed to be carried by the MiG-31 aircraft, and is capable of engaging both small fighter targets as well as large high value targets such as AWACS.

The AA-9 is guided by command guidance throughout most of its flight, and it will then switch to semi-active radar homing in the terminal stage. Maximum engagement range is typically 35 – 40nm. head-on, increasing to almost 50 – 60nm. against head-on, high speed targets at high altitudes. The minimum range is approximately 1.4nm.. In terms of maneuverability, this missile is capable of engaging targets turning up to 6 – 7g, and its kinematic performance is generally similar to the AIM-54 Phoenix. The loft trajectory of this missile means that the terminal attack is often a dive from high altitudes. This gives the missile a very high closure rate and a high degree of maneuverability.

The AA-9 is carried only by the MiG-31, and is a considerable threat to almost every aircraft, with the exception of the F-14. The ECCM features on the powerful MiG-31 radar means that it is difficult to defeat the missile with jamming and chaff. The long range and high speed of the missile means that it is likely to reach its target before the target is capable of retaliating.

<u>**ACTIVE RADAR HOMING MISSILES**</u>

The Rabid Dog – AIM-120 AMRAAM

The AIM-120 AMRAAM is the current frontline BVR missile for the US and Allied forces. The AMRAAM drew its first blood over Iraq, as part of the UN enforcement of the no-fly zone, and distinguished itself during Operation Allied Force, when it destroyed several Serbian aircraft over the skies of Kosovo.

The missile is guided inertially in the initial phase, but relies on the launch aircraft to provide periodic datalink update of the target's position. As the missile closes in on the target, it will transit into autonomous homing mode and turn on its onboard active radar. This usually occurs at about 13 seconds prior to projected impact (indicated by the "T13" mnemonic on the HUD count-down timer). The onboard radar will search at the last known location of the target.

Figure 74: AIM-120C loaded on F-16 wingtip, and AIM-120B on station 8. (Picture credit of USAF)

The AIM-120 seeker has an acquisition range in excess of 10nm., and operates in high PRF mode for initial target acquisition, after which it transits to medium PRF mode for guidance. In the presence of jamming, the missile will interleave between active transmission mode and passive HOJ mode for guidance.

If the launching aircraft loses radar lock, the missile will go active and search at the last known location. If it fails to find the target there, it will lock onto the closest target within its field of view. The missile will not distinguish between friends and foes, and this makes fratricide a serious concern. You should support the missile for as long as possible until it turns active, if anything to ensure that the missile locks onto the correct target.

The missile has a no-escape zone of about 5 – 7nm. in the rear quarter, and about 12 – 18nm. in the front quarter, with the lower ranges at low altitudes. Against a high speed non-maneuvering target, the missile is capable of reaching out to about 25 – 30nm. at high altitude. At close range, the missile can be fired up to 1 – 1.5nm. in the rear quarter, and 3 – 4nm. in the front quarter. At ranges below 10nm., the missile will almost always turn autonomous immediately upon launch.

Kinematically, the missile has quite a lot of energy to prosecute a target turning up to 8 – 9g when fired from under 12nm.. At longer ranges, the missile begins to lose energy and maneuverability. We will discuss tactics to counter threats with ARH missiles in a later section on tactics.

Protecting The Fleet – AIM-54C Phoenix

This was the first active radar guided missile in the US inventory. The AIM-54C was designed to destroy Soviet bombers from extremely long range, and designed around the AWG-9 fire control radar. This missile has a huge rocket motor that will propel it to Mach 5 at high altitude, and the missile adopts a very high loft trajectory. End game is often a terminal dive that preserves the energy state of the missile.

The missile can be fired from more than 45nm. away, against head-on high speed targets at high altitude. The head-on range shrinks to 30nm. at lower altitude, and about 15 – 20nm. in the rear quarter. It is designed to be fired in the TWS mode, conferring the F-14 a multi-target capability. Due to the older age of the missile, its ECCM and chaff resistance is not as good as the AIM-120. In terms of maneuverability, it is capable of prosecuting targets turning up to 7g without much trouble.

Figure 75: AIM-54C awaiting to be loaded on F-14. (Picture credit of USN)

Though never fired before in anger, the AIM-54 is nevertheless a capable performer, and deadly in expert hands. This is especially true when targeting bombers, the purpose for which the missile was originally designed. You are better off reserving this very expensive missile for engagement against bombers and high value targets such as AWACS, or high speed targets such as the MiG-25, than to waste it against less capable fighters such as MiG-21s. This is also the only US missile capable of engaging the Su-27 outside the range of the AA-10C.

The Russian Rabid Dog – AA-12 (R-77) Adder

Figure 76: AA-12 (R-77) Adder loaded on MiG-29M demonstrator

The AA-12 is the Russian answer to the AIM-120 missile. Also known as the RVV-AE and R-77, this missile is equipped with a larger rocket motor compared to the AMRAAM, but the cruciform lattice control fins results in a slightly higher drag. The seeker range is between 8 – 9nm., depending on target RCS. The initial acceleration and fly-out speed of the missile is higher compared to the AIM-120, and the maneuverability is better, but the missile loses energy slightly more rapidly compared to the AIM-120 when made to sustain high g maneuvers.

In terms of range, the AA-12 has a slight advantage of about 5% over the AIM-120B, solely due to the larger rocket motor. However, the shorter seeker range means that the launch aircraft must support the missile longer than the AIM-120 shooter, which somewhat negates the range advantage. This will allow the AIM-120 shooter to take evasive action slightly earlier than the AA-12 shooter.

The tactics to counter the AA-12 are similar to that of AIM-54 and AIM-120 (this will be discussed in the sub-section to follow).

AERIAL GUNS

When all else fails, you have the last resort, i.e. the onboard gun. We have moved on from the days of fighter pilots shooting at one another with pistols. The common American aerial gun is the 20 mm M61 Vulcan cannon, with a firing rate of 6,000 rounds per minute. If you are flying the A-10, you have the slower firing but harder hitting GAU-8 30 mm cannon, firing uranium core shells. The Russians have the Gsh-23 and Gsh-301 cannons.

In actual aerial combat, achieving gun hits on enemy aircraft is a difficult task. The high speed and wild maneuvering means that guns are ineffective beyond 4,000 feet of slant range. Real life gunfights often close in to less than 3,000 feet, and even 1,500 feet, before the guns become effective.

You will need to close in much more during a gun fight in Realism Patch, often within 3,000 feet, or else you will be wasting the ammunition. You will also need to position your pipper accurately to obtain the kill. It is extremely difficult to score a hit against a head-on target, due to the small frontal profile of most fighters.

As such, resort to guns only if you are out of missiles, or if the target is totally defenseless. Do not hang around if you are out of missiles, as the enemy can easily overwhelm you. However, if you are caught in a phone booth fight with nowhere else to go, the gun may be your only hope of getting out of the fight, so learn to use it properly.

MISSILE EVASION

Generating LOS Problems

All missiles have LOS tracking rate limits. The LOS rate is at its highest in a front quarter close range engagement, or in the beam, and reduces towards the rear quarter due to the lower closure rates. You should understand the tracking rate limit of each missile, so that you are in a position to assess the possibility of generating rates high enough to gimbal-out the missile during evasion.

Remember to maintain your airspeed above corner speed. This maximizes your maneuver potential and the ability to turn quickly to generate LOS problems for the missile. You should execute your maneuver when the missile is within 1 – 2nm. of you, and a hard turn into it at high speed will often generate a lot of LOS rate.

Dragging and Beaming

Depending on the range at which the missile is fired, dragging or beaming are feasible tactics. If the missile is fired at a range midway between Rmax2 and Rmax1, it may be feasible to turn tail and drag the missile out. This is especially true if the missile is fired head-on. The moment you beam the missile or turn tail, you will change the engagement geometry such that you will end up towards the Rmax1 range of the missile.

You should also aim to generate as much as speed as possible, and maybe descend to lower altitudes if the missile is fired co-altitude with you or from slightly above. This forces the missile to fly into the denser air at lower altitude, and exacerbates its energy retention problem. Alternatively, if the missile is fired from below you, a zoom climb to higher altitudes will force the missile to expend energy climbing after you, and leave it with less maneuvering potential for end game target prosecution.

Power Reduction and Aspect Changes

Power reduction is only useful against IR missiles fired from long range. Rapid throttling back reduces the IR signature significantly, more so if combined with aspect changes by turning towards the missile. This will usually reduce the IR signature such that it makes flares more effective, if not break the IR missile lock completely if the missile has a low IR seeker sensitivity.

Electronic Countermeasures

Dispensing chaff and flares is obviously an important component of missile evasion. For IR missiles with no IRCCM or mediocre IRCCM, dispensation of flares will usually decoy the missile. For missiles with good flare rejection capabilities, you may have to dispense many more flares rapidly, combined with power reduction and aspect changes to reduce IR signature.

Figure 77: F-16C dispensing flares over Kosovo during Operation Allied Force in 1999. (Picture credit of USAF)

As for chaff, it is more effective against SARH missiles throughout their entire guided flight, but only effective against ARH missiles in the initial stage of target acquisition. Again, rapid dispensation of 3 – 4 bundles of chaff can sometimes break a lock, but this is heavily dependent on the missile range and intercept geometry. You should nevertheless activate your countermeasures immediately and use a combination of maneuver and decoys to evade. Chaff is barely useful against pulse doppler radars (radars that are capable of look-down shoot-down performance), as its rapid deceleration upon dispense can be readily identified by the radar processor and ignored. However, chaff is still useful against SARH missiles under some circumstances, since SARH guidance relies on measurement of the target's doppler velocity from the CW or HPRF illuminating signals. At target aspects close to the beam, the target's doppler returns can diminish to an extent where chaff can be useful.

ECM can be very effective against SAMs, provided you stay outside the burn-through range. Usage of ECM against aircraft is more dicey, as it will compromise your position and allow them to vector towards you. Since SAM sites cannot move so rapidly, even though you will compromise your position, this is less of a concern.

Do remember to turn off your ECM system once you have defeated the threat. Forgetting to turn it off will often attract a huge gaggle of enemy fighters on your tail, and this is hardly the kind of attention that you will want.

Dealing With SARH Missiles

You need to remember that as long as you can defeat the radar on the launching aircraft, you will succeed in defeating the missile. This means that you must make life as hard as possible for the host radar, by beaming, employing ECM, and forcing the radar to look-down into ground clutter, plus employing chaff. You can decrease your altitude rapidly, while flying a course that puts the threat radar on your beam. You will need to adjust your course all the time to maintain the threat radar in your beam, and this is easy to do using the RWR. Combined with decoys, this can often defeat the host radar and break its lock. When all else fails, you will need to defeat the missile kinematically.

Defeating ARH Missiles

Please see the sub-section, "*Modeling the ARH Missile Seekers (Monopulse with Home-On-Jam)*" in the designer's notes section titled "*The Electronic Battlefield*," for the background information on how these ARH missile seekers work. You are best served if you understand the characteristics of the ARH missile seekers, so that you can take the appropriate actions to counter them.

Jamming will not work well against these missiles, and you may be making matters worse by giving the missile a beacon to home on. As such, the first reaction should be to turn off your jammer so that you will not trigger the HOJ mode of the missile and give it a beacon to track. You should also dispense chaff immediately (and at a rapid rate) before the missile has a lock on you. Once locked on, the missile is exceedingly difficult to decoy with chaff. In fact, if you are unaware of the missile launch until the missile symbology appears on the RWR, chances of defeating the missiles are very low, but you might want to try a maximum g break into the missile (it is useless to employ chaff by now). With luck, you may generate sufficiently high LOS rates that will exceed the missile's tracking ability.

The best way to defeat an ARH missile is to commence evasion at the point of launch, so that you can defeat it kinematically. This is difficult as the RWR does not show whether the bandit has launched or not and the only indication you will get is when the missile goes autonomous, by which time it is almost on top of you.

You should fly an arcing path that will bring you around the missile, keeping it in your beam for as long as possible. This forces the missile to fly an arcing path to you, allowing you to bleed the missile of its energy after its motor has burnt out. At the same time, it also degrades the seeker radar signal return and keeps you within the doppler notch of the missile. You should note that it is important to fly so as to beam the radar in the missile not the radar in the launching aircraft once the missile radar goes active.

Effective evasion will require a combination of different tactics, and you should also strive to dive towards the ground and force the missile to acquire you amidst the ground clutter. The combination of beaming and look-down will often delay the missile target acquisition, and increase chaff effectiveness. At the same time, it allows you to bleed energy from the missile, thus decreasing its end game maneuverability. The by-product of diving towards the ground is also to force the missile to fly into the denser air at lower altitudes, where the drag will be higher, thus increasing its energy bleed rate.

You should also utilize uplink starvation tactics to deny the missile of datalink updates. This means that you should break the launch aircraft's radar lock as soon as possible when he has launched, and rapidly change your spatial location so that you will be outside the missile seeker field of view when it turns autonomous after the inertial phase. The missile will search for you in the vicinity of your last known location prior to you breaking the launch aircraft's radar lock, so it is imperative that you fly out of its search area. This is easier said than done considering that you will not have any launch indication other than the visual signature of the missile's motor. Remember that you should be beaming the launch aircraft before the missile turns active (by keeping the RWR symbol at the 3 or 9 o'clock position), but once the missile goes active, you should be beaming the missile.

If the missile is fired at longer ranges, the most effective tactic is to turn tail and drag the missile out. If you are heavily loaded, you should consider jettisoning the weapons to clean up the aircraft, and accelerate as fast as possible away from the missile.

The fact that the launch warning is absent will force you to change your tactics. You will need to identify the threat on the RWR and determine the aircraft type, and if the emitter is capable of carrying ARH missiles, you will need to accord it the respect it deserves. You can ill afford to go charging straight at the threat and hope to get off a missile before it does, and will need to utilize proper F-pole and A-pole tactics to approach the threat, while denying it the opportunity to obtain a radar lock on you. Hopefully, you will get off a shot first before it does. This is where understanding the radar and missile capabilities of each threat becomes extremely important. Understanding the threat's capabilities will allow you to ascertain if you are within its effective weapon employment range. If necessary, you will need to fly defensively and assume the worst case scenario that the threat has already fired a missile at you.

MISSILE ARMING AND FUSING

An important factor to remember during the employment of missiles is the arming and fusing time required. All missiles have an arming and fusing delay. This is a safety mechanism, and inhibits the warhead from detonating until the missile has flown to a distance sufficiently far away from the launch aircraft such that any inadvertent warhead detonation will not harm the launch aircraft. For long range SAMs with booster sections or strapped-on booster motors, the warhead will often arm only after booster separation.

This means that while the missile may commence guidance immediately upon launch, there is still minimum time of flight required for the missile. The range within which the warhead will not arm is dependent on the engagement geometry, with the greatest distance in the front quarter. In general, the rule of thumb to use for estimating the minimum range of air-to-air missiles are as follows:

Rear quarter shots:	1,500 to 2,500 feet
Beam shots:	3,000 to 6,000 feet
Front quarter shots:	6,000 to 9,000 feet

The arming time is often dependent on the size of the warhead. The larger the warhead, the longer the arming time required. Hence, you should expect short range A/A missiles to have a tighter Rmin compared to long range A/A missiles.

For medium and long range SAMs, the arming time typically ranges from 4 to over 10 seconds. For MANPADS, the arming time is fairly short. For SAMs such as the SA-2, SA-3, and SA-5, the need for booster separation to occur means that the minimum range of the SAM will range from 1 to 10nm.. However, you should treat all missiles launched at you with respect, and assume that the warhead is armed and capable of doing damage. For more details on how this is implemented in the Realism Patch, you are advised to read the section titled "*The Long And Short Of Fuses*" in the Designer's Notes.

FREQUENTLY ASKED QUESTIONS ON MISSILES

Why is it that the AIM-9P is now so easy to evade?

The AIM-9P-3 missile has no IRCCM capability. Any flares will decoy the missile regardless of target aspect. In addition, the seeker is also easily decoyed by ground IR clutter and the Sun. The low tracking rate means that the target needs to be positioned correctly within the HUD, with minimal line of sight movement before a successful launch can be assured.

The AIM-9M missile seems a lot less effective than before and misses head-on shots more compared to before.

Head-on shots occur with very high closure rates. The high closure means that the tracking rate increases tremendously as the missile closes in, and this often exceeds the ability of the missile to maintain track. The AIM-9M seeker performance has also been adjusted to reflect more correctly what the actual performance should be. This missile is capable of successfully shooting down targets up to about 2-3nm. away.

Why isn't the AA-10A/C (or any other missile) capable of its published maximum range?

Missile range is dependent on the missile kinematics and engagement geometry. The published maximum range is useless unless the launch conditions and geometry are known. Missile manufacturers quote different ranges to different sources, and the favorite is to quote head-on high closure engagements at extremely high altitudes, such as co-speed, co-altitude Mach 1.6 head-on engagement at 40,000 feet altitude, against a non-maneuvering target. Missile ranges decrease dramatically at lower altitudes typical of most air combat encounters, due to the denser air and higher drag, and also against maneuvering targets (with anything more than 2-3g).

Does semi-active radar homing missile possess greater effective range than active missiles?

No. Semi-active radar missiles are constrained by seeker sensitivity. Most seekers are not sensitive enough to detect reflected radiation from the target at ranges greater than 13-18nm.. Also, SARH missiles do not have true range information, and must rely on extrapolation from the launch condition, using the target Doppler shift. SARH missiles are also more easily decoyed by chaff, since it does not possess onboard radar and the sophistication of onboard radars. Guidance is by homing on the reflected energy and comparing signal coherency by having rear-facing receivers to receive the radiated energy from the parent aircraft. The missile knows the target range at the point of launch, but once it leaves the launcher, range is derived from extrapolating the initial target range from the doppler shift of the reflected radiation sensed by the seeker.

When chaff is dispensed, the bloom characteristics can flood the target return with a bigger return than the actual aircraft, making it very difficult for the seeker to determine the true target return from the chaff target return. Due to the nature of the seeker, SARH missiles may be kinematically able to hit more distant targets, but the effective range is usually constrained by seeker performance to shorter distances. When launched outside the seeker sensitivity range, SARH missiles like the AA-6 rely on inertial updates from the parent aircraft. However, this form of guidance only allows the missile to begin searching for the target return at the expected area (known as the uncertainty zone). The size of this uncertainty zone depends on the track stability of the parent radar, and any target maneuvers such as beaming, ECM, or chaffing will reduce the track stability and increase the uncertainty zone. This decreases missile Pk tremendously, compared to launching at targets inside the seeker sensitivity range. Inertial target location update occurs at a much lower frequency compared to the seeker sensing the actual target radar return, and as such, the Pk decreases dramatically.

Why is it so easy to dodge some missiles now?

The original Falcon 4 missile-tracking rate is way too high and unrealistic for the missiles represented. They have been decreased to realistic values. It is now possible to pull into a missile and force the missile the break lock (provided you maneuver correctly) by exceeding the missile tracking rate through a rapid pull across the seeker line of sight.

Why are AA-10B launched so close to the target when Internet sources stated that they have inertial guidance?

The AA-10B does not have any inertial guidance. This missile is designed as a "run-down" missile, having enough energy to pursue a high-speed target from further out in a tail chase scenario. Short range missiles such as AIM-9M and AA-11 will run out of energy in such engagements, while the AA-10B will have sufficient energy to catch up with the target. As with the AIM-9M and AA-11 this missile needs to lock on to the target before it can be launched.

Does having an IRST increase the acquisition range of IR seekers?

No, it does not. Heat seeking missiles need to detect a heat source above the guidance threshold in order to initiate a tracking solution. Although an IRST can be used to cue the missile seeker, an IRST is an imaging IR sensor that forms an image of the IR scene. Most IR air-to-air missiles have reticle scan mirror seekers and track using heat sources instead of IR images. A target that provides sufficient IR contrast to imaging IR sensors may not provide sufficient thermal radiation to enable a tracking solution. This is because reticle seekers cannot be overly sensitive in order to reject ground IR clutter and solar radiation. All that an IRST does is to cue to seeker in the right direction. The launch criteria is still the seeker being able to physically lock onto the target.

Will the MiG-29, Su-27, and Su-30 launch the AA-11 at high off boresight angles?

Yes, the helmet-mounted sight is now implemented in the AI. The AI will launch the AA-11 missiles at high off-boresight angles, up to 65% of the seeker gimbal limit. For the AA-11, the AI will launch it at off-boresight angles of up to 43°. This makes merging with any AA-11 equipped opponent a very hair raising experience, as the AI can now shoot at you without needing to point its nose in your direction. You should review the tactics to counter HMS equipped opponents, in the next section titled "*Chivalry Is Dead*."

Can I use real world launch denial tactics with IR missiles?

This may or may not work. Flare susceptibility is modeled as a simple probability in Falcon 4. As such, with an uncaged missile, if the target drops flares, you will not find the missile going after the flare, but rather, it will simply break lock and go ballistic. However, against a missile launched from the edge of the IR detection envelope, tactics to reduce IR signature do work just as in real life. Examples of such tactics are cutting the throttle and turning head-on against a missile launched from the beam.

The AMRAAM used to hit targets out to 20nm. with a very high success rate prior to the RP. Why is it so bad now?

The AMRAAM has a smaller no escape zone, mainly constrained by seeker performance and missile kinematics. It will still hit targets out to 20+nm., but if the target performs an escape maneuver by dragging or beaming the missile, it may be defeated easily.

I thought the missiles ought to pull more lead, why is it that the proportional navigation gain is so low now?

The missile's kinematic and guidance performance is affected by thrust, aerodynamics, and the navigation gain. These three factors need to be adjusted in unison. The combination in the missile data files represent the numbers required to replicate missile kinematics and guidance performance, such that the missile envelope is reasonably accurate compared to the actual article.

How is the Rmin modeled in the new missile models?

Microprose did not model Rmin properly, as the warhead fusing time was never taken into account. In the Realism Patch, this has been changed. The default AIM-120 model can actually be fired at targets well within 1nm. of range head on, and still obtain a hit. The time to safe and arm missiles plays a very important role in constraining the Rmin for missiles. From RP5 onwards, the safe and arming time for missiles is now modeled. Missile warhead safe and arming usually occurs within 300-400 meters from the launch aircraft, which corresponds to about 900-1500 feet. The typical arming time is about 2 to 3 seconds for an air-to-air missile, and may be more than 10 seconds for a long range surface-to-air missile due to the needs for booster separation. If you fire the missile at ranges under Rmin, the missile may still guide properly, but the warhead will not detonate and you will waste the shot. In general, Rmin is about 1,500 to 2,500 feet for rear quarter shots, 3,000 to 6,000 feet in the beam, and between 6,000 and 9,000 feet for front quarter shots.

How do you interpret missile range and performance from published specifications?

Missile ranges are often quoted in reputable journals and publications. These ranges are however often quoted without the firing conditions and geometry. Firing geometry and target maneuver will influence missile range considerably. Taking the AA-10 as an example, when fired head-on at a non-maneuvering target, its range is approximately 3 times more than a maneuvering target in a constant 5g turn. In the latter case, the AA-10 is barely even BVR. The AMRAAM is also often quoted with a 50 km range. This range would only be practical in a head-on engagement against a non-maneuvering target.

The general rules of thumb are as follows:

Rmin is largest when firing at head-on, high closure targets. The higher the closure, the further Rmin becomes.

Rmin in tail-on engagements is smaller than Rmin in head-on engagements. This is only to be expected, since the missile needs to maneuver less to complete the intercept. Head-on shots often have high LOS crossing rates, and in many cases the rate may exceed the maximum maneuver capability of the missile thereby making a successful intercept impossible.

Rmax against a non-maneuvering target is also about 2-3 times more than a maneuvering target.
Head-on engagement range is greater than tail-on. This is plain kinematics. However, head-on ranges for IR missiles are limited by the seeker performance. Thus, IR missile head-on ranges are less than tail-on ranges, even for all aspect seekers.

New IR missiles generally have greater seeker acquisition range in the rear aspect than its kinematic range. Kinematic range will however exceed seeker acquisition range in the front aspect.

Anytime the missile is made to maneuver, it will lose energy rapidly. Prior to motor burnout, the missile can maneuver without losing much energy. Once the motor has burnt out, you should expect the missile to lose energy fairly quickly even when not maneuvering. Missile drag at high supersonic Mach numbers is considerable.

Why is it that AA-10C is fired only within 30nm. of the target?

Falcon 4.0 can only model SARH missiles effectively when the target and the shooter are within the air bubble, and the default air bubble is set to 30nm.. SARH missiles, when fired outside the air bubble, will go ballistic, as the AI does not gain a radar lock first before shooting. As such, AA-10C can only be fired inside the bubble, even though kinematically the missile is more capable. However, human pilots can fire at targets successfully outside the 30nm. air bubble. Testing has that revealed successful shots are possible out to about 30-35nm. range head-on. If you increase the bubble slider setting, the AA-10C will be fired further out, depending on the size of the bubble, and may reach a maximum of 45nm. at high altitude with high closure speeds.

Is the altitude effect on missile range modeled?

Yes and no. A reasonable correct atmosphere model is captured in F4, and this will give lower air density at high altitudes. As a result, missile drag decreases with increasing altitude, leading to greater range at higher altitudes than lower altitudes. However, the effect on the rocket plume pressure pattern and thrust is not modeled. Real life ratio of high altitude range versus low altitude range is about 3:1, and this is not achievable in F4 due to the lack of an accurate missile plume model. The achievable range ratio is closer to 2.5:1 and 2:1. This effect is modeled for the AI as well, and is reflected in the HUD DLZ scale.

Why is the MiG-25 capable of launching the IR guided AA-6 from BVR ranges and the missile will still guide?

The IR AA-6 has a command link to the launch aircraft where the launch aircraft can update the missile will the target location real time even though the missile does not have a valid lock. This will guide the missile towards the target, for it to employ its onboard seeker for terminal guidance. The behavior and tactical employment is modeled in the game by giving the seeker a very large acquisition range, as F4 does not model command guidance. The missile will thus be launched from as far as 15nm. out head-on, though tail-on launch range is restricted to under 10nm. by the missile range breakpoints.

Why is it that the F-14 chooses to fire other radar or SARH missiles first before the AIM-54?

The AI is coded to always fire the missile loaded on the forward fuselage hardpoints first. As such, if any other missile is loaded at the two forward fuselage hardpoints, these get fired first before any other missiles, even though AIM-54s may be loaded under the wing or on the aft fuselage hardpoints. To force the F-14 to shoot the AIM-54 first, you will need to manually alter the loadout and load the AIM-54 in the forward fuselage hardpoints.

Why is the hit rate of the SA-7 so bad?

SA-7 is a man portable missile with an uncooled seeker head. As such, its seeker sensitivity is low and it breaks lock easily when the target aspect changes. In addition, it is also very prone to ground IR clutter, and is easily decoyed by clouds and sun. Most of the shots that seem to be launched ballistically are due to guidance problems, i.e. the missile locks onto something else like the sun. As with all man portable SAMs, these missiles have very small control fins, and are limited in their maneuverability. Hence, against higher speed targets, they are usually not able to complete the intercept due to rapid energy loss. This problem affects all MANPADS such as Stinger, SA-7, SA-14, and HN-5A.

Why can't the Daewoo Chun-Ma (K-SAM) be decoyed by flares or chaff?

The Daewoo Chun-Ma (Pegasus) SAM system relies on command guidance. The missile has no onboard seeker, and relies on rear facing antenna to receive guidance signals from the launch vehicle. Guidance is through the gunner tracking the target on a FLIR targeting sight, and the fire control system sends out steering commands to the missile by collimating the missile flight path with the line of sight to the target. As such, this mode of guidance is impervious to counter measures such as flares and chaff. However, the command link can be jammed, though this aspect is not modeled in F4. The only means of defeating the missile is to out maneuver or out-run it, which should not be too difficult given the low proportional navigation gain and tracking rate of the missile.

Why is it that the SA-2 is only marginally effective above 60,000 feet? Did it not shoot down a U-2 from 72,000 feet once?

The U-2 was shot down at 72,000 feet over Soviet Union. At that time, a total of approximately 14 SA-2 were fired, and only one struck. The U-2 has a very low cruise indicated airspeed in the region of 150+ knots, and as such, it does not require a missile of tremendous energy state to reach it. The SA-2 that stuck the U-2 only needed to fly slightly faster to complete the intercept. Against fighter type targets, the SA-2 will stand a lesser chance of completing the intercept due to the higher target speed.

Why do I get an "M" symbol on the RWR whenever the SA-5 fires?

The SA-5 is a command guided missile in the initial stage, but is equipped with an onboard active radar seeker for terminal homing. The seeker is usually activated close to the target location, and as such, it will trigger the RWR system to display the "M" symbol, indicating that the SA-5 launch crew has activated the missile's onboard seeker for terminal guidance.

The SAMs in F4 are killing me, and the kill ratios are much higher than actual combat statistics. Are the SAMs too maneuverable?

The SAM kinematic and guidance models have been tested in stock firing profiles to evaluate the kinematic performance as well as guidance characteristics against a variety of different engagement scenarios and profiles. Tests have allowed the kinematic models to be tuned such that the performance are commensurate with their design and size, and as such, are as accurate as possible within the limitations of publicly available information.

Combat experience and statistics are influenced by a variety of different factors. An integrated air defense suppression plan, in the form of stand-off jammers (SOJ) such as EA-6B, EF-111 and EC-130 (the "soft" kill assets), as well as SEAD strikers such as F-4G and F-16 (the "hard" kill assets), precedes every strike in real combat. The SOJ often employ broad band noise jamming techniques to deny the SAM radars any chance of detecting and locking onto targets by flooding the receivers with noise and drowning out the true target radar returns. This prevents the fire control radars from achieving firing solutions. In addition, the SEAD strikers equipped with HARMs often launch preemptively at any SAM radars that actively emit. Such techniques prevent lock-ons by active emitters, and at the same time kills the emitters that are radiating. This forces the air defenses not to emit so as to deny a HARM shot. The consequence is that the air defense network is neutralized.

Without fire control information, SAMs are often fired ballistically or optically aimed, resulting in reduced effectiveness. In addition, SAMs are often fired in barrages, aimed or otherwise, to deter strikers from approaching the target area. All these factors contribute to the low kill statistics of SAMs in actual conflicts. The defensive ECM suite present on a strike aircraft not only serves to delay or deny a lock-on by SAM radars, but it also represents just one small part of a larger integrated electronic warfare plan.

F4 does not model strike packages accurately, in that most strike packages are not accompanied by stand off jammers, and many packages are similarly not accompanied by SEAD packages with HARMs. As such, strike packages often face the full wrath of the integrated air defense system, resulting in the higher SAM kill statistics in F4.

All podded defensive ECM have effective coverage arcs that do not encompass the entire aircraft, and the emitter must be within the coverage arcs in order for the jammer to be effective. Once the aircraft takes evasive action, the SAM site may not stay within the coverage arc for a significant amount of time for the jammer to become effective.

Jammer effectiveness is also governed by the jamming to signal ratio. This ratio is higher when the jammer is further away, and progressively decreases with range reduction. As such, the closer the target is to the SAM radar, the higher the chance of the SAM radar "burning through," and this happens when the target return signal is high enough and exceeds the jammer signal. When this happens, the jammer loses it effectiveness. This aspect is modeled in F4.

I used to be able to lock-on to targets from 10-15nm. away using the Maverick, but the Maverick tracking gates now begin to pulse only at closer ranges. What happened?

Maverick missiles (TV and IIR) guide using the contrast of the video picture. The original AGM-65B seeker in F4 was over-modeled, especially against small sized targets such as ground vehicles. This aspect has been corrected, and the new lock-on range is an average between small sized targets and larger sized targets. In addition, due to the limited zoom capability on the AGM-65B, the lock-on range have been decreased slightly to model its characteristics more accurately. In addition, the target has to achieve a certain size in the Maverick video before the tracking solution can be arrived. Currently, this aspect is similarly over represented in F4.

As for the IR Mavericks, the IR seeker's acquisition range is dependent on humidity, thermal differences, atmospheric particulate count, etc. For the seeker sensitivity wavelengths in the Maverick, the seeker's acquisition range is expected to be lower in the Korean atmosphere. This aspect is similarly captured by scaling back the seeker range. The video picture over-represents the imaging capabilities against small targets, and as such, the acquisition range have been reined in.

How do flares and chaff work in Falcon 4?

The details on how chaff and flares work in Falcon 4 is explained in the section "*The Electronic Battlefield*," in the designer's notes. The effectiveness of chaff and flares against various missiles can be computed for each seeker type to determine their lethality as part of your mission planning.

Why do I not get any launch warning when AIM-120, AIM-54 and AA-12 are launched at me?

See answer in the section, "*Frequently Asked Questions On Radars, Jammers, and RWR*."

CHIVALRY IS DEAD

Air-to-Air Combat Tactical Considerations in Realism Patch
By "Hoola"

GETTING THE BASICS

We will not be discussing the basics of intercept and BFM. These topics are better covered by others more qualified than myself, such as Pete Bonnani and Robert Shaw. For a start, we suggest that you become really familiar with the weapon characteristics as well as sensor employment, until these become second nature. This will free up some mental capacity for thinking about tactics. You will need to get your act together if you wish to have a long and successful virtual fighter pilot career in Falcon 4.

You should begin by reviewing and familiarizing yourself with all the radio commands available, especially the AWACS and flight/element commands. This is covered in chapter 23 of the Falcon 4 user's manual. Next, familiarize and review Part 4 of the Falcon 4 user's manual on enemy tactics.

"*The Prima's Official Strategy Guide to Falcon 4.0*" (published by Prima Publishing, 1999, ISBN 7615-0108-8, written by Pete Bonnani and Jamie Reiner) is a good source of information on Basic Fighter Maneuvers (BFM), intercept tactics, and advanced tactics, tailored to the Falcon 4 environment. For a doctorate level work on fighter combat and tactics, Robert L Shaw's "*Fighter Combat: Tactics and Maneuvering*" (published by Naval Institute Press, 1985, ISBN 0-87021-059-9) is an excellent choice. Lastly, *the "USAF Multi-Command Handbook 11-F16, Volume 5, F-16 Combat Aircraft Fundamentals*," available at http://www.fas.org/man/dod-101/sys/ac/docs/16v5.pdf, is an excellent reference source for real world F-16 tactics.

What we will be covering here will be specific to the Realism Patch. The purpose of this section is to supplement the material covered elsewhere.

F-POLE VERSUS F-POLE

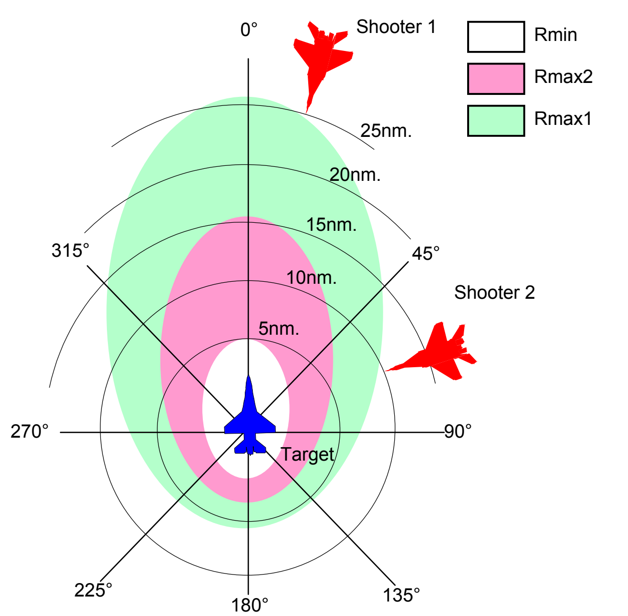

Figure 78: Missile range relationship with target aspect

For years, F-pole tactics formed the bread and butter of Western and Russian tactics. F-pole tactics involve the usage of SARH BVR missiles. In the dark days before the advent of the AMRAAM and AA-12, the winner of the F-pole fight was the one who could lengthen the stick he carried while shortening the stick that his enemy carried.

The range of the missile is dependent on its initial energy state at the point of launch. If the launch aircraft is at a higher speed, then the missile's initial energy state is higher. If the launch aircraft is at a higher altitude, then the potential energy imparted onto the missile can be traded for kinetic energy during the missile's end-game intercept. You will thus improve the missile's reach if you are able to out accelerate and out-climb your opponent prior to the merge.

Strive to get as high an airspeed as possible, and get an altitude advantage on the bandit. This creates problems for the bandit's missile, as the missile will be required to climb after you and trade off its kinetic energy, leaving it with a lower maneuver potential. You should ensure that the intercept begins this way from well beyond visual range, and maneuver to counter the bandit's re-positioning to maintain your energy advantage.

Figure 79: PRC Su-27 taking off during an exercise

Based on missile kinematics, the range is the furthest whenever you are targeting a head-on bandit. For the example in Figure 78, the target is at the center of the picture, and the two shooters are at angles of about 15° and 70° to its right side. You can see that for the shooter at approximately 15° off the right side of the target, it is just at the Rmax1 range of its own missiles, i.e. about 25nm.. For the shooter at an angle of about 70° off the target's right side, it will not even be able to take an in-range missile shot even though it is closer to the target, at a range of 10nm.. Hence, to maximize your own missile's range, head-on engagement is the way to go. However, this has the effect of also maximizing the bandit's missile range. What you can do is to obtain an offset from the bandit, and only turn towards it as you are getting ready to shoot. You should also avoid going STT on the bandit so as not to trip off his RWR. Maintaining the bandit as a bugged target in RWS/CRM is a good way of ensuring timely track update, yet retaining the search ability to detect any trailers behind the bandit. As the bandit gets closer, make sure that there are no trailers to ambush you before you convert on the bandit. You should then go into STT to ensure a more stable radar lock.

As you get ready to shoot, turn into the bandit to maximize your missile range. Once you have fired, if the bandit does not shoot back, you can continue to head towards it, and be ready to follow up with a second shot if necessary. You should also be concerned about the bandit shooting back, in which case, you should crank away from the bandit, but ensure you keep it inside your radar gimbal limits.

The result of turning away after firing (but still keeping the bandit within the radar gimbals) is that you will minimize the bandit's shoot range for retaliation, by changing his engagement geometry. Using Figure 78 as an example, we will assume that the target initially turns towards shooter 2 and fires an SARH missile at it, and then turns away to put shooter 2 at a position of 70° off its right side. If the target is able to keep shooter 2 inside its radar gimbal at this position, it is able to provide target illumination for its own missile that is in flight. Shooter 2 will however not be able to retaliate with a return missile shot as the target has changed the engagement geometry such that it is now outside shooter 2's missile range. This tactic is sometimes called cranking.

F-POLE VERSUS A-POLE

With the introduction of AMRAAM, A-pole is now the name of the game (A-pole refers to ARH missile usage). If you are armed with SARH missiles and are fighting against A-pole shooters, the obvious disadvantage is that the A-pole shooter will not need to support his missile throughout the entire flight. In fact, the A-pole shooter can break away and turn tail once the missile is within 8 – 10nm. of the target, while the F-pole shooter has to stay engaged until missile impact.

The consideration in the fight is the same as a pure F-pole fight, i.e. maximizing your shoot range. In fact, this now becomes more important, as the F-pole shooter is disadvantaged in a fight where both sides are trading shots. With an active missile in the air, it becomes untenable to support one's own missile in flight while carrying out evasive actions.

You should not go charging at the A-pole shooter, as there is no way of telling when the bandit has fired its missiles against you, since the RWR will not indicate the launch. What you should do is minimize the ability of the A-pole shooter to gain a radar lock on you. Then you can get a shot off before he does, you have put him on the defensive. The AA-10C shooter has the advantage here, in that the missile out-ranges the AIM-120. The Su-27 has a radar big enough to burn through the jamming before the AIM-120 can be fired at it.

Figure 80: Fox 1 kill as an AIM-7 fired from a F-14 scores a direct hit on the target drone. (Picture credit of USN)

You should also consider taking a shot under marginal Rmax1 conditions once you are in range to put the bandit in the defensive mode first. Shooting you will then be the last thing on his mind. If the A-pole shooter has already fired, taking a shot at him will force him to abandon support of his missile as he will have to honor the inbound missile. This will deprive his missile with the datalink update, thus decreasing the probability of the ARH missile finding you when it turns autonomous. You should then do whatever you can to get out of the vicinity when the ARH missile turns active. Do not bother about whether your missile will hit or not, as the main objective is to force the A-pole shooter to abandon his missile that is in-flight, and put him on the defensive. If you can initiate evasive maneuvers while keeping your radar lock on the bandit, so much the better. This will at least give you a fighting chance.

Bear in mind that your survival chances against an A-pole shooter are the greatest if you can successfully deny the ARH missile with its uplink from the bandit. You should tailor your tactics to force the bandit onto the defensive, and the bandit's RWR launch warning is a good thing to exploit.

A-POLE VERSUS A-POLE

Now things get a little more dicey with fighting pure A-pole. Both you and the bandit will not have a clue that a missile has been fired until the RWR detects the missile turning autonomous. Obviously trading shots is a bad way to win a fight, and you cannot force the bandit to abandon support of his own missile just by shooting back, as the launch of your missile will not trigger his RWR launch warning.

What you should do is still the same, i.e. to maximize your own shoot range while minimizing the bandit's. Again, having a huge altitude and speed advantage helps to maximize your own missile's range. When you initiate your intercept, you should always assume the worst case that the bandit has fired, and be very careful anytime you get within 25nm. of the bandit (for AIM-120 and AA-12). Shooting in RWS/CRM or TWS mode also has the advantage of not highlighting to the bandit that he now has your attention.

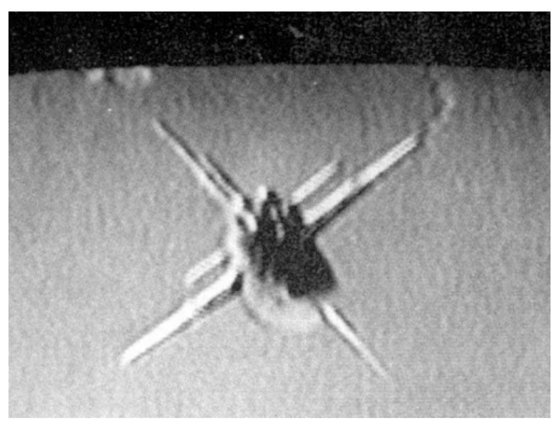

Figure 81: An AIM-7 Sparrow missile as seen by the target drone, moments before the missile impact.

The AA-12 shooter has the advantage of a longer range compared to the AMRAAM shooter, though the latter requires less support from the launch aircraft compared to the former (about 20% difference in seeker range). The AIM-54 shooter has the advantage of out-ranging both AIM-120 and AA-12, but the onboard seeker is slightly less sophisticated.

As long as you play the defensive game, you should be able to survive the skirmish. Keep in mind that your chances of survival get drastically lower once the missile turns active and locks onto you. If you suspect that the enemy has fired at you, and you are still not in firing parameters, light the afterburner and get out of the dodge first. It is often better to save your own skin and fight on another day, when the dice is loaded in your favor, than to hang around and try to get a shot off.

IRCM TACTICS

In the event that you are not able to eliminate the bandit from BVR, you may have to merge. IRCM tactics will allow you to remain offensive by denying the bandit a chance to shoot at you. It is a myth that all aspect IR missiles can always be fired in the front quarter regardless of the target's throttle setting. Aerodynamic heating on an airframe seldom exceeds 150°C, and this means that the airframe IR signature (discounting the exhaust plume) is often not visible at longer ranges. The key to denying a front quarter all aspect missile shot is to throttle back prior to the merge, and reduce your own IR signature. Merging with afterburners blazing is a sure way of being put on the defensive immediately, as you are just presenting a big IR target for the opponent's missile.

Figure 82: Su-27UB from the PLAAF. This aircraft is capable of fighting F-pole and A-pole, as well as having an off-boresight WVR targeting capability.

You should aim to maintain your energy at a high state prior to the merge. This allows you to retain as much energy as possible even when you throttle back. At about 6 – 8nm. away from the bandit, you should throttle back below AB to reduce your IR signature, and if necessary, throttle back below MIL, depending on what aircraft you are flying.

In general, throttling back to about 80% will often reduce your IR signature sufficiently to prevent an opponent's all aspect IR missile from being launched beyond Rmin. Even if the opponent shoots, the range will be too close, and a break into the missile will often defeat it. For example, throttling back to 80% will only allow the AIM-9M and AA-11 to obtain an IR lock at 1nm. head-on, which is inside the minimum range of the missiles. You need to remember that the engine needs time to cool down, so if you initiate the IRCM tactic too late (for example, inside 5nm.), you may not cool the engines in time to prevent a front sector launch. You may also want to dispense flares pre-emptively in case the bandit shoots.

The bulk of the DPRK aircraft are not equipped with countermeasure dispensers, and as such, they are vulnerable to the AIM-9P. PRC and Russian aircraft are better protected with self protection systems and countermeasure dispensers. Hence, you should learn to arm the aircraft appropriately for the threat that they will encounter over the battlefield.

For ground attack aircraft, you can often conserve their stock of AIM-9M by arming them with older AIM-9P, if the threats that they are expected to face over the battlefield are not equipped with chaff/flare dispensers. Against newer aircraft or aircraft equipped with dispensers, these missiles will be close to useless unless fired without the target detecting it. While this may appear to penalize the OPFOR aircraft, it also means that the Su-27 and MiG-29 aircraft have become the greatest air threat, as long as you do not allow the OPFOR to sneak an older missile up your tail without you realizing it.

You will need to be aware of the threats that you will be facing, in case you feel like engaging in some air combat. You will need to learn to recognize the threats on the RWR, and know if the target has any countermeasure capabilities, if you are unfortunate enough to be equipped with older IR missiles. Bear in mind that merging with aircraft that are equipped with chaff/flare dispensers may be a waste of time if you are equipped with missiles that have little or no IRCCM capabilities, so you may be better off concentrating on the air-to-ground mission.

FIGHTING OFF-BORESIGHT CAPABLE MISSILES

Fighting off-boresight capable missiles such as the AA-11, AIM-9X, and Python 4 can be a hair raising experience. IRCM launch denial tactics will allow you to prevent an off-boresight launch. However, you should bear in mind that the bandit can engage you up to 40 – 50 degrees off its nose, so it does not necessarily have to point its nose at you to shoot. Now that the AI is capable of taking full advantage of the capabilities of such missiles, it is even more important for you to learn how to counter them.

You should exercise caution whenever you are in front of the bandit's 3 – 9 line. As you merge, force a one-circle fight instead of getting into a two-circle fight, as it leaves you on an even keel with the bandit after the turn, and keeps you inside the minimum range of the AA-11. If you get into a two-circle fight, the bandit will be in a position to shoot at you across the circle before you can shoot at it, as you will end up outside the minimum range of the AA-11 after ¾ of a turn. Taking Figure 84 as an example, with both fighters entering into a two-circle fight, the F-16 will enter into the AA-11 firing envelope before the MiG-29 enters into the AIM-9M firing envelope, at position number 3. This gives the MiG-29 pilot the first shot opportunity, enabling him to fire across the turn circle, thus putting the F-16 on the defensive. The wider AA-11 seeker gimbal envelope is hence more advantageous in a close fight. By forcing a one-circle fight, the separation between the two fighters will be less, keeping you inside the AA-11's minimum firing range all the time, and denying the bandit of a shot.

Figure 83: Russian helmet mounted sight for the MiG-29 and Su-27.

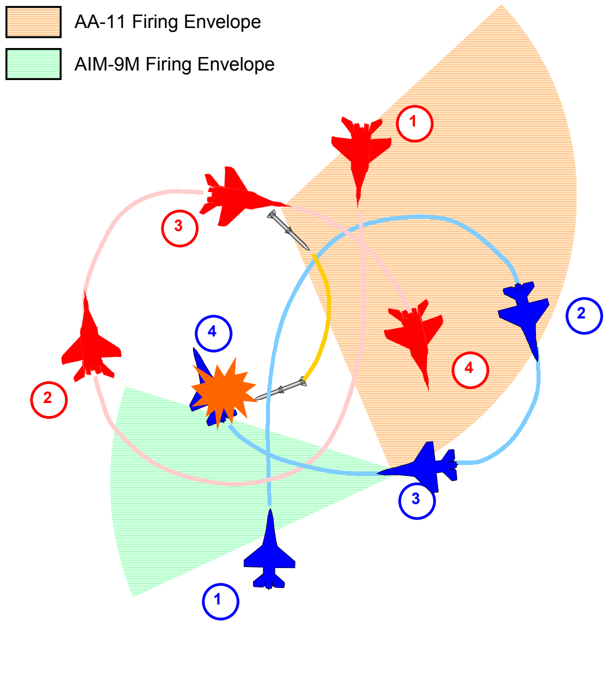

Figure 84: A two-circle fight will give off-boresight missile armed opponent the first shot opportunity

Be careful about throttling up as you go past the bandit. If you power up too early, the bandit may still be able to take a shot at you. The AA-11 has sufficient energy and seeker gimbal angle to complete a 180 degrees turn and chase you down. Be patient and maneuver to get yourself into a position to shoot, and always bear in mind that the bandit does not need to point its nose at you to kill you. Proper throttle and energy management will help prevent you from being put on the defensive.

The flip side of a missile shot fired at high off-boresight angles is the huge amount of energy that the missile has to expend to negotiate the turn. This often leaves the missile with a lot less energy than if it had been fired at smaller off-boresight angles. The consequence of this is a reduction in the missile's maneuverability during the end game. You can try to exploit this by maintaining a high energy state, and "blowing through" the engagement as fast as possible, forcing the missile into a tail chase engagement scenario after it has negotiated the initial turn to pursue you. With some luck, the missile may not have sufficient energy to hunt you down. If you are the one firing the off-boresight missile, then bear in mind that engaging high off-boresight targets more than 2nm. away will decrease the missile's energy state tremendously, thus lowering the kinematic Pk of the missile.

The HMS/AA-11 combination is an extremely effective combat capability, and it can compensate for the lack of flying skills and aircraft performance. The effectiveness of the HMS/AA-11 combination was quantified during the development of the Realism Patch, by a series of dogfights between AIM-9M armed F-16 and HMS/AA-11 armed MiG-29. The results are shown below:

F-16 Skill Level	MiG-29 Skill Level	Kill Ratio (F-16:MiG-29)
Ace	Ace	1 : 1.5
Ace	Veteran	1 : 1.41
Ace	Cadets	1.2 : 1
Ace	Recruit	1.63 : 1

Without the HMS, and armed only with the AA-11 (thus limiting the AA-11 to the same firing constraints as the AIM-9M), the kill ratio of Ace F-16 versus Ace MiG-29 became 1.48 : 1, in favor of the F-16. As you can see, the HMS expands the engagement zone of the AA-11 tremendously, and this off-boresight targeting ability reverses the odds against the F-16, and allowed even Cadet MiG-29 pilots to come close to winning a WVR fight against Ace F-16 pilots. The HMS/AA-11 combination more than compensates for the poorer flying skills, making it an extremely high threat even in less-than-competent hands. The USAF and USN has only begun to redress this imbalance with the JHMCS (Joint Helmet Mounted Cueing and Sighting system) and the AIM-9X program, while the Israelis have had the Elbit DASH HMD (Helmet Mounted Display) and Python 4 in service since the early 1990s. The JHMCS/AIM-9X and DASH/Python 4 combination is even more deadly than the HMS/AA-11 combination.

Your best tactic against such opponents is to exploit the BVR advantage of the F-16, and engage the enemy at BVR ranges. The A-pole advantage of the F-16 should be exploited to its fullest. Learn to make use of the means available to you, and if you are not able to engage the target beyond visual range, you should always consider a retreat to preserve your forces. Courage is not just about charging into a fight fearlessly, but also about knowing when to disengage and fight on another day under conditions that are more favorable to you.

USING THE HELMET MOUNTED SIGHT (FOR RUSSIAN AIRCRAFT)

For aircraft equipped with a helmet mounted sight (MiG-29, Su-27, and the Su-30MKK), the advantage conferred to the pilot is tremendous. The helmet mounted sight allows the pilot to literally "point and shoot," as the pilot can designate the target using his helmet mounted sight instead of his radar. The ability to turn his head and cue missiles removes some of the need for him to maneuver, and makes him a serious threat.

The helmet mounted sight in the Realism Patch is mechanized to simulate the Russian sighting system. When used with the AA-11 Archer, the HMS allows the pilot to engage targets up to the full gimbal limit of the missile seeker. This mode of targeting works in the Padlock view. When you command the missile the uncage, an aiming reticle will appear at the center of your field of view. This aiming reticle has a sighting crosshair at its center, and the missile will automatically be cued to it. If you padlock any aircraft, the missile will automatically be slaved to your target of interest, and you may fire the missile normally.

MOTHERING THE AI

Managing the AI Wingman in Air-to-Ground Missions
By Alex Easton

INTRODUCTION

The AI in Falcon 4 has a lot of problems. While the Realism Patch has attempted to rectify many of the deficiencies, there are several tricks that you can apply to help your AI wingman out, and prevent them from killing themselves. This will not solve everything, as the AI has a mind of its own at times, but it will put right some of the problems that you may have experienced.

EXAMPLE 1: ATTACKING IN TRAIL FORMATION

The Situation

You are tasked on a CAS mission, and you approach the target with your wingman in trail. You lockup a target on the A/G radar, and issue him the "Attack targets" command. You then launch your own Maverick missiles, and decide to orbit the target at a range of 5nm. and an altitude of 12,000 feet, so as to keep the target deaggregated. Your intention is to commence your bombing run when the AI has completed his attack runs with the Maverick missiles. As the AI launches its last missile, you are at the opposite side of the target, and you decided to wait until his missiles have struck their targets. You suddenly hear it call "I'm a dot," and when you try to ask him what is going on, the command menu is blanked out.

What Went Wrong

What happened was that as soon as the AI has fired all its Maverick missiles, it tries to rejoin, as it always does. You have to give it a new attack command before it will attack with its bombs. **However, the AI has to overfly the target to get to you, as you have positioned yourself on the far side of the target**. The AI is at a low altitude when it has finished its Maverick attack, and is trying to climb in order to get to you. This places the AI in the middle of the AAA engagement zone.

The Solution

Position yourself such that when the AI tries to rejoin, it does not have to overfly the target. It is a good idea to orbit around the target area, as you will be able to cover the AI during its attack run. However, I suggest that you orbit around the target on the same side as the AI's previous attack pass. You should also try to trail the AI, and be offset to its side when it completes the AI, as this makes it easier for the AI to rejoin on you.

EXAMPLE 2: ATTACKING IN SPREAD FORMATION

The Situation

You have learnt from your previous mistake in the first case, and have been tasked for another bombing mission. You elect to put the AI into trail formation, bomb the target, and then you orbit the target on the same side as the AI. When the AI has completed its attack run and is rejoining you, you begin to turn for home. However, the AI wingman called "I'm a dot," and your wingman communications menu goes blank. You have lost another AI wingman.

What Went Wrong

The AI did everything that you asked it to do, and tried to rejoin on you. Unfortunately, the AI is still in trail formation, so it flies **away** from you for a short distance, in order to get obtain the correct spacing for the formation. This puts the AI directly over the target, and the AAA defending the target managed to shoot down the AI.

The Solution

You can issue the "Go spread" command anytime after the AI has commenced its attack run. This command does not have a "Rejoin" command attached to it. When the AI has completed its attack, or when you recall the AI prior to it completing its attack, it will attempt to rejoin in the spread formation. This prevents the AI from flying away from you before rejoining in trail.

EXAMPLE 3: ATTACKING WITH MAVERICK MISSILES

The Situation

Your flight is in the spread formation, and you have been tasked on a BAI mission. You do not know the exact location of the target, and decided to approach the target at an altitude of 15,000 feet, so as to avoid the AAA and SHORAD threats. You spotted the target at a range of 6nm., and promptly locked up a vehicle on your A/G radar. You then issued the "Attack targets" command to your wingman, and watched as it commenced its attack run with its Maverick missiles. However, you did not hear your wingman call out "Rifle," but instead, it flew off to the right, and overflew another armored unit and was promptly shot down.

What Went Wrong

The AI needs to get into position for a Maverick missile attack (at an altitude of about 1,500 feet, and lined up with the target) at a range of 7.5nm. from the target, before it can commence its attack run. If it cannot make it to this position, it will pull off to the right, and attempt to obtain the required separation before it turns back to commence the attack.

The Solution

You should give the order to attack from further out. If you are approaching from a higher altitude, give the AI more space to commence its descend. For an approach altitude of 8,000 feet, I suggest that you issue the attack command at a range of no less than 8.5nm. from the target. This should be increased for higher approach altitudes. As you close in on the target, you should descend a little to see if you can spot the target. If you managed to spot the targets late, you should mark the target, and then pull back to a range of about 12nm. before turning back to attack it.

EXAMPLE 4: SEAD ESCORT

The Situation

You have been tasked on a SEAD escort mission, and are armed with HARM missiles and cluster bombs. You intend to destroy the radars with the HARM missiles, and the AAA sites with the cluster bombs. As you approached the target, you detected a SA-3 site, and locked up on its radar. You ordered your wingman to attack the SA-3 radar, with the "Attack targets" command, and veered off to destroy a SA-2 radar that you have detected. As you are about to launch your own HARM missile, you hear you wingman make the "Magnum" calls. A few seconds later, you hear your wingman call "Cluster bombs away," and the next moment, your wingman has been shot down.

What Went Wrong

The AI will not rejoin after firing its HARM missiles, when tasked on a SEAD escort mission. They will carry on the attack with their bombs or Maverick missiles, and will only rejoin automatically after expending their ordnance.

The Solution

You should recall your wingman the moment you hear them make the “Magnum” call.

EXAMPLE 5: ATTACKING HEAVILY DEFENDED TARGETS

The Situation

You are tasked on a CAS mission against a Russian HQ battalion, and are armed with Maverick missiles. You ordered your wingman to attack the battalion, and the wingman duly obeyed by firing two missiles. As it turns away from the target for another attack run, you hear a SAM launch warning, and your wingman is shot down.

What Went Wrong

Russian HQ battalions are defended by SA-8 missiles. This missile is very dangerous, and the AI will enter the engagement zone of this missile when it attacks the target.

The Solution

You have been tasked to attack a heavily defended target. It is important that you know the ORBAT of the ground units that you are likely to encounter, more so the ground unit that you are tasked to attack. Many of these ground units are defended by modern SAMs, such as the SA-8, SA-13, SA-15, and the 2S6. These air defense systems are very dangerous to both your as a player, and the AI. The AI will inevitably enter the weapon engagement zone of these SAM systems, and will be very vulnerable during its attack runs. You will need to adapt your tactics when you are attacking such ground units. For example, you can try to attack the unit yourself first, so as to reduce the risk. You may also elect to carry HARMs so that you can destroy the air defense vehicles before your wingman commences its attack. Alternatively, you can try to distract the SAMs by flying just within the weapon engagement zone of these systems, thereby giving your wingman a clear run at the targets. As a last resort, you can choose another mission that is less risky.

EXAMPLE 6: FLIGHT PATH DECONFLICTION

The Situation

You are tasked to attack a depot, and decided to execute a single-side offset attack. Both you and your wingman are armed with two bombs each, and you intend to release both bombs in a pair. The attack will be conducted in the spread formation.

The attack begins according to the plan. At a range of 20nm. from the target, and an altitude of 12,000 feet, you scanned the airspace ahead with your radar, and confirmed with the AWACS that there are no airborne threats in the vicinity. Your RWR is silent, and you commanded your wingman to “Kick out.”

When your wingman is in position, you locked up the depot on your A/G radar, and commanded your wingman to attack it with the “Attack my target command.” You plan to accelerate and get ahead of your wingman, and then climb to the right to achieve an altitude of 15,000 feet, before leveling off with the target at your 9 o'clock. The attack will commence with a roll into the target, in a 10° dive, and a minimum bomb release altitude of 8,000 feet. You plan to commence your own attack run as the AI calls "Bombs away." This will ensure that the target is not obscured by the explosions from the AI's bombs. You intend to pull off to the left as you come off the attack, and allow your wingman to rejoin you smoothly.

You see your wingman commence its attack, and you commenced your own attack. As you pull off the target, you hear a loud explosion, and your aircraft is destroyed.

What Went Wrong

The attack was executed perfectly. However, you collided with your wingman due to flight path conflict! As the AI released its bombs at an altitude of 4,000 feet, and then climbed to rejoin the formation on your left, you were heading towards it in a descend. When you pulled off to the left, you crossed the AI's flight path and collided with it.

The Solution

The art of getting your AI wingman to rejoin the formation quickly and safely following a bombing run is difficult to master. However, the behavior of the AI is predictable. The AI will execute a 45° turn towards you and engage afterburner as soon as it releases its weapons, and will climb or descend as required to formate on you, before shallowing off its turn. The AI will head directly towards you, and as it closes in on you, will maneuver towards its formation position on your left.

There was nothing wrong with this plan, except the execution timing. You should delay your roll onto the target until the AI is in a position such that your flight path will not conflict with it as it tries to regain formation. In this example, if you have executed your attack 10 seconds after the AI has completed its own attack, the AI will be **behind** you as you turn into the target. The AI will be flying towards your rear as you release the bombs and pull off to your left.

You can deconflict your operating altitudes. The AI was climbing to meet you as you were descending on your bombing run. Both of you will be at the same altitude at some point in time, and you should make sure that you are not at the same location as the AI when this happens. You need to consider the AI's actions when it tries to rejoin you after a bombing run, and adjust your own actions accordingly to deconflict with it, as the AI will not be changing its own actions to suit you.

EXAMPLE 7: ATTACKING TARGETS IN HILLY TERRAIN

The Situation

Your flight has been tasked to attack a battalion with Maverick missiles. The battalion is situated amongst some hills. The AI responded to your order to attack by firing its missiles, and misses all its targets.

What Went Wrong

This problem is most probably caused by the AI's Maverick missile impacting on intervening terrain, as the AI will normally launch its Maverick missiles from low altitudes.

The Solution

You should make sure that the AI is approaching the targets from flat terrain.

EXAMPLE 8: ATTACKING AT LOW LEVEL

The Situation

Your flight is tasked to bomb a target, and you intend to check the target for threats on the approach, and cover the AI as it attacks. The approach was made at low level, over hilly terrain, with a pop up at the IP. Before you reached the IP, you put your AI wingman into trail formation to give it some time to set up the formation. As you reached the IP, you tried to issue the “Attack my target” command, and found that your AI wingman has crashed.

What Went Wrong

There are many possibilities for this situation. One of the possibility is that the AI crashed while trying to get into trail formation. The wingman will execute a specific maneuver when commanded to switch into the trail formation, from a spread or wedge formation. On receiving the command, the AI will execute a 360° turn at 1.2g, and end up more or less in the appropriate trail formation. This works like a treat, as long as you are not travelling too fast, and keep to a constant airspeed. However, the AI is not good at low-level flying. They are adequate when flying in a straight line, but incompetent when turning sharply over hilly terrain. It appears that the AI will only see the objects that are directly in front of them when they maneuver (although this is not true when the AI launches the Maverick missile), and if they are at the side of a hill when turning into it, they fail to climb quickly and thus plough into the ground.

The Solution

First of all, when you command the AI to fly in a trail formation (or command any change in the formation), do not fly at too high an airspeed while the AI wingmen are switching formation. You should keep your airspeed constant as this helps the AI. Secondly, you should avoid ordering the AI into trail formation at low altitudes. Finally, if you **must** be flying at low altitudes when you give the "Go trail" command, then plan it so that the final approach to the IP (also known as the pre-IP, where you will normally give the command to change formation) is on level terrain, and the level terrain extends for about 3nm. back along the flight path. You should also leave plenty of distance between the pre-IP and the IP to let the AI form up in trail formation.

I have some techniques that I use as a matter of routine. For example, if I'm turning **right** at the pre-IP, towards the IP, I will have the AI wingman in spread formation on my left, and will kick the wingman out twice (this is to make sure that there will not be any trouble on your left at this point). I will usually do this in the minute leading up to the pre-IP, and give the AI some time between the "Kick out" commands, so that this is done smoothly. As I begin the right hand turn to the IP, I will give the "Go trail" command. The AI will **already** be a few miles behind me after the turn, and almost in the trail formation. This helps to save fuel as the AI will not try to catch up with you as it takes the wider turn and longer route around the corner. If you do not command it to go into the trail formation, the AI will attempt to catch up with you to stay in the spread formation.

EXAMPLE 9: FLYING PASS SAM SITES

The Situation

You are tasked for an attack mission, and your approach route to the IP takes you between some SA-2 SAM sites. You elect to stay at low altitudes, and pop-up at the IP for your bombing run.

The AI switches to trail formation perfectly, and makes the ingress to the IP at an altitude of 500 feet. You ordered the AI with the “Attack my target” command as you commence your pop-up maneuver. You pulled down to the right after releasing your bombs and commenced a low-level egress along a river valley that bypasses the SAM sites and then realize that your wingman is not with you. You recalled hearing your wingman call out a SAM launch, followed by the all-too-familiar "I'm a dot."

What Went Wrong

When you give the attack command, the **first** reaction of your wingman, wherever it is, is to climb to its designated bombing altitude. This is approximately 7,000 feet for a bombing mission against fixed targets. The AI popped up too soon, and entered into the weapon engagement zone of the SAM sites in the vicinity.

The Solution

This is a difficult problem to solve. You should close up the formation so that the AI is close behind you and in trail when you give the command to attack. If it is safe for you to execute the pop up maneuver, then it is also safe for the AI to do so. You can also consider putting the AI in a spread formation instead of a trail formation. You should hit the target first, so that the AI will be behind you (this is to provide flight path deconfliction). Make sure that you pull off in the correct direction as the AI commences its attack, as it will rejoin on your wing after its attack. Finally, you should consider planning the mission differently, such as planning a SEAD escort or a different ingress route.

EXAMPLE 10: AI FUEL MANAGEMENT

The Situation

You are tasked on a deep strike against an armored battalion. The mission was planned and you took every care to manage your AI wingman properly, and managed to complete the attack without losing your wingman. During the egress, your AI wingman gave you a “Bingo” call. Your flight is still a long way from home, and you cannot afford to conserve fuel by flying at high altitude or low airspeed. As you search for an alternate airfield to land, your wingman announces that it is running on fumes, and then crashes.

What Went Wrong

The root cause of this problem is the AI’s poor fuel management skills. This is caused in part by the player, as formation keeping and other flight duties may require the AI to use afterburner if the player does not fly smoothly. The indiscriminate loading of the aircraft, often with all the hardpoints loaded with ordnance instead of additional fuel tanks, does not help with the situation. In addition, protracted high-speed low level flight will increase the fuel consumption tremendously. As the AI tries its best to maintain formation and perform the duties that the player expects them to, the fuel consumption will increase as compared to the player. Admittedly, the AI uses the afterburner indiscriminately, but the player can help in the situation by looking after the AI.

The Solution

You should do your best to help the AI with its fuel management throughout the entire mission. The following is not an exhaustive list of the various techniques::

1. Upon taking off, you should turn off the runway in the **wrong** direction, and then orbit the airfield before heading for the second steerpoint. The AI will not be far behind you when they take off, and will not need to consume a lot of fuel as they try to catch up with you. You should also adjust the TOS of the second and the third steerpoint to allow for this.
2. If you do not need to fly at low altitudes, then you should not, especially when you are flying over friendly territory.
3. If you do not need to fly at high airspeeds, you should not, especially when you are flying over friendly territory.

4. You should accelerate slowly if it is possible. This will prevent the AI from using afterburner indiscriminately.
5. You should avoid afterburner usage yourself, if this is possible. If you do, you will give the AI the permission to use afterburner as well.
6. If you need to change your heading at a steerpoint, you should keep your wingman close to you. For example, you should close up a spread and trail formation if you are turning right. While this may appear to make the AI go the “long way round,” it makes it easier for the AI to rejoin on your wing after the turn if they are on the outside of the turn. If the AI is on the inside of the turn, closing up the formation will shorten the AI’s route around the corner.
7. You should use some of the techniques described in example 8 when you command the AI to change formation.
8. You should avoid loading the AI with too much ordnance. The maneuvering at the target area will consume a lot of fuel if the aircraft is too heavily loaded. “One Pass, Haul Ass” tactics will help in AI survivability as well as fuel management.
9. You should give the AI external fuel tanks whenever you are in doubt.
10. You should learn to refuel in flight. The AI will do this.
11. You should learn to use the cruise management page on the DED. This gives the most fuel efficient flight condition to fly at.

CHAPTER 4: TACTICAL REFERENCE

INTRODUCTION

The F4 tactical reference provides excellent on-line electronic reference for the equipment in the Falcon 4 virtual universe. This chapter provides a different perspective, in that it will not list the developmental history and specifications of the equipment, but instead, it will discuss the employment tactics as well as strengths and weaknesses of each piece of equipment (except aerial weapons as these are covered in the earlier chapters). You will find tips on how to counter these threats, so as to maximize your own advantage.

Figure 85: Detailed study of the strengths and weaknesses of each threat is an absolute requirement for a successful mission. (Picture credit of USAF)

The section, titled "*Fighters And Targets*," will give you brief descriptions of the fighters that are likely to be a threat to you over the F4 virtual skies, as well as aircraft that will be supporting you in your mission. We will discuss in some detail the strengths and weaknesses of each platform, and what you will need to watch out for. Learn to tailor your responses and tactics according to the threats that you will face. Half the battle is already won if you have in-depth knowledge of your opponent.

The Surface to Air missile threat is covered and discussed in the section titled "*Flying Telephone Poles*." We will discuss the strengths and weaknesses of the SAM systems that you are expected to encounter, and the best means of countering them. You will find handy descriptive write-ups on each of the SAM systems, where you are likely to encounter them, and what you can do to stay out of harm's way.

Finally, the AAA threat is covered and discussed in the section titled "*The Golden BBs*." We will discuss the details of each AAA system that you will encounter over the battlefield, from the OPFOR systems to those belonging to the friendly forces. This section is meant as a handy reference to supplement the AAA briefing that you have received earlier in the section titled "*The AAA Menace*."

The sections in this chapter will expand with each release of the Realism Patch, as our research and testing enable us to gather more information.

FIGHTERS AND TARGETS

Airplanes In The Realism Patch
By “Hoola”

OPFOR FIGHTER AIRCRAFT

MAPO MiG-19S / Shenyang J-6 Farmer

This aircraft is primarily used for air-to-ground attack purposes by the DPRK and PRC forces. The A/A armament consists of the AA-2C and AA-2D Atoll, which are not much of a threat against a high performance fighter aircraft such as the F-16.

Figure 86: PRC J-6 (MiG-19 clone)

The aircraft can attain supersonic speeds, but is limited in fuel capacity and acceleration. Due to the low thrust to weight ratio, these airplanes will fight mainly in the horizontal plane, allowing the F-16 pilot to exploit his advantage in the vertical plane of maneuver. You should have no trouble running rings around this airplane, and simple breaks and countermeasures will usually defeat its obsolete A/A weapons. An F-4 pilot will need to exploit the acceleration advantage to out-climb this aircraft in a fight, while an F-5 pilot will still have the energy advantage compared to this aircraft. The airplane has a blind arc of about 20 – 30° in the rear, making it relatively easy to sneak up from the rear undetected.

In terms of A/G ordnance, this aircraft is not fitted with the appropriate equipment to perform precision strikes, and is limited to rockets and unguided bombs. You will find them employed mainly in the BAI/CAS roles, usually with two AA-2 missiles for self defense. The lack of onboard countermeasure dispensers and a sub-standard RWR means that this aircraft is ill equipped to defend itself over the modern battlefield, and will easily fall prey to BVR missiles and even non-IRCCM equipped missiles such as the AIM-9P. The onboard radar is a range-only unit, providing no look-down capabilities and extremely susceptible to countermeasures and chaff. This unit provides only rudimentary CW support for the AA-2C missile, and is not capable of detecting targets beyond 8 – 12nm..

The lack of all aspect A/A missile armament for this airplane means that it is not much of a threat anytime it is in your front quarter. However, you should not sit idly by and allow this aircraft to slip onto your six. In capable hands, the MiG-19/J-6 can be a good dogfight aircraft, and has distinguished itself against aircraft such as the F-4 during the Vietnam war.

MAPO MiG-21PF/PFM/bis Fishbed-F/Fishbed-N

Figure 87: MiG-21PF Fishbed-F

This airplane is one of the most produced airplanes in the entire Soviet military aerospace industry. The bulk of the DPRK MiG-21 force is comprised of the early model MiG-21PF/PFM Fishbed-F, which is equipped with a less powerful R-11F2 engine. This gives the airplane a lot less acceleration capability compared to the late model MiG-21bis that is equipped with R-25-300 engine. The DPRK has also purchased a total of 40 MiG-21bis from Khazakstan in 1998, and equipped them with a total of 80 AA-8 (R-60M) missiles. This gives the DPRK MiG-21 inventory a mixture of 80% MiG-21PF/PFM, and 20% MiG-21bis.

Tactically, the aircraft will usually utilize ambush and slash-and-run tactics. The delta wing design results in tremendous drag in a turning fight, and will rapidly bleed the energy from the aircraft even in full afterburner. Against a high performance airplane such as the F-16, it can be easily out-turned in two circles, and the lower thrust-to-weight ratio puts this airplane at a distinct disadvantage in a dogfight compared to the F-16. The higher thrust on the MiG-21bis does help the aircraft retain energy a little better, making it more difficult for fighters such as the F-4 and the F-5 to fight against.

The Sirena-3 RWR on this airplane will only allow it to detect the F-16 at a range of no more than 20nm., making it very susceptible to long range high altitude BVR shots. The performance of the pulse-only Sapfir RP-21M radar (on the MiG-21PF/PFM) and the Sapfir RP-22 “Jaybird” (on the MiG-21bis) also does not allow it to detect targets in look-down situations, and look-up range is a paltry 12 - 14nm.. This aircraft is also not equipped with any self defense measures such as jammers and CMDS, which makes it very susceptible to SHORAD and even AIM-9P missiles.

You are likely to find the MiG-21PF/PFM equipped with AA-2C and AA-2D missiles, and employed for point defense CAP over strategic facilities such as airfields. The MiG-21bis may be equipped with the AA-2C, AA-2D, and the more capable all aspect AA-8 missile. The airplane is a good dogfighter at altitudes below 15,000 feet, and is an even match for the F-5 and the F-4 (at least in the horizontal plane). This airplane has a limited A/G ability with unguided bombs and rockets. There are no provisions for delivery of precision munitions. By and large, the antiquated avionics fit means that the airplane does not pose a serious threat to modern fighters, but can still be a handful to fight for airplanes such as F-5, AV-8, and F-4. As with the MiG-19/J-6, the lack of BVR weapons and all aspect WVR missiles means that this airplane is not much of a threat until it gets to the rear quarter. You should note that the MiG-21bis can be a threat in the front quarter due to the all aspect capable AA-8 missile.

Figure 88: Serbian MiG-21bis taking off. Note the bulged spine on the aircraft compared to the MiG-21PF

Chengdu J-7 III

Figure 89: Chengdu J-7 of the PLAAF

This is a PRC clone of the MiG-21M. The aircraft has a more powerful 14,550lb. static thrust engine compared to the 13,500lb. thrust R-11F2 for the MiG-21PF/PFM. This gives it a slightly better acceleration and climb capabilities, and together with slightly improved aerodynamics, the J-7 has slightly better sustained and instantaneous turn capabilities compared to the MiG-21PF.

The radar is the Chinese JL-7 pulse-only unit, which is only slightly improved in performance compared to the Russian RP-21M. The Chinese RWR fit is however slightly inferior to the Russian Sirena-3, and is of similar performance compared to the J-6. This makes the airplane almost blind to BVR threats beyond 20nm.. However, in terms of self defense capabilities, this airplane is equipped with CMDS, giving it protection against IR and radar guided missile threats. You will find the AIM-9P less useful against this airplane, unless you can sneak up to it undetected. Rearward visibility from the cockpit is similar to the MiG-21, with a blind cone of approximately 20 – 30°.

The armament for this airplane is however more potent than the AA-2 only fit for the MiG-21PF/PFM. The PL-7 is a rear aspect missile, and though poor in seeker performance, it is still aerodynamically more agile than the AIM-9P missile. The most potent missile available is the PL-8, which is a copy of the Israeli Python 3. Both missiles have tremendous acceleration and turn capabilities, with the latter matching the AIM-9M. If you happen to get into a turning fight with a J-7, you should exercise more caution compared to the MiG-21, as the missiles that will fly off its rails have a lot more maneuvering potential and capabilities than the AA-2.

Tactically, the J-7 III fights in the same way as the MiG-21, i.e. slashing missile attacks and then a quick get away. Keep a look-out on the RWR for it, and be aware of the differences compared to the MiG-21. If you are flying the F-5, this airplane will be more of a handful due to the all-aspect PL-8 missile, and you are better off not engaging, as the AIM-9P pales in comparison to the PL-8, and will be useless due to the CMDS on the J-7 III. You should accord this airplane the appropriate respect and treat it differently compared to the MiG-21, as careless throttle management can often mean an in-your-face shot with the PL-8.

MAPO MiG-23ML Flogger-G

Figure 90: Polish MiG-23ML with AA-7 and AA-8 missiles

The MiG-23 is a much maligned airplane, and many Western analysts have given it scant regard due to its poor combat record against the Israelis over the Bekaa Valley and against the USN F-14 over the Gulf of Sidra. However, many analysts forgot that the version of the MiG-23 encountered was the export MiG-23MS, which was a downgraded MiG-23 with avionics capabilities similar to that of the MiG-21 and having no BVR capabilities at all.

The MiG-23ML is a look-down shoot-down capable machine with BVR engagement capabilities. The lighter airframe of the MiG-23ML and the more powerful R-35-300 engine means that the airplane has a tremendous acceleration ability, often matching the F-4 and late model F-16s even with the uprated IPE engines. The Israeli evaluation of the defected Syrian MiG-23ML showed the aircraft to be a match for the F-16 in some respects. Turn ability is helped by the leading edge slats and the ability to vary the wing sweep to optimize performance.

The pulse doppler SP-23L “High Lark” radar is capable of look-down target acquisition, though the performance is not as good as the APG-68 on the F-16. Together with the AA-7, this gives the aircraft a BVR capability of about 14nm. head-on. The onboard Sirena-3 RWR is of similar performance to the MiG-21, giving it a detection ability of about 20 – 23nm. against the F-16. You should bear this in mind when encountering this aircraft. You should also be aware that this airplane is equipped with an IRST, capable of passively detecting MIL power targets up to 12nm. in the rear aspect. Though it may not give sufficiently accurate range information for BVR targeting, it does mean that the airplane is still capable of vectoring towards the target in an environment where heavy jamming prevents its own radar from detecting targets.

The acceleration ability of the MiG-23ML gives it the ability to fight in the vertical plane, and make a quick get-away ability if need be. In terms of turn performance, as long as the F-16 is kept at the corner speed of between 350 – 420 knots indicated, it should be able to out-turn the MiG-23 eventually. The MiG-23 is not a good close-in fighter due to the poor performance of the AA-8, but the ability to carry a total of 6 missiles (two AA-7 and four AA-8) does give it some degree of combat persistence.

The downside of this aircraft is the lack of CMDS for protection against IR and radar guided missiles. Such self defense aids are unfortunately only fitted on the Russian MiG-23MLD Flogger-K airplanes. The all aspect WVR and BVR capability does mean that this airplane is a serious threat to airplanes such as the F-4, F-5, and AV-8, and the shoot-down ability will pose a serious threats to ground pounders. If you detect the presence of the MiG-23 in the vicinity, you should pay serious attention to ensure that you are not its intended target.

MAPO MiG-25PD Foxbat-E

Strictly speaking, this airplane is not part of the DPRK inventory. The airplane is equipped with the RP-25 look-down shoot-down radar, and originally designed as a high speed high altitude interceptor against the XB-70 Valkyrie bomber and the SR-71 Blackbird.

Figure 91: MiG-25 with IR and SARH versions of the AA-6 missile

This aircraft relies on its huge speed advantage and acceleration capabilities to fight. When targeting it, its ability to accelerate rapidly means that it can often out-run missiles given sufficient notice of the missile launch. Its high speed also confers an F-pole advantage to it by giving its missile higher initial velocities.

The threat posed by the aircraft is BVR. The AA-6 missiles can be launched from in excess of 20nm., and the IR version is datalink guided in the initial stage. The AA-6 will almost always out-range the AIM-120 and AIM-7 due to the F-pole advantage and the high speed. It is also difficult for you to obtain a reasonable Pk with AIM-120 and AIM-7 against the MiG-25 at ranges in excess of 15nm. due to the high speed and acceleration ability. You will need to defeat the aircraft through ECM by otherwise denying it a missile shot opportunity, and close in for the kill.

For WVR engagement, the MiG-25 is equipped with AA-8. However, the poor turning ability of this aircraft means that it will employ ambush slash-and-run tactics, as it is not designed for a turning fight. Again, the high speed means that it can often disengage and run quite easily against aircraft equipped only with WVR missiles. However, the lack of CMDS and onboard jammers means that this aircraft is vulnerable to almost all missiles, if it is not able to out-run the missile. The recent budget crisis in the Russian armed forces and the high maintenance cost of this aircraft has forced the Russian Frontal Aviation and Air Defense Force to retire the MiG-25 from service. These aircraft have now been completely replaced by the MiG-31.

MAPO MiG-29 Fulcrum-A (9-12) / Fulcrum-C (9-13)

The DPRK MiG-29 is the early Fulcrum-A variant, with the early 9-12 airframe. This airplane is equipped with the N-019E Slotback look-down shoot-down radar. The airplane is also equipped with the SPO-15 RWR system, capable of detecting the F-16 out to 23 – 25nm. away, and a passive IRST that is capable of detecting MIL power targets out to about 12nm. in the rear quarter. The onboard self defensive suite consists of CMDS only.

The MiG-29 possesses excellent slow speed handling qualities and is capable of better turn and high AOA performance than the F-16 below 250 knots. Acceleration at low speeds is quick due to the high thrust of the RD-33 engines, and the aircraft is more than a match for the F-16 in the slow speed regime. However, the F-16 is better above 400 knots, and you should aim to fight the MiG-29 at higher speeds. The IPE engine on the Block 50/52 F-16 also gives it a slight edge at higher airspeeds, where the engine really come into its own. The MIL power thrust from the RD-33 engines is however fairly low, and the MiG-29 will need to utilize afterburners to obtain the thrust required to sustain its high turn rate. With the fuel hungry nature of the engine, this prevents the MiG-29 from venturing further out on deep strike or sweep missions.

In the WVR arena, the MiG-29 is a very capable opponent with the HMS/AA-11 combination. Even in less than capable hands, this combination can bring about rapid grief to most Western fighters. IRCM tactics will obviously be in order here to deny the front quarter AA-11 shot, but you should be aware that a shot can be taken up to 45° off boresight. Whenever possible, you should avoid engaging the MiG-29 in a knife fight, as this is where the MiG-29 really shines. If you do, remember to keep your speed high and above 350 knots so as to maximize the F-16's advantage, and avoid getting slow.

Figure 92: MiG-29 with a full complement of AA-10 and AA-11.

The N-019E radar is a handicap for the MiG-29, due to the susceptibility to jamming and notching. You should exploit your ECM equipment to maximize your advantage in BVR, and engage the MiG-29 from BVR. The DPRK MiG-29 lacks ARH missile capability, so this is where the F-16 with the AIM-120 has the edge. The MiG-29/AA-10A combination does not give it much BVR range (this is only slightly further than the AIM-7), and ECM usage should prevent a shot from up to 12 – 15nm. away. Having an early AIM-120 shot at it will put the MiG-29 driver on the defensive, allowing you to deal with it at arms length and avoid a close-in fight.

Figure 93: Russian MiG-29 Fulcrum-C. Note the enlarged dorsal spine containing some additional fuel and an internal jammer.

However, the Russian MiG-29 is of the Fulcrum-C variant (9-13 designation). This airplane is considerably more capable, with the N-019ME Topaz radar. This radar is more hardened against ECM and less susceptible to notching, and the airplane is also equipped with an internal jammer and CMDS. This means that the MiG-29C is more capable than its DPRK cousin, and much more of a BVR threat. The RWR signature will not show a difference as the N-019ME Topaz radar is a N-019E Slotback radar receiver married to an upgraded digital processor. Usage of jammers against it will only prevent BVR shots out to 15 – 18nm. away, and this puts the MiG-29C on almost equal footing with the AIM-120 armed F-16, with both parties getting a BVR shot opportunity almost at the same time. The A-pole advantage of the F-16 still holds, and will allow you to break off and take evasive actions earlier.

One way of distinguishing the MiG-29 variants that you may encounter is to use STT lock on the contact. If the target breaks your lock with jamming, you are facing the Russian MiG-29C. Always bear in mind the MiG's advantage in WVR with its HMS/AA-11 combination. Proper throttle management and positioning will decrease the shot opportunity and improve your chances of survival.

MAPO MiG-31B Foxhound-A

The MiG-31 is a more capable replacement of the MiG-25. This aircraft was designed as a dedicated interceptor, and is adequately equipped with a powerful phased-array radar, onboard jammers, and a sophisticated datalink system. The NIIP N007 S-800 SBI-16 Zaslon (also known by an alternate Russian designation of RP-31, or by its NATO designation of “Flash Dance”) electronically scanned phased array radar is capable of detecting F-16 sized targets up to 65nm. away. This radar will also burn through the self protection jammers at ranges exceeding 22nm., allowing the MiG-31 to take BVR shots well outside most AIM-120 engagement ranges. This radar is also more more resistant to chaff, and is almost as difficult to defeat with counter-measures as the best of the Western fighter radars. The MiG-31 is also equipped with a passive IRST. This IRST is capable of detecting MIL power targets up to about 12nm. in the rear quarter.

The onboard self defensive equipment include CMDS, SPO-155L RWR, and an internal jammer. This gives the MiG-31 a self defense capability equivalent if not better than most Western fighters. The typical missile complement consists of four fuselage mounted AA-9 long range SARH missiles, a pair of AA-6 IR guided BVR missiles on the inboard pylons, and two pairs of short range AA-8 IR missiles on the outboard pylons. This gives the MiG-31 a mixture of six long range and four short range air-to-air missiles.

The RWR performance is similar to that of the MiG-29, and is capable of detecting the APG-68 transmissions up to 23 – 25nm. away. The wide azimuth and elevation gmbal limit of 70° gives the MiG-31 a tremendous amount of search capability, and an ability to operate autonomously and independent of GCI control.

Figure 94: MiG-31 fully armed with four AA-9 and two AA-6 missiles

The threat posed by the MiG-31 is mainly BVR. The AA-9 missile is capable of reaching up to 60nm. at high altitudes, allowing the MiG-31 to engage most targets even before they are able to detect it. The passive IR AA-6 missiles also allows the MiG-31 to stalk and attack its prey passively, making the MiG-31 a feasome aircraft to fight against. The high thrust from its Aviadvigatel D-30F6 engines enables the MiG-31 to accelerate very rapidly. The efficient air intakes of this airplane allows it to sustain supersonic flight at high altitudes with afterburners. This allows the MiG-31 to fly faster and higher than most other Western fighters, giving it a tremendous F-pole advantage. The internal fuel capacity is 34,300lb., giving the MiG-31 an un-refuelled CAP endurance that exceeds all other airplanes in the Falcon 4 world.

In close-in WVR fight, the MiG-31 is severely handicapped by its size. If you are able to get within visual range of this aircraft, defeating it will be reasonably easy. However, if the MiG-31 has a speed advantage over you, it is often able to out-accelerate its pursuers. As long as the MiG-31 operates at high altitudes exceeding 30,000 feet, and keeps its airspeed high, the chances of successfully intercepting this aircraft in an F-16 is marginal, though F-14 and F-15 pilots may still stand a chance.

The best defense against this aircraft is to stay out of its reach, and attempt to sneak up to it. Its capable radar will not make it any easier for you to stay undetected. The only “advantage” that you will have is that this aircraft is still not capable of carrying the AA-12 missiles, and should it engage you, you will have ample notice of its missile launch from your RWR. This will be your signal to get away as quickly as you can. Thankfully, this airplane is only in service with the Russian VVS (Frontal Aviation) and VPVO (Air Defense Force), so as long as the Russians do not join in the war, you should not expect to encounter the MiG-31 over the skies.

Sukhoi Su-27 Flanker-B

The Su-27 is the Russian equivalent of the F-15. Designed primarily for the air superiority mission, the Flanker is adequately equipped with up to 10 air-to-air missiles, and a powerful radar. The onboard NIIP N001 Myech ("Slotback") radar has ample power compared to the MiG-29 N-019E, and is capable of detecting the F-16 out to 48nm. or more. In terms of raw power, this radar will burn through self protection jammers at ranges exceeding 22nm., allowing the Su-27 to take BVR shots beyond most AIM-120 engagement ranges. The RWR signature of the N001 radar is also very similar to that of the N-019E Slotback on the MiG-29A and N-019ME Topaz on the MiG-29C, making it impossible to distinguish either of the three.

The onboard self defensive equipment include CMDS, SPO-15 RWR, and the airplane can be equipped with wingtip mounted Sorbtsiya self protection ECM pods. This gives the Su-27 a formidable amount of self defense capabilities, equivalent to most Western fighters. The missile complement is up to 10 air-to-air missiles, being reduced to 8 when the wingtip ECM pods are fitted.

Figure 95: PRC Su-27 with wingtip Sorbtsiya ECM pods, AA-11, and AA-10A missiles (foreground). The aircraft in the background is armed with rocket pods.

The RWR performance is similar to that of the MiG-29, i.e. being able to detect the APG-68 transmissions up to 23 – 25nm. away. However, the powerful radar and the wide azimuth gimbal limit exceeding 70° gives the airplane a tremendous amount of target search abilities, and this airplane, unlike traditional Russian fighters, is capable of autonomous operations, independent of GCI control.

The threat posed by the Su-27 is primarily BVR. The N001 radar is hardened against ECM and countermeasures, making chaff less useful. Together with the long range AA-10C, this allows the Su-27 to strike at ranges beyond most other Western airplanes. With 10 air-to-air missiles, the combat persistence of the Su-27 exceeds most Western fighters. Even when fired at the radar burn-through range of 22nm., the AA-10C will be closer to its Rmax2 range compared to other Western missiles. This means that the missiles will arrive at the target with a very high energy state. The huge acceleration capability of the Su-27 also confers it an F-pole and A-pole advantage over most other fighters.

The Su-27 is also capable of A-pole tactics, with the ability to carry up to six AA-12 missiles. This gives it even better combat persistence than the F-15C. When detecting an RWR contact, due to the similar radar characteristics between the Su-27's N001 radar and the MiG-29's N-019 radar, you can never tell which aircraft has locked you up. If you lock up the threat and it employs ECM, you can be reasonably sure that it is either a Russian MiG-29C or a PRC or Russian Su-27. As such, treat the contact as a Su-27 until you can verify otherwise. If you want to close in for an engagement, bear in mind that you may be unknowingly flying yourself into AA-12 envelope.

At WVR ranges, fighting the Su-27 will be similar to fighting the F-15C. The aircraft has tremendous ability to accelerate at lower weights. The Su-27 will be operating at heavier weights during most encounters, making considerably less agile than what most aerospace observers are used to seeing at air shows. However, the missile complement of up to four AA-11 makes fighting the Su-27 an even more nerve wrecking experience at close quarters compared to the F-14 or F-15.

The slow speed handling characteristics of the airplane are excellent, with good nose pointing capabilities. However, due to the heavy operating weight, the F-16 driver may be able to bring the nose around to the Su-27 slightly faster and out-turn the Su-27, though the HMS/AA-11 advantage will redress this disadvantage somewhat. When encountering the Su-27 at close quarters, make sure that you stay out of the cone extending from its 10 o'clock position to its 2 o'clock position, as this is the AA-11 launch envelope. As with the MiG-29, proper throttle management and IRCM tactics will help you stay out of trouble (hopefully) by denying an IR missile lock.

Sukhoi Su-30MKK Flanker

The Su-30MKK is an advanced development of the Su-27, and was designed as a multi-role fighter similar to the F-15E. The Su-30MKK was developed from the Su-27UB two-seater combat-capable trainer, and the PLAAF has ordered at least 30 units of this very capable airplane. This airplane is in service only with the PRC, and not with the Russian VVS.

Figure 96: Su-30MKK prototype taking off with a full complement of precision and non-precision air-to-ground ordnance

The Su-30MKK is equipped with a more accurate navigation system, a TV command guidance system, a guidance system for anti-radiation missiles, and a display system in the rear cockpit for the WSO. All these avionics give the Su-30MKK a capability to operated as a SEAD aircraft, as well as a precision strike platform.

The SU-30MKK is equipped with an updated version of the NIIP M001 Myech ("Slotback") radar. This radar is capable of detecting the F-16 out to 48nm. or more, and will burn through self protection jammers at ranges exceeding 22nm., allowing the Su-30MKK to take BVR shots beyond most AIM-120 engagement ranges. The RWR signature of the N001 radar is also very similar to that of the N-019E Slotback on the MiG-29A, N-019ME Topaz on the MiG-29C, and the older version of the NIIP N001, making it impossible to distinguish the Su-30MKK from them. The updated radar has some limited air-to-ground modes to support the multi-role capability of this airplane.

The onboard self defensive suite is the same as the Su-27, and the Su-30MKK is equipped with CMDS, and the SPO-15 RWR. As with the Su-27, the airplane can be equipped with wingtip mounted Sorbtsiya self protection ECM pods. RWR and jammer performance is exactly the same as the Su-27, and in terms of the threat posed by the Su-30MKK, this is the same as the Su-27.

However, the Su-30MKK is capable of carrying up to 8 AA-12 missiles, in addition to the normal range of the air-to-air weapons of the Su-27. Even when not configured for A/A missions, the Su-30MKK has a tremendous ability to defend itself. In the ground attack role, the Su-30MKK is capable of carrying most of the iron bombs in the Russian inventory, including the FAB series of dumb bombs, as well as the KAB series of laser guided bombs. For precision strike, the Su-30MKK can carry up to two AS-18 (Kh-59M) "Kingbolt" stand-off air-to-ground missiles, or four AS-10 (Kh-25) air-to-ground missiles. The AS-14 (Kh-29) "Kedge" missile may also be carried. These missiles give the Su-30MKK the ability to strike deep into enemy territory, and the ability to engage targets outside the range of their air defenses. In the SEAD role, the Su-30MKK can be configured with the AS-17 (Kh-31P) long range hypersonic anti-radiation missiles. The long reach of this missile allows the Su-30MKK to engage Nike and Patriot batteries at ranges in excess of 45nm., giving it the ability to perform hit-and-run tactics.

Figure 97: The first production model of the Su-30MKK for the PLAAF, photographed during taxi trials at the Sukhoi OKB flight test center. The airplane is painted in PLAAF colors , though the national insignia is the Russian red star.

Although the Su-30MKK is used primarily for air-to-ground missiles, it is nevertheless a very capable air-to-air fighter. The tactics to counter it is similar to that of the Su-27, but the Su-30MKK will be slightly less maneuverable due to its higher gross weight. If you are tasked with DCA or BARCAP, you will need to place your CAP route sufficiently far away from the ground assets that you are defending, as the Su-30MKK is capable of long range stand-off attacks. If your CAP route is too close to the ground asset that you are defending, the Su-30MKK will be able to strike it just when you are intercepting it.

Together with the Su-27, the Su-30MKK is one of the most capable OPFOR airplane that you will face. Treat this airplane with respect, for the slightest under-estimation of its capabilities can well get you killed.

FRIENDLY FIGHTER AIRCRAFT

Northrop-Grumman F-5E Tiger II

The Northrop F-5E was designed as a cheap supersonic fighter meant for Foreign Military Sales and military aid for friendly countries. This small airplane is equipped with a pulse only APG-159 radar, giving it rudimentary search and track ability against air and ground targets, but the airplane lacks any look-down shoot-down capabilities, and the radar also lacks any ECCM capabilities. The radar is very susceptible to chaff and jamming, and look-up range against F-16 type targets is limited to about 12 – 14nm. only.

Figure 98: ROK F-5E in formation. (Picture credit of ROKAF)

The self defensive avionics suite includes the ALE-40 CMDS, as well as the crystal video receiver based ALR-46 RWR. This allows the F-5E to detect the APG-68 transmissions out to about 24nm.. The aircraft lacks any ability to carry self protection jammers, and relies on its small radar cross section to remain undetected.

In terms of air-to-air armament, combat persistence is low as the aircraft is only capable of carrying two AIM-9P missiles. The lack of BVR capability and a decent missile complement makes the airplane unsuitable for air defense roles over the battlefield, except when the enemy air threat is low, or the threats are of the MiG-19/MiG-21 class.

The lack of a sophisticated avionics suite also makes the aircraft less survivable over the battlefield. The airplane is not capable of a large payload, and is better suited to BAI/CAS mission types in Falcon 4. Sending the airplane against more sophisticated air defenses will be suicidal, and the airplane is totally unsuitable for missions such as deep strike.

In capable hands, the F-5E can be a handful to fight against. Its small size makes visual acquisition extremely difficult, and it is not unheard of for pilots to roll out behind an F-5 at 1.5nm. and yet not be able to see it. F-5 pilots should use the small size to their best advantage, as pilots used to fighting larger airplanes will find the F-5 extremely easy to lose sight of. This will allow the F-5 pilot to sneak behind the target for a rear aspect missile shot, with its radar turned off.

The airplane has fairly good high AOA and acceleration capabilities, as long as you fight below 20,000 feet. While it may be limited to 7.33g, the airplane has a good nose pointing ability, even at slow speeds. Corner speed is in the vicinity of 350 knots. The limited fuel capacity of this airplane will be a handicap, as it often relies on the additional thrust in afterburner to generate the maneuverability. Forcing a lengthy BFM fight will usually result in the F-5 having to disengage due to fuel shortage. Once commited in a visual fight, the F-5 pilot should also leave the engines in afterburner. This helps in energy retention, as MIL power thrust from the small J-85 engines is too low to be useful in a dogfight. The F-5 pilot should aim to use slash and run ambush tactics against more capable airplanes such as the F-15 and the F-16. Fighting in a wolfpack will allow wingman and other elements to get a chance to shoot, and this can be employed very effectively when co-ordinated properly.

For the F-16 driver, as long as you do not lose sight of this airplane, you should be able to out-turn it under most circumstances. As long as you can keep it off your tail, the chances of getting shot at will be minimal. The threat posed by the F-5E is WVR, and even so, the lack of an all aspect IRCCM capable missile means that it is largely ineffective against CMDS equipped airplanes, as long as the missile launch is spotted.

Boeing F-4E Phantom II

The “Rhino” is currently in service with several air forces, including the ROK forces, but has been retired from USAF service. The variants in service with the ROK air force include the F-4D and the F-4E, and are primarily used for strike and BAI/CAS missions, to deliver both guided and unguided munitions.

Figure 99: ROK F-4E in formation over Jindo Bridge, South Korea. (Picture credit of ROKAF)

The F-4E is equipped with a Norden AN/APQ-120 pulse-doppler radar, conferring it a certain degree of look-down shoot-down capability. This old radar is however not hardened against ECM, and lacks the many sophisticated ECCM features such as HOJ, AOJ, and can be easily defeated. The radar is also equipped with a CW illuminator for AIM-7 guidance, but lacks any ability to carry ARH missiles.

Self defensive aids include the APR-36 or APR-39 RWR, which is based on a crystal video receiver. This gives it limited sensitivity, and it is only capable of detecting the F-16’s APG-68 transmissions out to 24nm.. This is however still better than most Russian RWR systems, allowing it to detect the MiG-29 before the F-4 enters the engagement zone. Against the Su-27, this RWR will only detect the presence after the Su-27 has fired the AA-10C. Other self defensive aids include CMDS, and the ability to carry external jammer pods in the right forward fuselage AIM-7 missile well.

In terms of air-to-air capabilities, the F-4E has a BVR capability in the AIM-7 missile, and is hence a viable threat against aircraft such as the MiG-23 and MiG-25. This is also a viable threat against the MiG-29A and MiG-29C in the BVR arena. WVR armament is limited to the AIM-9P, making the F-4E less of a WVR threat. The radar’s lack of sophistication is however a disadvantage, as it is susceptible to chaff. Jamming will also whittle away the BVR capabilities of the F-4, forcing it to close in for a visual fight.

The large size and nasty high AOA characteristics of the aircraft are a big disadvantage to the F-4 pilot in the air combat arena. While useful against less capable threats such as the MiG-23, this airplane is simply out-classed by the MiG-29, Su-27, and F-15. When used against smaller and more nimble fighters such as the MiG-19 and MiG-21, the F-4 should use its advantage in thrust to weight ratio to fight in the vertical, and avoid getting into a slow speed fight. As long as the airspeed is kept above 450 KCAS, the F-4 will stand a good chance of surviving the fight and perhaps walk away victorious. The BVR ability should be maximized in such scenarios. One major disadvantage of the F-4 is its smoky engines in MIL thrust, which is a dead give-away, allowing the F-4 to be spotted from BVR distances.

Most newer fighters should have no problems out-turning the F-4E. Less capable fighters, such as the F-5 and MiG-19, should be able to bring about a quick death for the F-4 as long as it can be drawn into a low speed WVR fight.

The Rhino is at its best when mud-moving. It has a large payload capacity, and is capable of delivering both precision and unguided munitions. The ROK air force has also procured the AGM-142 stand-off missile for integration on their F-4E, giving it an all weather precision stand-off strike capability against heavily defended and fortified targets. In the BAI/CAS role, the F-4 can be configured with the GBU-15 glide bomb, or laser guided bombs. The hardiness of the airframe allows the F-4 to take an incredible amount of damage and still fly home.

Northrop-Grumman F-14B Tomcat

The F-14 Tomcat began life as a dedicated interceptor, with not an ounce of air-to-ground capability. The aircraft was designed around the powerful AWG-9 radar system and the AIM-54 Phoenix air-to-air missile. This gives the F-14 a detection range in excess of 60nm. against F-16 type of targets, and in excess of 120nm. for bombers.

Figure 100: F-14B with Paveway III laser guided bombs. (Picture credit of USN)

The AWG-9 radar is capable of operating in both pulse and pulse-doppler modes, and as such, beaming against the AWG-9 is less effective as the radar can switch to pulse mode and continue tracking the target, though this is less useful in look-down situations. The high power of the radar also enables it to burn through most self protection jamming at ranges exceeding 25nm. or more, allowing it ample chance to commence a missile engagement.

The onboard self protection suite consists of the AN/APR-67 super-heterodyne based RWR, with a much higher sensitivity compared to the crystal-video based RWR, and the AN/ALE-39 chaff/flare dispenser. The defensive suite is completed by the internal ALQ-126 deception jammer. This greatly enhances the ability of the F-14B to survive in the modern battlefield.

The aircraft may be armed with up to six AIM-54 missiles, allowing it to engage most targets beyond 30nm., depending on altitude and speed. The air-to-air armament of the F-14 easily out-ranges any airplane in the Falcon 4 world. This gives the F-14 an unparalleled ability to engage targets before they can even retaliate. The alternative BVR weapon is the the AIM-7. WVR weapons include the M61 20mm cannon and two AIM-9M missiles.

The threat posed by the F-14 is primarily BVR, and most airplanes will not be able to do anything about it, except avoiding detection and denying a long range AIM-54 shot. The lack of launch warning for the AIM-54 also makes it difficult to counter, so opponents will need to fly very defensively when engaging the F-14. The only aircraft with the ability to engage at such long range is the Su-27 and the MiG-31. An early AA-10C or AA-9 shot at the F-14 may force the airplane onto the defensive, thus forcing it to abandon support of its missiles in-flight.

The best way to counter the F-14 is to avoid a BVR engagement, and force a visual fight. In the WVR fight, the upgraded F110 engines give the aircraft a much higher thrust to weight ratio compared to the old TF-30 engines. This gives the aircraft a tremendous amount of maneuvering capability for an airplane its size. However, the limited number of WVR missiles means that the F-14 does not have the persistence for a close-in fight. In the slow speed regime, the F-16 will have an upper hand. Less endowed airplanes like the F-4, F-5, and early MiGs will find the F-14 a handful to fight, and should strive to whittle down the F-14's airspeed to 200 knots or less.

With the F-14B, a limited precision and unguided strike capability was added with the integration of the LANTIRN targeting pod. This allows the F-14B a strike capability with unguided Mk-80 series bombs and laser guided bombs. This was first used in anger over the skies of Bosnia in 1995, where F-14s from VF-41 struck several Bosnian Serb installations with LGBs.

Boeing F-15C Eagle

Figure 101: F-15C with full afterburners blazing during takeoff. (Picture credit of USAF)

The F-15C is currently the frontline air superiority fighter deployed by the USAF. Powered by two F100-PW-220 engines, the F-15C has an incredibly high thrust to weight ratio, allowing it to accelerate vertically at low weights. This allows the F-15 to operate at altitudes higher and speeds faster than most other airplanes. The speed and altitude advantage maximizes the F-15's F-pole and A-pole advantage, allowing its missiles to reach out further.

The F-15C is equipped with the APG-70 radar, with a typical detection range of 60nm. or more against fighter type targets. This very powerful radar will burn through self protection jamming at ranges beyond the missile engagement range of the F-15, and hence, jamming is not useful when defending against the F-15C. You are better off forcing a look-down engagement and flying a weaving flight path to notch the APG-70 radar.

The onboard self protection suite consist of an internal AN/ALQ-135 jammer, ALE-45 CMDS, and the ALR-56C RWR. The RWR allows the F-15C to detect targets passively at ranges exceeding the lethal engagement range of the emitters, while the jammer protects the aircraft against both pulse, pulse-doppler, and CW threats.

The F-15C's armament typically consist of four AIM-9M and four AIM-7M or AIM-120. As with other A-pole threats, the best defense against the F-15 is denying it a BVR shot, though this is very difficult due to the long detection range of the radar. The F-15 can fly at altitudes in excess of 40,000 feet during an intercept, forcing its targets into a shoot-up situation, further decreasing their missile range while increasing the F-15's A- and F-pole advantage.

In the WVR arena, the F-15's size is its biggest disadvantage, as it can be spotted at ranges exceeding 8 – 10nm. on a good day. Its high thrust gives it a distinctive advantage and it can rapidly regain lost energy. This also improves its sustained turn performance considerably. You should force the F-15 to bleed off its energy until the jet is below 250 KCAS, so as to minimize its maneuverability, however bear in mind that it is capable of rapidly regaining the lost energy.

The corner speed of the F-15 is around 400 KCAS, but the airplane fights well above and below this speed due to its low wing loading. The Eagle will also match the F-16C's ability to fight in the vertical, although its high AOA performance is not as sterling. At heavier operating weights, the F-16, F-18 and MiG-29 will have the upper hand, with their slow speed maneuverability and high AOA performance. The Eagle driver will be wise to avoid a visual fight with these airplanes, and should engage them BVR. The F-15C should also use its large thrust to its advantage by engaging these threats from higher altitudes and speeds, as it is able to retain a lot of its performance and maneuverability at altitudes exceeding 30,000 feet due to its high thrust and low wing loading. Under such engagement conditions, even the F-16 and MiG-29 will have trouble maintaining altitude or speeds matching those of the Eagle, and will need to fly at lower altitudes to maintain maneuverability.

This airplane was designed to project air superiority, and does it well. The only serious threat to it is the Su-27 with the AA-10C and AA-12 missiles. As long as the F-15 driver can avoid a visual fight, the incredible F-pole and A-pole advantage of this airplane and the powerful radar will allow it to destroy most threats before they are able to retaliate.

Boeing F-15E Strike Eagle

Affectionately known as the "Mud Hen" by its pilots, the F-15E is not used in the interceptor role, but in the strike role. However, the I-band radar is the same APG-70 as the F-15C, giving it similar detection abilities. Self protection equipment is the same as the F-15C, with the ALQ-135 internal jammer, ALR-56C RWR, and ALE-45 CMDS.

The usual air-to-air armament of the F-15E consists of a pair of AIM-120 on the outside of the wing pylons, and a pair of AIM-9M on the inside. The fuselage hardpoints on the FAST packs are usually dedicated to air-to-ground ordnance. The LANTIRN targeting and navigation pods may also be carried under the fuselage.

Figure 102: F-15E with LANTIRN pods and cluster bombs loaded, preparing to takeoff for a dawn strike against Serbian targets during Operation Allied Force. (Picture credit of USAF)

Although the F-15E is not used for air superiority missions, it is still nevertheless a considerable BVR threat due to its powerful radar and AIM-120 armament. However, the higher operating gross weight of the F-15E means that its thrust to weight ratio and wing loading are seriously compromised, and as such, general performance has deteriorated considerably compared to the F-15C, even with the latest F100-PW-229 engines. It is not unheard of for the F-15E to even require minimum afterburners to keep pace with air refueling tankers at higher altitudes, when operating at its full gross weight.

As such, the A- and F-pole advantage of the F-15E is a lot less than the F-15C. In the WVR arena, the F-15E lacks the maneuverability of the F-15C, and can be very easily out-turned and out-climbed. The F-16, F-18 and MiG-29 will be able to run rings around the F-15E, unlike the F-15C. As such, the best bet for the F-15E driver is not to run after air targets and get into a fight, but to concentrate on the ground pounding mission. The onboard missile armament is useful as a self defensive measure, but when faced with a WVR threat, the F-15E should make a quick exit to avoid being embarrassed in the visual fight.

The F-15E can carry an impressive array of air-to-ground weapons, ranging from the Mk-80 series of bombs, to laser guided bombs and stand-off weapons such as the AGM-130. The well designed airframe is capable of withstanding a lot of punishment, and the aircraft is often able to fly home even after sustaining extensive amounts of battle damage. With the retirement of the F-111 from USAF service, the F-15E has now become the primary strike airplane in the USAF's inventory.

Lockheed Martin F-16C Fighting Falcon

The Viper is the rationale of the Falcon 4 game, and is very well discussed and described in the Falcon 4 manual, so we will not dwell on it much here. The model in the game is the USAF Block 50 Viper, with the conventional HUD and the APG-68V(5) radar. Onboard self defensive suite includes the ALR-56M RWR and the ALE-40 CMDS. Self protection jamming exists in form of the ALQ-131 jammer pod. The standard mission CMDS load is 60 chaff cartridges and 30 flare cartridges. This is evenly divided in the four chaff/flare dispenser cannisters mounted on the underside of the aft fuselage chines.

Figure 103: F-16CJ takes off against Serbia during Operation Allied Force with HTS and HARMs. (Picture credit of USAF)

The F-16 is a capable BVR fighter when equipped with the AIM-120. A typical USAF mission load is comprised of a pair of AIM-120 mounted on the wingtips, and a pair of AIM-9M on the outboard stations. However, mission loads comprising four AIM-120 have been observed during Operation Allied Force.

The model of the F-16CJ in Realism Patch is the USAF aircraft, with the HTS capability. This version retains the capability of using the LANTIRN navigation and targeting pods, although it is not normally tasked to deliver laser guided bombs. The ability to carry and utilize the LANTIRN targeting pod is similar to that of the Block 40 (F-16CG) Vipers, but the lack of a wide angle holographic HUD limits the field of view of the LANTIRN navigation pod's FLIR image that can be presented, and as such, it is less suitable for low level terrain following missions. The F-16CJ saw extensive combat action during Operation Allied Force, over the skies of Kosovo. With the retirement of the trusty F-4G Wild Weasel, the F-16CJ has now become the primary SEAD platform in the USAF.

Foreign versions of the Block 50 Viper may sometimes be fitted with the APX-109+ or APX-110 Advanced IFF (AIFF), the ALQ-165 ASPJ internal jammer, the ASPIS internal jammer (Greek aircraft), and ALE-47 CMDS. Israeli F-16s are also equipped with internal jammers, the Elbit DASH helmet mounted display, and the highly capably Python 4 WVR missile.

Boeing F-18C Hornet

The Boeing F-18 Hornet was developed from the YF-17 that lost the USAF lightweight fighter competition, but has grown significantly since. The F-18 is equipped with the powerful APG-73 radar, giving it an excellent air-to-air and air-to-ground detection ability. The wide gimbal limit of 70° also gives it a wider search volume than the F-16. The APG-73 radar has a detection range of 50nm. against F-16 targets. The ECCM sophistication of this radar is better than the APG-68, and this gives the F-18 an edge over the F-16.

The onboard self defensive suite consists of the ALQ-126B internal jammer, ALR-67 RWR, and ALE-47 CMDS. The internalized jammer saves the airplane from needing a hardpoint to carry defensive electronics, unlike the F-16.

Figure 104: F-18C launching from the catapult of an aircraft carrier. (Picture credit of USN)

In the BVR arena, the F-18's sophisticated radar will give it an edge in detection and target track over the F-16, as it will burn-through self protection jamming at longer ranges, giving it a first shot ability in comparison to the F-16 and MiG-29. The ability to carry up to ten AIM-120 is an obvious advantage in terms of BVR combat persistence. The large RCS of the F-18 will however work against it compared to the smaller F-16.

Slow speed performance is where the F-18 really excels. The F-18 has an incredible high AOA ability, and out-shines the F-16. Below 300 KCAS, the F-18 will have an advantage over the F-16, and is evenly matched with the MiG-29. Acceleration ability is lack luster compared to the Block 50 Viper though, particularly between 450 KCAS and 600 KCAS. The Hornet will be an even match with the Viper throughout most of the flight envelope, and more than a match below 250 KCAS, where its nose pointing ability will be better. In capable hands, the F-18 is deadly in the WVR fight.

One of the disadvantages of the Hornet is the engine. The F404 engines run hotter than most other engines, giving the Hornet a larger IR signature. Throttle management will be in order here to avoid a face shot. The other short coming is the lack of endurance and range, hopefully this will be addressed with the F-18E Super Hornet.

The multi-role F-18C can carry a vast array of different air-to-ground ordnance, ranging from dumb bombs, to precision stand-off weapons such as the AGM-84E SLAM. The F-18C can also carry the Nitehawk FLIR targeting pod, giving it a self-lasing capability for LGB delivery. The Hornet will usually carry two AIM-9M and two AIM-120 during strike and BAI/CAS missions. This gives the Hornet a formidable self defense capability, allowing the Hornet to engage airborne threats from beyond-visual-range, without having to first jettison the air-to-ground ordnance.

OPFOR STRIKE AIRCRAFT

MAPO MiG-17F / Shenyang J-5

Figure 105: North Korean MiG-17/J-5 at the Nellis AFB threat training facility (Picture credit of USAF)

Development of the Mikoyan MiG-17 began in 1949, and the aircraft first entered service in 1951. The MiG-17 saw service with the North Vietnamese air force, and was credited with the destruction of many USAF fighters during the Vietnam War. With the introduction of newer fighters, the MiG-17 was used relegated to the ground attack role. China produced its first licensed copy of the MiG-17 in 1956, and carried the local designation of J-5. The aircraft was credited with the destruction of several Taiwanese fighter jets, including two F-84Gs, six F-86s, and one F-100 in 1958, a RB-57 in 1957, and an F-4 in 1967. North Korea purchased up to 200 copies of the J-5 for ground attack duties.

The J-5 is a very basic fighter, with almost no modern avionics. This airplane lacks a radar, and lacks even a radar warning receiver. Since the pilot has to see the target in order to attack it, the J-5 is often forced to fly into SHORAD envelope in order to attack its targets. The lack of chaff/flare dispensers and an RWR means that the airplane is extremely vulnerable to ground fire and air defense systems.

The J-5 is a fairly capable fighter in good hands. Its slow speed handling is excellent, and this airplane can easily out-turn an F-4 below 300 KCAS. However, the poor thrust of the Klimov VK-1F engine does not allow the J-5 to fight well in the vertical plane. The flight controls are also unpowered, and this is a serious handicap. At airspeeds above 450 KCAS, the J-5 is not capable of rolling in any direction, as the dynamic pressure on the flight controls will be too strong for the pilot to overcome, such that it is possible for the pilot to move the flight control stick without the aircraft responding. The key to fighting the J-5 is to maintain the airspeed above 350 KCAS, and exploit the poor roll performance of the J-5.

The J-5 can carry a pair of AA-2 for self protection. This obsolete missile is not much of a threat, though the hard hitting 30 mm cannon on the J-5 makes it a serious threat inside gun range. However, the poor performance of the J-5, together with its antiquated avionics, means that this airplane is more of a target than a serious threat in a modern battlefield.

Sukhoi Su-25 Frogfoot-A

The Su-25 was designed as a Russian equivalent of the Fairchild A-10 Warthog, but primarily optimized for close air support missions instead of anti-tank missions. The Su-25 first saw combat service in Afghanistan in April 1980, when the 200th Independent Shturmovik Squadron was sent to provide low level close air support for the Soviet ground forces. The Su-25 flew over 60,000 sorties during the eight year occupation of Afghanistan by the Soviet forces, with a loss of 23 aircraft. All but 2 of the 139 laser-guided air-to-ground missiles found their target, a testimony of the effectiveness of this aircraft. The Su-25 saw extensive service during the Chechnya conflict in 1999, where it provided close air support to Russian troops fighting to dislodge the Chechen rebels.

Figure 106: Russian Su-25 firing a heavy S-24 rocket

The Su-25 is equipped with a laser rangefinder and designator in the nose. The designator is capable of providing laser designation for the AS-10 missiles carried by this airplane. Self defensive equipment includes the Sirena-3 RWR, as well as the ASQ-2V chaff/flare dispensers. There are no provisions for internal nor external jammers in the Su-25A, though the experimental Su-25TK (now re-designated as the Su-39) is equipped with wingtip jammer pods.

The Su-25 is capable of carrying a wide variety of air-to-ground ordnance, ranging from iron bombs, cluster bombs, and rocket pods, to precision munitions such as the AS-7 and AS-10 missiles. For self defense, the AA-2 and AA-8 missiles may be carried. The aircraft is also equipped with a twin-barrel AO-17A 30 mm cannon, with a 3,000 rounds per minute rate of fire. The ammunition load is 250 rounds.

The Su-25 will not pose a significant threat to any fast jet, due to its low speed, lack of radar, and poor air-to-air missile armament. However, if you wish to make a quick kill on the Su-25, you will still need to be wary of overshooting it and presenting you hot jet pipe to its AA-2 and AA-8 missiles. The normal flying speed of the Su-25 ranges from 300 to 450 KCAS. You will need to manage your airspeed properly to avoid overshooting it, especially if you are trying for a gun shot. The aircraft is very well protected against ground fire, and can often still limp home after sustaining a hit from MANPADS or short range air-to-air missiles such as the AIM-9. Even a long range AMRAAM shot may sometimes fail to destroy the target, and the Su-25 may still be able to fly home.

Although the Su-25 is not a serious threat to any fast jet, it is nevetheless a very capable strike aircraft. You should keep a lookout for this aircraft over the battlefield, as it can bring about rapid destruction of your ground forces.

Ilyushin Il-28 Beagle / Harbin H-5

Figure 107: Ilyushin Il-28 light bomber in Russian colors

The Ilyushin Il-28 Beagle is a light bomber that is produced unlicensed by China, and known as the Harbin H-5 bomber. This obsolete aircraft was exported to North Korea, and form an integral part of the DPRK bomber force. The Il-28 is of a simple construction, and is woefully inadequate in any modern conflict.

The Il-28 is equipped with a visual bombing system, and has no provisions for precision strike. This restricts the aircraft to daytime operations, and it needs to overfly the target in order to attack it. The Il-28 has no provisions for chaff/flare dispensers, and neither is it equipped with a RWR. This means that the aircraft is almost totally blind to any BVR threats. Its rearward vision is also limited, making it extremely easy to sneak up onto it for a rear quarter missile shot. This makes the Il-28 an easy prey even for aircraft such as the F-5E.

The Il-28 is equipped with an optically aimed tail gun for self defense. This gun is notoriously inaccurate, though you should not dismiss the threat entirely if you decide to close in for a gunshot. The aircraft carries its weapons internally, and is capable of delivering the FAB series of iron bombs, as well as cluster bombs.

The low thrust of its non-afterburning Harbin WP-5 turbojets means that this aircraft is not capable of speeds above 450 knots when loaded, and the fuel hungry nature of turbojets do not give the aircraft long legs. You should expect the DPRK forces to use this bomber mainly for close air support, though it may sometimes be tasked with airfield strikes. However, the lack of any self defensive equipment means that the Il-28 is more often a target than a serious threat.

Tupolev Tu-16A Badger-A / Xian H-6A

The Tupolev Tu-16 was first seen in 1954, during the May Day fly-past in Moscow. It entered service with the PRC in the 1959, and was produced locally under the H-6 designation. This aircraft is primarily designed for strategic bombing, as well as maritime strike, and still remains in service with the PLAAF, although it has been retired from Russian service.

The Tu-16A is a simple, all-metal aircraft, powered by a pair of RD-3M-500 (AM-3M) turbojets. It is equipped with a mapping radar, and a simple Sirena-2 RWR, allowing it to detect the APG-68 transmissions up to 23nm. away. The onboard self defensive equipment includes only a 23 mm tail gun, and the aircraft has no provisions for internal jammers nor chaff/flare dispensers. The RWR does give the Tu-16 some ability to detect threats, and take evasive actions, before being engaged. However, once engaged, the Tu-16 has very little means of defending itself, as the 23 mm tail gun needs to be optically aimed, and is known to be woefully inaccurate.

Figure 108: PRC licensed produced Tu-16 (Xian H-6) being prepared for a bombing mission

The Tu-16/H-6 can be configured with up to 40 FAB-250 bombs, or an assortment of other iron bombs and cluster bombs, to perform its strategic bombing role. In the maritime strike role, the aircraft can be armed with a pair of antiquated AS-6 “Kingfish” missiles. You will most likely find the Tu-16 tasked to bomb targets such as cities and airfields. As the aircraft is not capable of delivering precision strike munitions, it lacks any stand-off attack capability, and has to penetrate the air defenses of its targets before it can attack. The inadequate self defense equipment will make the Tu-16 a sitting duck for any fighter pilot and SAM crew.

The large ordnance load that can be carried by this aircraft does mean that it is capable of inflicting considerable damage on its target if it is allowed to attack it. Although it may not be chivalrous to attack a poorly defended bomber, you should not allow this bomber to slip past you unmolested.

Tupolev Tu-95MS Bear-H

Figure 109: Tupolev Tu-95MS Bear-H

The Tu-95MS is a Russian bomber developed specifically to launch the AS-15 (RK-55) cruise missile. This bomber is based on the Tu-142 maritime bomber, and modified with more powerful NK-12MV engines. This huge propeller driven bomber is capable of carrying up to 16 of the AS-15 cruise missiles. The turbofan engined weapon weighs 3,750lb., and has a range of more than 2,175nm.. Cruise missiles are not modeled in Falcon 4, and as such, the Tu-95MS Bear-H is rarely useful in the game, and is available only in the TE module.

For self defense, the Tu-95MS carries a rear gun turret, containing a twin-barreled Gsh-23L cannon. The Bear-H is equipped with an RWR, an internal jammer, and chaff/flare dispensers. A total of 40 of these bombers remain in service with the Russian armed forces, although the recent cut-backs in defense spending has reduced the serviceability of these aircraft to a questionable state.

FRIENDLY STRIKE AIRCRAFT

Northrop-Grumman A-10 Thunderbolt II

Originally conceived as a counter-insurgency aircraft to help the war effort in Southeast Asia, the A-10 emerged as a dedicated close air support aircraft, with the primary role of destroying enemy armor. Affectionately known as the “Hog,” the A-10 saw its first combat service over the skies of Iraq and Kuwait, during Operation Desert Storm in 1991, and subsequently over the skies of Kosovo and Serbia during Operation Allied Force in 1999. In recent years, its close air support role has been assumed by F-16s, but in return, the A-10 has assumed the role of forward air control.

The A-10 is a simple, yet survivable aircraft, powered by two widely separated General Electric TF34-GE-100 turbofans. These engines have a very high bypass ratio, and helps to minimize the IR signature of the aircraft. The A-10 is not equipped with a radar, and relies on the Mark-1 eyeball of the pilot as well as ground based controllers for its targeting information. Although its slow speed helps in target acquisition, the aircraft is however susceptible to ground fire. The A-10 was limited to operations above 15,000 feet during Operation Allied Force, and this reduced its effectiveness considerably, although it improved the aircraft's survivability.

The A-10 is equipped with an ALR-69 RWR and chaff/flare dispensers. The A-10 is also capable of carrying the ALQ-119 and ALQ-131 self protection jammer on the left outboard hardpoint. This is usually balanced by a pair of AIM-9M on the right outboard hardpoint. The AIM-9M gives the "Hog" a very respectable self defense capability against any fast jet pilot who wants to try his mettle with the "Hog." The slow speed of the "Hog" is its advantage when it comes to air combat, as it allows the A-10 to execute very tight turns and force its opponents to overshoot. Engaging the "Hog" in air combat is a hazardous business, as the "Hog" usually operates at low altitudes, and the risk of crashing into the ground while dogfighting the "Hog" is real.

Figure 110: A-10 Thunderbolt II during Operation Allied Force. This airplane carries an ALQ-131 and a pair of AIM-9M for self defense, in addition to the AGM-65D and cluster bombs. (Picture credit of USAF)

The A-10 may be configured to carry an assortment of iron bombs, cluster bombs, and air-to-ground missiles. Although it is capable of carrying laser guided bombs, these are rarely seen on the "Hog" since it lacks the ability to lase for itself. It is also equipped with the massive 30 mm GAU-8 cannon, which fires depleted uranium shells the size of a Coca-Cola bottle. This gun has a firing rate of 3,900 rounds per minute, and is capable of destroying tanks as well as any aircraft that finds itself at the wrong end of its barrels. The most common load during Operation Desert Storm include 6 cluster bombs, and two AGM-65D Mavericks. The A-10 rarely if ever uses all its available hardpoints, as this will reduce the maneuverability of the aircraft considerably, and is detrimental to its survivability.

The A-10 is one of the most capable ground attack aircraft. Although it is built to survive missile hits, you should try not to use the "Hog" for low level missions in an environment where the SHORAD threat is heavy, as this will decrease its survivability dramatically.

Lockheed Martin F-111F Aardvark

The F-111F Aardvark is the last of the F-111's production variant. Designed as a deep-strike interdictor for the USAF, the F-111 had a long and troubled development, and only achieved much of true potential late in its career. The F-111 saw limited combat service during the Vietnam War, and the F-111F variant saw combat service over the skies of Tripoli during Operation El Dorado Canyon in 1986, and over the skies of Iraq during Operation Desert Storm in 1991.

Affectionately known as the "Pig," the F-111F is equipped with a pair of fuel-efficient TF30-P-100 turbofan engines. These powerful engines allow the F-111F to "supercruise" in the clean configuration. The variable geometry wing sweeps from 16° to 72.5°, and provides excellent flying characteristics for both slow and high-speed regimes. The F-111F's attack avionics include the AN/APQ-161 air-to-ground radar, as well as the AN/APQ-171 terrain following radar. These sensors allow the F-111F to penetrate hostile airspace while flying at extremely low altitudes and high speeds, while flying totally hands-off. The high speed of the Aardvark makes it a very difficult target to pursue at low altitudes, even for aircraft such as the F-16.

Figure 111: F-111F from the 48th TFW at RAF Lakenheath on a high speed, low level flight over the North Sea. (Picture credit of USAF)

While the F-111F may be armed with a 20 mm cannon, this is usually not carried. The internal weapons bay is also never utilized, and the AN/AVQ-26 Pave Tack targeting pod is carried instead. The targeting pod has a FLIR sensor and a boresighted laser designator, allowing the airplane to deliver laser guided bombs autonomously. Self protection equipment include an RWR, and chaff/flare dispensers. An ALQ-131 jammer pod is usually carried under the fuselage.

Although this airplane may be armed with the AIM-9P missiles, it cannot be armed with the more capable AIM-9M missiles due to weapon clearance problems. As such, the best defensive tactic for the F-111 is to use its high speed to out-run its pursuers.

The F-111F may be configured to carry an assortment of precision and iron bombs. The primary weapon for the F-111F are the GBU-12 and GBU-10 Paveway II laser guided bombs, as well as the newer GBU-24 Paveway III laser guided bomb. It is also capable of carrying the GBU-28 "Deep Throat" 4,000lb. Laser guided bomb, designed to penetrate hardened command bunkers. Another favorite weapon is the GBU-15 glide bomb.

Although the F-111F has proven to be a huge success during Operation Desert Storm, its high maintenance costs has forced the USAF to retire the F-111F. The roles assumed by the F-111F have now been performed by the F-15E Strike Eagle.

Lockheed Martin F-117 NightHawk

The F-117 Nighthawk began development in 1978, under the Senior Trend program. The development program followed after a highly successful trial of two sub-scale technology demonstrators, codename Have Blue. For many years, the F-117 remained shrouded in secrecy, and operated only during the night, from a secret facility at Tonopah Test Range. Prior to its public appearance on April 21, 1990, the F-117 took part in Operation Just Cause, and bombed the facilities of the Panamanian Defense Forces. Shortly after its public appearance, the F-117 was deployed for Operation Desert Storm, where it proved the stealth concept to be highly successful.

Figure 112: F-117 releasing an inert GBU-10 laser guided bomb. (Picture credit of USAF)

The F-117 is a relatively large airplane, powered by a pair of non-afterburning F404-GE-F1D2 turbofans. The engine efflux is cleverly diffused by a specially designed exhaust system, thus reducing the IR signature of the F-117 considerably. The F-117 relies on its low observability for its survival, and all its onboard sensors are entirely passive. This prevents it from being detected by ELINT equipment, and works in conjunction with its reduced IR signature and radar cross section. There are no provisions for internal jammers at all, since the F-117 does not need it.

The targeting sensor on the F-117 is comprised of an IR acquisition and designation system. This consists of a FLIR in the front of the cockpit, and a DLIR (Downward Looking IR) sensor mounted on the underside of the cockpit. Both IR sensors incorporate a laser designator.

The weapons load for the F-117 is surprisingly small for an airplane of its size. The need for low observability has limited weapon carriage to the internal weapons bay. The bomb bay can carry up to two GBU-10/24 laser guided bombs. Although some sources have claimed that the F-117 can carry the AGM-65 Maverick missile, as well as unguided bombs, these weapons have never been seen on the F-117 before, and it is not conceivable that the USAF will use the airplane as such, since these weapons do not provide much stand off range.

The F-117 is best suited for night operations, where the cover of darkness prevents it from being detected by optical sensors. Although it is difficult to detect the F-117, it is not impossible, as evident from the shootdown of one such aircraft by the Serbians during Operation Allied Force. The F-117 is not a high performance fighter, and the best survival tactics is to avoid detection totally. You should only use the F-117 for night missions against high value targets, where the F-117 can attack from medium or high altitudes. This minimizes the exposure of this airplane to SHORAD and AAA.

Boeing B-1B Lancer

The Boeing B-1B Lancer was a development of the supersonic B-1A bomber, which was originally designed to deliver nuclear weapons. The B-1A development was cancelled by the Carter administration in 1977, and the B-1B development arose in 1981, during the Reagan presidency.

Figure 113: B-1B releasing a stick of BSU-49/B bombs while dispensing flares to defeat IR missiles. (Picture credit of USAF)

Although the B-1B is externally similar to the B-1A, the performance of the B-1B was downgraded compared to the B-1A, primarily due to cost. Major structural improvements were introduced, and the B-1A's high-speed supersonic dash capability of Mach 2.5 was deleted. The low-level, high-speed penetration role was to be carried out using jammers, and application of "low observables" technology. As a result, even though the B-1B is of the same size as the B-52, its radar cross section is only 1% that of the B-52.

The heart of the B-1B's self defense suite is the AN/ALQ-161A. This is a comprehensive electronic counter-measures suite that will detect, and counter enemy threats. The self protection response is totally automated, and the system will use a combination of jamming and decoys such as chaff and flares to defeat the threats.

After the end of the Cold War, the Conventional Munitions Upgrade Program (CMUP) was initiated to improve the B-1B's conventional warfighting capabilities. The upgrade program allowed the B-1B to carry up to 84 500lb. Mk-82 bombs, or 30 cluster bombs (CBU-87 and CBU-97), or a combination of these. JDAM and JSOW capabilities are to be added. This gives the B-1B a tremendous ability to conduct strategic and tactical bombing, and it is equally capable of the carpet bombing role as the older B-52.

The best defensive tactic for the B-1B is to make use of its sophisticated onboard ECM equipment, as well as its high speed at low altitudes, to evade and avoid airborne threats. You should always provide the B-1 with fighter escorts, and refrain from sending the B-1 into low level missions if it is expected to face a considerable SHORAD threat, since this will expose the aircraft to unnecessary risks. The B-1's ALQ-161 is capable of detecting the emissions of all fighter and SAM radars beyond the range at which the fighter and SAM battery can detect it, and you should take full advantage of this, and fly around the threat.

Boeing B-52H Stratofortress

The Boeing B-52H Stratofortress (or more affectionately known as the "Buff") was originally intended to serve as a carrier for the Douglas GAM-87A Skybolt air-launched ballistic missile. The B-52H was extensively modified for a low level penetration mission, including uprated Pratt & Whitney TF33-P-1 turbofans. A total of 106 B-52H were built, and, today, these remain as the last survivors of the B-52 family in service with the USAF.

Figure 114: Boeing B-52H releasing a stick of Mk-82 bombs over the range. (Picture credit of USAF)

The Buff is equipped with a sophisticated self defensive suite, comprising of an ALT-28 jammer on the nose, the ALQ-172 jammer on the sides, the ALQ-172 jammer in the rear, and the ALQ-155 jammer on the forward and rear fuselage. The Buff is also equipped with the highly sensitive AN/ALR-46 digital RWR, allowing it detect radar emissions at ranges far beyond normal RWRs. The MiG-29 radar emissions can be detected at ranges of up to 58nm. away, giving ample opportunities for the Buff to commence defensive and evasive actions. The self protection suite is completed by chaff and flare dispensers.

The B-52H is capable of carrying up to 45 Mk-84 bombs, or up to 51 750lb. M117 HE bombs. A flight of 3 B-52s can lay down a total of 153 bombs in one run, and the carpet bombing tactics is both destructive in terms of material, as well as psychologically. The Buff may also be configured to carry up to four AGM-142 Have Nap stand-off missiles for precision strike.

The AN/ASQ-151 low light level TV camera and FLIR system, as well as the Norden APQ-156 targeting radar, allows the B-52H to operate in all weather conditions. The Buff is equally adept at carpet bombing and precision strike.

Although the B-52H is equipped with a tail mounted cannon for self defense, you should not be deluded into thinking that it will afford protection against enemy fighters. You should only send in the Buffs when you have achieved air superiority, and the Buffs should always be escorted by fighters. In the event that you encounter enemy air opposition when unescorted, it is often wiser to retreat and save the mission for another day.

Although the airframe is old, the Buff has been repeatedly upgraded, and has served faithfully in all the major wars that the USAF had participated in since the Vietnam War. It is foreseen that the Buff will continue to soldier on for many more years to come.

OPFOR ELECTRONIC WARFARE SUPPORT AIRCRAFT

Beriev (Ilyushin) A-50M Mainstay

Figure 115: Beriev A-50M Mainstay

The Beriev A-50 Mainstay was developed from the Ilyushin Il-76 transport aircraft, and development work began in the 1970's. Production was commenced in the 1980's, at a rate of 5 aircraft per year. The A-50 entered service with the Russian Air Defense Forces (PVO), and were maintained on round-the-clock patrol over the Black Sea during the 1991 Gulf War, monitoring the activities of USAF warplanes operating out of Turkey, as well as Allied air operations over Iraq.

The A-50 is a large aircraft, and is equipped with the Shmel-2 airborne early warning radar. This is housed in a 9-meter diameter rotodome. The radar is capable of detecting fighter-sized targets at ranges up to 200nm., and is manned by a crew of 10. The radar is capable of controlling up to ten simultaneous engagements, and tracking up to 50 over-land target tracks. The mission suite includes VHF, UHF, and satellite communication systems, as well as IFF and ESM sub-systems.

The A-50 is equipped with chaff and flare dispensers for self defense. The onboard ESM equipment should allow it to detect threats at ranges sufficiently far for it to take evasive actions. The A-50 is an important component of the Russian Integrated Air Defense System, and gives the OPFOR an important early warning capability. This aircraft is considered a high value asset that is highly protected, and being equipped with the ability to detect low flying targets, it will help to negate some of the advantages of NOE tactics. You should aim to eliminate this aircraft as early as possible, as its value to the IADS is greater than ground based radars.

FRIENDLY ELECTRONIC WARFARE SUPPORT AIRCRAFT

Northrop-Grumman EF-111A Raven

Affectionately known as the "Spark Vark," the EF-111A Raven is based on the F-111A variant of the strike fighter. Northrop-Grumman was responsible for the development of the EF-111A, and the conversion of the F-111A airframe into the specialized electronic warfare platform capable of undertaking stand-off jamming and penetration support missions. Development began in 1974, and a total of 42 aircraft were converted.

Figure 116: EF-111A Raven over the skies of Naples, Italy. (Picture credit of USAF)

The core of the EF-111A's capability lies in the AN/ALQ-99 Tactical Jamming System (TJS). The EF-111A uses an internalized version of the TJS, rather than the podded version used on the EA-

6B. The system is highly automated, with receiving antennas located in the distinctive bulbous fin-cap fairing, and the jamming transmitters located in the under-fuselage fairing.

The high speed performance of the EF-111A allows it to function more effectively than the EA-6B in the strike escort role, especially when supporting high performance jets. However, it is not capable of firing any anti-radiation missiles, and this limits its effectiveness to "soft kill" only. The Raven relies on its performance to evade enemy fighters, and saw combat service during the 1991 Gulf War. The Raven is an important component in any strike force, especially when the air defenses are dense.

The Raven was retired from USAF service in April 1998, and the USAF achieves the tactical radar jamming mission through its reliance on the Navy and Marine Corp's EA-6B Prowler.

Northrop-Grumman EA-6B Prowler

Figure 117: EA-6B Prowler, carrying a mixed load of jammer pods and AGM-88 HARM missile. This is a reflection of the EA-6A's unique combination of lethal and non-lethal SEAD capabilities. (Picture credit of USAF)

Development of the electronic warfare version of the A-6 Intruder commenced in 1966, and the first flight was flown on May 25, 1968. A total number of 170 were produced, with the last example of the Northrop-Grumman EA-6B Prowler delivered in 1991. The efforts to improve the capabilities of the Prowler are still continuing, and the latest variant of the EA-6B in service is the Block 89A ICAP-II aircraft.

The core of the EA-6B's functionality is the AN/ALQ-99 Tactical Jamming System (TJS). This is housed in a total of up to five pods (four of which are carried underwing, and one under the fuselage). Each pod has its own power supply, and houses two jamming transmitters that cover one of seven frequency bands. Each pod can jam in two frequency bands simultaneously, with each jamming transmitter operating in a different band. A mixture of three pods will allow the Prowler to cover six out of seven frequency bands.

The Prowler's mission system includes the AN/AYK-14 central digital computer, sensitive surveillance receivers at the fin top for long range passive detection of hostile radars, as well as the AN/TSQ-142 Tactical Mission Support System. The crew of four consists of the pilot and the co-pilot, and two EW officers in the back. The Block 89A Prowler is also equipped with the USQ-113V(3) radio counter-measures set, which gives the aircraft the ability to monitor, analyze, and jam voice and data communications. Self defensive equipment includes chaff and flare dispensers. The onboard ESM equipment and the TJS gives the Prowler a unique ESM and jamming capability way more advanced than RWRs and self protection jammers.

One unique advantage of the Prowler over the retired EF-111A Raven is its unique combination of "hard kill" and "soft kill" capability. The Block 89A ICAP-II Prowler can carry up to four of the Texas Instruments AGM-88 HARM anti-radiation missile, and this allows it not just to jam hostile radars, but also to destroy them if necessary. With its jamming and High-Speed Anti-Radiation Missile (HARM) capability, the Prowler is a unique asset that will be deployed from land bases and aircraft carriers. Its ability to monitor the electromagnetic spectrum and actively deny an adversary's use of radar and communications is unmatched by any airborne platform worldwide.

The Prowler is not optimized to provide a safe haven by virtue of an "umbrella of electrons." However, if used efficiently and effectively, this asset can provide a decisive tactical advantage. The EA-6B can be employed in the strike escort or stand-off jamming role. The former may be performed with a mixture of jammer pods and HARMs, while the latter may be performed with a full complement of five jammer pods. This is a high value asset, and you should always assign fighters to protect it against the enemy.

The Prowler is currently the only electronic warfare and support aircraft available in the US inventory, and is considered a joint service asset. Four of the dozen Navy EA-6B squadrons are manned by a joint team of USN and USAF personnel, and the Prowler can be expected to operate from land bases as well as aircraft carriers.

Boeing E-3B Sentry

The Boeing E-3B Sentry is the West's principal AWACS platform, and uses the airframe of the Boeing 707-320B airliner. The prototype flew in 1972, and a total of 34 were procured by the USAF. A total of 24 airframes were modified to the Block 20 E-3B standard, with ECM resistant communication systems, faster computers, maritime surveillance capability, and self defense equipment.

The heart of the E-3B Sentry is the AN/APY-1 radar, mounted in the 30 feet diameter rotodome. The rotodome rotates at a rate of 6 RPM, and operates in the E/F band. This radar can function both in the pulse and the pulse doppler mode, with additional pulse compression and sea clutter adaptive processing. The radar is capable of detecting airborne targets, as well as maritime targets, and is credited with a detection range in excess of 200nm. against fighter sized targets in look-down situations. The radar operates in the PDNES (pulse doppler non-elevation scan), PDES (pulse doppler elevation scan), BTH (beyond the horizon), maritime, and interleaved modes. The radar is also capable of operating in the passive mode, as an ESM sensor.

Figure 118: USAF E-3B Sentry approaching a KC-135 tanker for refueling. (Picture credit of USAF)

The E-3B has a crew of 18, out of which 14 are AWACS specialists. The onboard communications equipment include TADIL-J datalink, HF, VHF, UHF, and satellite communications that operate in clear or secure mode, in voice and digital form. The E-3 also carries an IFF interrogator for interrogating targets. The huge array of communications equipment allows the E-3 to control an air battle effectively, supporting of friendly fighters and strike aircraft by providing them with the air picture.

The E-3 is not equipped with any self defense equipment, and is vulnerable to any airborne or ground based threats. Hence, it should never be operated across the FLOT. The long range of the radar allows it to look deep into enemy territory while operating in the relative safety of friendly airspace. You should however protect the E-3 with HAVCAPs, as this is a prime target for the enemy. As with the A-50 Mainstay, the E-3 is one of the most important components in an integrated air defense system, due to its long range and look-down ability. The completeness of the air picture can be improved tremendously whenever the Sentry is airborne, and you should always consider enlisting the support of the E-3 in any air campaign.

FLYING TELEPHONE POLES

SAMs In Falcon 4 Realism Patch
By "Hoola"

OPFOR SURFACE-TO-AIR MISSILE SYSTEMS

We will discuss in some detail the OPFOR SAMs that you are expected to face over the battlefield in F4. Where appropriate, their strengths and weaknesses will be discussed. You should learn to tailor your tactics according to the SAM threat that you are fighting against, and be aware of the differences between each of them to optimize your defense strategy.

SA-2 (Almaz S-75 Dvina/Volkhov) "Guideline"

This is a static shelter mounted SAM system designated as the S-75, and the missile is designated as the V-750. First blooded on 1 May 1960 against Gary Power's U-2, the SA-2 system has been upgraded repeatedly over the years, and has been indigenously produced by PRC under the designation HQ-2.

Figure 119: SA-2 missile on launcher.

The missile consists of a booster section with four large fins, and has a liquid fuel sustainer motor, with four powered fins at the tail end for control. The solid fuel booster will burn for 4.5 seconds to lift the weapon away from the launcher, and is then jettisoned, before the sustainer motor (with a 22 second burn time) takes over. The missile will reach its maximum velocity only when it reaches an altitude of approximately 24,000 feet.

Missile guidance is provided by the "Fan Song" E/F-band missile guidance radar, capable of controlling up to two missiles in flight. The missile receives guidance signal from four rear facing dielectric aerials. Target acquisition is usually provided by the P-8 Dolphin "Knife-Rest A" or "Spoon Rest" early warning search radars. Destruction of the Fan Song missile guidance radar will shut down the SAM site.

The missile has an engagement range of up to 13nm., and an engagement altitude of approximately 70,000 feet. When facing self protection jamming, the effective range is reduced to 6 – 7nm.. The minimum range is approximately 2 – 3nm., with a minimum firing altitude of 1,200 feet (usually). The missile is relatively easy to out-maneuver if you spot it early enough, and have sufficient airspeed. A hard turn of 6 – 7g into the missile and dispensing chaff will usually defeat the missile, due to the low maneuvering potential.

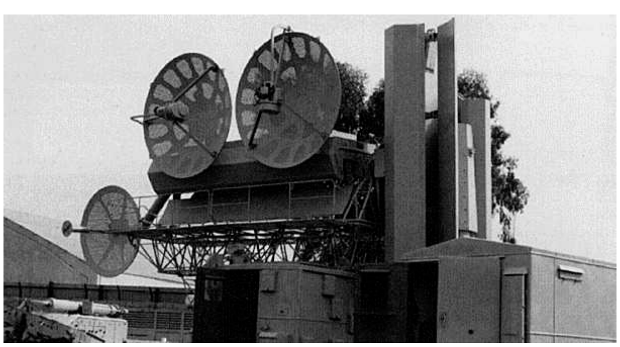

Figure 120: Fan Song missile control radar

The Fan Song radar has some degree of moving target capability, and is slightly more resistant to chaff than the SA-3 and the SA-5. However, this should not cause too much problems as the electronic capabilities of this old system has been well compromised. The long range of the HARM should allow strike packages to neutralize the SA-2 threat from beyond its effective engagement range. As long as you are able to achieve this during the first wave of attack across the FLOT, the SA-2 should not be much of a threat.

Each SAM site normally consists of six trainable launchers and one Fan Song radar, with the battery command post and fire control team. The launchers are usually arranged in a circle, with the Fan Song and the battery command post in the center. The launchers and command posts are usually not hardened, and are susceptible to cluster bomb attacks. If you arm the SEAD packages with HARMs and cluster bombs, the entire SAM site can be neutralized and destroyed fairly easily, with the HARM conducting stand-off attack on the Fan Song radar to first neutralize it, and the cluster bombs used to mop up the remaining launchers.

SA-3 (Almaz S-125 Neva) "Goa"

This command guided missile system was originally designed to complement the SA-2 and SA-5 missile systems, as a low to medium level SAM. The SA-3 system was first blooded over the Egyptian skies during the War of Attrition against Israel, having been credited with 5 kills against F-4 Phantoms. It was also used by the Vietnamese in 1972, and successfully brought down a F-4 Phantom. Another 6 Israeli jets were lost to this system during the 1973 Yom Kippur War. The most recent use of the SA-3 was by the Serbian forces against the NATO airplanes over the skies of Kosovo.

Figure 121: Low Blow missile control radar. (Picture credit of USAF)

The SA-3 system consists of four twin or quadruple round launchers carrying the 5V27 missile, a trailer mounted I-band fire control/missile control radar known as the "Low Blow," and early warning is usually provided by the C-band P-15 "Flat Face" or P-15M "Squat Eye" air defense radars. The missile has a 2.6 second burn-time booster, and a 18.7 second burn-time sustainer motor. Effective engagement range is up to 11nm., and up to an altitude of 48,000 feet. Minimum effective range is just under 1nm.. Self protecting jamming will usually reduce the effective range to 6 – 7nm.. The SA-3 battery will usually not engage below 5,000 feet in altitude.

Figure 122: SA-3 missiles mounted on quadruple launcher

As with the SA-2 missile, the SA-3 missile is not capable of high-g maneuvers. It can be defeated kinematically with a 6 – 7g turn into the missile. Chaff is usually effective at defeating the Low Blow radar. As with the SA-2, once the missile control radar is destroyed, the SAM site is effectively neutralized. The SA-3 is semi-mobile, but usually deployed at fixed sites, making mission planning fairly easy and thus making the SAM site very vulnerable to pre-planned HARM strikes. Though effective in the days of the Vietnam and Arab-Israeli wars, this SAM system is now obsolete, even though they have been upgraded with optical trackers. Destruction of the Low Blow radar will still render the SAM site ineffective, as the optical tracking system relies on the missile control radar for providing guidance signals.

SA-4 (Antey 2K11 Krug) "Ganef"

The Antey 2K11 Krug (SA-4 Ganef) system was developed in 1958, by the OKB-8 GKAT bureau, under the direction of L. V. Lyul'yev. It made its first public appearance in 1964, and was fully deployed in 1967. The SA-4 system never saw combat service at all.

Each SA-4 battalion consists of three "Ganef" batteries, one "Long Track" mobile detection radar, and one "Thin Skin" height finding radar. Each battery consists of one 1S32 "Pat Hand" target illuminating and missile guidance radar, as well as three SA-4 self-propelled launcher units with two missiles each. The SA-4 system is usually deployed between 5 to 15nm. behind the FEBA, and forms part of the overall air defense umbrella consisting of MANPADS, self propelled and static SAMs, as well as AAA guns.

Figure 123: SA-4 medium to high altitude SAM

The 3M8M2 missile has four solid rocket booster motors mounted externally on the body. The booster motor will burn for 15 seconds, and propels the missile to a velocity of over Mach 1. The sustainer motor then takes over after booster jettison. The kerosene fueled sustainer motor will then accelerate the missile to a speed of about Mach 2.5. The need for booster jettison limits the SA-4 to a minimum effective engagement range of about 4nm.. The effective engagement range is up to 21nm., and up to an altitude of 80,000 feet. Self protection jamming will usually reduce this to about 16nm.. The SA-4 will usually not engage targets below 1,500 feet in altitude. The 3M8M2 missile is guided via command signals from the Pat Hand radar in its initial flight phase. Terminal guidance is via semi-active radar homing.

Figure 124: Long Track target detection radar

The SAM is easy to defeat kinematically with a 5 – 6g turn. Chaff is also very effective against it. As with the SA-2 and SA-3, once the Long Track radar is destroyed, the SAM site is effectively neutralized (strictly speaking, this is incorrect since the Long Track radar is a search radar, but this is a game constraint). The SA-4 system is mobile, and this makes it rather difficult to pinpoint its location for a pre-planned HARM strike. The relatively long range of the SA-4 means that it will be difficult to avoid being shot at while attacking it with HARMs, unless the attacker is protected by self protection jamming. However, the SAM system is obsolete, and will only be marginally effective in the modern battlefield.

SA-5 (Antey S-200 Angara) "Gammon"

Development of the S-200 Angara system began in the 1950's to meet a requirement for a long range high altitude SAM to complement the SA-2 and SA-1 systems. Initial deployment began in 1961, and over the years, this SAM has been repeatedly fired at USAF SR-71 aircraft with no recorded success at all. The Libyans also used this SAM against the USN aircraft over the Gulf of Sidra in 1986 with no success.

Figure 125: SA-5 high-altitude SAM

This SAM was designed to counter the new generation American high-altitude and high-speed bombers, such as the XB-70. The target set also included B-52, F-111, SR-71, and stand-off jammers. The SAM system consists of six trainable single-rail launchers, with one

E/F-band P-35M “Bar Lock” target acquisition radar, and one H-band “Square Pair” missile control radar.

The missile consists of four solid fuel rocket boosters strapped to the side, and a dual-thrust sustainer motor. The boosters are jettisoned after usage, and this requirement limits the minimum range of the SA-5 missile to about 3 – 5nm. The missile’s maneuverability is also low, making it useful only against larger non-maneuvering targets. The missile is initially guided via command signals in the initial stage. Once near the target interception point, the launch crew will activate the missile’s onboard active radar seeker. The maximum effective range of the SA-5 is about 40nm., up to an altitude of 80,000 feet. The SAM will usually not engage targets below an altitude of 6,000 feet.

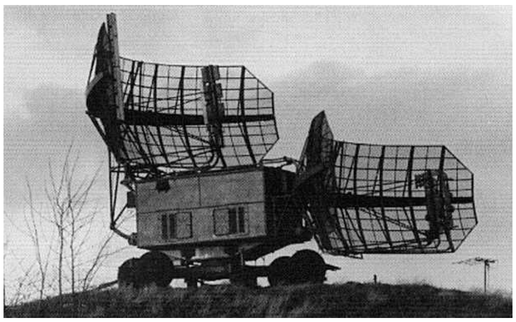

Figure 126: P-35M "Bar Lock" target acquisition radar

The SAM is easy to defeat kinematically, and a 5 – 6g turn will be more than sufficient as the SAM will not be capable of generating the maneuverability to complete the intercept. The onboard active radar seeker is of the pulse type, and is very susceptible to jamming and chaff. You should have no problems defeating the SA-5. This SAM system is more of a nuisance than anything else. It will usually force attackers to fly at lower altitudes, where they can be engaged by the more effective low to medium altitude SAMs. Against fighter aircraft, the SA-5 is almost totally ineffective. Even when used against bombers such as the B-52 and B-1, the integrated defensive suite onboard these bombers will usually defeat the SA-5 easily.

The long range of the SA-5 means that you will not be able to conduct stand-off HARM attacks against it without getting shot at. However, the poor performance of the SAM means that it is usually not very hazardous to close in and attack with HARMs even after the SAM has been fired at you. Destruction of the Bar Lock radar will knock out the SAM site in F4 (strictly speaking, this is incorrect as the Bar Lock is a search radar, but this is a game constraint). Cluster bombs should be used to mop up the remainder of the SAM battery.

SA-6 (NII Priborostroeniya 2K12 Kub) “Gainful”

Figure 127: SA-6 launcher vehicle

The SA-6 was first seen in public during the 1967 Moscow parade. This SAM system entered full operational service in 1970, and was designed to be air portable by An-22 and Il-76 transports. The first combat use of the SA-6 system was recorded by Syria and Egypt in 1973, where it proved highly effective against Israeli aircraft. The latest victim of the SA-6 system was an USAF F-16, shot down by the Bosnian Serbs while overflying Bosnia-Herzegovina, in 1995.

The SA-6 is a semi-mobile SAM system, consisting of surveillance radars (“Thin Skin-B,” “Long Track,” “Flat Face,” or “Spoon Rest”), G/H/I-band “Straight Flush” missile control radar mounted on a tracked chassis, and missile launcher vehicles carrying three missiles each. The “Straight Flush” radar is capable of tracking and illumination, as well as providing missile command guidance. It also has a limited search ability.

The 3M9M3 missile has an integral ramjet/rocket propulsion system. Missile guidance is via command uplink, and the missile will switch to semi-active radar homing in the terminal stage. The rocket ignites in the boost phase, and burns for 4.1 seconds to bring the missile to about Mach 1.5. The solid fuel ramjet then takes over and burns for 22.5 seconds. The missile is accelerated to a maximum speed of Mach 2.8, and is capable of a maximum of 15g sustained turn performance. The SA-6 battery will usually engage at a range of about 10 – 11nm., and altitudes of between 800 feet to 40,000 feet. Self protection jammers will often reduce the engagement range to 7 – 8nm..

Figure 128: Straight Flush missile guidance radar vehicle

In a typical engagement, the Straight Flush radar will begin to track and illuminate the target from a range of about 15nm.. The radar can control up to three missiles in flight. The missile flies a lead pursuit course, and the warhead is detonated by proximity fuse. In many cases, the Straight Flush radar may be modified with an optical tracker to provide missile tracking function, thus allowing the battery to remain in action even though heavy ECM may have prevented the radar from detecting the target.

The difficulty in dealing with the SA-6 stems from its mobile nature. The SAM system can be rapidly re-deployed in a matter of hours, thus making pre-planned SEAD strikes difficult. However, the SAM range is still low enough to allow stand-off HARM strikes, though AGM-45 shooters will be disadvantaged and need to fly into the SA-6 engagement envelope in order to shoot. With ECM protection, strikers without HARMs should be able to close in to AGM-65 range and take a shot just shy of the engagement range. As with other SAM systems, destruction of the Straight Flush radar vehicle will shut the SAM site down, allowing the strikers to destroy the launchers and ancillary equipment at leisure.

The missile is more resistant to chaff compared to the SA-2, SA-3, and SA-5 systems. Kinematically, it is also very difficult to defeat, though not impossible. As long as you keep your airspeed high, sustained 8 – 9g turns may force the missile to overshoot if you time the turn properly, while dispensing chaff.

SA-7 (Kolomna KBM Strela-2M) "Grail"

This is a man portable low level air defense system, first designed in the 1960's. The SA-7b uses a primitive 1.7 to 2.8 μm uncooled lead sulfide seeker, with a low 9°/sec tracking rate. The low seeker sensitivity and low tracking rate makes the missile only capable of tail chase engagements, and is effective only when fired from behind the hot exhaust pipe.

Figure 129: SA-7 "Grail" MANPADS. (Picture credit of USAF)

The missile is expelled from the launcher tube by a booster charge that accelerates the missile to 28 m/sec. The booster charge burns out in 0.05 seconds, and is then jettisoned. The fins then unfold and the sustainer motor cuts in and burns for 1.25 seconds, bringing the missile to its maximum speed of close to Mach 1.7 (altitude dependent). The missile uses an extremely fuel inefficient lag pursuit trajectory, and can be easily out-run. If the missile fails to make contact with the target, it will self destruct after 17 seconds of flight.

The poor seeker sensitivity also means that the missile is extremely sensitive to background IR clutter, and firing at targets with the sun in the missile's field of view will usually result in ballistic launches. Similarly, dispensing flares will always decoy the missile. However, due to its small size and light weight, the SA-7 is an integral component of even the most basic infantry units, providing them with some means of organic ADA capabilities, no matter how primitive.

This missile should not be much of a threat to you, with its limited range of 1.5nm. and its poor seeker performance. It will be launched against targets up to about 7,000 feet in altitude, and though the missile can definitely fly up to about 12,000 feet, the energy state of the missile will be very low by then. As long as you stay above 12,000 feet, you should not have to worry about the SA-7 threat at all, since most of the time, even if the missile is launched at you, it will not have the energy to intercept you. The minimum launch altitude of the SA-7 is 200 feet. If you need to descend into SA-7 envelope for your attack, then regularly dispensing flares should keep any SA-7 launched at you from guiding.

SA-8 (Antey 9K33 Osa) "Gecko"

The SA-8 missile system consists of the 9A33BM3 launch vehicle, the 9M33M3 missile, the 9T217BM2 reload vehicle, the 9V210M3 technical maintenance vehicle, and other ancillary support vehicles. SA-8 SAM systems are usually dedicated to mobile air defense battalions that are attached to maneuver divisions. A typical SA-8 regiment consists of a regimental headquarters, target acquisition and early warning battery, transport company, maintenance company, missile support battery, and eight firing batteries with four launcher vehicles each.

Figure 130: SA-8 mounted on 9A33BM3 launch vehicle

The SA-8 launch vehicle has a rear mounted H-band, conical scanning, fire control radar known as the "Land Roll," and six ready-to-launch 9M33M3 missiles. The twin monopulse missile guidance uplink transmitters operate in the I-band, and can control a salvo of two missiles at a single target. The 9M33M3 missile is designed by the Fakel PKB, and is powered by a dual stage solid rocket motor with a 2 second boost phase and a 15 second sustainer phase, giving the missile a maximum velocity of Mach 2.4. The effective engagement range is about 5 – 7nm., and the SAM is effective from 300 feet to 15,000 feet. The missile will self destruct after 25 seconds if it does not make contact with the target.

The deployment time of the battery is a short 26 seconds, and the mobile nature of the battery makes this a very difficult target to attack. As the missile guidance radar is integral on each launch vehicle, this makes HARM attacks extremely difficult, as destruction of one launch vehicle will not shut down the battery, and every single launch vehicle need to be destroyed to render the battery ineffective.

However, the short range of the missile makes stand-off AGM-65 attacks a possibility, as well as medium altitude CCRP toss attacks with cluster bombs feasible. This SAM system is not used by the DPRK and PRC forces, and you should only encounter it against the Russian forces.

The missile has considerable amount of maneuverability, and it is difficult to defeat kinematically. Jamming will not be effective as the short engagement range means that the SA-8 will usually burn through the self protection jamming even before you enter the engagement range. Chaff will however be effective if dispensed quickly and copiously. Your best counter towards the SA-8 regiment is to stay out of its firing envelope, and attack it at stand-off ranges or from medium level altitudes.

SA-9 (Nudelman 9K31 Strela-1) "Gaskin"

The SA-9 system was developed together with the ZSU-23-4 vehicle and attained operational status in 1968. The SA-9 was designed as a clear weather low altitude air defense system, organic to anti-aircraft batteries of motorized and tank regiments.

The SA-9 system consists of a 9P31 BRDM-2 transporter-erector-launcher vehicle, with four ready-to-launch launcher boxes. The 9M31M variant of the missile is equipped with an uncooled 1 – 5 μm lead sulfide seeker, and is capable of rear aspect engagements only. The seeker is also susceptible to background IR clutter, and has no IRCCM capabilities. The missile has a maximum velocity of Mach 1.8, and an effective engagement range of about 3 – 4nm.. The maximum effective altitude is about 14,000 feet, and the minimum target altitude is 300 feet.

The gunner commences the engagement by directing the turret to the desired azimuth bearing and acquiring the target through an optical sight. The rear aspect only seeker limits the missile to a lag pursuit trajectory, further reducing its effectiveness. In terms of maneuverability, this missile can be defeated kinematically by a hard 8 – 9g turn into the missile. However, the lack of IRCCM makes the missile susceptible to even one single flare.

Figure 131: SA-9 Gaskin low altitude IR SAM

As the SA-9 battery lacks a search radar, you will often not be aware of its presence until the missile is launched, unless you are aware of the composition of the battalion that you are attacking. Dispensing flares at regular intervals while bombing will keep you out of trouble in case you fail to spot the missile launch. The combat performance of this SAM system has not been good, and the SA-9 system has largely been replaced by the SA-13 system in the Russian forces.

SA-10 (Almaz S-300PMU1) "Grumble"

Figure 132: 30N6 "Flap Lid" missile guidance and tracking radar

The S-300 system began development in 1967, at the Russian "Almaz" Scientific Industrial Corporation. The SAM system was designed as a semi-mobile all-weather strategic air defense system, to replace the obsolete S-25 "Berkut" (SA-1 "Guild") missile network around Moscow, and for use against small targets such as cruise missiles.

The S-300PMU1 system is the third generation version of the S-300 family, and carries the NATO designation of "SA-10d Grumble." The system is packaged to fit on a modified MAZ-542 (8x8) truck chassis, and can be emplaced on an unsurveyed site within about five minutes. This gives the SAM battery a great degree of mobility.

The SA-10 firing battery consists of a 1T12-2M survey vehicle, which prepares the site for the battery's occupation; self propelled 5P85 launcher vehicles; and a self-propelled 30N6 engagement radar vehicle. Other supporting elements include 5T58 missile transport vehicles, and 22T6 missile reloading vehicles. At the brigade/regiment level, airspace surveillance is conducted by either the 38D6 "Tin Shield" S-band radar, supplemented by the LEMZ 76N6 "Clam Shell" radar. The latter can detect targets up to 50nm. away, and is capable of tracking up to 180 targets.

The Fakel 5V55RUD missile is a track-via-missile (TVM) command-guided missile, with a single stage solid rocket motor. This is the first Russian missile to incorporate a significant level of solid state electronics in its guidance system. Guidance is transmitted to the missile by the phased-array I/J-band 30N6 “Flap Lid” missile tracking and guidance radar. This radar has good ECCM features, and is very difficult to jam. The battery operators are located in an F-9 shelter unit that is placed away from the radar mast. The F-9 shelter serves a similar function as the Engagement Control Station (ECS) on the Patriot SAM system.

The missile is ejected vertically from the launcher tube, and the rocket motor fires when the missile reaches a height of 80 feet. The missile has a 295lb. HE fragmentation warhead, and an effective engagement range of approximately 50nm.. Under ideal circumstances, the missile can travel at speeds up to Mach 6, and is capable of engaging targets flying at 500 feet, and up to an altitude of 90,000 feet.

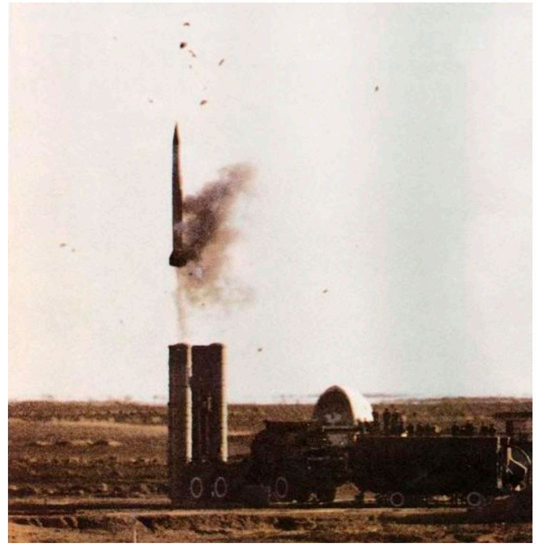

Figure 133: SA-10 missile being launched from the 5P85 vehicle

Figure 134: The complete S-300PMU system, consisting (from the left to right) of the 30N6 guidance radar, the 70N6 surveillance radar (mounted on the mast), and the 5P85 launcher vehicles.

This SAM system is very effective in providing air defense coverage for high value targets such as C^3I facilities, as well as cities and air bases. The good ECCM features and high power output of the engagement radar means that ECM is less effective, and the 30N6 radar will usually burn through the self protection jamming at ranges exceeding 35nm.. This allows the SA-10 battery to engage targets outside the range of the AGM-88 HARM missiles. The missile is also fairly agile for its size, though it is not impossible to defeat it kinematically with a tight 8 – 9g turn at high speed. Chaff is almost useless against the SA-10, and the best defense against it is to avoid getting fired at. This may force you to use terrain masking and fly at low altitudes. This will however put you into SHORAD envelope.

You will find the SA-10 batteries with the PRC forces as well as the Russian forces. The only way of attacking this SAM is to sneak up to it at low altitudes, and hopefully fire off the HARM missile before the battery engages you. You should also swamp the SA-10 battery with multiple strike packages to improve the chances of being able to sneak in on the battery without being engaged.

SA-13 (NII Priborostroeniya 9K35 Strela-10) “Gopher”

The SA-13 IR SAM system was designed as a replacement of the far less capable SA-9 “Gaskin” on a one-for-one basis, to improve the mobility of the anti-aircraft batteries in the motorized rifle and tank divisions. This system saw operational usage in Chad and in Angola, and claimed a South African Mirage F1-AZ fighter in 1987/88 in the hands of the FAPLA.

The transporter-erector-launcher and radar (TELAR) launch vehicle consists of a ranging radar known as the 9S86 "Snap Shot," and four ready-to-fire container launcher boxes. The Strela-10M2 (9M37M) missile has a cooled indium antimonide mid-band IR seeker with IRCCM logic. This gives the missile an all aspect engagement capability, with good background IR clutter rejection and flare rejection ability.


Figure 135: SA-13 missile leaving the launcher mounted on the 9A34M2 vehicle

The missile has an effective engagement range of up to 4nm., and an effective altitude of 12,000 to 14,000 feet. The minimum target altitude is 300 feet. The missile has considerable amount of maneuverability, and is not easy to defeat kinematically. Rapidly dispensing 3 – 4 flares will usually decoy the missile, although you will need to act quickly.

This SAM system is fairly effective in protecting troops on the march from low level air attacks by precision munitions, and is organic to motorized rifle and tank regiments. If you attack from altitudes above 12,000 feet to 14,000 feet, you will be well outside its engagement envelope. CCRP or dive toss from medium level altitudes will keep you out of trouble. Unlike the MANPADS, the SA-13 packs a lot more punch and maneuver potential and is a serious threat that you can ill afford to disregard. You should develop the habit of setting your low altitude warning to remind you whenever your descend into its effective engagement altitude. This will be a handy warning to you in case you become task saturated during the attack.

SA-14 (Kolomna KBM Strela-3M) "Gremlin"

This MANPADS was designed as a replacement of the poor performing SA-7 "Grail" IR MANPADS. Unlike its predecessor, the SA-14 is capable of head-on all aspect engagements, and the cooled 3 – 5 μm seeker provides relatively good background IR clutter rejection abilities. The wider seeker gimbal limit also means that the SA-14 missile is less likely to gimbal out compared to the SA-7. With the all aspect capability, the missile flies a more efficient proportional navigation course, giving it a slightly expanded engagement envelope.

As with the SA-7, the missile is expelled from the launcher tube by a booster charge that accelerates the missile to 28 m/sec. The booster charge burns out and is jettisoned. The fins unfold and the dual thrust motor will cut in to bring the missile to its maximum speed. If the missile fails to make contact with the target, it will self destruct after 17 seconds of flight. The more efficient motor and pursuit trajectory gives the SA-14 an effective range of about 2.5nm., and an effective altitude of about 14,000 feet. The missile may be launched at targets flying as low as 200 feet.

Unlike the SA-7, you will need to fly at a higher altitude when dealing with the SA-14 threat, in order to avoid getting shot at. The poor IRCCM capabilities of this missile means that flares will usually do the job, and if your airspeed is sufficiently high, you stand a chance of out-running the missile when it is fired tail-on. You should bear in mind that the SA-14 is more dangerous than the SA-7, and is a threat that you cannot dismiss lightly. The fact that this missile equips many different types of combat units means that you are likely to come across SA-14 equipped units frequently over the FLOT, making low level attacks a dangerous tactic to use.

SA-15 (Antey Tor) "Gauntlet"

Figure 136: SA-15 Tor-M1 mobile SAM system

The SA-15 "Gauntlet" was designed as a mobile and highly automated integral SAM system, based on the Russian Navy's Kynshal SA-N-9 system. The SA-15 system entered service under the designation Tor-M1 in 1991, and was exported to China and Greece.

This SAM system consists of the 9A331 vehicle, with a mechanically steered G-band surveillance radar mounted at the rear. This 3-D radar system is capable of providing range, azimuth, and elevation information for up to 48 targets to the digital fire control system. Automatic track initiation can be performed on 10 of the targets assessed to be the most dangerous.

The front part of the vehicle is occupied by the K-band phased array pulse doppler target tracking radar. This is complemented by an autonomous TV tracking camera for use in a heavy ECM environment. The frequency band of the tracking radar is above most self protection jammer systems and the radar is highly resistant to jamming, making ECM less useful. The high power of the tracking radar ensures that it will burn through the self protection jamming before the target enters the SA-15's effective engagement envelope.

The command guided missile is propelled out of the launcher box using a cold launch ejection system. The thruster jets then ignites to turn the missile towards its target. The sustainer motor cuts in and the missile is steered to the intercept point. The SA-15 system will engage inside 5nm., and up to an altitude of 15,000 feet. The SA-15 system will also engage targets flying as low as 150 feet AGL. The missile is capable of up to 30g maneuvers, and is capable of intercepting targets maneuvering up to 12g at missile motor burn-out. This makes the SA-15 a very difficult system to defeat kinematically, and electronically.

Figure 137: SA-15 TOR firing during exercise. This missile is a formidable threat even at medium altitude levels.

The SA-15 system, though of relatively short range, provides a very effective low level air defense capability to motorized rifle and tank divisions. This highly capable threat is gradually replacing the SA-8 throughout the Russian Army, on a one-to-one basis. As with the SA-8, your best protection is to fly above its effective engagement envelope, and utilize medium level bombing tactics against SA-15 equipped units. Chaff may be marginally effective, and you will certainly be pressing your luck if you insist in repeatedly entering its engagement envelope and hoping to get away all the time. This is certainly one of the nastiest SAM systems.

SA-16 (9M313 Igla 1) "Gimlet"

Design of the SA-16 "Gimlet" commenced in the mid 1970's. The existence of this MANPADS was first revealed by the South Africans in 1987, following the capture of several units of this missile in Angola. This MANPADS was designed to be a replacement of the venerable SA-14, which, although improved in seeker performance compared to the SA-7, still lacks the range to target fast jets in a tail chase.

The SA-16 is housed in a longer launcher tube compared to the SA-14. The protective IR dome cover over the launcher tube is conical in shape, and the missile is just slightly heavier than the SA-14. The cooled IR seeker has a nose spike to keep the glass radome cooler at high speeds, and the seeker has an improved all aspect engagement capability compared to the SA-14. The seeker also incorporates IRCCM features, thus improving its ability to defeat flare decoys.

Figure 138: SA-16 (9M313 Igla 1) and its launcher

As with the SA-14, the missile is expelled from the launcher tube by a booster charge. The booster charge burns out and is jettisoned. The fins unfold and the dual thrust motor will cut in to bring the missile to its maximum speed. If the missile fails to make contact with the target, it will self destruct after 17 seconds of flight. The large motor and efficient pursuit trajectory gives the SA-16 an effective range of about 2.8nm.. The effective altitude is between 50 to 15,000 feet.

As with the SA-14, you will need to fly at a higher altitude when dealing with the SA-16 threat, in order to avoid getting shot at. However, this missile still performs as poorly as the SA-14 when the target dispenses flares. The larger motor and more efficient pursuit trajectory also means that it is more difficult to out-run the missile when it is fired from the tail-on aspect. You should bear in mind that the SA-16 is more capable than the SA-14, and is a threat that you ill afford to ignore. However, this missile is used only by the Russian units, and the higher cost means that you will find fewer combat units that are equipped with it, compared to the SA-14.

SA-19 (9M311) “Grison” / 2S6M Quad 30mm Tunguska

The 2S6M Tunguska is a unique combination of a quad 30 mm gun system and the SA-19 command guided “Grison” SAM system. The 2S6M vehicle forms part of the 2K22M air defense system (missiles, guns, vehicle, and associated support equipment), and was designed to replace the older 23 mm ZSU-23-4 self propelled anti-aircraft gun system. The Tunguska was developed by the Ulyanovsk Mechanical Plant.

Figure 139: 2S6M anti-aircraft air defense system with twin 30 mm cannons and SA-19 missile system

The layout of the 2S6M vehicle is similar to the German Gepard twin 35 mm self propelled anti-aircraft gun system. The 1RL144M “Hot Shot” radar system consists of an E-band surveillance radar and a J-band tracking radar. This radar is capable of detecting targets up to 10nm. away. At ranges below 6nm., detected targets are transferred to the tracking radar.

The 30 mm 2A38M guns are water-cooled, gas-operated, and electrically fired. The effective slant range is approximately 10,000 feet. The guns have a cyclic firing rate of 4,000 to 5,000 rounds per minute, and usually fire in bursts of 83 rounds (one second) or 250 rounds (three seconds). The gun fires a combination of HE-T and HE-I rounds, fitted with impact and time fuse. The gunner has the option of using radar or optical sight to lay the guns.

The SA-19 missile (9M311M Treugolnik) is only fired when the 2S6M vehicle is stationary. Two banks of four missiles are located on either sides of the 2S6M turret, below the 30 mm guns. The command guided missiles may be tracked by radar or by the gunner’s optical sight. The effective engagement range is up to 5nm., with an effective altitude of 10,000 feet. The minimum target altitude is 100 feet.

Figure 140: SA-19 (9M311) missile fired from the 2S6M vehicle

The missile has a large booster stage which propels it to a velocity of close to 3,000 feet/sec before being jettisoned. The missile has four fixed fins and four control surfaces, and is equipped with a high explosive fragmentation rod-type warhead. The very high speed of the missile means that engagement time is often short, leaving the target with very little time for reaction. The short engagement range means that self protection jammers are often less useful as the 1RL144M radar system will burn through the jamming, though chaff still remains marginally useful.

The 2S6M Tunguska is a more dangerous anti-aircraft weapon system compared to the ZSU-23-4, due to its unique combination of missiles and guns. As this system is gradually replacing the ZSU-23-4 in the Russian motor rifle and tank divisions, the chances of encountering it increases. Do note that the RWR will recognize the 2S6 as an anti-aircraft gun, but you should be aware of its unique RWR aural tone compared to the Firecan radar for the KS-19/KS-12/S-60 guns, and the Gun Dish radar for the ZSU-23-4. As with other low level SHORAD systems, medium level tactics should keep you well above the threat posed by the 2S6M system, though the missile can potentially reach up to an altitude of 15,000 feet.

CPMEIC Hongying HN-5A

This is a PRC product improved version of the Russian SA-7 "Grail" man portable SAM system. Externally, the HN-5A missile looks similar to the SA-7, but is equipped with a cooled lead sulfide seeker with a greater detection range and reduced susceptibility to IR background clutter. The missile seeker lacks IRCCM capabilties.

Figure 141: CPMIEC HN-5A in the hands of a PLA soldier

The HN-5A system is capable of limited all aspect engagements, and the pursuit trajectory is mid-way between the less capable SA-7 and the more capable SA-14. This gives an effective range of slightly under 2nm., and an effective engagement altitude of 8,000 feet. The minimum target altitude is 200 feet. The wide proliferation of this weapon amongst infantry units means that the chances of encountering it is high. As with the SA-7 and SA-14, the most effective way of countering the HN-5A threat is to fly above its effective engagement altitude. If you need to fly into its engagement envelope, you should develop a habit of dispensing flares regularly. Remember to keep your airspeed high, as this may allow you to out-run the missile if it is fired from the tail-on aspect close to its maximum range.

FRIENDLY SURFACE-TO-AIR MISSILE SYSTEMS

Daewoo Pegasus (Chun-Ma)

The Daewoo Pegasus SAM system was developed by the South Korean Daewoo Heavy Industries Special Products Division in 1996. This SAM system was developed in response to the operational requirement for an all weather air defense system to protect the South Korean mechanized forces.

Figure 142: Daewoo Pegasus SAM system undergoing firing trials

The chassis of the Pegasus system is based on the tracked KIFV (Korean Infantry Fighting Vehicle) family of vehicles. The power-operated, unmanned turret has two banks of four ready-to-launch missiles on each side. The sensor package consists of an S-band pulse doppler surveillance radar with a range of 12nm., and a Ku-band tracking radar with a range of 7nm.. The tracking system also consist of a forward looking infra-red (FLIR) camera with a narrow and wide field of view, and a daylight TV system. The optical tracking system is used to track and guide the missile.

The missile is guided via command-to-line of sight (CLOS), and has an effective range of just under 5nm.. The effective altitude is from 200 to 10,000 feet. The missile has a peak maneuver capability of up to 30g. The missile tracking is via the FLIR camera system. This makes the missile impervious to most jamming techniques and flares. However, the tracking rate is fairly low, and the CLOS pursuit trajectory is not as energy efficient. Conventional countermeasures will not defeat this system, though you can try to out maneuver the missile by generating sufficient line-of-sight movement rate to break the tracking solution.

You will normally find the Pegasus system deployed around airbases and strategic targets to provide low level air defense. The prevalence of this SAM system around the FLOT makes this a serious low level threat to attackers, though you will often get prior warning of its presence through the RWR, by picking up the transmissions from the surveillance and tracking radars.

Matra Bae Dynamics Mistral

The Mistral MANPADS began development in 1980, following a decision by the French Direction des Engins/Delegation Generale pour l'Armement (Missile Division of the French Weapons Procurement Authority) to procure a third generation SHORAD system. The development contract was awarded to Matra, and test firings commenced in 1983. The Mistral system entered operational service with the French armed forces in 1989, and has since been widely exported to at least 18 countries worldwide.

Figure 143: Mistral firing team. Note the unique pyramidal seeker dome.

The Mistral system comprises of the missile in its container-launcher tube, the vertical tripod stand, a pre-launch electronic box, a daytime sighting system, and the battery/coolant unit. A thermal sight for night-time use and an IFF interrogator may be added if required. Mistral firing teams are usually transported in a light vehicle, though the crew will man-pack the system to the firing site. The system can also be mounted on a light vehicle, thus giving the firing team a high degree of mobility.

The missile is ejected from its launcher by a booster charge, reaching a velocity of 40 m/sec. The sustainer motor will then ignite to accelerate the missile to a peak velocity of Mach 2.5 within 2.5 seconds. The cooled IR seeker is derived from the seeker on the Matra Magic 2 air-to-air missile, and has a multi-element seeker and a digital processing unit. The seeker is capable of acquiring MIL power targets at an impressive ranges of up to 2nm., and is equipped with sophisticated IRCCM algorithms. The drag of the missile is further reduced by the pyramidal-shaped seeker cover, thus improving the missile's maneuverability during end-game. The missile has a maximum flight time of 14 seconds, after which it will self destruct. The effective range is up to 2.5nm., and the missile has an effective altitude of 10,000 feet. The missile can be launched at targets flying as low as 50 feet AGL.

The Mistral MANPADS is used by the South Korean infantry and mechanized units. This provides the South Korean forces with a very effective low altitude SHORAD capability. The wide spread distribution of the Mistral system amongst South Korean units means that these forces are well equipped to defend themselves against any low level attackers.

The good IRCCM ability means that you will need to dispense flares quickly and in large numbers (4 to 6 flares within 2 – 3 seconds). Although it is possible to defeat the missile kinematically due to its small control fins, you should bear in mind that the missile will accelerate quicker than other MANPADS. As long as the attacker keeps the airspeed high, the survivability against a Mistral attack increases.

Raytheon FIM-92 Stinger

The FIM-92 Stinger MANPADS was developed as a replacement of the Redeye system in 1974. The Stinger system is usually deployed in the SAM role, though modifications have been made to allow it to be fired from helicopters (known as the ATAS system).

Figure 144: FIM-92 Stinger missile and launcher

The current FIM-92D Block 2 Stinger has a two stage solid propellant motor. The first stage ejects the missile from the launcher tube and is then jettisoned. The sustainer motor then cuts in and accelerates the missile to Mach 2.2. The missile has its self destruct timer set to 20 seconds, and has an effective engagement range of about 2.5nm.. The maximum effective altitude is about 12,000 feet., though the missile is capable of flying up to 14,000 feet. The minimum engagement altitude is 50 feet.

The cooled IR seeker has a wide gimbal limit and high sensitivity. Its background IR clutter rejection ability is excellent, and it is not easily decoyed by the sun. The image scan algorithm of the seeker enhances target detection, and the two color IR/UV seeker provides an option to track in either wavelength. The software logic of the missile is reprogrammable and may be updated via an external plug interface. This gives the missile reasonably good IRCCM capabilities (for a missile this small in size).

The Stinger MANPADS is deployed in infantry and mechanized units. Friendly infantry units are equipped with Stinger squads to provide SHORAD capabilities. The missile is also mounted various air defense vehicles (described separately). These provide the mechanized forces with their own organic SHORAD capabilities against low level air attacks. The wide spread distribution of the Stinger amongst combat units means that it is a serious threat to any low level attacker.

The good IRCCM ability makes flares less useful unless dispensed quickly and in large numbers (4 to 6 flares within 2 – 3 seconds), though it is still possible to defeat the missile kinematically due to its small control fins. As long as the attacker keeps the airspeed high, the survivability against a Stinger attack increases. As with all other SHORAD systems, medium level attack tactics will keep you out of its envelope and help you stay out of trouble.

Boeing Avenger Self Propelled Air Defense System

The Boeing Avenger self propelled air defense system was designed in the early 1980's, and entered operational service in 1989 with the US Army 3rd Armored Cavalry Regiment at Fort Bliss. During the evaluation by the US Army Air Defense Board in August 1984, the Avenger system successfully engaged a total of 171 out of 178 fixed and rotary wing targets during day and night operations.

The Avenger is a shoot-on-the-move air defense weapon, based on an AM General 4x4 High Mobility Multipurpose Wheeled Vehicle (HMMWV). The gunner sits in the electrically powered turret, with two side mounted Stinger pods. Each Stinger pod houses four ready-to-fire Stinger missiles, and the gunner aim the missiles by looking through a sight glass. The sensor package on the turret consists of an optical sight, a Magnavox AN/VLR-1 FLIR, automatic video tracker (AVT), and a laser rangefinder. The combination of sensors allows the gunner to acquire and track targets under all weather conditions.

Figure 145: The Stinger missile fired from the Avenger air defense vehicle.

The sensor package will process the target information, and cue the gunner when the target is inside the Stinger's engagement envelope. The gunner can also transfer the target tracking function to an automatic tracking system. The driver of the Avenger vehicle may also control the turret through a Remote Control Unit (RCU). This is fitted with the same controls and displays as the turret, and allows the Avenger crew to conduct engagements from remote positions when dismounted.

The Avenger is also equipped with a 12.7 mm M3P machine gun, mounted as a supplementary armament. This gun is used for self-protection, and provides close in air defense coverage within the Stinger's dead zone. The M3P is an improved version of the AN-M3 machine gun, with a cyclic rate of fire of 1,100 rounds per minute. In addition to the eight ready-to-fire Stinger missiles on the turret, an additional of eight Stinger missiles are carried in reserve.

The Avenger system equips the US Army and Marine Corps, and has been exported to the Taiwanese and ROK Army. This air defense system may be found in armored units, HQ units, as well as MLRS units. Unlike Russian SAM systems, the Avenger does not rely on radar information for its targeting, and as such, will not light up the RWR. This makes launch detection extremely difficult, unless the missile launch is spotted visually. The IRCCM performance of the Stinger missile confers a high degree of effectiveness to the Avenger system, making medium level bombing or stand-off tactics even more important to ensure the safety of the attacking aircraft.

M2A2 Bradley Stinger Fighting Vehicle (BSFV)/Bradley Linebacker

The original BSFV concept involved a M2 Bradley IFV with a three-man crew and two-man Stinger team in a MANPADS-under-armor configuration, and required the Stinger team to dismount to engage targets. This concept is known as the BSFV-MANPADS Under Armor (BSFV-MUA), and has since grown into a full-fledged modification of the Bradley IFV. Boeing Defense and Space Group was selected to develop the BSFV-Enhanced concept, officially named as the Bradley Linebacker SHORAD system. The Linebacker system has begun replacing the BSFV-MUA vehicles.

The BSFV Linebacker system is a modified M2A2 IFV (and some earlier M2A0), fitted with a Hughes 4-round Stinger Standard Vehicle-Mounted Launcher. The mounting gives the system a fire-under-armor capability. Targeting data is provided by the Forward Area Air Defense (FAAD) Command, Control, Communications and Intelligence (C3I). This C3I complement provides early earning and

Figure 146: The M2 Bradley Stinger Fighting Vehicle (BSFV)

alerting, as well as the complete air picture, slew-to-cue, and IFF functions. In addition to the Stinger launching system, the Linebacker carries the standard Bradley IFV weapons: the M242 25 mm Bushmaster gun, and the 7.62 mm machine gun. The former provides additional air defense fire power, and may be used as a ground attack weapon, while the latter provides self defense capability against dismounted ground troops.

The BSFV equips the US Army heavy armor brigades, as well as Cavalry regiments and mechanized infantry. This provides an organic air defense capability to the heavy forces, and protects them against helicopter threats, UAVs, as well as fixed wing attack aircraft. As with the other Stinger based systems, the excellent IRCCM capabilities of the Stinger makes this a serious SHORAD threat, forcing attackers to use medium level bombing tactics or to rely on the more expensive stand-off weapons to attack the armored forces.

Lockheed Martin Light Armored Vehicle (LAV) Air Defense System

The Lockheed Martin LAV-AD self propelled air defense system was designed in 1996, in response to the US Marine Corp's requirement for an air portable air defense vehicle that is capable of a secondary ground combat role. The system first entered service in 1997, and a total of 17 units were delivered to the US Marine Corps.

The LAV-AD system is based on a modified LAV (8x8) chassis, with a two-man turret. The Blazer turret is armed with the GAU-12/U 25 mm Gatling gun, and two pods of Stinger missiles are mounted on each side of the turret. Each of the Stinger pods contains four ready-to-fire missiles. Eight more Stinger missiles are stored as reserve in the vehicle, and a standard Stinger grip-stock is carried to enable the Stingers to be used in the dismounted role. The GAU-12/U Gatling gun provides a limited anti-aircraft capability against targets inside the inner launch boundary of the Stinger, and confers the LAV-AD a considerable ground engagement capability.

Figure 147: Lockheed Martin LAV Air Defense Vehicle

The turret houses a sensor suite that consists of a FLIR, daylight TV, laser rangefinder, and automatic tracking system. Target information may be datalinked to the LAV-AD through the SINC-GARS radio suite. Both the commander and the gunner may control the electrically powered turret, and are provided with separate windows in the turret to search and scan the air from inside the vehicle. The stabilization system gives the LAV-AD an ability to engage targets on the move.

The LAV-AD normally equips the Marine Corp units, but the limited number of these vehicles means that the chances of encountering them are slim, compared to the Bradley Linebacker and Avenger systems. As with other Stinger based system, the presence of such air defense assets cannot be detected due to the lack of a radar signature. As such, unless you are absolutely sure that the ground unit that you are attacking is not equipped with such SHORAD systems, it may be more prudent to employ medium level attack tactics rather than risk getting shot at.

MIM-14 Nike Hercules

The MIM-14 SAM system was developed in 1954 by the then Western Electric Company. This was developed as a replacement for the MIM-3 Nike-Ajax system, and designed to provide defense for critical installations and urban population centers. Semi-mobile units provided theater level air defense capabilities. This SAM system has since been replaced in the US service by the more capable MIM-104 Patriot, but still remains in service with the South Korean defense forces.

Figure 148: MIM-14 Nike-Hercules SAM system

The command guided missile consists of a cluster of four solid propellant boosters, and a solid propellant missile body. Guidance is activated only after booster jettison, limiting the missile to a minimum range of about 5nm.. The Nike Hercules battery will normally engage at ranges up to 40nm., and altitudes up to 80,000 feet. The large size of the missile limits its maneuverability, and this SAM system is more suitable against large bombers than nimble fighter aircraft. The SAM system will not engage targets flying below 4,500 feet.

The SAM system may be defeated by a hard 6 – 7g turn into the missile, and this will usually exceed the missile's ability to maneuver and complete the intercept. Under jamming conditions, the missile may be launched up to 30nm. away. The old architecture of the electronics and the cumbersome missile body means that the Nike-Hercules system is currently more suited as a ground-to-ground missile than a SAM in the modern battlefield, and the South Koreans do employ this missile system in the ground attack role.

The long range of the SAM makes stand-off attack more difficult without getting shot at. However, adequately armed attackers with missiles such as the AS-17 may be able to get a shot off at about 25 – 30nm.. As with other command guided SAM systems, destruction of the guidance radar will neutralize the SAM battery and allow other attackers to mop up at their own leisure.

Raytheon MIM-23B Improved-HAWK

Development of the HAWK (Homing All the Way Killer) semi-active radar homing medium range SAM system commenced in 1952, and the MIM-23B Improved HAWK version entered service in 1964. The I-HAWK has claimed many victims over the years, beginning with the Israeli Air Force, which destroyed over 27 Arab aircraft between 1967 and 1989, including a high speed MiG-25. The Iranians also claimed to have shot down 40 Iraqi airplanes with the HAWK system during the first Gulf War. France claimed a Libyan Tu-22 "Blinder" bomber over the skies of Chad in 1987.

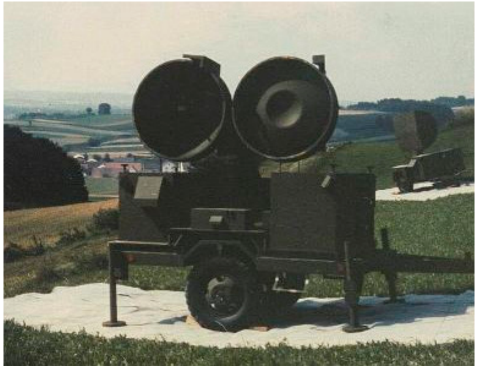

Figure 149: I-HAWK high power illuminator radar (HPI)

The I-HAWK missile uses a two stage boost-sustain motor that has a 23-seconds burn time, and flies a proportional navigation collision course trajectory. In-flight guidance commands are generated by the onboard semi-active radar homing inverse monopulse seeker head. The I-HAWK battery will usually engage at a range of 13nm., with an effective altitude of 50,000 feet. The minimum range is just under 1nm., and the battery will usually not engage targets below 700 feet altitude.

Figure 150: I-HAWK missile leaving the M192 launcher in pursuit of its target.

Target acquisition is by the acquisition radar attached to the battery, which may be the AN/MPQ-46 in Falcon 4, or AN/MPQ-50, AN/MPQ-55, or AN/MPQ-62. The C-band acquisition radar has several ECCM features. The target data is used to slew the battery's High-Power Illuminator (HPI). Affectionately called the "Mickey Mouse" by some of the I-HAWK operators due to its unique shape, the HPI radar searches for the target with either CW or sector search, and locks onto the reflected energy from the target. Transmissions from the HPI will indicate that a missile is about to be launched, and this will trigger the target's RWR launch warning. The HPI has sufficient power to burn through most self protection jamming at a range of about 16nm., which is outside the effective engagement range of the I-HAWK missile. Hence, self protection jamming is useless against the I-HAWK as it will not decrease the effective engagement range. The HPI's reflected energy from the target is tracked by the missile and used for its guidance.

The other components of an I-HAWK battery includes the PCP (Platoon Command Post) or the BCP (Battery Command Post), in addition to the acquisition radars and the HPI. The missiles are loaded on three-round M192 launchers.

The I-HAWK missile is capable of up to 30g sustained maneuvers, and can be extremely difficult to shake off. While jamming does not help in breaking the HPI's lock unless you are outside of 16nm., chaff should still remain slightly effective if used in copious amounts. This SAM system is a considerable threat to most airplanes, and both low level and medium level tactics will not give you much protection against it.

Raytheon MIM-104 Patriot PAC-2

The MIM-104 Patriot High- to Medium-Altitude Air Defense (HIMAD) system claimed its fame during the 1991 Gulf War. The CNN video clips of the Patriot batteries firing at inbound Iraqi Scud missiles were etched in the memory of many who watched the war from the television. The Patriot is a replacement of the I-HAWK system in the US Army, and has been exported to Israel, Taiwan, Japan, and several other countries.

Figure 151: MIM-104 Patriot missile firing during trials

The Patriot battery consist of the AN/MSQ-104 Engagement Control Station (ECS), the AN/MPQ-53 phased array multi-function radar, the AN/MSQ-24 power plant, and the M901 launcher station. The ECS is manned by three operators, and controls the tactical engagements. This performs the "brain" function of the SAM system, including target detection and missile tracking. It also provides the overall battle picture. E-3 AWACS air picture is also automatically datalinked down to the ECS.

The AN/MPQ-53 phase array multi-function radar operates in the G-band. It consist of 5,161 element arrays, providing search and detection, target track and illumination, and missile command and uplink functions. The radar is capable of simultaneously tracking up to 100 targets and supporting 9 missiles in-flight. The radar has an effective range of about 80 – 110nm. against fighter type targets, and frequency agility combined with sophisticated ECCM functions makes it extremely difficult to jam effectively.

The MIM-104A missile is shipped in a container box as a certified round. The Lockheed Martin manufactured missile is equipped with a monopulse seeker unit, and has a Thiokol single stage motor. The motor provides a thrust of 24,000lb. and burns for 11.5 seconds. This propels the missile to a velocity in excess 5,000 feet per second, and the missile is capable of undertaking sustained 20g maneuvers and 30g short-term maneuvers. The missile can cope with targets evading with sustained 6g maneuvers. The maximum missile flight time is 170 seconds.

Figure 152: AN/MPQ-53 phased array multi-function radar

Missile guidance is via command with track-via-missile (TVM) homing. The ECS directs the missile seeker to look in the target's direction, and the seeker then begins to intercept the increasingly precise returns from the reflected energy. This in turn triggers the missile's G/H-band datalink to transmit target data from the missile seeker back to the ECS. The ECS then uses this information to generate guidance instructions, which are then passed back to the missile via the ECS uplink. This process is repeated until the missile intercepts the target. All target computations are performed by the ECS, and the missile does not undertake any processing.

The track-via-missile guidance mode means that the fire control radar remains in search and track mode throughout the entire duration of the engagement, and as with the SA-10, it is not possible for the target's RWR to be alerted of a missile launch. The lack of a launch warning makes it extremely difficult to detect a missile launch. If you are flying in a formation, this also makes it impossible to determine which aircraft is being targeted, until the missile impacts.

The Patriot is an extremely fast missile, with an incredibly long reach. The battery will usually engage at a range of about 50nm., and against targets flying up to stratospheric altitudes. The minimum range is about 1.5nm.. The Patriot battery will usually not engage targets flying at altitudes below 500 feet AGL. You will find that chaff is not very useful even at long ranges. The TVM guidance makes it very easy to distinguish chaff blooms. The phase array AN/MPQ-53 radar is also exceedingly difficult to jam and defeat. You can try making 6 – 9g turns into the missile to evade, but with the high speed of the missile, the success of such evasion tactics will depend on how you time the initiation of the evasion maneuver. The best survival tactic is to avoid an engagement, or to flood the Patriot battery with an overwhelming force. Hopefully, the leakers can sneak in an anti-radiation missile shot to destroy the radar and the ECS. However, the long reach of the missile means that the Patriot can engage targets well outside the effective engagement range of most if not all anti-radiation missiles.

OPFOR ANTI-AIRCRAFT ARTILLERY

All integrated air defense systems (IADS) consist of a network of fighters/interceptors, surface-to-air missiles, and anti-aircraft artillery. The combination of these elements can often complicate defense for the attackers, as tactics that can be used to counter one threat will often drive the enemy into the firing envelope of another. You should learn to understand the unique characteristics of each anti-aircraft system, and tailor your tactics accordingly. For example, flying down the enemy runway may not be a good idea if the airfield is defended by ZSU-23-4, while it may not be much of a problem if it is defended only by KS-19s.

KS-19 100 mm Anti-Aircraft Gun

The KS-19 towed AA gun was first introduced in the late 1940's. It has since been replaced by surface-to-air missiles in the Russian Army, but the DPRK forces still retain 500 pieces of it in active service. This AAA piece has also been manufactured in the PRC as the Type 59 AA gun.

Figure 153: KS-19 single barrel 100 mm AA gun. (Picture credit of USAF)

The effectiveness of this gun against the modern aircraft is limited. This gun has a power rammer and an automatic fuse setter, and fires in single shots. The gun is normally used in a battery, and in conjunction with the PUAZO-6/19 director and SON-9/SON-9A fire control radar, also known as the "Firecan." This AAA radar operates in the low A/B-band and is susceptible to jamming.

Figure 154: SON-9A Firecan AAA gun director radar. (Picture credit of USAF)

The KS-19 fires the BR-412B armor-piecing-tracer rounds, equipped with a proximity or time fuse. The practical rate of fire is 15 rounds per minute. The gun muzzle velocity is about 2,900 feet/sec, and a typical DPRK AAA battery will consist of 4 of these guns. The guns will normally engage at a horizontal range of 7.5nm., and up to a maximum target altitude of 45,000 feet. The AAA rounds are timed to detonate at the target altitude, forming a horizontal engagement zone, making horizontal evasive actions less effective than rapid changes in altitude. You need to bear in mind that these guns can be directed optically, so even if you have jammed or destroyed the gun director radar, you will not be able to shut down the AAA site totally. As long as you keep your airspeed high, these guns should not be much of a threat to you, and should be no more than an irritant. The Firecan radar will also light up the RWR at ranges exceeding 9nm., allowing you some reaction time to fly around the guns and avoid being engaged.

KS-12 85 mm Anti-Aircraft Gun

The KS-12 towed AA gun was designed by M N Loginov and introduced into the Red Army shortly before the start of the Second World War. This AA gun has been out of Russian service for many years, though it still remains in active service with the DPRK forces (about 400 pieces in total).

This towed AA gun is held in the firing position on its carriage by four screw jacks, similar to the KS-19. Though it does not confer the AA battery an ability to fire on the move, it does allow the battery to deploy quickly into action. Gun elevation is up to 82°. Typically, each DPRK AAA battery will consist of four of these guns, in addition to the KS-19. The KS-12 is normally used with the SON-9/SON-9A Firecan radar, and fires fragmentation ammunition. It also has the ability to fire the 85 mm rounds used by the Russian assault guns, field, and tank guns, which also makes it a handy weapon for ground combat. The rate of fire in the AA role is between 15 – 20 rounds per minute.

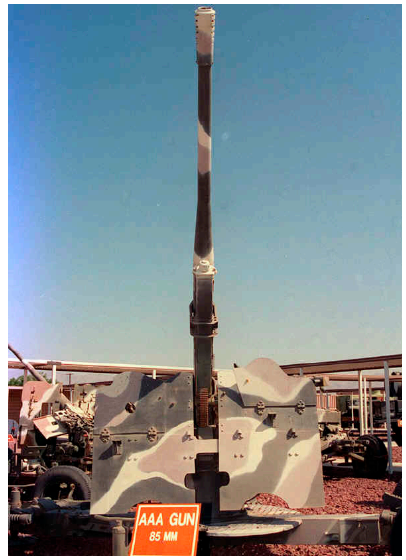

Figure 155: KS-12 85 mm single barrel AA gun. (Picture credit of USAF)

The O-365 AA round can be fitted with a powder train or mechanical time fuse, and the gun muzzle velocity is about 2,600 feet/sec. Alternative ammunition include the BR-365 armor piecing tracer round, AP-T round, or HVAP-T round. The guns will typically engage at a horizontal range of 3.5nm., and at target altitudes of up to 20,000 feet. The time fuse will detonate the rounds at the target altitude, and the guns are trained to fire in a horizontal engagement zone to bracket the target. As with the KS-19, horizontal evasive actions are less useful than vertical jinks. The KS-12 is also manufactured in the PRC as the Type 56 AA gun.

S-60 57 mm Automatic Anti-Aircraft Gun

Figure 156: S-60 57 mm automatic AA gun. (Picture credit of USAF)

The S-60 57 mm towed automatic AA gun was designed by L V Loktev and introduced into service in 1950 as a replacement for the 37 mm M1939 AA gun. The main improvements over the latter include increased range and the facility to use an off-carriage gun director system.

The S-60 AA gun is normally used in conjunction with the PUAZO-6/60 director and SON-9A Firecan radar, as with the KS-12 and KS-19 guns. Typical DPRK AAA batteries will contain six of these medium altitude flak guns, in addition to the heavy AAA artillery in the form of KS-12 and KS-19. These guns may alternatively be used with the I-band “Flap Wheel” radar, and such a setup was used by the Iraqis during the 1991 Gulf War.

The S-60 gun is raised off the ground and the carriage supported by four screw jacks in the firing position. The guns can be fired on its wheels in an emergency, and fire control equipment consist of a reflex sight for AA use, and a telescopic sight for ground use. The gun may be operated in four modes: manual, with the handwheels operated by the crew; assisted, with the handwheels operated by the crew with motor assistance; automatic, remotely controlled by a director; and automatic, remotely controlled by a radar.

The S-60 gun has an elevation of 87°, and fires the OR-281 or OR-281U fragmentation tracer round, fitted with a MG-57 time fuse. The muzzle velocity is 3,000 feet/sec, and the guns are loaded via four round clips. The practical firing rate is about 70 rounds per minute. The gun has a maximum engagement altitude of 15,000 feet, and a typical horizontal engagement range of 2.5nm.. Defense against the S-60 guns is similar as that against the KS-12 and KS-19, i.e. to jink in the vertical plane and avoid the flak bursts. The lower engagement altitude of the S-60 guns means that you can avoid being engaged at all by flying at altitudes above 15,000 feet. This makes medium level CCRP bombing tactics useful against targets defended by S-60 guns, as long as you don’t go below 15,000 feet altitude.

This gun is also manufactured in the PRC as the Type 59 AA gun, and shares the same ordnance as the self propelled ZSU-57-2. The S-60 AA gun is still in reserve service with the Russian forces, and is in use with the PRC forces. The DPRK air defense forces is reported to be equipped with up to 600 of these guns.

M1939 37 mm Automatic Anti-Aircraft Gun

The M1939 towed 37 mm automatic AA gun first entered service with the Russian Army before the start of the Second World War, and was based on the Swedish Bofors 40 mm design used by the US and the UK during the same time period. The gun was designed by L A Loktev and M N Loginov collaboratively at Kalinigrad, near Moscow. It was also manufactured in the PRC as the Type 55 AA gun.

Figure 157: Captured Iraqi M1939 37 mm AA gun during Operation Desert Storm

The M1939 gun system is a clear weather only AA gun, with no ability for radar guidance. The towed carriage is raised off the ground and supported by four screw jacks in the firing position. The gun consist of a single barrel, firing the OR-167/OR-167N rounds fitted with time and proximity fuses. The muzzle velocity is 2,850 feet/sec, and the gun is directed entirely by the optical reflex sights mounted at the gunner’s position. Ammunition is fed to the gun via five round clips, and the gun may be elevated up to 85°. Practical firing rate of the gun is about 80 rounds per minute, though the cyclic rate is at 160 to 180 rounds per minute.

The M1939 guns will normally engage at a horizontal range of up to 2nm., and target altitudes of up to 12,000 feet. A typical DPRK AAA battery will consist of six of these guns. The optically laid nature of the gun limits its effectiveness against modern aircraft, and thus the threat posed by the gun can be easily mitigated either by flying above its effective engagement altitude, or flying at higher airspeeds. However, this gun equips all the HART sites as well as AAA battalions, and the effect created by large number of these guns firing at the same time can be quite disconcerting to a pilot.

ZU-23 Twin 23 mm Automatic Anti-Aircraft Gun

Figure 158: Croatian ZU-23 twin barreled AA gun

The towed ZU-23 twin automatic AA gun was introduced into the Russian Army in the 1960’s as a replacement of the 14.5 mm ZPU-2 and ZPU-4 AA guns. These towed guns have since been replaced in the Russian airborne divisions by the SA-9 “Gaskin” SAM system. The gun is normally towed by the ZIL-135 truck.

When in the firing position, the ZU-23 carriage is raised off the ground and supported on its triangular platform, which has three screw jacks. The quick change barrels have flash suppressors, and the guns are the same as those used in the self propelled ZSU-23-4 Shilka. The water-cooled guns are capable of a cyclic firing rate of 800 –

1,000 rounds per minute, although the practical firing rate is about 200 rounds per minute.

The ZU-23 gun fires the API-T (BZT) and HEI-T (MG25) rounds. The muzzle velocity is about 3,200 feet/sec, and the gun has an effective horizontal engagement range of 2nm., and a maximum engagement altitude of just under 7,000 feet. The guns are optically directed, and hence will not light up the RWR. You first indication of possible ZU-23 threats will be its firing signature and smoke, and seeing the tracers flying towards you. These towed artillery pieces are organic to most DPRK units such as infantry battalions, rocket artillery battalions, and FROG-7 battalions. Though optically guided and of low accuracy, the high firing rate and wide proliferation means that the chances of encountering this gun over the battlefield is very high. Medium level attacks will keep you safe from them, and you should learn to make use of the ground mapping and GMT capabilities of the radar for bombing runs, rather than risk entering the engagement zone of these guns by bombing visually.

ZPU-2 14.5 mm Anti-Aircraft Machine Guns

The ZPU-2 first entered service in 1949, and uses the 14.5 mm Vladimirov KPV heavy machine gun, which has a quick change barrel. The ZPU-2 has two of these 14.5 mm guns mounted on a two wheel carriage with a tow bar. The wheels are removed when the gun is in the firing position, and the weapon rests on a three-point platform, each point being equipped with a screw jack for leveling.

Figure 159: ZPU-2 twin barreled 14.5 mm AA machine guns. (Picture credit of USAF)

The guns have a cyclic firing rate of 600 rounds per minute, although heating problems restrict the practical firing rate to 150 rounds per minute. The gun is manned by a crew of 5, and the gun mount may be traversed through 360° in azimuth and 85° in elevation.

The ZPU-2 is no longer in front-line service with the Russian Army, though it still remains in active service with the DPRK forces. A typical DPRK AAA battery will consist of six of these guns, in addition to medium and high altitude guns. These guns pose a serious threat below 6,000 feet in altitude, and will continue firing down to very low target altitudes. Although optically directed and limited in accuracy, the high volume of fire that can be delivered from these guns means that it will be a considerable threat to low flying aircraft, and makes strafing and rocket runs against the AAA batteries a dangerous exercise. The ZPU-2 is also manufactured in the PRC as the Type 56 AA gun.

ZSU-57-2 "Sparka" Twin 57 mm Self Propelled Anti-Aircraft Gun System

The ZSU-57-2 was developed in early 1951 and was first seen in public during a parade in Moscow in 1957. The system consist of a chassis based on the T-54 tank, and a large open top turret armed with twin 57 mm S-68 guns. These guns have the same ballistic performance as the towed S-60 guns. The SPAAG was initially deployed to Russian tank and motorized rifle divisions, but has now been replaced by the more effective ZSU-23-4. This system is also known as the "Sparka."

The twin 57 mm S-68 guns can be elevated to an angle of 85°, and fires either the OR-281, OR0281U, or BR-281 fragmentation tracer rounds. These rounds may be fitted with time or proximity fuses. The ammunition is loaded in clips of five rounds, giving a practical firing rate of 70 rounds per gun per minute. The fully automatic, recoil-operated guns have a typical horizontal engagement range of 2.5nm., and an engagement altitude of 15,000 feet.

Elevation and traverse of the turret are powered, with emergency manual controls. The guns are manually loaded, and are directed by a simple optical computing reflex sight with a mechanical backup. These guns cannot be directed by radar, and as such, do not have the same accuracy as the towed S-60 guns.

The main drawback of the ZSU-57-2 is the lack of all weather fire control system. This gun system is however, highly effective in the ground role, and is capable of destroying most AFVs on the battlefield, with the exception of main battle tanks. The ZSU-57-2 has also been manufactured locally by the PRC, as the Type 80 SPAAG. This uses a Type 69-II MBT chassis fitted with a Chinese copy of the ZSU-57-2 turret. The DPRK forces employ the ZSU-57-2 to provide organic medium level air defense capability for HQ units. The low level air defense needs of such units are bolstered by the HN-5A SAMs as well as the ZSU-23-4.

Figure 160: Russian ZSU-57-2 SPAAG

ZSU-23-4 "Shilka" Quad 23 mm Self Propelled Anti-Aircraft Gun System

Figure 161: ZSU-23-4 quad 23 mm self propelled anti-aircraft gun

The ZSU-23-4 (Zenitnaia Samokhodnaia Ustanovka 23-4) first claimed its fame over the skies of the Sinai Desert in the hands of the Egyptian Army, during the 1973 Yom Kippur War, where it claimed 30% of the aircraft lost by the Israeli Air Force. First designed in the late 1950's by the Astrov KB design bureau, and based on the PT-76 light amphibious tank chassis, the ZSU-23-4 entered Russian service in 1965, and was given the name "Shilka."

The Shilka replaced the clear weather ZSU-57-2 in the front-line Russian units, and was issued on the scale of four ZSU-23-4 per motorized rifle and tank regiment. The Shilka is often used together with SA-9 or SA-13 batteries, and usually operates in pairs with approximately 300 to 700 feet between individual vehicles. The Shilka is now being supplemented in Russian service by the 30 mm 2S6M Tunguska system (see entry in the section titled "*Flying Telephone Poles*."

The main armament of the ZSU-23-4 comprises four AZP-23M 23 mm cannon (basically the same cannon as the ZU-23), with an elevation of 85°, and 360° turret traverse. The gas operated, water cooled cannons have a cycle rate of fire of 1,000 rounds per minute, but the ZSU-23-4 can only engage targets with one or two of its four cannons. The ZSU-23-4 normally fires in bursts of three to five, five to ten, or a maximum of 30 rounds per barrel. The muzzle velocity is 3,200 feet/sec. Each vehicle is equipped with a total of 2,000 rounds of ammunition, held in 40 boxes of 50 belted rounds each. Each ammunition belt consist of one API-T round and three HEI-T rounds in sequence. Hence, for each tracer that you see, a total of four rounds have been fired.

The RPK-2 fire control system consists of the radar, sighting device, computer, and stabilization system. The J-band 1RL33M1 "Gun Dish" radar has a tracking range of 6nm., and is subject to ground clutter interference when used against low level targets flying at 600 feet altitude or below. In heavy

ECM environment, the gunner has the ability to revert to using an optical sight. Although the ZSU-23-4 can fire on the move, its accuracy is reduced by up to half.

The Shilka equips many combat and support units, and will usually engage targets below 7,000 feet in altitude. Although the range is limited, the radar guided guns can be highly accurate at close ranges, and the large volume of fire makes this a very serious threat to low level attackers. The ZSU-23-4 normally travels at the tail end of the armored columns, so if you destroy the tail end of the column first, you will usually neutralize the organic air defenses (other than the MANPADS), and can deal with the rest of the vehicles at your leisure.

M-1992 Twin 30 mm Self Propelled Anti-Aircraft Gun

Figure 162: M-1992 30 mm SPAAG

The M-1992 twin 30 mm SPAAG is an indigenous North Korean development. The gun system is mounted on a ZSU-23-4 variant chassis, known as the AT-S full tracked chassis. Externally, the M-1992 SPAAG resembles the ZSU-23-4, but armed with only 2 guns. The 30 mm cannons fire at a cyclic rate of 800 rounds per minute, although heating problems will limit the practical firing rates.

The AA gun is radar guided, and the fire control radar is similar to the "Gun Dish" used on the ZSU-23-4. Although it is not known if the radar has the same surveillance and tracking ability as the "Gun Dish," the RWR signature is similar to that of the ZSU-23-4, with similar aural tone and RWR symbology. The guns may be elevated to an angle of 85°, and fires HEI-T tracer rounds. As with other small caliber AA guns, the rounds are equipped with impact fuses. The accuracy of this SPAAG system is limited against modern aircraft, but the wide proliferation of this system amongst the DPRK forces means that the chances of encountering it is high.

The M-1992 equips the DPRK mechanized forces, and together with the SA-7, forms the organic air defense capability of such tank forces in the North Korean Army.

FRIENDLY ANTI-AIRCRAFT ARTILLERY

Daewoo K-200 20 mm Self Propelled Anti-Aircraft Gun System

The Daewoo K-200 air defense vehicle is an indigenous South Korean effort at equipping its mechanized forces with an organic low-level air defense capability. The design concept is similar to the M163 Vulcan air defense vehicle. The KIFV (Korean Infantry Fighting Vehicle) based vehicle has a one man operated powered turret, adapted from the Vulcan M163 vehicle. The turret is equipped with the six barreled M168 Vulcan cannon.

Figure 163: K-200 20 mm SPAAG

The gun is capable of cyclic firing rates of 1,000 and 3,000 rounds per minute. The lower firing rate is used against ground targets, while the higher firing is used against aircraft. The M168 cannon can be fired in bursts of 10, 30, 60, or 100 rounds. Gun elevation is from -5° to +80°. The ammunition load is 1,850 rounds. The gun fires the M53 APT, M54 HPT, M56A3 HEI, and M242 HEIT rounds. Typical muzzle velocities are about 3,500 feet/sec.

The fire control system consists of a signal current generator, fire control radar, and a gyro-stabilized lead computing gun sight. The EMTECH AN/VPS-2 I-band pulse doppler range-only radar provides range information. The gunner acquires the target visually and tracks with the lead-computing gun sight, while the radar supplies the range, range rate, and angular tracking of the optical line of sight to drive the signal current generator. With this information, the lead-computing gun sight computes the future target location and adds the required super-elevation to hit the target.

The K-200 air defense vehicle is normally deployed as an organic low-level air defense asset for HQ and mechanized forces. It also equips dedicated AAA battalions that are normally deployed around friendly airstrips, cities, and major infrastructure. The large number of these vehicles in a dedicated air defense battalion means that an incredible amount of fire may be brought to bear on any low level attacker, and this is an extremely serious threat to airplanes flying below 7,000 feet in altitude. The radar has a tracking range of about 7nm., providing ample notice of the presence of this vehicle for avoidance actions to be taken. Medium level or stand-off tactics should be used against targets defended by K-200 air defense battalions. Low level delivery profiles will often bring the attacker into the heart of the engagement envelope, and the radar guided guns will bring about rapid demise to any attacker fool hardy enough to try such tactics.

PART

III

DESIGNER'S NOTES

This section contains information on how the various changes in the Realism Patch are implemented. The design considerations and technical implementation are elaborated on a topical basis. The inner workings of F4 that we discovered during the course of creating the Realism Patch will also be elaborated.

I CAN'T HEAR YOU !

Communication Fixes
By Kurt "Froglips" Giesselman

COMM FILE FIXES (FROM POOGEN)

After the 1.08US fixes, the following four items did not work correctly:

First, the "Vector to Target" request always resulted in the same response, "bearing 300," no matter where the threat was located. The commFile.bin was changed so that you will now get the correct response for the "Bearing to Threat."

Second, the "Vector to Tanker" request would always result in the response of "Merged PLOT." Both the commFile.bin and the falcon exe files were changed to get the response of the flight bearing to the tanker.

The Airport Identity bug resulted in no base identification in response to requests for tower instructions. All you would get were directions to the airfield but if you had forgotten the briefing or had to go to an alternate landing area, you would not know what TACAN settings to input. This was corrected by changes to the Falcon.exe and the evalFile.bin. The exe now calls the correct Airport ID from the evalFile.bin. Now when you request instructions from the tower, it will first properly identify itself before giving the instruction. For, example if you request an emergency landing you'll receive something like, "This is Haemi Tower, cleared for immediate landing on runway ###, notifying the SOF. Good luck, sir."

As for the last fix, it seems that if you were a flight with an ID number larger than one (example: Cowboy **3**-1), the comms call "Say Position" would yield: "Cowboy 3-2, Cowboy **1**-3, say position." This has now been corrected with all elements in a package being correctly identified.

THE INVULNERABLE VEHICLES

Solving The Mystery of The Invulnerable Vehicles
By Alex Easton

PREAMBLE

There has been a long-term problem of vehicles being invulnerable to cluster bomb attacks when placed at double-runway bases. An additional manifestation of this problem is that most SAMs (with the exception of the SA-2 and Nike) explode on the launcher and won't launch.

This is a problem with ALL airbases, but for the single-runway bases, MPS had already moved the positions air defense vehicles take up off the edges of the base, so solving the problem. The double runway bases were by-and-large untouched, and the problem remained. The same solution has now been implemented at double-runway bases.

The opportunity was taken to improve the dispersal of air defense units at other military bases and to correct some obvious errors in the taxiing data for some of the bases.

There are two types of entry for vehicles in an air defense unit - AAA/support and SAM/support. The former was intended to be used but are currently inactive. They may be able to be activated at a later date. The second is a real mess. At airbases, MOST air defense units use only the "support" and "radar" positions, where the RDR VCL slot in the FALCON4.UCD file places all units in that slot into the radar position. However, SOME vehicles use the "sam" positions - the SA-8, Stinger squad, K-200. For military sites other than airbases, all units use all of the positions (sam, radar AND support) without distinction in the sequence that they appear on the file. At non-military sites like towns, there is no positioning data and the units take up pre-determined formations.

You can examine a typical dispersal by over-flying a site, recording it on ACMI and then viewing using the satellite view.

Sylvain and Joel have also independently solved the cluster bomb problem by adjusting the cluster bombs to treat proximity damage better. You will still damage the runway, taxiway or lights with cluster bombs, but this will no longer protect the units stationed within the boundary box of the base. So even combat units, which can straddle the base, and taxiing aircraft are now vulnerable to cluster bomb attacks.

CHANGES IN REALISM PATCH

Falcon4.phd file

Entry no 31 for Osan was changed to type 4 - i.e. from a helicopter-type entry to a sam/support-type entry.

Falcon4.pd file

Double runway airbases

1) Moved SAM, AAA, support and radar positions to the edges of airbases to enable ALL SAMs to launch and make the vehicles vulnerable to destruction by cluster bombs
2) Arranged in positions to improve the effectiveness against attacks from all directions but particularly runway bombing approaches
3) Arranged in positions to reduce vulnerability against cluster bomb attacks
4) Corrected obvious errors in taxiing data for aircraft

Single runway airbases

1) Adjusted slightly some SAM/support positions further from the base to allow maneuvering by vehicles while keeping them vulnerable to destruction by cluster bombs
2) Reorganized AAA/support positions (currently unused) in case they can be activated at later date
3) Corrected obvious errors in taxiing data

Osan airbase

Changed the pd entry, which listed 13 helicopter landing/take-off positions (an obvious error) to SAM/support positions and arranged them as for a double-runway base.

Highway strips

1) Moved vehicles further from runway so as not to intrude on the strip
2) Gave them better dispersal
3) Arranged them as far as possible so as not to overlap with combat/support units also placed at the base.

Depots, Radar sites and Army bases

1) Dispersed units to make them less vulnerable to a cluster bomb attack
2) Spread them round the approaches to the site so as to provide better defense against attacks from all directions
3) Moved them away from buildings so as not to overlap buildings and make them less vulnerable against attacks on the targets at the site

Outstanding Problems

1) There is still a problem with combat units based at airbases sometimes straddling the base and thus preventing their own SAMs such as the SA-15 from firing
2) There remain some anomalies in the taxiing data for some bases. This may occasionally result in odd behavior during taxiing of AI-controlled aircraft.

To Do List

1) Reorganize slightly dispersal patterns at ports (there are cases where vehicles overlap each other and structures at the site)
2) Investigate possible errors in taxiing data for some sites (the uncorrected "errors" may not be errors, but if they are, they may be the cause for some strange behavior of aircraft at some bases)
3) Investigate effects of small changes in helicopter landing positions (currently only #1 lands and the rest of the flight hover near the landing sites)
4) Investigate how to activate the AAA/support positions
5) Investigate why some vehicles can occupy the "sam" positions, while MOST occupy only the "support" positions.

STRUCTURE OF THE PHD AND PD FILES

Here are some of the things in the PhD and Pd files that I am sure of - or not so sure of! Of course, there may be more than one effect from each of the entries, but here is what I have been able to identify. It is clear to me where MPS was heading with all this stuff. It is also clear that they did not finish it.

PHD Entry

Pd - counter for number of sets of positional data in the entry
Pd Ptr - entry in the Pd file which contains positional data
chain - the next entry in the chain for that objective. Equals zero for last entry.
Heading/L/R - corresponds to "instructions" from ATO on which runway to land
Rwy No - Probably relates to position on which AI plane appears
Type - relates to type of data in Pd entry
Feature (6 boxes) unknown
sin/cos (hdg) the sine and cosine or the heading (in degrees). Use unknown.

Entry Types

1 : Taxiing/takeoff/landing data for AI
4: Positions of vehicles in SAM battery
5: Artillery positions
6: Positions of AAA air defense vehicles (apparently not used)
8 : Runway ends
11: Boundaries of "parks." Use unknown
14: Positions for helicopter landing/taking off.
16 : Defines a small dock at a port. Possibly for positioning ships in a port.

Position Types

X and Y refer to positions in feet from a local origin. X-axis is E-W and Y-axis is N-S. "flags" delimits the first and last in the list.

1: "runway" far end of runway. Probably point to be aimed at along runway for AI planes taking off. Or "touch-down point for AI planes landing

2 : "takeoff" point at which AI plane holds before take off

3: "taxi" Taxiing sps for planes preparing to take off, or taxiing after landing. Route traveled in reverse on taking off/landing. Planes "disappear" on reaching last point, and "appear at one of these points depending on number of other planes in the queue to take off.

4: "sam" For use by launchers in SAM batteries. Currently used for most vehicles in an air defense battalion

5: "artillery" Defines positions of artillery vehicles at a HART site

6: "aaa" presumably intended for use by guns in AAA battery. Apparently not used.

7: "radar" Exclusive slot reserved for vehicle in "Rdr Vcl" slot defined in unit file. Not used in non-AD units, and used by SOME vehicles in air defense batteries even if Rdr Vcl is not set.

8: "runwayDim" marks out ends of entire runway. Use unknown, but maybe landing/taking off data for AI or positional data for runway strobe lights??

9: "support" In AAA and sam entry, presumably intended for support vehicles. Apparently not used in AAA entry, but used for all vehicles in SAM entry.

11: "small park" Defines boundaries of a "small park" or area. Use unknown

12 : "large park" Defines boundaries of a "large park" or area. Use unknown

13: "small dock" Defines boundaries of a "small dock" at a port. Presumably positioning data for placement of (small??) ships

14: "large dock" Defines boundaries of a "large dock" at a port. Presumably positioning data for placement of (large??) ships at a port.

15: "take runway" point at which taxiing plane turns onto runway, or landing plane turns off runway onto taxiway

16: "helicopter" positions from which helicopters take off and land at a site.

DOCKING SHIPS AND BOATS

Correcting Docks and Piers in Falcon 4
By Alex Easton

PREAMBLE

One of the problems in Falcon 4 is the position of ships at ports. The ships are often docked perpendicular to the piers, and very often, cut right across the pier structure. This is best illustrated in Figure 164. This stems from the way Falcon 4 interprets the data for docks. In the Realism Patch, this has now been changed, and extensive changes were made to all ports and docks. All the changes are made to the FALCON4.PD and FALCON4.PHD data files.

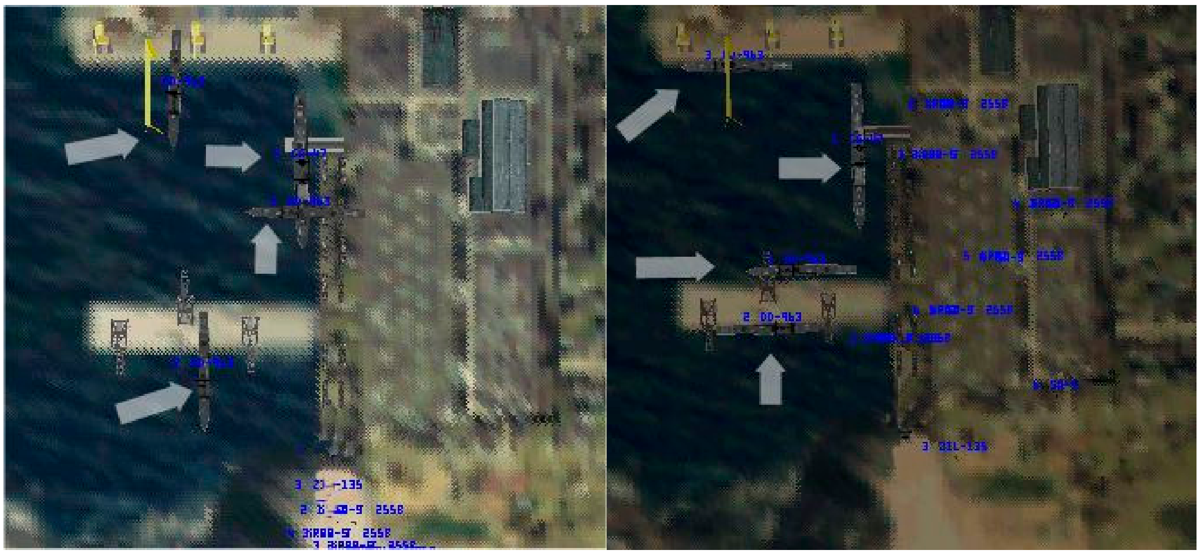

Figure 164: Positional changes made to docks and ports to correct docking discrepancies. The left screen shot depicts the original Falcon 4 docks (the gray arrows pointing out the inconsistencies), while the screen shot on the right depicts the corrections made in the Realism Patch.

CHANGES MADE

12. The data for small docks were removed. The way the game sees this is erratic. For example, if the PD entry begins with a pair of data for small docks, **all** docking data in the entry is ignored and the ships form up as if they were out at sea. On the other hand, if the entry starts with a pair of data for large docks, **all** data in the entry are treated as data for large docks. Therefore, all the dock data were changed to "large dock" to avoid inconsistencies.

13. Most ports have 4 docking positions in the port. The exceptions are Nachoda, Vladivostok, Nampo Naval Base, Haejo Shipyard and Tasa-ri Naval Base. These ports have two docking positions each. If more ships are placed in a port than there are docking points available, the remaining ships will form up as if they were at sea.

14. Two ports are wrong up because MPS placed the port in the wrong position, thus placing the wharves and docks on land. The piers do not reach the sea. Mokp'o is one of the ports. Ships at these ports are placed further out in the bays and not against the wharves.

15. Because different sized ships can occupy docking positions, there is a choice of either:

a. placing the small ships against the wharves, but with the penalty that the big ships will overlap the wharves
b. placing the big ships against the wharves (and under the cranes), with the penalty that the smaller ships will have a gap between themselves and the pier.

I have chosen the second because then nothing looks bad, and ships often do sit at some distance from the dock if they have finished unloading. The widest ship in the game sits tight against the pier/wharf.

16. Each docking position consists of two sub-positions. The first defines the center of the position, and the second defines the point at which the ship is pointing when docked.

17. The dispersal of the vehicles in the Air Defense Battalion posted at the docks has been improved in the same way as for the airbases and army bases.

18. The major remaining problem is with the aircraft carrier. This is currently too big to fit into any port.

19. The following ports are used by the OCD entries:

00C : Nachoda, Vladivostok, Namp'o NB, Haejo S/Y, Tasa-ri NB
66D : N/W Seoul
731 : Mokpo
795 : Incheon
79A : Chodo-ri NB, Pusan S/Y
79B : Mayang NB, Wosan, Pusan port
79D : Sinp'o
79E : Namp'o S/Y, Nanam, Hamhung
7A0 : Najin, Pohang, Dahaitsu
7A1 : Toejo NB, Sagon-ni NB, Chongjin, Pupo-ri NB
7A6 : Kosong NB
7A5 : Pipa-got Submarine base
7A2 : Kinchaek NB

CORRECTING THE GOLDEN BB

Air Defense Changes in Realism Patch
By Alex Easton

CHANGES TO SAMS/AAA

1) Up to now, there has been an abrupt reduction in the range of air defense systems at the altitude of 10,000ft. For example, at 10,100ft, the range of the SA-15 is about 4.5nm, while at 9,900ft, it is 1.5nm. This is completely unrealistic and allowed unrealistic tactics to be developed. Typically, the range is reduced to one third below 10,000ft, but this was only approximately true for some systems, depending on the settings of the air and low air hit chances in the weapons file.

In Realism Patch version 4, this discontinuity as been halved. Taking the above example, the range below 10,000ft has been increased to 3nm.. For future patches, each system will be investigated individually to try to achieve the maximum realism for each system, but in RP4, the interim measure has been taken to reduce the discontinuity by half.

Changes Made

In FALCON4.AII file, the parameter `LowAirRangeModifier` has been increased from 33 to 66

2) As far as it goes, the flak AAA is well modeled in F4, but there are some serious limitations in the modeling. One of the main deficiency is that the probability of a hit is the same for short and long slant ranges. This means that you are no safer at higher altitudes and longer horizontal ranges than you are low down and close to the guns.

In addition, although it is safer to keep your speed high simply because you spend less time in the weapon's engagement zone, there was no difference in the probability per second at low and high speeds.

Sylvain Gagnon has produced an EXE patch that lowers the probability of a hit when the speed of the target is high, and the probability reduces progressively with increasing slant range to the target. Although this does not increase the survival rate when jinking, especially at large slant ranges, it does improve the survival rate at all times when the slant range and/or speed is high.

3) Previously, the radar would only switch on and the guns start to "fire" when the DPRK AAA unit deaggregated at 6nm. This curtailed the maximum horizontal range of the KS-19 from 7.5 to 6nm. and meant that there would be no warning on the RWR before the guns started to "fire." This problem has been addressed by increasing the UDD for the unit to 8.5nm and the Firecan AAA radar range extended to 14nm

With these changes, the KS-19s will begin to shoot at you earlier than before when you are below 25,000 feet, but the reduction in horizontal range with altitude means that above this altitude, you will see no change other than an earlier warning on your RWR. The other guns have engagement ranges that are less than 6nm. and so remain unaffected.

Changes Made

Firecan radar range increased to 14nm.
UDD for DRPK AAA unit increased to 8.5nm.

4) The setting RDR VCL in the unit file has some consequences in addition to protecting vehicles in the slot from "disappearing" at low object density and force level settings.

Firstly, at airbases, the units in the slot defined by RDR VCL sit on a dedicated radar position around the airbase. If there is more than one vehicle in this slot, all the vehicles will sit directly on top of each other and can all be destroyed by a single Maverick shot. Secondly, if the vehicles in this slot are all destroyed, any remaining radars in the battalion will cease to operate.

This is acceptable for units such as the SA-5, where the single vehicle in the RDR VCL slot is the Barlock-B radar vehicle. When this is destroyed, the SA-5s cannot launch, and this is how it should be. It is also acceptable for units with no radar-carrying vehicles, where RDR VCL is set at 255. But for units like the SA-15 battery, knocking out both vehicles in the RDR VCL position will turn off the radar on the surviving launchers and prevent them from firing. The whole unit can therefore effectively be neutralized with one shot.

The partially effective solution is to set the RDR VCL at a carefully chosen "virtual slot." There are only 16 REAL slots -(0 - 15) and setting RDR VCL above 15 will mean that there is no real RDR VCL slot, so nothing will be placed in the dedicated radar position around airbases. But there will still be some real, occupied slots which, when the vehicles contained in them are destroyed, will shut down the remaining radars in the battalion. This appears to be unavoidable without exe hacking, but we have optimized it by choosing a virtual slot for the RDR VCL that puts a number of well-dispersed vehicles in the critical slot - the one which will shut down the radar if emptied. It will therefore no longer be possible to shut down the radar in the battalions listed below with a single shot, and on average at least half the launchers/guns have to be destroyed before the radar shuts off.

For combat/support battalions containing radar-carrying vehicles such as the ZSU-23-4, the RDR VCL is correctly set at the slot containing the SAM launchers (e.g. the SA-15). The SAMs can only be prevented from launching by destroying all the launchers - which is how it should be.

The ROK K-200 AAA battalion has been rearranged to put a larger number of vehicles in the critical slot, making it less vulnerable to having its radar shut down with a small number of hits.

Changes Made

DRPK KS-19 AAA battery : RDR VCL = 20
DPRK SA-15 SAM battery : RDR VCL = 21
DPRK SA-8 SAM battery : RDR VCL = 17
DPRK Towed AAA battery : RDR VCL = 20
ROK K-200 AAA battery : RDR VCL = 17

Ordering of the K-200 AAA battery
slot 0 - 3xK-200
slot 1 - 3xK-200
slot 2 - 2xK-200
slot 3 - 3xM-977
slot 4 - 3xM-977
slot 5 - 3xM-113

5) The tracer-type AAA for some of the guns have their effectiveness reduced by too much in RP3. With more knowledge about how the F4browse parameters "blast radius" and "rate of fire" work for different classes of weapon, we have been able to set values that give these guns more realistic performances. The problems were with the ZSU-23-4, the ZU-23 and the K-200 vehicles carrying the 23mm and 20mm AAA tracer-type guns.

Changes Made

GUN	Blast Radius	Rate of Fire
12.7	3	2
14.5	4	2
20mm	69	8
20mm (RG)	139	8

23mm	65	6
23mm (RG)	130	6
30mm (RG)	302	6
25mm	50	3
All small arms	2	2

6) As mentioned in the section titled "*The Invulnerable Vehicles*," the dispersal patterns for air defense systems around military targets - airbases, depots, army bases and radar installations - have been changed to enable these units to better defend the site and render them less vulnerable to mass destruction by cluster bomb attacks.

CHANGES TO AAA ACCURACY

One of the problems that we have experienced during the development of the Realism Patch is the difficulty in achieving good performance for small caliber AAA at lower altitudes. The AAA vehicles such as ZSU-23-4 and the K-200AD were not achieving any degree of accuracy, and we were able to fly around at low altitude in lazy circles and not get hit.

In addition, flagging any vehicle as "Air Defense" does nothing to improve its accuracy, but instead decreased its accuracy. The guns will also stop firing under 3,000 feet in range. This allows the planes to fly in at low level below 3,000 feet altitude and not have any air defense guns shoot. As a result, most of the low altitude hits were actually scored by Ak-47 rifles.

With the Realism Patch, these have now been changed as follows by Sylvain Gagnon's exe patch:

1. Increased gun accuracy. F4 was aiming the guns with gravity compensation, which is not necessary. F4's default aiming algorithm reduces the z-axis velocity but let the x and y axis velocities remain, and as a result, lead to a very low accuracy. The trajectory of the bullets and rounds are still subjected to gravity though.

2. Firing rate of guns have been increased. Default 1.08US fires in bursts of 3 rounds, with 6 to 20 seconds between bursts (depending on skills). With RP, the guns will fire at 0.5 second interval between bursts, until the target exits the engagement zone. The guns will however wait for 6 to 20 seconds (skill dependent) after you have entered their engagement zone before commencing initial firing. Shells are fired at two every second.

3. Some randomness is introduced to air defense guns such that they will not be shooting in a linear pattern but the tracers will have a dispersion pattern of a few hundred feet around the target.

4. The weapon selection criteria in RP is such that if the weapon is a gun, the target's range in kilometers must be less than $1/11^{th}$ that of the gun's range, or less than 2 km. If $1/11^{th}$ of the gun's range is more than 2 km (i.e. the gun has a range in excess of 22 km) it will be skipped.

5. Varying muzzle velocities for each gun, and time-to-live for the bullets. This allows the bullet speed and time-to-live for every gun be customized.

6. Varying skill ratings for the air defense artillery crew. The accuracy of the AAA is multiplied by the skill factor, which is 0.57 for recruits, 1.29 for cadets, 2.29 for rookies, 3.57 for veterans, and 5.14 for aces.

This produces a huge increase in low level small caliber AAA fire, and with great accuracy. Your best way to survive is to jink constantly, or better still, avoid it altogether.

The Changed Battlescape

Background and Philosophy of Ground and Air Unit Changes
By Jeffery "Rhino" Babineau

Changes Made to Ground Units

Significant work has been done to duplicate battle formations as best as Falcon 4.0 will allow. No unit fights pure. There is always mutual support from other units in the battalion. In all cases this is mission directed. Engineer units are commonly assigned to attacking units to support the breach of obstacles used for defenses and cross bridges. In the defense, engineer units prepare the defense but are then held back as these are mostly lightly armored vehicles, if they are armored at all.

In the case of rocket units (MLRS, BM24) and SAM units, we decided to split up the unit to reflect a deployed battery instead of a deployed battalion. In no case that I can think of is a SAM battalion all placed in one location. In the Falcon 4.0 world that location could be one sq. km. Now you can take a SAM battery and protect a city and another battery to protect another city. If you look at Patriot deployment to South Korea, you will see that we have one Patriot Battalion for the whole county. Where would you place it? Now we have the option to place a battery around Seoul, Pusan, Chuncheon, etc. In all of these cases supporting vehicles have been assigned. SAM batteries are commonly supported with handheld portable weapons such as the SA7 and stinger.

Falcon 4.0 allows a limited number of vehicles to occupy a battalion (the basic unit structure in F4 – also represented as a single UNIT entry in the UCD). The maximum number of vehicles an F4 battalion can hold is 48. There are far more vehicles in a real battalion, but unfortunately we cannot include every vehicle that a battalion would normally include.

The ratio of non-combat (trucks, etc.) to combat vehicles (tanks, IFVs) is now quite balanced, beginning from version 3 of the Realism Patch. In addition, different nations organize their battalions differently. We are lucky, that in some cases, eastern forces (DPRK, China) tend to copy the Russian model. Western units (ROK) in F4 copy the US model. There are significant differences in the number of combat vehicles included a Russian maneuver unit and a US maneuver unit. Russian units tend to have 30 combat vehicles while US units would typically have 58. What Falcon allows is a reasonable representation of Russian type units, while only allowing about 2/3 of a US style unit.

The modifications incorporated since Realism Patch v3.0 are meant to bring the battalions into a "realistic" representation of their real world counterparts, and to balance the ratio between the different types of units.

We have also found that the force ratio slider has an impact on the amount of these vehicles when deployed. This could have potentially serious effects. You can inadvertently leave significant vehicles out of the unit by moving the slider one way or the other. Imagine a Mechanized task force with no tanks! We had originally designed these units around how they would typically deploy, as we knew that F4 moved them in column formations. Now we must arrange them based on slider settings. Slider 0 would only use vehicles in UCD slots 0-6. Slider position 6 will use ALL the vehicles resident in the UNIT UCD record. When you create your campaign difficulty settings, please be aware that the center setting is based on "most accurate size" for both ground and air units.

Example: A US Armor battalion has approximately 58 tanks. In F4 if the unit were totally pure with tanks, it could only have 82% of its full strength. However it is typical that at least one company of tanks gets cross attached to a mechanized battalion and one company from that mechanized battalion gets attached to that Armor battalion. Now we have 42 tanks, and 14 IFVs or 12 platoons of tanks and four platoons of IFVs. Also hindering our effort is that Falcon will not allow you to place more than three vehicles in a UCD entry slot and the US units deploy in platoons of four. Therefore, we now end up with cutting the US unit back further as each "slot" in F4 can be called a platoon. But with all the support vehicles that are still needed like scouts, mortars, air defense attachments, trucks, and HUMWVEEs, the US battalion is shrunk in combat power even further.

CHANGES MADE TO AIR UNITS

Starting from version 3 of the Realism Patch, changes were made to the squadron sizes to reflect actual order of battle. The air units (squadron size) used in F4's campaign by default are 24 aircraft in size. Recent research has discovered that Russian squadron sizes are in-fact smaller. Information gathered from references in the 80's show Russian bomber units of only nine aircraft. Russian fighter and fighter-bomber units are typically between 12-15 aircraft in size. Looking at current force structures of the Hungarian Air Regiments used in Kosovo confirms these numbers.

In fact, even US squadrons have reduced in size, with the average USAF fighter squadron now with 18 aircraft and not 24. In some cases, you can still find larger sized squadrons but in most situations, you will find smaller unit sizes.

Other aircraft unit sizes are surprisingly small too. It is a matter of simple math - there are 606 C-130 aircraft in 40 squadrons. This averages out to be 15 aircraft per squadron and not 24. ROK, DPRK, CHINA and the rest are assumed to use their allied squadron organizations, which means that they adopt the squadron sizing constructs of their "big brothers" – the US and Russia.

We also know that Falcon 4.0 does not, and probably could not, do a Korean War on a 1-for-1 basis. Over 200 J-5 aircraft (Mig15, 17 types) are not even depicted, but since we have now allowed the MIG19 to perform the same missions as the J-5, we have accommodated and implemented a lost but vital part of a war in Korea. Numerical superiority in the DPRK is prevalent in the number of squadrons available in F4. Falcon currently does a good job of showing more DPRK units than NATO. Chopper units in the real world, in some cases, are actually much larger than F4 allows. However, the attack helicopter units on both sides are well represented.

Although maintenance and repair is a critical issue, it was not used for consideration. Poor countries sometimes have such a poor military budget that they just cannot keep their aircraft flying. It is arguable that of the 60 or so MiG-29s the DPRK has, only about 30-40 are combat capable at any one time. Most of the DPRK fleet is older, outdated, and near museum pieces from the 50's and 60's. Although the fleet has been modernized through the years, and is rumored to actually be licensed builders of the MiG 29, the DPRK does not throw away any aircraft. An air war in Korea will still feature MiG-15s, even today.

The campaign force slider can change the number of aircraft in a campaign slightly. In building these units, we recommend a middle slider setting to get the most realistic known squadron size. The force slider is bugged in that it will not stay where you put it. Move the slider one notch to the right and it will then move to the center position.

The UCD (unit) modifications were built with force reductions representing real world known aviation unit sizes. Where unknown, we used "lie" units - the DPRK would use Russian types and ROK would use US types. Force sliders assumed to be centered with no more than 25% changes from low to mid or mid to high.

CHANGES MADE TO SQUADRON STORES:

Merely updated to support new units in the squadron/battalion and new weapons on those aircraft or vehicles.

ABSTRACT COMBAT

Fighting in the 2D World
By Jeffery "Rhino" Babineau

Abstract combat exists when weapons that have no flight model, no collision bubble, no seeker head with sensors, and yet still have blast areas and damage values, are used in combat in the Falcon world.

We know that combat exists because in tank vs. tank combat, we can see tanks exploding but no objects flying through the air. We see tracers but these are only graphics and have no effect on the combat at all. We know this because we can change the graphical effects to portray a single shot weapon and the combat will still resolve in the same way. This effect governs the sounds played as you view the object.

A review of the CT file in F4 shows that all objects that fly through the air are classified as AIR VEHICLES. These weapons will only fire when they are deaggregated. This is why you are always seeing this type of activity. If you did not enter the bubble of the ground unit, he would execute his abstract combat and use calculated results. This type of war has also been called the "statistical war."

However, your entrance into his bubble triggers the unit into launching his "air vehicles." Prior to the deaggregation process, they remain in abstract combat. Every time you break into the deaggregation bubble, you will see missiles fire. This effect is entirely eye candy. It is not necessary to resolve the combat. In rocket combat, we have always seen that rockets will fly through the air and airburst. However what most people fail to see is that combat is still resolved on the ground at a cost of lower frame rates, which is arguably less realistic, because the chance a combat pilot will see a surface-to-surface rocket or missile flying through the air is quite remote.

We also get some very unrealistic missile side effects such as: 1) flying incorrectly and bursting in the air 2) only fire when its deaggregated 3) fires directly into any object it is placed behind (i.e. friendly fire). In testing this concept we placed all surface-to-surface missiles in an abstract category like tank guns and found that all combat was resolved and vehicles received damage and they were removed from play even at extended ranges outside of current ranges. Frame rates improved in some cases 100%, rockets no longer destroyed the city they were protecting. So we decided that we would place most all of the ground weapons in this abstract category. Surface combat is now nearly 100% "abstract" and happens all the time in the game, in the bubble, out of the bubble, when it actually happens.

One of our concerns was aircraft that launch "abstract" weapons. This cannot happen. It will crash the game. However, the only aircraft that actually fire ground-based missiles are helicopters. Currently F4 will not allow helicopters to fire. The immersive feel that we've all come to expect in Falcon4 is still there. In the future with faster CPU's and continued development of the RP, we can continue to deploy new individual surface-to-surface missile flight models and warhead/seeker heads and allow them to be seen in the Falcon world and engage accurately as their real world counterparts.

The missiles changed to abstract combat were the AT-3, AT-4, AT-5, Dragon, LAAW, 122mm Rocket, MLRS, 240mm Rocket, and 57mm Rocket.

Blast and Damage Models

Understanding the Blast and Damage Modeling in Realism Patch
By Jeffery "Rhino" Babineau

Design Considerations

A formula was used to take into account the weapon's warhead size and type in proportion to all similar types. The formula was used to ensure correct relative values between similar types. Some items could, perhaps, be more researched to determine if 6kg of C4 is more powerful than 6kg of TNT (I did not go that far....yet!)

You will find damage values that will look blatantly wrong at first glance. It is then that you need to understand that all damage values have different effects based on their damage type. Air blast is different than GP/HE blast that is again different from incendiary and armor penetration. Even penetration alone has very different determining values that Falcon may not understand. Armor penetration from tank to tank is very different than armor penetration of bomb to ground. So ultimately we end up with data and values that need to be translated into the Falcon world.

In some cases, we are talking pure art, feel, or gameplay. In others it is a cold and hard fact that this tank gun *will* penetrate that tank. Now in tank vs. tank damage, we need to look at the *vast* differences in armor types and penetrators. Shaped charge weapons, i.e. AGM-65B's, HEAT penetrate very differently than do 120mm APFSDS kinetic rounds. On the other side is the effect that standard hardened steel offers much less protection against HEAT rounds than does composite armor like the M1A1 and reactive armor like the T80's normally carry. However, both of those types of armor do not offer any significant effect to a standard APFSDS round. There is only one case in the world, that I know of, where a composite armor offers both chemical and kinetic protection, that is the depleted uranium (DU) armored M1A2.

Also, the armor on a tanks frontal arc is vastly different than the armor on its roof, sides and rear. Luckily Falcon accounts for this by allowing damage to accumulate on the target. A T-55 unit could pound a M1A1 unit all day in the frontal arc and never kill a tank. In Falcon it will end up getting kills. I think this is a good tradeoff to simulate the effects of maneuvering for side and rear aspect shots.

Now in the case of air dropped munitions, we need to understand that although they may be exclusively shaped charge weapons, with relatively little penetration (3 to 7 inches), they are tasked with raining down on the most unarmored part of the tank. I say "tanks" in most of this discussion. They are on the far end of the armor spectrum. Most APC's and IFV's are so lightly armored that, in most cases, troops ride on top of them to get out quickly *when* they blow up because nearly every weapon in the world can kill an APC.

Now, with all this being understood, you will find in some rare cases weapons do not fit into my "formula" for all of these described reasons. And let us also remember that in fact APCs do offer protection from small arms fire and most artillery fragments. It only takes 1.5 inches of hardened steel to stop the shrapnel of a 500lb bomb at 10 feet from impact. Most APC's have about 1 inch and in the case of almost all OPFOR vehicles, 20mm and *less*. Yes, in fact it is true. A .50 caliber or 12.7mm AP round will penetrate one of these vehicles at close range. Another reason why ZSU 23-4's are nasty house-to-house weapons as well as AAA terrors.

Addendum: Different weapons have different characteristics and F4 allows different TYPE warheads. GP/HE is calculated based on shear *mass* of weapon. AP or armor piercing is calculated on *armor penetration* value. Bullets are also calculated differently. Each target in F4 has "vulnerability areas' against each weapon type. In an extreme example, a Durandal has an *anti-runway* warhead in F4. If the target, i.e. a BTR-70, has a Vulnerability of 0 against *anti-runway*, the target would receive little if any damage effects at all.

Some people might get confused as to why a 2000lb bomb has less "blast" than a Maverick. Answer: 2000lbs of C4 is different than 1000mm of High Explosive Anti-Tank. (a shaped charge weapon).

The Maverick G is a "penetrator" much like the BLUs. It is a HE round encased in more steel to allow it to get deeper into concrete bunkers and dug in emplacements, but it is not a "shaped charge" explosive.

Blast areas for shaped charges are much smaller due to the fact that the explosion is manipulated to cause overpressures in the millions of pounds per square inch. This provides the energy to punch a 20-30mm hole through up to 4 feet of steel and *not* to disperse it's energy over a wide area like an HE round. The shaped charge also needs enough BAE (behind armor effects) to cause damage to equipment and crew. Punching a hole is meaningless unless it can ruin a crew's day.

It is also very likely that MPS used its blast radius more for the F-16. There are minimum safe altitudes to drop ordnance. These altitudes are based on less than a 1-10% chance of doing any damage to your aircraft. Those tables are easily found. In the Falcon world, this is translated into weapons that equally distribute their damage over an area and (this causes large weapons to have large damage values) destroy or disable formations of vehicles where in reality they would need a direct hit to destroy the vehicle. Although this is a speculative assumption, I am guessing that minimum safe altitude is lower now.

EFFECTS OF NAPALM AND THE REDUCTION OF ITS DAMAGE VALUE

The effects of napalm were toned down based on extensive research on its true effects. The following passages, re-printed from USAF Intelligence targeting guide AIR FORCE PAMPHLET 14-210 Intelligence 1 FEBRUARY 1998, illustrates:

A6.1.5. Flame and Incendiary Effects. Firebombs can be highly effective in close air support. Their short, well-defined range of effects can interrupt enemy operations without endangering friendly forces. They are also effective against supplies stored in light wooden structures or wooden containers.

A6.1.5.1. **Flame and incendiary weapons, however, are often misleading as to the actual physical damage they inflict**. Even a relatively small firebomb can provide a spectacular display but **often does less damage than might be expected**. When a large firebomb splashes burning gel over an area the size of a football field, it may boil flames a hundred feet into the air. This effect is impressive to the untrained observer, and experienced troops have broken off attacks and fled when exposed to napalm attack. However, soldiers can be trained against this tendency to panic. They can be taught to take cover, put out the fires, and even to brush burning material off their own clothing.

A6.1.5.2. **Near misses with firebombs seldom cause damage to vehicles, and the number of troops actually incapacitated by the attacks is usually rather small**. Incendiaries of the type that started great fires in Japanese and German cities in World War II projected nonmetallic fragments. They had little penetrating capability. Today's newer munitions have full fragmentation and penetrating capabilities, as well as incendiary devices. However, both types can penetrate and start fires and are highly effective against fuel storage tanks or stacked drums of flammable material of any sort.

ARMING THE BIRDS OF PREY

Loadouts and Weapons Changes
By Eric "Snacko" Marlow, Jeffery "Rhino" Babineau and Lloyd "Hunter" Cole

CBU-97 SENSOR FUSED WEAPON: THE SMART TANK KILLER

The CBU-97 was added to the inventory of the USAF.

http://www.fas.org/man/dod-101/sys/dumb/cbu-97.htm

The CBU-97 is a standard weapon that is carried on the F-16, and it's pretty mean - meaner than the Mk-20, as the little sub-munitions in the CBU-97 are "smart" and are guided. The CBU-97 has already seen action in Kosovo. For detailed description of this new weapon, please see the link above.

http://www.afa.org/magazine/0398dev.html

From the Air Force Magazine link above: "No one expects each SFW slug to destroy a target. The goal is to stop the vehicle in its tracks. Latas noted, "The goal is a *mobility* kill, not a *catastrophic* kill." He added, however, "a mobility kill is just as good as anything else, when you can cover that kind of area and affect that many targets per sortie. USAF has postulated three levels of mobility kill, differentiated by how quickly a target stops functioning. Latas said the SFW achieves the highest-level mobility kill currently measured by the Air Force. The SFW's kill probability is classified, but Latas said, "We've seen in testing that, with the current threat, this is going to be a pretty devastating weapon." The Air Force has run more than 111 SFW tests so far and, Wise noted, it has exceeded its requirements.

also of note:

"The CBU-97 is the first multiple-kills-per-pass smart anti-armor weapon in production, said Col. Bill Wise, director of the Area Attack Systems Program Office at Eglin. Wise said it represents a significant capability for combat forces."

and best of all:

"In more than 100 tests of CBU-97s, each weapon, or dispenser, delivered against a representative column of armored vehicles and trucks, has damaged, on average, three to four armored vehicles. Average spacing between the armored vehicles in these columns has been around 50 meters. Thus, for the eight armored vehicles that fall within a single weapon's 400-meter "footprint," we can expect that nearly half of them will be damaged to at least an "availability kill" (or "A-kill") level. This means that some component of the vehicle has been damaged to the extent that the vehicle must be withdrawn from the line of march and repaired before continuing on."

Therefore, in F4 terms, we really must consider an "A-kill" to be a destroyed vehicle. Repair and reinforcement are not modeled. I would expect that for one bomb dropped (no other bombs dropped for fear of damage overlap), I would consider on average 4 T-72 class kills to be appropriate.

ARMING THE PLANES: LOADOUT CHANGES

Falcon has the most realistic loads ever seen in a flight simulation. The scope of the firepower available to the player is awesome to say the least. Each weapon in Falcon is designed for a specific mission profile, whether it is a SEAD, BARCAP, CAS, or Special.

The player can select his loads and configure his plane as he wants and each of these weapons will perform as it is supposed to.

When Falcon was first released, the weapons were somewhat exaggerated in their yield, force, what hard points they were carried on often was incorrect and in some cases, such as the A-10, resulted in the plane being so overweight it could barely take off.

The results left a lot of people questioning the MPS design team. It often left the player with an unsatisfied idea of what a GBU would do to a runway. Sometimes it would take several CBUs to eliminate a runway, where one or two direct hits would knock it out for a extended period of time in reality.

When Infogrames “killed“ Falcon in December 1999, iBeta began the first of the RP series. By using hex editing we were able to redo the weapons and reconfigure what an aircraft was able to carry. The goal is correct weapon on the correct hardpoint on all airplanes.

Through research from sources ranging from Jane’s Information Group, World Air Power Journal, actual Department of Defense and Armed Forces manuals as well as through input from the crewdogs, pilots of the actual planes, iBeta and now the Realism Patch Group we were able to put together a load out sheet for each plane in Falcon 4.

All data we have used to create these patches is **Not Classified**! The weapon performance is documented and available in the public domain. Some of these weapons such as the Nukes like the B-61 and B-83 are semi classified. We know that these weapons are carried by some aircraft like the B-52H, B-1B, B-2A, Tu-22, and Tu-16. These planes were designed to be strategic bombers. We don’t know the exact total of these weapons carried by these planes. And as Falcon 4 does not model the Nukes we have not made them usable in our patches.

This is not to say that groups like F4 Alliance or other independents haven’t made them available and can be added to the simulation. F4 Alliance’s magnificent B-1B add-on does include it.

F-16

The Falcon modeled here is the Block 52 version. Most know the history of the plane so it won’t be dealt with here. The F-16 loads have been researched and verified as all of the aircraft here. These weapons range from the Mk-82 to the B-61 Tactical Nuke, which is not available. We have created a master list of all legal loadouts for the F-16C block 50/52, but some of them are controversial. Addition/removal of certain weapons are easy to support with documentation, but we may not want to start a battle over which items to keep/remove. Below are the changes:

- ALL LGBs - not tasked for use in block USAF 50/52 loadouts, but we aren't removing them
- AIM-7 Sparrow – USAF does not use in block 50/52 with APG-68 and USAF APG-68 is not capable of supporting AIM-7 operation - removed
- Addition of the CBU-97 - cool weapon
- Ability to carry 1 Maverick on inner hardpoint (4/6) - realistic and will be changed
- Ability to carry only 1 AGM-65G on HP 3/7 because of weight concerns – realistic and will be changed
- Ability to carry 3 Mk-20s on HP 3/7 and 4/6 - realistic and will be changed
- LAU-3/A - ability to carry 2 pods on HP 3/7 - realistic and will be changed
- CBU-52 - can now carry 3 on HP 3/7 and 3 on HP 4/6 (deleted 1 bomb from HP 3/7) - realistic
- CBU-58 - can now carry 3 on HP 3/7 and 3 on HP 4/6 (added 1 bomb to HP 4/6) - realistic
- BLU-109 - can only carry 1 bomb on HP 3/7 - removed ability to carry 1 bomb on HP 4/6 - realistic
- GBU-12 - now you can only carry 2 on HP 3/7 and 1 on HP 4/6 - realistic
- We kept the Mk77, even though it's not realistic

We should also point out that carriage of weapons on certain hardpoints is dependent on what is currently on other HP stations. Unfortunately, F4 does not contain the complex logic needed to validate certain combinations of loadouts. We also recognize that there are usually fuel considerations to take into account, and most F-16C combat sorties usually include two 370gal wing tanks. We generally erred toward being liberal with the ability to place weapons.

A-10

During the development of version 3 of the Realism Patch, we were able to obtain access to some excellent material regarding the A-10. With the new “Fly Any Plane” patch, human pilots are now allowed to jump into the cockpit of the ‘Hog’. We realize the importance of further developing the realism of the A-10. While there are additional areas that will need to be explored (the flight model was not modified for Realism Patch v3.0), we have addressed many concerns.

If Falcon is left to it’s original programming, the A-10 would carry every hard point fully loaded. This often resulted in the aircraft being seriously overloaded and its performance somewhat lacking. In the course of our research, we discovered that the USAF leaves several hard points empty in order to give the A-10 a better performance envelope. Several A-10 drivers have verified this.

The OA-10A represents a mission change, not a model change. The USAF recognized the need for a multi mission capable aircraft to replace the old OV-10D Bronco in the Forward Air Control mission. The changes made to the aircraft to enable it to perform this mission are mainly the addition of safety features and electronics. It is still capable of performing its original mission. Below are some of our changes:

- The Maximum Take Off Weight (MTOW) was changed to 51,000lb.
- The fuel load was adjusted to 10,700lb.
- The “roles” that the A-10 performs (what the campaign ATO generator schedules the A-10 to execute) were adjusted to include those roles traditionally performed by the A-10: CAS, Interdiction, BAI, and FAC. No more will the A-10 be scheduled to fly OCA missions against airbases or anti-shipping sorties.
- The biggest change is regarding the A-10s is legal loadouts. The A-10 has 11 hardpoints (five on each side with one on the centerline). With all these hardpoints loaded, the issue became one of weight and maneuverability. With a MTOW of 51,000, if all of the 11 hardpoints were loaded up by the campaign auto-loadmaster, the A-10 would far too often be overloaded – exceeding its MTOW. In F4, when a plane exceeds it MTOW, it will not take off – it is just not smart enough to balance the load accordingly.

Our research also recognized that a combat operational A-10 NEVER goes fully loaded on all hardpoints, even if the weight comes in under the MTOW. The reason is maneuverability. As most of you already know, the A-10 is not a very fast plane – it relies on its maneuverability to perform well at low altitudes. A combat operationally A-10 typically loads stores on all hardpoints except HPs 2/10 and 5/7. There are other reasons besides weight for not loading ordnance on those hardpoints: interference with the wheel wells and missile exhaust blowback.

Therefore, for the reasons stated above, we have chosen to remove HPs 2/10 and 5/7 from the A-10. We think you will find the A-10 now performs in a much better capacity than it did before, both as an AI plane and when you fly it yourself.

Even though we removed several hardpoints, we made it a point to make sure that the remaining hardpoints could carry all the ordnance that they could legally carry, including weapon type and numbers. We have even included LGBs, which typically are not used on the A-10 (due to the roles they perform, and the altitudes they normally perform those roles from).

Typically, on an A-10, two AIM-9s are carried on HP 1 and one ALQ-119/131 is carried on HP 11. The AIM-9s are for self-protection and the possible helicopters that get in the way. Unfortunately, the hardpoint logic included in F4 does not like non-symmetrical loadouts. Even though we have specified that the ONLY store that can be carried on HP 1 is the AIM-9, the F4 auto-loadmaster will not load them up, as it selects the ALQ by default FIRST for HP 11. The auto-loadmaster will not load up two ALQs, but it will not load up the AIM-9s either. It is legal to add the AIM-9s manually, but the loadmaster will not do it for you. This is a problem we are still trying to overcome.

B-1B

Changes to this plane has been to give it the correct number of weapons each bay is capable of carrying. There are no wing pylons on this craft.

B-2A

This plane is not in FALCON, but given the nature of this “dead” simulation, it will be but a matter of time before it will be available.

B-52H

The changes made to this plane were to correct amount of bombs carried on the wing pylons, bomb bays, and the type of weapons. The type was changed from the B-52 G, which has been retired, to the B-52H. This plane is capable of launching ACLBMs (cruise missiles) as well as performing regular bombing runs. It doesn’t carry as large a bomb load as the Vietnam era B-52G, which was modified to do so. But, it still carries a hefty load. It is slow, and can’t penetrate modern air defenses like the B-1B, B-2A, and F-117A. With the right use of tactics, it can still be formidable as the Iraqi’s found out during the Gulf War.

F-117A

This plane is not a fighter but a bomber. During its early development and deployment, it was given the “F” designation to further confuse the Soviet Union. It has a remarkable combat record. Not one F-117A was lost during the Gulf War. It led the first waves that decimated the Iraqi’s communications and EW radar as well as going after the Scuds. Nine years later, one F-117A would be shot down during the NATO raids into Kosovo and Yugoslavia.

It carries its loads in an internal bay, which keeps its radar signature to a minimum. It’s load out is somewhat secret, but it is known to carry an assortment of GBU-10/12/24/28s weapons in it’s bomb bay. It carries no gun or A2A missiles. It relies on its stealth characteristics and is usually flown at night where it’s jet black color blends into the darkness.

F-15E

This is the bomber version of the F-15C EAGLE. It has a crew of two, a pilot and a weapons officer. This plane is capable of carrying an awesome amount of bombs and yet is capable of engaging enemy aircraft in air to air combat. Just one of these planes carries more explosive power than did two WWII B-17s.

It is larger than the F-16 and more expensive, but is a proven design. The USAF plans on operating the F-15E well into the 21st Century when it will be replaced by the JSF. The changes in the load out of this plane have been the addition of the LANTRIN pods. All weapons are legal.

F-18C

Carrier based fighter/attack aircraft. This plane replaced the old A-7 Corsair II attack jets in the Navy. In the USMC, the Hornet replaced the F-4S Phantom II and the A-4M Skyhawk as the primary attack/fighter jet. When the Marines refitted with the Hornet, several of the old Skyhawk squadrons were retired and the Phantom squadrons given attack missions. Changes made to this plane were to add additional weapon systems to the newer E models.

F-14A/B

This carrier based Interceptor entered service just after the Vietnam War and was designed to replace the F-4S Phantom II in both the Marines and Navy. The Marines decided against this and used the money to improve the existing F-4s.

The F-14 is a variable geometry wing aircraft like the F-111A and B-1B. This movable wing helps give the F-14 an astounding range of speed from slow to supersonic. The F-14, while missing Vietnam, has proven itself as a MiG Killer, having nailed two Libyan MiGs over the Gulf of Sidra in 1982 and then again in the Gulf. The Phoenix missile system is the F-14's main weapon, capable of locking on and destroying a target BVR. It also carries AIM-9L/M, AIM-7, and AIM–54. Due to rising costs to operate and maintain the F-14A, the Navy plans on replacing the F-14 with the F/A-18E Super Hornet. The F-14 is now modified for an air-to-ground role, with provisions for carriage of the LANTIRN targeting pod, LGBs, Mk-20 cluster bombs, and Mk-82/83 iron bombs.

F-22A

This is the USAF's next generation fighter. It's slated to replace the F-15C and F-16C as the air superiority fighter. This plane has stealth technology; variable thrust vectoring, exotic avionics, and supersonic cruise speed. It carries weapons internally, but has hardpoints for external weapon loads.

MiG-19/J-5

It has 20mm cannon and can fire the older AA-2 missile. This plane and its Chinese copy are still in use by the DPRK Air Force, but in a ground support role. It is pretty much obsolete, but still is deadly if it catches an F-16 pilot daydreaming.

MiG-21

This day fighter is a nasty plane. Its radar is not very good, but it is highly maneuverable, and carries a pair of all aspect AA-8 missiles (for the newer MiG-21bis variant, which is not in use by the DPRK), or the older AA-2 missiles. Though obsolete, this plane can be deadly if it is allowed to sneak behind any aircraft.

Other Aircraft

Other aircraft modeled in Falcon are:

AV-8B Harrier, F-5 E Tiger II, F-4G Wild Weasel, MiG-19/J-5, MiG-25, MiG-27, MiG-31,C-130, AC-130, IL-28, TU-16, TU-22, TU-95, SU-27, SU-25, SU-24, FB-111A

Helicopters
KA-50, MI-28,MI-8,MI-26, CH-53E,CH-47,CH-46 ,UH-1N, UH-60A, AH-1G,AH-64D, OH-58D, AH-66

Utility
KC-10, KC-37, RC-135, P-3, EA-6B, EF-111, U-2A, TR-1, SR-71, OV-10D, E-2C, E-3, E-8C, C-5A, C-141,C-17,AN-12,AN-21,AN-124, AN-225,AN-24 , AN-70 , AN-71

Most of these planes can be flown with the fly any plane patch. As we get more into the program, more of these planes will become available.
As they do, we will continue to adjust the loads that they carry.

FLIGHT MODELS

Creating The Accurate Flight Models
By Tom "Saint" Launder

NEW AIRCRAFT LIMITERS

One of the odd things that always presented itself in Falcon 4 was the flight behavior of the bomber aircraft. While reviewing the data on the flight models, you can see that the F-16 fly-by-wire flight model is using 17 flight model limiters in its data. Understanding that this is information used for the flight model and is probably how the on board FLCS calculates its flight model, what effect would it have on other flight models? The other aircraft in the game were using only four limiters. Nevertheless, we know that ALL these limiters are necessary for an accurate flight model.

In the F-16, these limiters are used to keep the aircraft from departing from controlled flight. In other aircraft, HUMAN input is the only tool that allows the aircraft to try and stay in its flight envelope. There is no human input in the AI aircraft. So, what is the effect? Once I was able to fly other aircraft in Falcon 4, I discovered that as a HUMAN flies the aircraft he is in fact NOT restricted by the same limits that the player in an F-16 has. The A-10, fully laden with MK-82's, was able to pull up and do 360° loops with no noticeable adverse effects. In the A-10 flight model, as all other AI aircraft, there were no drag limiters, CAT 1 / CAT 3 limiter, no pitch limiter, etc. Once these 17 flight model limiters were in place, the A-10 that I flew could no longer easily perform those maneuvers. Once I set in place these 17 limiters for ALL AI aircraft, I began to see a lessening of dog fighting, barrel rolling bombers. It still does happen and perhaps these values need to be tweaked for each aircraft but as it stands now, the changes at least "limited" the wild flight behavior of the AI bombers.

The 17 limiters in the F16.dat file are used to model the aircraft behavior, but MPS is obviously taking a shortcut by using them only for fly-by-wire aircraft, and using simple dampers for other aircraft. However, the other data do play a part in controlling AI plane behavior and maximum allowable G.

If you look under the file, the maximum allowable g will control how much g you can pull. I tried flying an F-15E with it set to 7.33 and that is what I got. The other data such as maximum roll angle will control how much an aircraft rolls, and one of the reason why the Tu-95 and other bombers dogfight with you is because their dat files have this set to 190, which allows them to roll over.

Most of the data inside the dat files is off, like maximum VCAS speed, which is very high, and peak roll rates, which are too high. The data in the limiter block mirrors the F-16 digital flight controls, but not exactly. Some aspects are off, like the AOA limiter allowing AOA up to 30x. It should have been 25.5° instead, etc.

FLIGHT MODELS

Part of the genius of Falcon 4.0 is that much of the data used for the simulation are in files that can be modified using a simple text editor like Notepad. Thankfully the flight model data is similar. Though every variable is not adjustable, many are and that gives us the ability to enhance the flight models. The RP includes many new models worked on by certain individuals and many in accordance with fighter pilot input. Because F4 is a home PC simulation, absolute realism is not achievable. This is where pilot input is often very helpful. A flight model designer can spend hours adjusting the numbers for lift, drag, and acceleration only to have a pilot comment that the model is unrealistic. Overall, every model that is reworked is better than the originals. Why is that the case? The models are better because in the beginning the flight model data used was generic. This works well for the AI since the AI will not be pushing the aircraft like a human player will. But with the advent of "fly any aircraft" human players are now able to fly a MIG-29, F-15C, A-10, etc. When left with the original data files, the problems become quite apparent.

When flight models are modified to be more realistic, the primary areas of rework are in drag, thrust, and roll rate. The original models were too drag heavy at higher speeds and very few models would ever hit their book numbers for acceleration and top speeds. Roll rates for some of the fighters were too low and for the bombers too high. Take a flight in the B-52 or C-130 and the changes will be very obvious. Still, with all the improvements, some areas remain that are not very realistic. The primary difficulty is with low speed characteristics. The F-16C model is more dynamic and handles low speed stall much better than the other flight models. Because of this, you can often get another aircraft model to hold high AOA and not nose drop. If the home PC pilot has realistic expectations about what a PC simulation can provide, the new models will satisfy. The flight model project has been about "realism within realistic limits." The models included are better and should enhance the F4 experience.

FLIGHT MODELS DE-MYSTIFIED

The Physics Behind the Flight Models in Falcon 4
By "Hoola"

FLIGHT MODEL PARAMETERS

The flight models in Falcon 4 can be found in the zips/simdata.zip file, or the sim/acdata directory. Each flight model is a text file that is read by the Falcon 4 executable. The parameters in the flight models are explained here. I will not discuss in detail what each parameter mean, as this requires some background in aerodynamics. There are textbooks that will explain the aerodynamic equations better than I can.

 # Input Mass and Geometric Properties
This specifies the aircraft empty weight in pounds (i.e. without fuel and ordnance, but inclusive of expendables and pilot), wing area in square feet, and internal fuel load in pounds.

 # Angle of Attack and Sideslip Limits
This specifies the maximum and minimum AOA and sideslip limits for the aircraft. For most aircraft, the sideslip limit is less than ±18° for controlled flight. For AOA, the maximum limit is usually between 20 to 35°. This is used by the AI and by the player.

 # Maximum G's for structural limit
This specifies the maximum allowable g for the aircraft.

 # Maximum roll angle
This specifies the maximum roll angle that the aircraft can and will roll through. If it is set to 190, the aircraft will roll through 180°. This is only used by the AI.

 # Minimum Vcas Speed
This specifies the minimum speed for the flight model. This parameter interacts with the landing algorithm, and if it is set at too high a value, the AI controlled aircraft will not be able to extend their undercarriage for landing.

 # Maximum Vcas Speed
This specifies the maximum speed for the flight model. This parameter is only used by the AI.

 # Attack Speed
This specifies the typical corner speed of the flight model, and is used by the AI for determining its combat speeds.

 # Max Theta
This specifies the maximum pitch angle, and I suspect that it is only used by the AI.

 # Num Gear
This specifies the number of gears in the undercarriage system.

 # Nose Gear X, Y, Z, Rng
This specifies the x, y, and z co-ordinates of the nose undercarriage. The *Rng* field is unknown, but probably relates to the angular travel of the undercarriage during retraction/extension.

 # Lt Gear X, Y, Z, Rng
As for the nose undercarriage, this is the data for the left main undercarriage.

 # Rt Gear X, Y, Z, Rng
As for the nose undercarriage, this is the data for the right main undercarriage.
 # CG Location in ft from nose

The center of gravity location of the airplane, relative to its nose (along the x-axis, which is defined as positive from the nose to the tail).

Length in ft
The length of the aircraft in feet. This is not used at all.

 # Span in Ft
The wingspan of the aircraft in feet. This is not used at all.

 # Fus Radius in ft
The average fuselage radius of the aircraft in feet. This is not used at all.

 # Tail height in ft
The height of the tail of the aircraft in feet. This is not used at all.

 # Num MACH
This defines the Mach breakpoints basic aerodynamic coefficients on the aircraft. This section specifies the number of Mach numbers (and the corresponding Mach numbers) in the data matrix. The default flight model uses 7 Mach breakpoints, at 0.0, 0.2, 0.8, 0.9, 1.0, 1.1, and 2.5. More breakpoints can be used to model the flight model in greater fidelity, but with the penalty of greater memory and computational requirements.

 # Num ALPHA
This defines the AOA (angle of attack) breakpoints. The default flight model uses 21 AOA breakpoints at –20, -10, -5, 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, and 90.

 # Lift Coefficient CL
This section specifies the lift coefficient for each Mach number and AOA. Every section specifies the lift coefficient for the entire AOA matrix at a single Mach numbers. Using the default 7 Mach number and 21 AOA breakpoints, there should be 7 sections of 21 numbers.

 # Table Multiplier
This specifies the multiplier factor that is to be used for multiplying the lift coefficient.

 # Drag Coefficient CD
This section specifies the drag coefficient for each Mach number and AOA. Every section specifies the drag coefficient for the entire AOA matrix at a single Mach numbers. Using the default 7 Mach number and 21 AOA breakpoints, there should be 7 sections of 21 numbers.

 # Table Multiplier
This specifies the multiplier factor that is to be used for multiplying the drag coefficient.

 # Side Force Derivative CY-BETA
This section specifies the side force derivative ($C_{Y\beta}$) coefficient for each Mach number and AOA. Every section specifies the $C_{Y\beta}$ coefficient for the entire AOA matrix at a single Mach numbers. Using the default 7 Mach number and 21 AOA breakpoints, there should be 7 sections of 21 numbers. This coefficient controls the rudder effectiveness in the game. The higher the number, the greater the rudder effectiveness.

 # Table Multiplier
This specifies the multiplier factor that is to be used for multiplying the side force derivative.

 # Propulsion Data
This section specifies the engine performance data.

 # Thrust multiplier

This is the multiplier factor for the engine thrust data.

 # Fuel Flow Multiplier
This is the multiplier factor to obtain the fuel flow based on engine thrust. We are not sure how Falcon 4 computes the fuel flow based on the engine thrust, but it seems like it assumes some degree of specific fuel consumption based on the actual thrust produced.

 # Mach Breakpoints
 # num MACH
This section specifies the Mach number breakpoints to be used for definition of engine performance data. There are usually 14 breakpoints, at Mach 0.0, 0.2, 0.4, 0.6, 0.8, 0.9, 1.0, 1.1, 1.2, 1.4, 1.6, 1.8, 2.0, and 2.5. More Mach breakpoints can be used to model the engine in greater fidelity.

 # Altitude Breakpoints
 # num ALT
This section specifies the altitude breakpoints to be used for definition of engine performance data. There are usually 8 breakpoints, at sea level, 5,000 feet, 10,000 feet, 15,000 feet, 20,000 feet, 35,000 feet, 50,000 feet, and 70,000 feet. More altitude breakpoints can be used to model the engine in greater fidelity.

 # THRST1 – Thrust at IDLE (THROTL = 0.0)
This specifies the engine thrust in pounds, at IDLE setting, for every Mach number at all the specific altitude breakpoints. For the default setup of 14 Mach number breakpoints and 8 altitude breakpoints, there should be 8 blocks of data with 14 numbers each.

 # THRST2 - Thrust at MIL Power Setting (THROTL = 1.0)
This specifies the engine thrust in pounds, at MIL power setting, for every Mach number at all the specific altitude breakpoints. For the default setup of 14 Mach number breakpoints and 8 altitude breakpoints, there should be 8 blocks of data with 14 numbers each.

 # THRST3 – Thrust at Full Afterburner (THROTL = 1.5)
This specifies the engine thrust in pounds, at maximum afterburner setting, for every Mach number at all the specific altitude breakpoints. For the default setup of 14 Mach number breakpoints and 8 altitude breakpoints, there should be 8 blocks of data with 14 numbers each.

 # Roll Data
 # num ALPHA
This section specifies the number of AOA breakpoints that are to be used for defining the roll performance of the flight model. The default flight model uses 7 AOA breakpoints, at –10, 0, 10, 20, 30, 40, and 90 degrees.

 # Dynamic Pressure Breakpoints
 # num QBAR
This section specifies the number of dynamic pressure (q_c) breakpoints that are to be used for defining the roll performance of the flight model. I am not too sure of the engineering units used to define dynamic pressure in Falcon 4, but I suspect that this is in pounds per square feet. The default flight model has 14 dynamic pressure breakpoints, at 0, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, and 2000.

 # Table Scale
This specifies the multiplier factor used to multiply the roll rate data.

 # RCMDMX – Peak Roll Rate
This section specifies the peak roll rate achievable at each AOA and dynamic pressure. The data is arranged in matrices. For a default setup with 7 AOA breakpoints and 14 dynamic pressure

breakpoints, there will be 7 blocks of data with 14 numbers each. The roll rate is specified in degrees per second.

 # Num Limiters
This specifies the number of limiters used to define the flight control system for the flight model. The full definition requires a total of 17 limiters. The limits are defined with three blocks of data, specifying the type, the key, and the values for the limiter. The keys for each limiter are as follows:

0	Negative g limiter
1	Positive g limiter in CAT I (air-to-air flight controls mode)
2	Roll rate limiter (CAT I)
3	Yaw alpha limiter
4	Yaw roll rate limiter
5	CAT III command type
6	CAT III AOA limiter
7	CAT III roll rate limiter
8	CAT III yaw alpha limiter
9	CAT III yaw roll rate limiter
10	Pitch and yaw control damper
11	Roll control damper
12	Command type
13	Low speed omega
14	Stores drag
15	CAT III max g
16	AOA limiter

 # Neg G Limiter
0 0 250.0 -3.0 100.0 0.0
This specifies the properties of the negative g limiter. I will use the example here. The data block specifies that this is a type 0 limiter, and the second 0 specifies that this is a negative g limiter. The values are specified in pairs, with the first number indicating the airspeed, and the second number in the pair indicating the negative g that the pilot can command. In this example, when the airspeed is 100 knots, the airplane will be limited to 0g, and the negative g limit is increased to –3g when the airspeed is at 250 knots and above.

 # Pos G Limiter (Cat I)
3 1 15.0 9.0 20.4 7.3 25.0 1.0
This specifies the properties of the CAT 1 positive g limiter. I will use the example here. The data block specifies that this is a type 3 limiter, and the 1 specifies that this is a positive g limiter. In the F-16, the g that the pilot can demand from the flight control system in CAT I is dependent on the AOA. The values are specified in pairs, with the first number in the pair indicating the AOA, and the second number in the pair indicating the positive g that the pilot can command. In this example, the pilot can command up to 9g when the AOA is at 15° or below, and this is reduced to 7.3g at 20.4° AOA, and further reduced to 1g at 25° AOA.

 # Roll Rate Limiter
0 2 15.0 1.0 29.0 0.0
This specifies the properties of the CAT 1 roll rate limiter. I will use the example here. The data block specifies that this is a type 0 limiter, and the 2 specifies that this is a CAT 1 roll rate limiter. In the F-16, the peak roll rate that the flight control system will generate is dependent on the AOA. The values are specified in pairs, with the first number in the pair indicating the AOA, and the second number in the pair indicating the multiplier factor for the peak roll rate. This multiplier factor is used to compute the achievable peak roll rate as AOA changes. In this example, the maximum peak roll rate can be achieved with AOA at 15° or below, and this is reduced linearly until the aircraft is incapable of rolling at 29° AOA.

 # Yaw Alpha Limiter

0 3 14.0 1.0 26.0 0.0

This specifies the properties of the CAT 1 rudder-AOA limiter. I will use the example here. The data block specifies that this is a type 0 limiter, and the 3 specifies that this is a CAT 1 yaw-AOA limiter. In the F-16, the flight control system reduces the rudder authority as AOA increases. The values are specified in pairs, with the first number in the pair indicating the AOA, and the second number in the pair indicating the multiplier factor for the rudder effectiveness. This multiplier factor is used to compute the rudder effectiveness as AOA changes. In this example, the maximum rudder effectiveness can be achieved with AOA at 14° or below, and this is reduced linearly until the aircraft ignores any pilot rudder inputs at 26° AOA.

 # Yaw Roll Rate Limiter

0 4 20.0 1.0 360.0 0.0

This specifies the properties of the CAT 1 roll rate limiter as a function of yaw angle. I will use the example here. The data block specifies that this is a type 0 limiter, and the 4 specifies that this is a CAT 1 yaw-roll rate limiter. This limiter functions to reduce the rudder authority as roll rate increases. The values are specified in pairs, with the first number in the pair indicating the roll rate, and the second number in the pair indicating the multiplier factor for the rudder effectiveness. This multiplier factor is used to compute the rudder effectiveness as roll rate changes. In this example, the maximum rudder effectiveness can be achieved with roll rate of up to 20°/sec, and this is reduced linearly until the aircraft ignores any pilot rudder inputs when the roll rate is at 360°/sec.

 # Cat III Command Type

0 5 100.0 7.0 420.0 15.0

This is supposedly the CAT 3 (air-to-ground) flight control system. Using the example here, the data block specifies that this is a type 0 limiter, and the 5 specifies that this is a CAT III command limiter. The exact nature of this limiter is unknown to me currently, but from the example shown here, the first number in the pair of values seems to be the airspeed, while the second number seems to be AOA. I suspect that the limiter restricts the AOA that the pilot can command according to the airspeed schedule.

 # Cat III AOA Limiter

1 6 17.0

This specifies the properties of the CAT 3 AOA limiter. I will use the example here. The data block specifies that this is a type 1 limiter, and the 6 specifies that this is a CAT 3 AOA limiter. This limiter functions to restrict the maximum allowable AOA in CAT 3. The value specified here indicates that the AOA will be limited to 17° in CAT 3.

 # Cat III Roll Rate Limiter

2 7 0.6

This specifies the properties of the CAT 3 roll rate limiter. I will use the example here. The data block specifies that this is a type 2 limiter, and the 7 specifies that this is a CAT 3 roll rate limiter. This limiter functions to restrict the maximum peak roll rate in CAT 3. The value specified here indicates that the CAT 3 peak roll rate will be limited to 60% of the CAT 1 peak roll rate.

 # Cat III Yaw Alpha Limiter

0 8 3.0 1.0 15.0 0.0

This specifies the properties of the CAT 3 rudder-AOA limiter. I will use the example here. The data block specifies that this is a type 0 limiter, and the 8 specifies that this is a CAT 3 yaw-AOA limiter. In the F-16, the flight control system reduces the rudder authority as AOA increases. The values are specified in pairs, with the first number in the pair indicating the AOA, and the second number in the pair indicating the multiplier factor for the rudder effectiveness. This multiplier factor is used to compute the rudder effectiveness as AOA changes. In this example, the maximum rudder effectiveness can be achieved with AOA at 3° or below, and this is reduced linearly until the aircraft ignores any pilot rudder inputs at 15° AOA.

 # Cat III Yaw Roll Rate Limiter

0 9 20.0 1.0 180.0 0.0

This specifies the properties of the CAT 3 roll rate limiter as a function of yaw angle. I will use the example here. The data block specifies that this is a type 0 limiter, and the 9 specifies that this is a CAT 3 yaw-roll rate limiter. This limiter functions to reduce the rudder authority as roll rate increases. The values are specified in pairs, with the first number in the pair indicating the roll rate, and the second number in the pair indicating the multiplier factor for the rudder effectiveness. This multiplier factor is used to compute the rudder effectiveness as roll rate changes. In this example, the maximum rudder effectiveness can be achieved with roll rate of up to 20°/sec, and this is reduced linearly until the aircraft ignores any pilot rudder inputs when the roll rate is at 180°/sec.

 # Pitch and Yaw Control Damper

3 10 50.0 1.0 15.0 0.85 0.0 0.3

This specifies the properties of the pitch and yaw control damper. Using the example here, the first number shows that this is a type 0 limiter, while the 10 indicates that this is the pitch and yaw control damper. The nature of data block is unknown, but this serves to damp out the aircraft pitch and yaw motions after control inputs, and minimizes aircraft pitch and yaw oscillations.

 # Roll Control Damper

3 11 50.0 1.0 15.0 0.85 0.0 0.6

This specifies the properties of the roll control damper. Using the example here, the first number shows that this is a type 3 limiter, while the 11 indicates that this is the roll control damper. The nature of data block is unknown, but this serves to damp out the aircraft roll motions after control inputs, and minimizes roll oscillations.

 # Command Type

1 12 15.0

The nature of this limiter is unknown.

 # Low Speed Omega

3 13 60.0 1.0 40.0 0.8 0.01 0.1

The nature of this limiter is unknown, but the first number in the pairs of values seem to indicate airspeed, while the second number in the pair seem to indicate the “omega.”

 # Stores Drag

0 14 0.9 0.00024 1.0 0.00033

The nature of this limiter is unknown, although it seems to pertain to how the flight model computes drag.

 # Cat III Max Gs

1 16 6.0

This specifies the properties of the CAT 3 g limiter. Using the example here, the first number shows that this is a type 1 limiter, while the 16 indicates that this is CAT 3 maximum g limiter. The value indicate the maximum allowable g in CAT 3, and in this example, this is limited to 6g.

 # AOA Limiter

1 17 30.0

This specifies the properties of the CAT 1 maximum AOA limiter. Using the example here, the first number shows that this is a type 1 limiter, while the 17 indicates that this is CAT 1 maximum AOA limiter. The value indicate the maximum allowable AOA in CAT 1, and in this example, this is limited to 30°.

ATMOSPHERIC MODEL

Microprose has coded into Falcon 4 an atmospheric model that is surprisingly accurate. The physics involved replicates the atmospheric pressure and density ratio relationship with altitude and temperature. This atmospheric model is based on the standard U.S. atmosphere (or what is commonly known in the aerospace industry as the International Standard Atmosphere), with the tropopause at 36,089 feet barometric altitude.

The atmospheric model captures the temperature lapse rate, and variation in density accurately. This allows Falcon 4 to compute Mach number and airspeed relationships accurately. However, there are no provisions for a different temperature profile, such as deserts and tropics. Regardless of whether the Falcon 4 campaign is taking place in summer or winter, in the Nordic countries or in the desert, the atmospheric model remains the same, and does not replicate the effects of non-standard conditions.

The merit of replicating the full atmospheric effect is arguable, as this complicates the engine model, since the engine model will require temperature compensation. While such an approach may provide a higher degree of fidelity in the performance of flight models, the utility is marginal since the memory and computational requirements will be increased tremendously, at the expense of gameplay performance.

One thing that the atmospheric model do not capture is the wind effects, and varying wind conditions at various altitudes. Contrail altitude is not dependent on the atmospheric model, and is fixed (although the user can change it by editing the files). Wind shear and jet streams are also not modeled, and neither is the effect of variations in wind on bomb ballistics.

ENGINE MODEL

The engine model in Falcon 4 is a simple look-up table of engine thrust at various throttle settings (IDLE, MIL, and maximum afterburner), and Mach numbers. Temperature effects are not modeled in Falcon 4, and as such, you will not see an increase in engine thrust on a cold day, and a decrease in engine thrust on a hot day. However, the model does allow ram effects to be modeled, by adjusting the thrust.

Inherent within the engine model is a fuel flow computation engine. This is related to the engine thrust. I have not discovered the exact details on how the fuel flow is computed. Similarly, engine spool timing and afterburner light-off timing are controlled within the Falcon 4 executable. As such, it is not possible to model different engine spool characteristics, and distinguish between the long spool-up timing of the engine on the Il-28, and the fast spool-up timing on the F-16's F110 engine.

In Realism Patch version 5, the flight model engine has been modified. For airplanes without the afterburner, the engine thrust will be the same for both max AB and MIL. The executable will no longer increase the fuel flow to afterburner rates even if the player (or the AI) engages afterburner.

PERFORMANCE AND FLYING QUALITIES

I will not discuss the physics behind how Falcon 4 computes aircraft performance. The equations used to compute lift and drag are standard aeronautical equations, and the coverage of such topics are beyond the scope of this article. For a detailed treatment on the topic of aircraft performance, you will be better served by textbooks that deal with this topic. An excellent source of information on the mathematics behind aircraft performance may be found at the US Navy Flight Test website, and the URL is http://flighttest.navair.navy.mil/unrestricted/FTM108.

Since Falcon 4 uses the standard aerodynamic coefficients (C_L, C_D, and $C_{Y\beta}$), and incorporates an accurate atmospheric model, the performance of flight model is based on a good understanding of physics, especially with regards to turn rate computation and specific excess power. I will instead concentrate on the simulation of the aircraft's flying qualities.

The first thing that is immediately apparent with the flight model is the lack of roll-yaw and pitch-roll coupling effects, from both the aerodynamic as well as the inertia point of view. Aerodynamically, an aircraft will couple in the roll-yaw plane, i.e. rolling the aircraft will cause the aircraft to yaw, and yawing the aircraft will also result in the aircraft rolling. While the actual F-16 has an aileron-rudder interconnect to automatically reduce the sideslip in rolls, the ailerons are not automatically used to compensate whenever the rudder is deflected by the pilot. Rudder deflection in Falcon 4 produces a pure yaw with no roll, and this is aerodynamically incorrect. This does not allow the aircraft to perform rudder rolls at high AOA.

Most F-16 pilots do not use rudders if at all when flying the aircraft, and this anomaly is by and large academic. However, for other aircraft such as the MiG-29 and F-5, the rudder allows the aircraft to roll at high angles of attack, where aileron rolls will otherwise result in a loss of control. Rudder rolls are hence common in conventional aircraft, and the flight model in Falcon 4 does not allow for this. Instead, ailerons will need to be used, when such techniques will actually result in a departure from controlled flight in a real aircraft.

There is also an absence of inertia coupling effects in Falcon 4. The inertia properties of an aircraft is such that it works in the pitch-roll plane, as well as the roll-yaw plane. Rolling at high angles of attack will cause the angle of attack to increase further due to pitch-roll inertia coupling. This is not so in Falcon 4.

Before you cry foul at Microprose for creating such crippled flight models, let's take a look at the underlying equations governing coupling effects:

$$\underbrace{\dot{P}}_{\dot{P}_{total}} = \underbrace{\left(-QR\frac{I_{zz}-I_{yy}}{I_{xx}} + (PQ+\dot{R})\frac{I_{xz}}{I_{xx}} + (\dot{Q}-PR)\frac{I_{xy}}{I_{xx}} + (Q^2-R^2)\frac{I_{yz}}{I_{xx}} \right)}_{\dot{P}_{inertia}} + \underbrace{\left(\frac{L}{I_{xx}} \right)}_{\dot{P}_{aero}} + \underbrace{\left(-\frac{\dot{h}_x}{I_{xx}} - Q\frac{h_z}{I_{xx}} + R\frac{h_y}{I_{xx}} \right)}_{\dot{P}_{gyro}}$$

$$\underbrace{\dot{Q}}_{\dot{Q}_{total}} = \underbrace{\left(-PR\frac{I_{zz}-I_{xx}}{I_{yy}} + (R^2+P^2)\frac{I_{xz}}{I_{yy}} + (QR+\dot{P})\frac{I_{xy}}{I_{yy}} + (\dot{R}-PQ)\frac{I_{yz}}{I_{yy}} \right)}_{\dot{Q}_{inertia}} + \underbrace{\left(\frac{M}{I_{yy}} \right)}_{\dot{Q}_{aero}} + \underbrace{\left(-\frac{\dot{h}_y}{I_{yy}} - R\frac{h_z}{I_{yy}} + P\frac{h_z}{I_{yy}} \right)}_{\dot{Q}_{gyro}}$$

$$\underbrace{\dot{R}}_{\dot{R}_{total}} = \underbrace{\left(-PQ\frac{I_{yy}-I_{xx}}{I_{zz}} + (\dot{P}-QR)\frac{I_{xz}}{I_{zz}} + (P^2-Q^2)\frac{I_{xy}}{I_{zz}} + (PR+\dot{Q})\frac{I_{yz}}{I_{zz}} \right)}_{\dot{R}_{inertia}}$$

$$+ \underbrace{\left(\frac{N}{I_{zz}}\right)}_{\dot{R}_{aero}} + \underbrace{\left(-\frac{\dot{h}_z}{I_{zz}} - P\frac{h_y}{I_{zz}} + Q\frac{h_x}{I_{zz}} \right)}_{\dot{R}_{gyro}}$$

The equations here state the total coupling effects in the pitch, roll, and yaw plane, contributed by inertia coupling, gyroscopic coupling, and aerodynamic coupling. Even if we ignore aerodynamic coupling and gyroscopic coupling, and deal only with inertia coupling, the computation in each axis is still considerable. There is also a need to compute the inertia for each aircraft individually, and this is affected by the ordnance loading on each and every aircraft in Falcon 4. Modeling inertia effects will lead to a large increase in computational as well as memory requirements, and the modeling is not complete unless the stability derivatives ($C_{l\beta}$, and $C_{N\beta}$) are taken into account, in which case, the memory requirements will be further increased.

Such effects are usually only modeled in dedicated flight simulations, where the software does not have to compute the outcome of a war. Flight simulations such as the Microsoft Flight Simulator, and X-plane, can model such effects since the computational and memory requirements are tailored for the single aircraft that the player is flying. The effects of inertia coupling is only apparent at high angles of attack, and the increase in fidelity will be fairly marginal from the perspective of the F-16 and other high performance fly-by-wire aircraft.

The flight control system model in Falcon 4 also does a commendable job of replicating the feel of the aircraft. However, the often heard complain by real F-16 pilots who have flown Falcon 4 is the apparent sluggish roll rate of the aircraft. This is a fallacy that can be proven wrong easily. The peak roll rate of the F-16 is about 250°/sec, and this is modeled in the simulation. You can roll the aircraft repeatedly in the simulation and time the rolls, and will obtain the same peak roll rate. If the same thing is performed on the actual aircraft, the same roll rate will be obtained as in the simulation.

The key factor is the perception of roll. The actual F-16 uses a fixed control stick that is force sensitive. A flick of the wrist will often produce considerable amount of force, and the aircraft will snap roll easily. Most joysticks uses displacement transducers instead of strain gages, and will need to be displaced by a fairly large amount to produce the same peak roll rate. For real F-16 pilots, this creates an apparent roll sluggishness, as he will be not able to generate a high roll rate just by flicking his wrist, but instead will need to move the control stick a lot more. The characteristics of the control stick is part of the flight control system, and similarly, the characteristics of the joystick form part of the control system in the simulation. The difference in the characteristics of the joystick and the control stick will result in a different “feel” compared to the actual aircraft, and this is a problem with the joystick and not the flight model.

The last thing concerning the flight model is modeling of out-of-control flight. Falcon 4 does not model the lateral-directional stability derivatives, nor any control surface derivatives. Modeling of departed flight requires such parameters to create proper flight dynamics. However, Microprose has chosen to model the deep stall effects in the game executable. Strictly speaking, the behavior of a deep stall is dependent on altitude. However, this is not modeled properly in the game. Without a total re-structuring of the way a flight model is represented, departure from controlled flight cannot be modeled with much fidelity, although Microprose’s approach did produce a reasonable representation of a deep stall, and captured its essence. Any attempts to model these effects should bear in mind the computational requirements, as most if not all 6 degree-of-freedom simulations cannot run in real time due to the computational requirements.

LIFE BEYOND FLYING THE F-16

Flying Other Planes in Falcon 4
By "Hoola"

THE REALISM PATCH VERSION 3 (AND BEYOND) WAY

This modification typifies the spirit of cooperation and sharing of knowledge that exists in the Falcon 4.0 community. Someone on the Delphi Falcon4 forum posted a note on how to simply edit a text file in the campaign folder that would allow you to join any squadron in a campaign. Unfortunately, we cannot remember that user's name, as that user rarely posts - we should thank him for his finding and subsequent sharing of information.

The excitement of the discovery overwhelmed those involved in exploiting it. Very quickly, this information was passed on to Marco Formato who discovered how the numbers were related to the Falcon4 file structure to identify F-16s. Rhino, then edited the file to include all the aircraft squadrons in the campaign. Later this was modified by Leonardo Rogic to include the helicopter squadrons as well.

Marco then discovered that he could edit the Falcon 4.0 executable to "skip" the check for an F-16 before the human flew his aircraft. Hence, one can now jump into ANY active squadron and await the campaign sortie generator to fly in the squadrons in campaign or TE. This now allows adversarial multiplayer flights with one team flying for the OPFOR and another team for NATO. This also created a huge push for players to begin to correct the flight models, cockpits, and ordnance loads of the other aircraft in the game.

To fly as any other aircraft in the Realism Patch, one must only start a campaign or TE and look at the different airbases that are available for tasking in the theatre window in the upper right-hand corner of the mission wrapper screen. If you click on one of the active airbases, you will see the squadrons available for tasking at that airbase. Then, if you click on one of the squadrons that are listed, you will see the different aircraft available to you. If you start the mission at this point, you will have joined as a member of that squadron, and the planes that squadron flies will be available to you.

While it is arguable that it is not realistic to be able to fly other airplanes with an F-16 cockpit and avionics, it is nevertheless a "fun" option that will contribute to the longevity of the simulation. This has allowed cockpit artists to make cockpits for other airplanes, and coders such as Miran Klemenc to model the avionics systems on other airplanes with a limited degree of success, giving a greater sense of immersion when you fly other airplanes.

FINGER PRINTING THE BIRDS OF PREY

Radar, Visual, and Infra-red Signatures for Airplanes
By "Hoola"

Together with the AI changes, each aircraft in Falcon 4 has been given unique IR and visual signatures. Prior to the Realism Patch, the only signature available for vehicles in the F4 world was the radar signature. Beginning with Realism Patch version 4, this is now expanded to include IR as well as visual signatures.

DESIGNING RADAR SIGNATURES

Radar signature in F4 is not mechanized as radar cross section, but instead is a linear multiplier. This form of representation is not necessarily inaccurate, as radar acquisition range is an exponential function with an exponent of 4, and very computationally intensive. For the purpose of the game, a linear multiplier is equally good.

In the design of the radar signature (or rather, re-design), we have utilized the F-16 as a baseline, and estimated its actual radar cross section. Based on this, we extended the estimation of the RCS to each airplane in the F4 world, and computed the detection distances based on actual monostatic two-way radar equations.

Radar detection is dependent on many variables such as aspect angles, maneuvers (thus causing glints and fluctuations in RCS), antenna capture area, antenna gain, etc. By using the F-16 APG-68 as a baseline, and the F-16 radar signature as a baseline, we have normalized all performance relative to the F-16 (this was what MPS did as well). The radar equation is thus reduced to include range as well as RCS.

Based on the estimated RCS, the detection range is computed, and then normalized against that of the F-16 to determine the final F4 radar multiplier factor for each airplane. For a detailed discussion on radars, as well as radar cross section, please refer to the USN Electronic Warfare and Radar Engineering Handbook, available at http://ewhdbks.mugu.navy.mil. This is an invaluable source that we have utilized to estimate the RCS, although it does require some engineering and mathematical background to use the information effectively.

DESIGNING VISUAL SIGNATURES

Visual signatures affect only AI target acquisition with their virtual Mark I eyeball. As with radar cross section, we have normalized visual detection distances against the F-16. This is set to a baseline detection distance of 1, and we then computed the visual acquisition distance for various AI skill levels.

The length and span of the F-16 are then determined, and the visual acuity (in terms of angular resolution from the AI's eye point to both the tip and tail of the aircraft, and from left wing tip to right wing tip of the aircraft), is computed. We then assumed that the visual acuity and optical resolution of the AI stays the same, and will be able to acquire a target that fulfills this visual acuity and optical resolution requirement.

The dimensions (length and span) of every individual aircraft is then computed, and the visual acquisition range determined. This forms the baseline visual detection range for the same visual resolution and optical resolution.

The visual signatures are then adjusted with a "fudge" factor. This factor will lower the visual detection ranges to account for atmospheric haze, atmospheric distortions, camouflage pattern on the airplane, glare, and the AI pilot having to look through helmet visors and canopy reflections. In our iterations with former military pilots, the “fudge” factor was adjusted so that the resultant visual acquisition ranges are more realistic and representative.

One important consideration was that F4 previously assumed a visual acquisition range of 10nm.. This is grossly overdone, as most fighter sized airplanes cannot be visually acquired until much closer. It is a known fact, for example, that the F-16 can be easily acquired visually out to only 3 – 4nm., and some aircraft like the F-5 and MiG-21 are hardly even visible in head-on or tail-on aspect at 1nm.. We have adjusted all the AI pilot’s visual acquisition ranges to much lower values to reflect this. As fighter pilots say, “Lose the sight, lose the fight.” The AI now has realistic eyesight, albeit still a wee bit on the high side so as not to neuter it.

DESIGNING INFRA-RED SIGNATURES

In Realism Patch version 4, we have also given each airplanes IR signature that is unique. The IR signature is created by utilizing spare bytes in the named entry of the FALCON4.VCD file (ditto visual signature), and requires an exe patch created by Sylvain Gagnon. This visual signature will affect the IR acquisition range of IR guided missiles, and performs as a multiplier factor. In the design of the IR signatures, the engine type was taken into account, for example:

i. Turbo-jet engines, non afterburning, with typical EGT of 400 – 900°C
ii. Turbo-jet engines, afterburning, with typical EGT of 400 – 950°C in MIL
iii. Turbo-fan engines, low bypass ratio, with typical MIL EGT of 450 – 1050°C
iv. Turbo-fan engines, high bypass ratio, with typical EGT of 400 – 900°C
v. Turbo-prop engines, with typical EGT of 400 – 750°C
vi. Turbo-shaft engines, with typical EGT of 400 – 750°C

We have also considered if the airplane has any schemes implemented to suppress its IR signature, for example, the F-117 and F-22, and the Mi-24 and AH-64. Presence of IR suppressors will improve cold air mixing with the exhaust air, resulting in lower IR signature. We have also considered the presence of propellers and rotors, which will create improved cold air/exhaust mixing to further lower the exhaust gas temperatures (EGT) downstream of the exhaust pipe.

Lastly, the total number of engines was also considered. The presence of multiple engines increase the overall exhaust plume size, and although the plume peripheral will mix with the atmospheric air, the exhaust plume core will still be of higher temperature, leading to a greater IR signature. These factors were all taken into account in the design of the IR signatures.

TURNING ON THE HEAT

Infra-Red Countermeasures in Falcon 4
By "Hoola"

One of the biggest changes to come into Falcon 4 is the incorporation of infra-red countermeasure tactics. This takes place in four different forms, in engine IR signature variation with throttle setting, unique vehicle IR signatures (described separately in the previous section), flare effectiveness adjustments, and lastly, equipping relevant aircraft with flare/chaff dispensers. Of all, the engine IR signature variation began life as a request from John "NavlAV8r" Simon, to Sylvain Gagnon, to improve the engine IR signature with throttle position.

ENGINE INFRA-RED SIGNATURE VARIATION

The design of this dates back to pre Realism Patch version 3, sometime in May 2000. This originated as a request to improve F4 so that it allows real life IRCM and launch denial tactics to be used for online head-to-head play, as F4 does not model engine IR signature well.

In the default implementation, F4 models the IR signature as a linear function of engine RPM, i.e., for 70% RPM, the IR signature will be 0.70 that of the baseline, increasing to 1.0 at MIL, and 1.03 in max afterburner. This obviously does not correlate well with how engine IR and exhaust temperatures vary, as engine exhaust gas temperature can range from 450°C at IDLE to over 1,000°C at full MIL, and even above 1,400°C in afterburner.

Also, the IR signature is tied to the RPM decay. While the RPM decay in F4 is somewhat realistic and close to what a jet engine will provide, exhaust gas temperatures often do not decrease quite as fast due to the need for the engine core to cool down. Relating the engine IR signature in a linear function to the RPM will hence result in the engine exhaust gas temperature cooling way too fast, which is unrealistic and can be exploited to result in IR missiles going ballistic easily.

Based on our knowledge of jet engines and typical engine spool times as well as EGT (exhaust gas temperature) decay times, the engine exhaust plume temperature are mechanized as follows:

- For engine RPM at MIL or below, IR signature is the percentage RPM (divided by 100) raised to an exponent of 4.5. Hence, at IDLE (70%), the IR signature will be 0.20 that of MIL.
- For afterburner at 101%, the IR signature is 1.3 that of MIL, increasing to 1.4 at 102% RPM, and 1.5 at 103% RPM.

Players can cycle the throttle up to max AB and then back down to IDLE, and not have their engine IR signature increase to afterburner levels as long as the engine RPM never breaches 100% and never results in AB light-off.

As for the cool-down timings after throttle reduction, it is mechanized as a function of the magnitude and speed of throttle movement. Generally, the engine will cool down slightly faster if the throttle is reduced drastically, compared to small throttle adjustments. As a rough guide, the engine IR signature decay timings are as follows:

- For max AB to MIL at 100%, engine exhaust IR signature will take approximately 6 seconds to decay from 1.5 to 1.0.
- For MIL to 80% RPM, engine exhaust IR signature will take approximately 8 seconds to decay from 1.0 to 0.366.
- For 80% to 70% RPM, engine exhaust IR signature will take approximately 8 to 10 seconds to decay from 0.366 to 0.20.

In addition, the engine exhaust temperature is now reflected in the FTIT (Fan Turbine Inlet Temperature) gauge in the cockpit, so players can monitor their engine temperature.

The design of the engine IR signature went through many iterations to remove possibilities of players "cheating" by chopping throttle to IDLE rapidly upon IR missile launch, thus causing missiles to lose lock and go ballistic. We utilized a time stepping computation to determine under various engagement scenarios, the optimal cool down timings so that IRCM tactics can be meaningfully employed without causing unrealistic problems such as missiles going ballistic. With Realism Patch, throttling back to 80-90% RPM at a sufficiently far range (thus allowing the engine to cool down first) prior to merge can often deny a front quarter IR missile launch, by delaying IR missile acquisition to ranges under the missile Rmin.

FLARE EFFECTIVENESS

The way flare effectiveness is mechanized is the same as chaff, and will not be repeated here (see the sub-section titled "*The Falcon 4 Radar and Electronic Warfare Algorithm*" in the section titled "*The Electronic Battlefield*." The default F4 flare effectiveness array is as follows:

[0   5500   11000   16500   27500]
[0   0.0   1.0   1.0   0.0]

As you can see, flares lose their effectiveness totally below 5,500 feet from the target. This implies that even missiles with absolutely no IRCCM (i.e. flare rejection) capabilities will become totally immune to flares when they are within 5,500 feet of the target. In addition, between a distance of 5,500 feet and 11,000 feet, the missile will gradually gain higher flare rejection capabilities with decreasing range. This is no doubt a simplified manner of accounting for all possible target aspect angles without incurring the overhead computational cost of computing engagement geometry.

We have undertaken to address this anomaly which accounts for the missiles with no IRCCM being totally flare resistant at short ranges. The discussion below ignores the effect of IRCCM first, which will only confuse the issue.

Flares have typical burn time of 6-12 seconds. For an IR missile, it tracks the strongest heat source, (ignoring any IRCCM logic). When ejected from afar, it will see a stronger heat source separating from what it is tracking and then follows the stronger of the two, as long as the flare is crossing its seeker FOV at a rate that does not exceed its tracking rate. At closer ranges, the relative LOS (line-of-sight) rate of the flare increases, and at some point in time, it will exceed the seeker's LOS tracking rate. When this happens, the seeker cannot switch track to it since the flare is going too fast.

Hence, for a seeker without IRCCM, flare effectiveness should be effectively almost in a plateau from afar, then as line of sight rate increases, it should decrease to zero at the point where the LOS rate exceeds the seeker tracking rate (which means it should really be missile dependent).

Now consider these two scenarios, tail-on and in the beam, and a flare ejection velocity of 100 feet/sec on average. For a tail-on case, the LOS rate of the flare is purely its ejection velocity (assuming it stays the same throughout, which is not a bad assumption). Assuming a seeker tracking rate of 12.5 deg/sec to cater for early missiles (the higher the rate, the closer the missile needs to be for the flare be ineffective due to exceedance of LOS tracking rate), the flare velocity will result in LOS rate exceedance at a distance of 451 feet from the flare. For a missile with 25 deg/sec track rate, this decreases to 214 feet.

For an in-the-beam case, the LOS rate of the flare is purely due to the aircraft pulling away, since flares are ejected normal to the aircraft velocity vector. Again, assuming a seeker tracking rate of 12.5 deg/sec, and an aircraft velocity of 600 knots (1013 feet/sec), the distance at which the flare LOS rate will exceed seeker tracking rate becomes 4,568 feet, reducing to 2,283 feet when the airplane velocity decreases to 300 knots. For 25 deg/sec seeker tracking rate, the distances for 600 knots and 300 knots are 2,172 feet and 1,086 feet respectively.

Now, taking the case of the flare burning out while the target is in the seeker FOV, lets assume a case of a nominal 10 second burning time for the flare, and a seeker FOV of 3 degrees. Assuming that the target is centered on the seeker, the flare will remain in the FOV for 1.5 degrees. Taking 10 seconds and a flare muzzle velocity of 100 ft/sec, the total distance traversed by the flare to result in 1.5 degrees of FOV change is 1,000 feet. This translates to a slant range of 38,188 feet, beyond which the flare will burn out while the target is still in the seeker FOV and the seeker will switch track to the target after flare burnout. This is of course for a case in the tail-on aspect. For beam aspect, the distance becomes 386,721 feet at 600 knots target crossing rate, and 193,360 feet at 300 knots crossing rate. At distances inside these numbers, the missile will completely switch track to the flare (again assuming no IRCCM) and never will be able to regain the target after flare burnout since the target has moved out of the FOV.

Hence, we can average all the distances to form an effectiveness curve that is a compromise between early model missiles with low tracking rate and late model missiles with higher tracking rates (again, ignoring IRCCM as it will confuse the issue right now). The first breakpoint is obviously [0 0].

For close in tail-on, we are looking at a minimum range of 214 feet to 451 feet, depending on missile type. None of these matter much, so we have put it at 451 feet as it will better cater to early model seekers (else these early model seekers will be better than they should be). Below this range, flares should be ineffective. The second breakpoint becomes [451 0].

Then, we considered the minimum range for the in-the-beam case. It will be between 4,568 feet and 2,283 feet, and 2,172 feet and 1,086 feet. The most constraining factor becomes the early model seekers, which is between 2,283 and 4,568 feet. We took a mid point for a compromise and then rounded off, with the third breakpoint becoming [3500 1]. This allows interpolation between second and third breakpoints, to cater for some aspect differences.

Going to the fourth breakpoint, it goes out to 38,188 feet tail-on, and between 386,721 and 193,360 feet. These numbers convert to 6.3nm., 31.8nm., and 63.64nm. respectively. Obviously the last two numbers are ridiculous as IR seekers will not be able to see this far, so effectively, only 38,188 is useful. Rounding off, the last breakpoint (the fifth one) then becomes [38000 0]

As missiles are typically fired from less than 2nm. for heaters, the fourth breakpoint is left at where it still is, i.e. 16500 feet (2.71nm.). The revised breakpoint for the flare effectiveness distance array becomes:

[0 451 3500 16500 38000]
[0 0 1 1 0]

Now, IRCCM in F4 just functions as a probability of the missile biting on the flare, which is the flare chance. The flares will now work in full effectiveness down to 3500 feet, compared to 11,000 feet as before, and will continue to work though with reduced effectiveness down to 451 feet, compared to flares losing their effectiveness totally at 5,500 feet previously. For missiles without IRCCM, the flare will always decoy them. These include AIM-9P, HN-5, SA-7, AA-2, SA-14, AA-6, and AA-7. Missiles with some IRCCM may sometimes go after the first flare, and probability of it going after flares increases with number and frequency of dispense, depending on how sophisticated their IRCCM logic is.

This makes a real distinction in the capabilities of each missile. Against targets equipped with chaff/flare dispensers, missiles without IRCCM or with less sophisticated IRCCM will be totally useless, as the AI will employ flares at a rapid rate to try to decoy the missile. This relegates the early generation missiles to targets such as helicopters and transport airplanes, and replicates the true missile capabilities and puts these missiles in their rightful place on the modern battlefield.

EQUIPPING THE AIRCRAFT WITH IRCM

The downside of F4 is that it assumes that every aircraft is equipped with flare/chaff dispensers. However, this is not the case. One downside of the original Falcon 4 was that all aircraft were assumed to have chaff and flare dispensers. Since flares effectively render older IR missiles useless, this gives an unfair advantage to aircraft that are erroneously equipped with flares. As a result it is important to model the aircraft in the Falcon 4 world properly to reflect IRCM capability or lack thereof in particular in order to maintain appropriate game play balance.

The Realism Patch models the airplane self defense capabilities by adding an additional data flag in the vehicle VCD entry, to enable chaff/flare dispensing. Checking of this flag will indicate that the particular airplane is equipped with chaff/flare dispensers.

While it is arguable that most fighters should have chaff/flare dispensers, this is not so for early generation aircraft such as MiG-19, MiG-21, and MiG-23. Russian design philosophy in the past (and in the present) has always neglected the fighter aircraft, choosing to protect the ground attack platforms with better self defense equipment. In the extensive research for individual aircraft in F4, the following airplanes are determined not to be equipped with chaff/flare dispensers, and are modeled as such in the Realism Patch:

1. A-37B Dragonfly
2. An-2 Colt
3. An-12 Cub
4. An-24 Coke
5. An-70
6. An-72 Coaler
7. An-124 Ruslan
8. An-225 Mriya
9. C-5 Galaxy
10. C-141 Starlifter
11. E-2C Hawkeye
12. E-3 Sentry
13. Il-28 Beagle
14. Il-76M Midas
15. Il-76 Candid
16. J-5
17. KC-10 Extender
18. KC-130R Hercules
19. KC-135 Stratotanker
20. MD-500 Defender
21. MiG-19 Farmer
22. MiG-21 Fishbed (MiG-21PF and MiG-21bis model in F4)
23. MiG-23 Flogger-G (DPRK MiG-23ML)
24. MiG-25 Foxbat
25. RC-135C Rivet Joint
26. SR-71 Blackbird
27. TR-1
28. TR-2
29. Tu-16
30. Tu-16N
31. U-2
32. UH-1N
33. Y-8

HIT BOXES

Creating The Accurate Hit Boxes for Airplanes
By "Hoola"

Have you ever wondered how the AI was able to gun your F-16 from more than 5,000 feet away while you were jinking all over the place? If you have, the answer is here. We have found that the hit boxes for most aircraft in the Falcon 4.0 universe are grossly out of proportion, with some being too large (such as the F-16 being 4-5 times larger than its actual dimensions), and some being too small (such as the C-5).

DESIGNING THE HIT BOXES

The hit boxes for all the aircraft are revised differently depending on their physical geometry, and other factors. We have divided the aircraft types into low aspect ratio wing aircraft (mainly fighters), high aspect ratio wing jet aircraft (jet transports), high aspect ratio wing prop aircraft (prop transports), and helicopters. The guidelines used to re-define the hit boxes for every single aircraft in F4 are as follows, with the objective of minimizing the inclusion of empty space within the rectangular box representing the aircraft hit volume:

Low Aspect Ratio Wing Aircraft

These are mainly fighter aircraft. The geometry of the fighter aircraft is such that the bulk of the planform area forms the wing. The fuselage is often slender, and contributes to the bulk of the frontal area. From the sideward planform, the fuselage also forms the majority of the area. Defining a hit box based on the height of the aircraft including the vertical fins would have resulted in inclusion of a tremendous amount of dead space both sideways and head-on. The guidelines for the hit box dimensions are:

Length: 70% to 90% of actual fuselage length, depending on fuselage geometry. This will exclude the forward fuselage ahead of the wing, as this component is often very slender compared to the wing span.
Height: Based on actual fuselage diameter (average of width and fuselage height, as fuselages are elliptical).
Width: 50% of the wing span. For variable geometry aircraft, this is based on 50% of the average span for wings fully swept back and wings fully swept forward. Such a guideline will cover the horizontal tail span and minimize dead space inclusion.

High Aspect Ratio Wing Aircraft (Jet and Props)

These are mainly transport aircraft. The geometry of the transport aircraft is such that the wing is often long and slender, and occupies a small length along the fuselage. The fuselage is often slender, and contributes to the bulk of the frontal area. From the sideward planform, the fuselage also forms the majority of the area. Defining a hit box based on the height of the aircraft including the vertical fins would have resulted in inclusion of a tremendous amount of dead space both sideways and head-on. However, the propeller airplanes, the prop disk will contribute to the frontal area, and has to be taken into account. This is obviously dependent on the number of engines. The guidelines for the hit box dimensions are:

Length: 70% - 90% of the actual fuselage length.
Height: Based on actual fuselage diameter (average of width and fuselage height, as fuselages are elliptical).
Width: For jet transports, 25% of the wing span as this minimizes dead space inclusion for planform as well as head-on profiles. For twin props, 30-35% of the wing span, depending on the location of the prop engine vis-à-vis the wing. For prop planes with four engines, 35-40% of the wing span, depending on prop location.

Rotary Wing Aircraft

These are all helicopters. The geometry of the helicopter is such that the cabin is the biggest portion, and the tail boom is often very slender and long. The number of rotor blades and the rotor RPM also affects the solidity of the rotor disk in the planform view. The guideline for the hit box dimensions are:

Length: Actual fuselage length sans tail boom. For aircraft such as the Chinook, this means the entire fuselage, as the CH-47 does not have a tail boom. This will minimize dead space inclusion in the length as the tail boom is very slender compared to the fuselage..

Height: Based on actual fuselage diameter (average of width and fuselage height, as fuselages are elliptical).

Width: For twin bladed helicopters, the fuselage cabin width. This is due to the very low rotor solidity contributed by the low rotor RPM and low rotor blade count. For multi-bladed helicopters, 30% of the rotor diameter is used. This is to cater for the higher blade count and higher RPM, resulting in higher rotor solidity. For the MD-500, this is further increased to 70% of the rotor diameter due to the very high rotor RPM.

HIT BOXES AND GAMEPLAY

In actual aerial combat, achieving gun hits on enemy aircraft is a difficult task. The high speed and wild maneuvering means that guns are largely ineffective beyond 4,000 feet of slant range. With the original Falcon 4 hit boxes, gun kills can easily be obtained from more than 5,500 feet away, with a pipper that is even offset from the target.

Real life gunfights often require the shooter to close in to less than 3,000 feet, or even 1,500 feet, before the guns become effective. The reduced hit boxes will allow a more interesting and accurate multiplayer air-to-air duels. You will need to close in much more compared to before, often within 3,000 feet, or you will be wasting ammunition. You will also need to position your pipper accurately to obtain the kill. Easy head-on shots against fighters will now be a thing of the past.

One related concern that arose in the course of the hit box design was the effect on the AI and AAA. Much testing was done to quantify the AAA effects, and the reduced hit boxes were found not to be detrimental to the AAA accuracy. The AI pilots experienced the greatest problems though gun hits were registered. Microprose originally coded the AI to begin firing from 10,000 feet slant range, and the AI will cease firing within 2,000 feet. The AI also pulls less lead during the shot, and as a result, AI gun kills plummeted. With the help of Sylvain Gagnon, the AI was made to begin the gunfight at 5,000 feet, and will continue to press in and shoot until 1,000 feet slant range (depending on closure and relative speed, as the AI will avoid collisions). The AI will also pull more lead during firing, and all these contributed to maintaining an AI pilot with reasonable gunfire accuracy.

OPEN HEART SURGERY ON ARTIFICIAL INTELLIGENCE

The AI Changes In Realism Patch
Sylvain Gagnon and "Hoola"

In Realism Patch 4.0 and 5.0, major changes have been made to the AI behavior, most of which are the result of the ingenuity and dedication of Sylvain Gagnon, who created these EXE patches. Marco Formato had also assisted greatly in improving the helicopters. The write-up includes some of the considerations taken into account during the development and design of the patches.

AI SKILL LEVEL

In the implementation of 1.08US, the skill level setting in TE is non-functional. Regardless of the setting the that player selects, the pilot skills obtained are only Veterans and Aces. For campaign, whenever new pilots are received as reinforcements, their skill levels are restricted to only Veterans and Aces.

With the AI changes, the skill levels obtained are now close to what the player selects, and will be a mixture. For example, if rookie is selected, the squadron will be manned with some recruits, some rookies, and some veterans (the skill levels will be a mixture of what is selected, plus one level above and one level below). The same is applicable to reinforcements received during campaigns. In addition, F4 displays the experience of the squadron according to the LOWEST pilot skill. For a squadron with all aces and one rookie, the squadron will be displayed with an experience level of the rookie. With RP, the squadron skill level is now the average of the pilots' skill.

It should be noted that the skill slider affects only enemy squadrons in campaign. For the squadrons on the player's side, they are either 'Reserve', 'Regulars', or 'Veterans'.

Also, in F4, If you create 'Sortie' mission already taken off, pilot skills for planes with UNASSIGNED pilots will be set to Recruits (lowest settings). This has been changed to DISABLE the Fly icon until you advance the time so these planes have assigned pilots, as the sortie type mission has a stopped clock.

AI ABORT BEHAVIOR

The default AI behavior in 1.08US is atrocious. Once the AI aborts, it is totally oblivious threats, and it is easy to formate on the AI enemy plane once it is in the abort mode. Regardless of what you do, the AI will refuse to engage even defensively. In addition, AI planes armed to the teeth will often abort even though they have the ability to engage the threat. Ace pilots that see the player will also abort if they detect you but do not have the missiles to reach you.

With RP, the abort conditions have been amended to the following:

i. The AI has nothing to shoot at you with, not even bullets
ii. The AI is greater than 7nm. away from you, and is alone and without a wingman.

With these changes, the problem of aborting and cowardly AI is reduced. The AI will also engage defensively when the bandit is 7nm. or less from it. However, this fix is limited to in-game air-to-air abort, and neither UI abort, nor in-game air-to-ground aborts are affected.

The behavior of the AI after an abort was also altered and the AI is now more sensible about surviving and less fixated about landing back home. Prior to version 4 of the Realism Patch, the AI will DISREGARD everything around it except defending against a missile shot, and is meek enough for you to fly formation with it. With RP, the AI who has aborted and RTB will now react to you, whenever you are within its effective weapon engagement zone (WEZ). It will begin to plot an intercept on you, and shoot when within the envelope.

For an AI equipped with BVR missiles, it allows the AI still to be partly offensive while in RTB mode. Similarly, once another plane enters its WVR envelope, the AI will also seize the chance to shoot. However, once landed, the AI will not takeoff again to engage. Such behavior is more consistent with human reactions, and has been designed with the help of an RP member who specializes in behavioral sciences.

AI COMBAT BEHAVIOR

The biggest change in the AI is in combat behavior. In all versions of F4 prior to RP, the AI's sensory perceptions are tied to its weapons engagement zone (WEZ) outside a WVR envelope of 10nm. radius. For an AI equipped with WVR weapons, if the target hovers just outside the 10nm. WVR engagement range, the AI will blissfully be unaware of the presence of the target. Once this distance is breached, the AI will suddenly commit.

In addition, the AI will often launch its radar guided BVR missiles without a valid radar lock, the moment the target enters the weapon engagement zone. What is more vexing is that the AI's sensors are not limited to their coverage zones once it has detected you. This results in the AI still being able to maintain radar lock even after it flies past you in a merge. The following describes the changes made to the AI with respect to its usage of onboard sensors, as well as BVR and WVR tactics.

Sensor Usage

In Falcon 4 as Microprose/Infogrames coded it, the instant the AI pilot detects a target with any of its onboard sensors (visual, radar, RWR, or IRST), every sensor on the AI plane is directed to point at the target. This results in the sensors not obeying their gimbal limits. For example, once a target is detected by say the RWR, the AI's radar is directed at the target. Even if you fly behind the target, its radar is still directed at you. Moreover, a poor form of GCI (Ground Controlled Intercept) is implemented by giving AI Ace and Veteran pilots an automatic target acquisition range of 15nm.. Hence, even if you ingress amongst the weeds and the AI is at 40,000 feet altitude, once inside 15nm., it will automatically detect you, never mind the fact that it's radar may not even be capable of look-down operation.

Beginning with RP4, the AI's sensors (RWR, IRST, radar, and visual) are constrained to their respective range and azimuth/elevation coverages. The AI will have to locate you on each of its sensors. As such, it is possible to sneak up to an AI undetected through its blind visual cone, with your radar turned off, and ambush the AI with an uncaged heat seeking missile. Similarly, the AI will no longer be able to automatically locate your presence if its sensors are not able to detect you. This makes real life low level ingress tactics possible.

More importantly, and tied to the effective operation of ECM, or rather the lack of effectiveness of ECM, the default algorithm for refreshing radar locks in F4 1.08US has the radar lock being maintained in perpetuity once the lock is obtained. The AI's radar does not drop track after it has obtained initial lock even when the signal strength decreases below detection level. As a result, the AI is able to maintain constant lock on you, despite jamming or beaming. This also accounts for why beaming and ECM are effective only if initiated before the radar lock is obtained, and fails to work thereafter. This is also rectified in RP, and is the main contributing factor to the whole new electronic warfare battlefield being created.

Also related to the AI's use of radar is how it regards ECM. Electronic counter-measures do not render full invisibility to the user. On the contrary, it will often result in tell tale traces of its approximate location on the radar screen, for example, snowing, or angular noise data, and the radar may sometimes be able to display angular information even though range and velocity measurements are denied. For a real pilot, they will have remembered where the target previously was prior to the ECM breaking their radar lock, and will continue to press in for re-acquisition on their radar. Such traces of information are also sometimes sufficient for pilots to determine approximate angular position of the jammer. This is now captured in the RP. Usage of ECM will leave behind sufficient traces and the AI will continue to press towards you even though it is not able to gain a valid track on you, as long as you are inside its radar coverage.

The AI wingman will also now employ ECM when the lead does. This allows the AI pilot to have ECM protection as well. As in the original F4, the lead pilot is the only one that will employ ECM, and other wingman will not activate their ECM even though they are carrying it.

A related bug fix was also with the AI's visual acquisition ability with respect to contrails. F4 implemented this erroneously, with contrails **decreasing** visual acquisition range by 4 times instead of increasing it. Contrails now will increase the visual acquisition range by 4 times, though clouds will still affect acquisition ranges for visual sensors. In addition, damage sustained by planes will leave a smoke trail that will similarly increase visual detection ranges, as will leaving the navigation lights turned on as the sky turns dark.

AI Skill Levels and Performance

The AI's performance and adeptness at using its onboard sensors is also now tied to the skill level. Pilots vary in their ability to operate their sensors effectively, and in their ability to transit smoothly from BVR fight into WVR fight. Novice pilots are known to be fixated on staring at radar scopes in vain to see their target when transiting from an intercept to a merge. Similarly, novice pilots and even experienced pilots are sometimes fixated on HUD presentation and forget that there is a whole world outside the HUD field of view. All these factors affect the ability of the pilot in successfully acquiring the target using their Mark I eyeball.

Beginning with RP4, the visual acquisition range of the AI pilot is mechanized as such:

Recruit:	0.83 times the visual acquisition range
Cadet:	1.18 times the visual acquisition range
Rookies:	1.44 times the visual acquisition range
Veterans:	1.67 times the visual acquisition range
Ace:	1.86 times the visual acquisition range

As every plane in F4 has its own vision envelope peculiar to it, AI pilots will lose sight in a dogfight if you enter its blind visual cone. With the default AI behavior in F4, the AI will immediately lose its awareness of your presence if it does not have any other onboard sensor that has acquired you. This can potentially lead to the AI transiting to RTB mode and becoming totally defenseless.

To overcome this potential shortcoming, the AI have been mechanized with a limited amount of "memory." The AI will retain its knowledge of where you were for a specific amount of time related to its skill level. For a recruit, this time will be 24 seconds, while for an Ace, this timing will be about 32 seconds. This confers the AI some degree of ability to keep fighting and reacquire the target visually.

The way the AI employs its weapons is also skill level related. In F4, the lower skilled pilots will wait a little longer before launching their weapons compared to higher skilled pilots. This results in the lower skilled pilots actually launching missiles within a firing envelope of higher Pk than the higher skilled pilots. This effect was due to the AI firing routine being run less frequently (it is tied to the AI's sensor routine) and hence the AI being closer to the target when they satisfy the shoot conditions.

In RP, this is modified such that the lower skilled pilots will shoot earlier (i.e. shoot at a range where the missile Pk is lower, i.e. closer to Rmax1), while the higher skilled pilots will wait a little longer before shooting (i.e. shoot at a range closer to Rmax2). This is mechanized by reducing internally within the AI the Rmax perceived by it, thus constraining the higher skilled AI to shoot closer.

For the RP AI's use of radar guided BVR missiles, skills will also affect missile evasion capabilities and how long the AI pilot will support its own missile in flight. If the AI already has a missile in flight towards the target, and the target retaliates by shooting at the AI, lower skilled pilots are more likely to commence evasive maneuvers immediately and forego supporting their missile in flight. Higher skilled pilots will wait a little longer before commencing the evasive maneuvers, thus giving their missile a higher chance of getting near the target or shooting down the target. This is mechanized as described below.

Recruits – random duration, ranging from 1 second to how long ago it launched its missile
Cadets – random duration, ranging from 2 seconds to how long ago it launched its missile
Rookies – random duration, ranging from 3 seconds to how long ago it launched its missile
Veterans – random duration, ranging from 4 seconds to how long ago it launched its missile
Aces – random duration, ranging from 5 seconds to how long ago it launched its missile

This gives the higher skilled pilots better Pk for a missile that is already in-flight for considerable duration. It will however evade sooner and increase its survival chances if the missile time of flight is still short.

BVR and WVR Behavior

One of the biggest changes made to F4 is the BVR engagement behavior. In fact, the AI changes originated from the aim of changing the AI BVR behavior. F4 does not distinguish between BVR and WVR combat, and employs basically the weapon with the greatest range. This makes modeling decent BVR fights impossible other than the AI taking long range shots at you while driving inbound. BVR intercept tactics such as pince and single side offsets are not possible due to this anemic representation. Also, Sylvain discovered that the AI wingman will only employ its visual sensor to check for other targets, while its radar will only scan for the target that the lead has locked onto.

The RP AI changes makes a distinction between BVR and WVR combat, with WVR combat defined as inside 10nm.. For BVR combat, once the AI sees the target, it will begin a pince or single side offset maneuver instead of driving straight at the target. For an element, the flight lead will take one side of the maneuver, and the wingman the opposing side. For the pince and single side offset, it is executed with a 4nm. separation between the lead and the wingman. The wingman will also use its radar to scan for all possible targets during the intercept, in addition to the one that the lead has locked onto.

BVR combat is set to commence at 30nm., or the WEZ of the longest range weapon loaded on the AI, whichever is higher, provided the AI has detected you. The BVR engagement range is also related to the mission type. For example, flights tasked with air-to-ground missions will not commit as far out as flights tasked with sweep or OCA. As this is tied to the onboard weapon WEZ, it allows for better armed AI pilots to initiate the BVR fight from further out (such as AA-10C, or AIM-54 armed airplanes), and lesser armed AI pilots to initiate from closer distances (such as AA-7 or AIM-7 armed airplanes). This prevents inadequately armed AI pilots from initiating the BVR fight from too far out. The 30nm. range was chosen as typical range for initiating BVR engagements.

In addition, both flight lead and wingman will now employ their onboard sensors throughout the maneuver, with each being able to take a shot whenever their respective shoot conditions are satisfied.

Weapon selection in F4 was also a simple case of the AI selecting the weapon with the Rmax **closest** to the target range. In a situation where the AI sensor is prevented from acquiring the target early (such as due to ECM), it will lead to cascading effect with the AI switching to WVR weapon when closing in from BVR (especially if WVR weapons have forward quarter WEZ beyond 10nm.). It will also sometimes lead to the AI not firing its missiles in a dogfight, preferring to employ guns instead.

With RP, unless the weapon is the AI's only weapon onboard, the weapon selection routine is changed to allow the AI will select the weapon based on the following conditions:

i. Weapon with the highest Rmax
ii. AI range to target must be greater than the weapon's Rmax divided by 3.5

For WVR combat, the AI's ability to gunfight is modified. In F4, the AI will commit to guns if the slant range is 10,000 feet or less, though if it has a missile, it will still use the missile. The AI will also not shoot below 2,000 feet in slant range. This results in the AI commencing gunfiring from more than 6,000 feet slant range if it only has guns, and with a realistic hit box for each aircraft, the AI is not capable of hitting anything. Realistically, gunfights are not committed until much closer ranges, often below 3,000 feet, and will carry on up to 1,000 feet or less.

With RP, the AI will commit to guns only at 5,000 feet slant range. This prevents the AI from shooting beyond this range and wasting ammunition. In addition, the AI will continue to shoot until 1,000 feet slant range, subjected to closure speeds that will not trigger the AI to avoid a collision. The aiming accuracy is also improved with the AI taking more lead before commencing firing.

The AI's ability to support their BVR weapon in flight when they are shot at is also added in the RP (see section on AI Skill Level for details). The AI will now try to hold the radar lock a little more before commencing evasive maneuvers, thereby giving their weapon a better chance at hitting the target.

One annoying problem with the AI in WVR combat is that it will often go into ground avoidance mode and maneuver strangely. The AI will always check for its height above ground, and if its calculated turn circle exceeds its altitude, it will enter ground avoidance mode and maneuver accordingly. This makes BFM fights quite weird, with the AI switching between fighting and avoiding the ground even in a horizontal turn. With RP, the AI will not ever go into ground avoidance mode if their altitude is higher than 10,000 feet.

The last change affects both the players and the AI. The default F4 way of computing missile WEZ is based on using the relative bearing of the shooter and the target. This is obviously wrong as missile WEZ is dependent on aspect angle instead. This is now reflected in RP, and the WEZ display in the HUD should be more sensible with aspect changes, and AI will also employ the weapons more sensibly as a result.

A/A and A/G Targeting Behavior

The way the AI targets other aircraft is also altered. This is mechanized slightly differently for AI flights targeting other flights, and the player's flight targeting others. In 1.08US and 1.08i2, if the player commands the wingman or element to attack a certain target, then they will only attack that target. With Realism Patch, up to two AI flight members will shoot at the target, until the player repeats the command again. This is to allow the player some degree of flexibility at sorting targets.

As for the way the AI flights target other flights, the flight lead will always target the opposing flight lead, while the others will target their respective counterparts. If the targeting flight is a four-ship flight, and the targeted flight is a two-ship flight, both the flight lead and the element lead will target the two-ship flight lead, while their wingmen will target the two-ship wingman. Conversely, for the two-ship flight being engaged, the lead will only target the opposing flight lead, while its wingman targets the opposing flight lead's wingman. The opposing element will not be targeted. This gives a slight improvement and prevents multiple AI ships from attacking and fixating on a single target while letting other targets off.

The AI targeting in 1.08US often resulted in multiple missile shots at the same target, even when the target was badly damaged and has lost control. Although F4 has code to prevent the AI from shooting when the target is about to explode, the time interval at which this is checked often meant that the AI will still be shooting if the target does not explode immediately.

With RP, the AI will now stop shooting when the target is badly damaged and out of control. The AI will also switch targets, but not if it is supporting an SARH missile in flight, unless it is being threatened itself, in which case self preservation will take precedence. The AI will also build its potential target list out to 20nm. away against fighters, and 5nm. away for other aircraft.

One related finding during the course of RP testing is that whenever the AI wingmen request for permission to engage, they set an internal count-down timer of 30 seconds for you to respond. If they are given a “Weapons Free” command, they will still not do anything as the “Weapons Free” command does not check for engagement (BVR, WVR, missiles, or guns). This means that they will only react when they are shot at.

With RP, the moment the “Weapons Free” command is given, the AI will proceed to find their own targets and you will not even need to designate one if you have not. Unless you want the AI to shoot at a specific target, a “Weapons Free” command will unleash them.

One of the annoying AI behaviors in 1.08US is that the AI will ask for permission to engage as they pass the IP, whether or not they have a target. When this happens, a variable is set to indicate that they have requested for permission. If a “Weapons Free” command is given, they will check this variable to confirm that they have asked for permission, and then clear it and look for a target. The problem is, if the AI cannot find a target, they will reply as “Unable,” and then they will no longer search for targets in response to subsequent “Weapons Free” commands. However, if you delay the issuing of the “Weapons Free” command until they are within 5.4nm. of the targets, they will have a target selected and will attack the target in response to the “Weapons Free” command. This search distance of 5.4nm. has now been extended to 8.3nm. in RP to improve the AI’s A/G abilities.

A new “Attack Targets” command has also been added in RP, and once this command is issued when you target a specific plane in a formation, the rest of the AI wingmen will target their respective counterparts. The opposing lead may however be left untargeted as this is the flight lead’s responsibility. The “Attack Targets” command also applies in A/G combat. It should be noted that the “Attack Targets” command should be used when you want the AI to attack a specific target(s), but the “Weapons Free” command should be given when you want to allow them to search and attack targets on their own. The AI will now also begin to search and monitor ground targets at the waypoint before the actual target waypoint. When they find one, they will now request for permission to engage, and will do so if you give them the “Weapons Free” command. Do note that if you have mistakenly targeted friendlies and requested the AI wingman to attack them, there is a chance that recruit and cadet AI pilots will comply, leading to fratricide.

A related change is with the AI’s response to your “Weapons Hold” command. In 1.08US, the AI will still engage even when you issue the “Weapons Hold” command. The “Weapons Hold” command was largely cosmetic. With RP, if the “Weapons Hold” command is given, the AI will withhold and not shoot. You will need to respond within 30 seconds of the AI requesting permission to engage, or else the AI will proceed to attack.

The A/G behavior of the AI wingman is also modified. Previously, once committed to an A/G attack, the AI would persist in the attack even when the player issued a command to rejoin or re-target the AI at inbound enemy aircraft. The targeting behavior in A/G was changed to also allow A/A targeting, and it is now possible for the AI to switch to A/A when ordered to.

In 1.08US, the AI flight lead will always choose a random feature to bomb during an A/G mission. The wingmen in the flight will choose their targets according to the order of features comprising of the target. This behavior accounts for the wingmen bombing taxi signs and taxiways during airfield strikes, instead of target the more important targets such as runways and control towers.

With the RP, the AI flight lead will now target the mission assigned target, unless the target has been destroyed, in which case it will select the next target on the feature list. The list of features for all the objectives are contained within the FALCON4.PHD, FALCON4.FED, and FALCON4.OCD files. The features that makes up objectives (examples of features are control towers and taxiways, and an example of an objective is an airbase) have been resorted for all the objectives, in order of decreasing value. As such, the features of the highest value are listed at the top. With the new AI A/G targeting behavior, the AI flight lead will always target the most important feature, and the wingmen will target the features of decreasing importance, in a sequence corresponding to their position in the flight (i.e. the lead's wingman will target the second feature of the objective, and so on). If their target has been destroyed, they will target the next feature. For example, if #1 (in a flight of 4) is assigned to destroy feature #1 and it had already been destroyed, it will then target feature #5. If feature #5 has already been destroyed, it will then target feature #9.

For AI attacking ground units, the default behavior of the flight lead in 1.08US was to switch to another undestroyed target after releasing one weapon. This ensures that the lead does not release two weapons at the same ground target. However, the targeting behavior of the AI wingman is different, and the AI wingman has a tendency to release two weapons (such as Maverick missiles) at the same target. This decreases the number of kills made by the wingman.

With the RP, the targeting behavior of the AI wingman is now the same as the AI flight lead. The AI wingman will switch to another target that has yet to be destroyed at the time of target selection, after releasing each weapon. For AI employing air-to-ground missiles such as the Maverick, the AI wingman will fire one missile at each target. This improves the A/G kill ratio of the AI wingman. The AI also will behave as described if the player is the flight lead, and if the player issues the "Attack targets" command. If the player issues an "Attack my target" command, the AI wingman will attack the target that the player has commanded it to. If the command is "Weapons free," the AI will behave like a pure AI flight.

Bombing and Ground Attack Behavior

One of the persistent problems in Falcon 4 is the AI's bombing behavior. The AI is consistently bombing approximately 50 feet short of the target. No discussion of bombing accuracy can be complete without a discussion of the bombing system.

Bombing accuracy is expressed in terms of Circular Error Probability (CEP). The CEP describes the distance from the target, within which 50% of all the bombs will impact. The total CEP of a bombing system consists of the individual CEP of the bombing sight, ballistic variations in individual bombs, inaccuracy in pilot techniques, and variations in weather (air density, altitude, wind gradient), as well as inaccuracy in radar azimuth and ranging information.

CCRP uses the radar to obtain target azimuth and ranging information. In all bombing systems, data from the inertial navigation system is also used to determine the winds aloft, at the aircraft's altitude. There are some assumptions made by all fire control computers, which will integrate and determine the wind gradient down to the target's altitude. This is used to determine the effect on the bomb ballistics, and compute the bombing solution.

However, temperature variations and difference in wind gradient will affect the ballistics of the bomb. This is made worse if the temperature variations and wind gradient differs from what the fire control computer thinks. Typically, the bomb will impact between 2 to 3 milliradians away from the intended impact point. At a slant range of 10,000 feet, this translates to a CEP of 25 feet (meaning that 50% of all the bombs will impact within a circle of 25 feet radius, centered on the target).

For CCIP, the accuracy in a perfect bomb run is typically less than 1 milliradian, translating to one foot per 1,000 feet in slant range. For a slant range of 10,000 feet, the CEP will be 10 feet. However, weather variations, and variation in pilot technique will often increase the CEP. CCIP systems typically require some time to "settle" down on the bombing solution, and require the pilot to place the pipper smoothly onto the target. At low altitudes, due to the larger apparent target size, pipper placement is easier. As the altitude increases, the apparent target size decreases, making pipper placement increasingly difficult. Battlefield smoke and dust will often obscure the target, leading to late or inaccurate pipper placement. Combat stress will also affect bombing performance, especially in the face of strong enemy air defenses. All these factors will contribute to bombing inaccuracy. Typically, newer pilots are more affected than experienced pilots.

The inaccuracy in bombing is now captured in the Realism Patch. The bombing accuracy is dependent on the aircraft altitude, as well as pilot skills. For ace AI aircrew, the bombs will impact between 0 to 63 feet away from the target, when the bombing is conducted at 10,000 feet. For recruits, the accuracy ranges from 0 to 315 feet at 10,000 feet. The bombing accuracy will result in the bombs falling short as well as long, to simulate the effect of CEP. Bombing accuracy is doubled at 5,000 feet, and halved at 20,000 feet. The variation between 5,000 feet and 20,000 feet is linear. The effect of such changes creates a penalty for releasing unguided bombs are medium level altitudes, as the accuracy suffers. Low altitude bombing increases the bombing accuracy, at the expense of exposing the strike aircraft to SHORAD threats. The mechanization if the bombing inaccuracy is as follows:

a. A random variable between –64 and +63 is set for the bomb impact point.
b. This random variable is multiplied by the result of subtracting the skill level from 5. For ace, the skill level is 4 for ace, and 0 for recruits.
c. The result is then multiplied by the aircraft's altitude, and then divided by 10,000, to obtain the offset for the impact point. When the aircraft is at 10,000 feet, the offset remains unchanged. This gives the offset for the impact position. For ace, the worst case impact point offset is 64 feet, while this becomes 320 feet for recruits. The altitude multiplication factor halves the offset point at 5,000 feet, and doubles it at 20,000 feet, thus penalizing medium altitude bombing.
d. The offset is then added to the designated impact point (which is the target's position), to obtain the true bomb impact point.

Bombing accuracy is also increased. In 1.08US, the AI will determine the bomb drop point by using the difference between the impact point and the target's co-ordinates. This always results in the AI bombing short by about 50 to 100 feet, and is noticeable only when you release Mk-82 bombs. The larger blast radii of other larger bombs will often obliterate the target and mask this problem. The altitude of the impact point is increased by 100 feet artificially in the AI aiming algorithm with the Realism Patch, and the AI will now bomb accurately, with the bombs hitting the desired aim point. The bombing inaccuracy and spread will be superimposed on this.

With 1.08US, the AI was coded to release bombs in pairs. This was in response to many user's complaints that the AI was rippling off all its bombs in a single pass. However, the change resulted in the AI making multiple passes over the target. With the more capable air defenses, such tactics are suicidal, and results in a high attrition rate for the AI. Such tactics are also not sound realistically, since most bombs are released in a ripple, especially in the presence of any significant surface-to-air threat. With the Realism Patch, the AI will now release all of the same type of bombs at one go. For example, if the AI is carrying a mixture of CBUs and low drag bombs, the AI will release all the CBUs in one pass, and all the low drag bombs in another pass. This reduces the number of repeated passes over the target, and is more consistent with real life tactics.

The default AI behavior in 1.08US also resulted in the AI overflying ground targets when employing air-to-ground missiles such as Mavericks. The AI will continue to ripple fire its missiles until it reaches the minimum range of the missile, by which time they would have entered the lethal engagement range of SHORAD systems defending the ground targets. This often result in a high attrition rate due to MANPADS and AAA, and lowers the survivability of the AI considerably.

The air-to-ground missile employment has been changed in the Realism Patch. The missile employment behavior has been altered, such that the AI will fire at most two missiles at each target. The original AI logic will command the AI pilot to initiate another pass when the weapon count reaches one. For example, if the AI is equipped with six missiles, it will only initiate another pass when it is left with one missile, and will fire off five missiles in the first pass. The AI is now commanded to initiate another pass whenever it has fired off two missiles (i.e., the third and fourth missile will be fired on the second pass, and so on). If the AI is still in firing parameters after releasing the first two missiles, it will wait for an interval of 5 seconds before firing the third missile. This results in the AI breaking off the pass much earlier, before it enters the SHORAD range of the ground targets. For AI pilots tasked with six Mavericks, this will result in three separate passes with two missiles fired per pass. Such behavior improves the survivability of the AI pilots, especially in the face of sophisticated SHORAD threats such as the SA-8, SA-15, and SA-16.

One of the bugs that we have discovered during the development of the A/G AI behavior is the tendency for the AI pilot to fire the first Maverick missile without a valid lock on the target. The AI is now forced the ensure that their Maverick missiles have locked onto the target, before they are allowed to shoot.

For AI tasked for search and destroy, interdiction, or BAI missions, or AI carrying air-to-ground missiles, they will now keep pounding their targets or keep looking for targets, as long as they have unexpended ordnance with them. With 1.08US, after every pass, the steerpoint will move to the next one. This leads to the AI bringing back unexpended ordnance. With the Realism Patch, the AI behavior has been modified such that the steerpoint will not increment to the next one until the AI has expended all its air-to-ground ordnance, or there is nothing else to destroy, or it has stayed in the target area for more than 10 minutes. This improves the air-to-ground capability of the AI, resulting in a higher number of kills.

One of the problems with the AI in 1.08US was the random occurrence of the AI lead requesting the wingman to rejoin, while the wingman is still carrying air-to-ground ordnance. The problem was with one of the wingman becoming the air-to-air target of the lead. When this happens, the AI lead request the wingman to rejoin since it cannot be a target, even though other wingmen may still be carrying air-to-ground ordnance and in the midst of attacking ground targets. With the Realism Patch, this bug is now fixed, and the AI lead will ignore air-to-air threats while engaging ground targets.

The main factor affecting AI survivability in 1.08US is the tendency for the AI to stay in trail formation after attacking ground targets. This is akin to lining up all the aircraft in the flight for target practice. With the Realism Patch, the AI wingmen will automatically assume the wedge formation after pulling off the ground targets, and they will also initiate tighter and harder turns away from the targets after attacking them. This improves the AI survivability by lowering the transit time through hostile territory, and the tighter pull-off from the target prevents the AI from overflying ground threats some of the time.

During the course of development of RP5, one of the problems that surfaced was the AI flight (especially the AI flight lead) loitering around the target area after attacking it, and then it would return to base, but not follow the steerpoints. This often results in the AI flight overflying ground threats, and affected the survivability of pure AI flights.

As it turned out, the AI lead was setting itself up for another pass over the target, even though it had expended all its ordnance in the preceding pass. The AI kept at this until it became too late for it to reach the next steerpoint on time, and it then skips the next steerpoint and heads directly back to base. This behavior is now corrected in the RP, and the AI flight lead will no longer loiter around the target area, but will proceed to the following steerpoint immediately. The altitude selected for the steerpoint immediately after the target defaults to the cruise altitude for each individual aircraft type (defined in the FALCON4.VCD file). For the F-16, this means that the AI will climb to 22,000 feet at 420 knots immediately after bombing, which will bring the AI flight out of SHORAD range, thus increasing their survivability. The default cruise altitude for all the aircraft have been adjusted to improve their survivability, and this is discussed in the sub-section titled "*Helping the Air Tasking Order Engine*."

One of the most important changes in the AI's survivability during bombing runs is the AI's self-defensive measures. The AI is mechanized to dispense one flare and two chaff packets as it completes a bomb run. This is a common tactic used by pilots, i.e., to release countermeasures pre-emptively, especially when flying over SHORAD threats.

The final change in the AI's behavior during A/G missions is the AI's ability to obey the "Rejoin" command. Prior to RP5, when the AI is attacking a ground target, and the player orders the AI to rejoin formation, the AI will ignore the command, and continue with the attack. The AI will only rejoin the formation when it has completed its attack. As a result, the AI cannot be ordered to break off a ground attack and prepare to defend itself against enemy fighters. The AI will also ignore the "Rejoin" command once they have set their next waypoint to the landing waypoint. This makes it impossible to request the AI to rejoin the formation once they are in transit to the airfield. With RP5, the AI will clear its ground target, and rejoin immediately. If the AI is defensive and evading a missile, it will defeat the missile first before it rejoins. The player can order the AI to attack another ground target, or to attack an air target. Once the "Rejoin" command is given, the AI will also set its waypoint to the player's current waypoint. The only time the AI will ignore a "Rejoin" command is during landing, or if the AI has landed. This gives the player a greater degree of control over the behavior of the AI.

SEAD Strikes and SEAD Escorts

For SEAD strikes, the entire flight is often loaded with only HARMs, and all the HARMs will be launched at a single radar. This results in a very high wastage, since SEAD strikes are often tasked to a flight of four, and with two HARMs per aircraft, up to seven missiles will be wasted. The same problem afflicts the AI's employment of the HARM missile. The AI will always fire the missile when it reaches half the missile's maximum range, even if the target radar is not emitting. SEAD escorts will not engage threats that they encounter along the route to the target, and neither will they engage multiple SAM targets. This behavior makes SEAD escorts practically useless in Falcon 4, as they fail to protect themselves as well as the flights that they are escorting.

Many changes were made to the AI tasked for SEAD strike and SEAD escort missions. The changes affect both 2D and 3D combat. In the RP, for 2D combat, if the IP is closed to the target steerpoint, the flight will not wait until they reach the IP before they will engage the target. The flights will commence engagement if their range to the target is less than the effective 2D-engagement range of the target against them. The 2D flights will also fire only one HARM per aircraft, instead of two as in 1.08US. This behavior permits the flights to engage at least two different targets in 2D

For 3D combat, the flight lead of a HARM equipped AI flight that is tasked for SEAD strike or escort will only target a radar vehicle or radar site, and the wingmen will ignore the radar vehicle/site. If the lead does not have HARM missiles loaded, another flight member will target the radar vehicle/site. The AI flight members will query the loadout of each member, thus preventing the flight members from shooting multiple missiles at the same target. If the wingmen are equipped with CBUs and HARMs, they will not fire their HARMs unless the flight lead is shot down, in which case the lead's wingman will assume the flight lead position and use its HARMs. The other wingmen will use their CBUs against the SAM launchers. This change improves the usage of HARMs and reduces wastage, while improving the targeting ability of the AI.

With the RP, the AI pilot will not use the HARM if the target radar is not radiating. When the AI closes to within half the effective engagement range of the HARM, and the target radar is still not radiating, it will switch to another weapon if available, as long as the AI is equipped with another type of air-to-ground ordnance (excluding guns). The AI will however check the radar status every 5 seconds, and should the radar start to radiate, it will attack it with HARMs. If the AI is equipped only with the HARM missile, the missile will not be fired when the target is not radiating, and the AI will fly to the next steerpoint if the target radar remains off. This prevents the AI from shooting at SAM radars that are not radiating. The AI will also launch the HARM and Maverick missiles at the deaggregation distance or weapon's range, whichever is shorter. SEAD escorts will also attack from stand-off distance if possible. If a 3D plane fires a HARM at an aggregated SEAD target, this will also prevent other flight members from attacking the same target with HARMs. In terms of target prioritization, the AI will prioritize radars that are radiating over radars that are not. Should a radar begin to radiate halfway through an attack, the AI will now re-prioritize and attack it.

The HARM launching algorithm was also refined. In 1.08US, the AI will pull away from the target and reset the HARM attack run if it is inside 1.1 times of Rmin, or if the target is more than 135° off its nose. The AI will also pull back by a distance of between 15 to 21 nm. This leads to the AI flying very far away before turning back to re-attack. With the Realism Patch, the AI will now pull away if the target is inside Rmin. The distance at which the AI will pull back 0.5 times the Rmax and then multiplied by the x and y offset of the target from the aircraft boresight. The AI will also employ the HARM if the target is within ±60° off its nose, as compared to ±15° in 1.08US.

For SEAD escorts in the Realism Patch, the AI will stop its attack when all the radar vehicles in the target SAM unit have been destroyed. SEAD strikes will continue to attack the target to total destruction. This behavior permits the SEAD escorts to stop attacking when the air defense unit is incapable of posing a threat anymore, and allows the AI to switch its attention onto other air defense threats. This is mechanized by allowing the SEAD escort flight lead to switch targets when the radar vehicle is destroyed, and it will order the AI wingman to rejoin and switch targets as well. For AAA units, the AI flight will only stop attacking when all the vehicles in the unit have been destroyed, as the guns can still fire without the fire control radar. The AI flight lead will also climb to 4,000 feet AGL when it is switching to LGBs/CBUs, instead of flying at low altitudes. This change in behavior gives the cluster bombs sufficient height to burst open. If the AI is carrying HARMs, it will remain at low altitudes. This improves the AI's survivability. The AI flight lead will also check at 5 seconds interval to see if its target is the same as the 2D engine's target, and will switch to the same target as the 2D engine if there is a mismatch. The AI's choice of its target is also related to its skills. The AI may choose a vehicle or feature at random (which could have been destroyed, or already being targeted by someone else). Recruit AI will have a probability of 5 out of 32 to do so, decreasing linearly to 1 out of 32 for Ace AI.

The ATO engine was also modified to permit SEAD strikes to attack targets of opportunity along their route. They will however still proceed to attack their primary targets. This allows the SEAD strikes to engage any SEAD targets that may be threatening them, and allows the AI to defend itself against such threats. This is made by assigning the SEAD action to all waypoints between the third and second last waypoints in the flight plan.

If the flight lead is evading a SAM, and other members of the flight still have air-to-ground ordnance and are not attacking any other targets, the wingmen will attack the SAM site that has launched at the flight lead. If the flight lead already has a target at the time of the SAM launch, the wingmen will attack the flight lead's target while the lead takes evasive actions. The AI will also react to missiles that are launched at them when they commenced their attack run. This behavior is a big improvement over 1.08US.

The changes in the behavior of the AI tasked for SEAD strikes and SEAD escorts drastically improved their effectiveness over 1.08US. The AI will now sweep and clear the route for strike flights effectively, and in many cases, will decimate the enemy air defenses, even if they have been caught in a SAM trap.

Ground Attack Altitudes

Changes were made in the AI's ground attack altitudes to improve its survivability as well as to model real world tactics. The driving factor behind the changes in the Realism Patch was the inability of the AI to adequately defend itself against low altitude AAA and SHORAD threats. The AI weapon delivery altitudes was also not differentiated properly in 1.08US.

With the Realism Patch, the changes have been made as such:

1. For SEAD flights, anti-radiation missiles will be launched at low altitudes. The AI will climb to an altitude of 4,000 feet in a pop-up maneuver if they need to deliver bombs (iron bombs, cluster bombs, and laser guided bombs).

2. Air-to-ground missiles will be delivered at a higher altitude of 4,000 feet, instead of the low 1,500 feet AGL in 1.08US.
3. Laser guided bombs will be delivered from an altitude of 13,000 feet. The AI will also continue to lase the target for a duration of 27 seconds.
4. Low drag iron bombs will be delivered from an altitude of 11,000 feet.
5. High drag iron bombs will be delivered at an altitude of 1,000 feet. High drag bombs are defined as bombs will drag factor of 0.9 or more, in the FALCON4.SWD entry.
6. Durandals (BLU-107) will be delivered from 250 feet. The AI will attempt to get as close to this delivery altitude as possible.
7. Cluster bombs will be delivered from an altitude of 5,000 feet. This gives the cluster bomb better performance, and allow the bombs to dispense their contents.
8. Rockets and gun strafe will commence in a dive towards the target, at a starting altitude of 7,000 feet.
9. Iron bomb and cluster bomb delivery altitudes can be constrained by the aircraft's designated minimum and maximum altitude in the FALCON4.VCD entry. If the minimum altitude is higher, the bombs will be delivered at the aircraft's minimum altitude.
10. With air-to-ground missiles, the AI will turn away at a heading of at least 90° for a distance of 3 to 5 nm after every attack pass, before it sets up for another pass. This allows the AI to pull back for a short distance and avoid closing in to the target too much with each succeeding attack pass.
11. The AI will not launch an air-to-ground missile unless it has a valid target lock.
12. The AI will loiter for a maximum of 7 minutes over the target area to complete its assigned attack mission.

The changes will allow the AI to attack from higher altitudes, where it is better able to avoid the small caliber AAA, and gain better survivability against MANPADS. It also differentiates between the different weapon types and their unique delivery requirements.

The standard USAF doctrine calls for LGB delivery above 10,000 feet, and the Realism Patch now models this change faithfully. You will find that some degree of bombing accuracy will be sacrificed by moving the attack altitude upwards, but this is a constraint that real pilots face as well. The gain in survivability is considered to be far more important than the slight loss in targeting accuracy. For cluster bomb weapons, their accuracy and effectiveness are increased at lower delivery altitudes due to lower wind effects, and the Realism Patch now models the lower delivery altitude requirements. The large reduction in CBU effectiveness when delivered from medium level altitudes was the factor that drove the USAF to develop the Wind Corrected Munitions Dispenser (WCMD).

Rocket Attack

The glaring bugs with the employment of rockets in 1.08US are the lack of accuracy (for the AI), and the total lack of debrief information after the flight. With the RP, these defects have now been rectified. The first problem lie with the selected aimpoint, which was off and does not correspond to the rocket ballistics. For the helicopters, the selected aimpoint was depressed by about 0.025 radians. The aimpoint for aircraft was raised by 0.028 radians. With these changes, rockets fired by the AI will land around the center of the intended aimpoint. The debriefing screen was also enabled for rockets.

With these changes, rocket employment is not possible for the AI. It should be cautioned that rockets are area weapons, and not intended for targeting small targets. It is near impossible to put a 2.75" FFAR through a vehicle. The effectiveness of rockets lies in the shrapnel effect created by the entire salvo. With the exception of the heavy S-24 rocket from the Russians, rockets should be used only as a last resort, due to their low effectiveness and the risk to the aircraft (from SHORAD) delivering it.

Missile Evasion and Guns Defense

Another change in the AI is in its ability to evade missiles. This is mechanized into AI reaction to active guided missiles, IR missiles, and SARH missiles. For a start, the missile launch will need to be detected by the AI. This can only be achieved either visually, or via the RWR (only for SARH and ARH missiles). Once the missile is detected, the AI will begin to evade as follows:

ii. For recruits, if the missile is more than 10nm. away, they will turn tail and drag the missile out. For ace, they will drag the missile out only if it is more than 16nm. away.
iii. If the missile is 10nm. or less away from a recruit, it will begin to beam the missile. For ace, it will begin to beam if the missile is closer than 16nm. from it.
iv. Three seconds before impact, the AI will attempt a last ditch maneuver and commence a turn into the missile, at the same time pump out chaff and flares at a rapid rate.
v. Once the AI has detected a missile inbound, it will begin to deploy countermeasures at a rate of 2 chaff packets and 1 flare per two seconds.

For SARH missiles, if the AI is equipped with a RWR, the missile launch will be detected immediately. For ARH missiles, the AI will detect the missile on the RWR once the missile turns autonomous. For AI not equipped with RWR, as well as for IR missiles, the AI will have to acquire the missile visually. The visual acquisition range is skill dependent and as follows:

Recruits – 1.5nm.
Cadets – 2.5nm.
Rookies – 3.5nm.
Veterans – 4.5nm.
Aces – 5.5nm.

Once the AI has commenced missile evasion, it will persist until the missile is defeated. When the missile is defeated, the AI will cease its missile evasion according to skill level, and ranges from 2 seconds for ace to 6 seconds for recruits. This simulates the pilot finally figuring out that the missile is no longer after him. The AI will however continue to monitor the missile, and if the missile re-acquires it, it will commence missile evasion again. The AI confirms whether the missile is still after him by checking on closure. If the distance between the missile and him is increasing, then the missile is considered defeated.

A problem with Falcon 4 is that the AI is only capable of reacting to the first missile fired at it, and will ignore subsequent missiles even if the first missile has missed but is still flying. This is now altered in Realism Patch. The AI pilot will be able to handle up to two missiles launched at it, and will evade the missile closest to him. For example, if an AIM-120 is inbound from afar and an AIM-9M is then fired, the AI will begin to evade the AIM-9M first, and once successful, then begin to evade the AIM-120.

In 1.08US, the AI will also not react to uncaged IR missiles that are fired at it (i.e. IR missile fired with a valid IR lock but without a radar lock), even though the missiles may be fired within visual acquisition envelope. With Realism Patch, this is now different. The AI now has the ability to detect an uncaged IR missile fired at it, provided it can acquire the missile launch visually (i.e. the missile is inside its visual envelope). If the AI has a target at the time of missile launch, its visual search volume is between ±50° to ±100° (skill dependent) to the sides and in the vertical plane (these must still be inside the AI visual envelope). This is to simulate some form of target fixation that results in less visual scanning. If the AI does not have a target at the point of missile launch, it will search its entire visual envelope.

Now if the AI cannot see the bandit that is shooting at it (i.e. the missile and the bandit are not within the AI's visual envelope), it may still spot the IR missile launch under the following circumstances:

1. If the missile is launched caged, the AI will have a 50% to 90% chance of spotting the missile (skill dependent, with Recruit at 50% and Ace at 90%).
2. If the missile is launched uncaged, then Veterans will have a 10% chance of detecting it, while Ace will have a 20% chance.

In addition, when evading an IR missile, AI veterans and aces will only use MIL power to beam or drag the missile, but will not go into afterburner so as to present a smaller IR signature. They will only utilize afterburner during the last ditch maneuver to obtain energy. The AI wingman will now also not warn you of incoming missiles if the AI wingman is more than 6nm. away, or if it is engaged defensively (i.e. evading a missile itself or jinking) and its skill level is less than Ace. An Ace AI wingman will always warn you of an incoming missile even when engaged defensively itself, as long as it is no further than 6nm. away.

For AI pilots flying fighters, if their speed is less than 85% of the airplane's corner speed, ace AI pilots will always jettison their A/G weapons whenever they are performing guns defense. Rookie and veteran AI pilots will jettison the A/G weapons 75% of the time. For cadet AI pilots, they will jettison their A/G weapons 60% of the time, but there is a 10% chance that they will jettison everything except A/A missiles. For recruit AI pilots, they will jettison everything except A/A missiles 50% of the time, but has an 80% chance of jettisoning A/G weapons only. Recruit AI pilots also have a chance of ejecting from their airplane 5% of the time.

The AI is now more adept at using ECM (if so equipped). The flight lead will turn off the ECM if he is no longer locked onto. In 1.08US, the wingman will not use their ECM, but with RP, they will now turn on their ECM if they have been locked onto by a threat radar. The wingmen will also turn on their ECM when the flight lead activates his ECM.

Helmet Mounted Sights

Although the AA-11 is a formidable missile that can be fired at high off-boresight angles, the AI in Falcon 4 has never taken advantage of this unique ability of the missile. This makes air combat with AA-11/hemlet mounted sight equipped opponents similar to fighting any other all aspect missile equipped airplanes. The player can engage in two circle fights with an AA-11 armed opponent without suffering the consequences of being shot at across the turn circle. In addition, a large proportion of MANPADS were fired very close to their gimbal limits. These MANPADS have seeker gimbal limits that is less than 30°, and most shots will become ballistic shortly upon due to the missiles exceeding their gimbal limits.

The root of the problem lies in the firing conditions for the AI. The AI will only shoot an IR missile under the following conditions:

i. The missile has a valid IR lock
ii. The target is in range
iii. The target is within ±20° of the AI's boresight

Due to the last condition, the AI is incapable of taking full advantage of the expanded seeker gimbal limit on the AA-11, and neither is it capable of improving its shots with missiles that have smaller gimbal limits.

This is now changed in the Realism Patch. The AI's firing constraints are now as follows:

i. The missile has a valid IR lock
ii. The target is in range
iii. The target is within ±65% of the IR missile's gimbal limits

With the amendment of the last condition, the AI is now capable of taking advantage of the expanded seeker limit of the AA-11, and it is also capable of making better use of missiles with smaller seeker gimbal limits. For example, for the AA-11, the AI will shoot the missile at off-boresight angles of up to 43°, which expands its potential engagement envelope tremendously. The AI will also shoot an SA-7 at off-boresight angles of up to 16°, which is slightly less than before, thus decreasing the chances of the missile reaching its gimbal limits.

Changes To the 2D AI

Some minor changes were also made to the 2D AI. In F4, the range of the best weapon is defines the distance at which a target can be detected. This is changed to allow the range to be the higher of the best weapon's range or 20nm.. This was changed to allow the AI better detection against one another in the 2D fight (aggregated planes), and has no effects on deaggregated planes in the 3D world. The last change to the 2D war is to the game engine. The game engine will now account for aircraft destroyed in the 3D world, and update the 2D war accordingly.

In 2D combat, aircraft that are tasked for air-to-ground missions will no longer aggressively engage enemy aircraft, since this is not their primary mission. They will however defend themselves if attacked, or if any enemy aircraft closes to within 16 km of them. This eliminated most if not all of the flight aborts. In the original Falcon 4, all fighters will abort their air-to-ground mission as soon as they detect any enemy flight within a radius of 128 km (approximately 71nm.) from them. These aircraft will jettison their air-to-ground ordnance, and attempt to attack the enemy aircraft. This in effect results in the aircraft aborting their primary mission, when they should have pressed on instead.

The behavior of all aircraft armed with air-to-air missiles have also been altered, such that they will actively defend themselves and consider all enemy aircraft within 16 km of them as threats, and will attack them accordingly. For CAPs, the AI will not attack any enemy targets beyond a range of 30nm. from them, but will attack all enemy targets inside a 30nm. radius from them.

The behavior of escort flights has been changed, and escorts will only peel off to attack enemy fighters when they close to within 25nm. of them. The escorts will not attack enemy bombers even when they fly to within 25nm. of them, unless the enemy bombers are within 16 km of them. HAVCAPs are assigned to protect high value assets such as AWACS, and as such, the behavior of HAVCAPs are the same as the behavior of escorts.

The 2D AI for sweep flights will also engage any enemy aircraft that they encounter, but the behavior has been changed in the Realism Patch, such that they will prefer to attack fighters if given a choice. All air-to-air flights will also RTB immediately once they are out of ordnance.

The 2D AI for ground attack flights will also not engage any enroute AAA that fire on them, if the AAA sites are not their target. This prevents the 2D AI from expending their ordnance on such targets of opportunity, instead of their assigned target. It also solves the problem of 3D airplanes arriving over their target with no ordnance, because the 2D engine has expended these ordnance by ordering the 2D flight to engage AAA sites enroute. The 2D AI will still react to flights shooting at them, and will defend themselves by attacking the offending bandit.

HELPING THE AIR TASKING ORDER ENGINE

Beginning with version 5 of the RP, some minor changes were made to help the ATO engine task aircraft "more responsibly." Some of the problems with the ATO engine include the tasking of stealth airplanes for daylight missions, at low altitudes, as well as default steerpoint altitudes that are too low, and exposing the aircraft to ground threats unnecessarily.

The tasking of aircraft for specific TOT is controlled by the "Night" flag in the aircraft's FALCON4.VCD entry. There are two wrong implementations in the ATO engine that results in stealth aircraft being tasked for daytime missions. The current time is used by the ATO engine to determine the TOT for the aircraft. The current time that is used also includes the days since day 1 of the campaign, and only time before dawn of the first day will be considered as night. This results in the stealth aircraft being tasked for early missions (if they are activated in the campaign). The change in RP amends the time used to the current time within the day. This ensures that the ATO engine is able to determine the TOT accurately.

The second error relates to the way the “Night” flag is used. In 1.08US, the “Night” flag is not used for tasking. With the RP, any aircraft flagged with “Night” can only be tasked for flights only if their TOT is at night. For aircraft that are not flagged as night capable, they can be tasked at night only the squadron’s morale is not broken. This allows the non night-capable aircraft to perform night intercepts under GCI control, as only squadrons with morale that is intact will be able to make use of GCI.

The default altitudes assigned by the ATO engine to various steerpoints are also controlled from the FALCON4.VCD. The entries used are “Min Alt,” “Max Alt,” and “Cruise Alt.” For aircraft such as the F-117 and B-52, the ATO engine assigns them altitude of less than 10,000 feet by default. This exposes the aircraft to SHORAD threats needlessly, unless the player intervenes and changes the altitudes. With the Realism Patch, these altitudes have been adjusted as follows:

i. For propeller airplanes, such as C-130 and An-24, the cruising altitudes have been adjusted to 18,000 feet. This is the typical cruise altitude based on cabin pressurization to prevent crew hypoxia (i.e. for the crew to fly without supplementary oxygen).
ii. For fighters that can conduct low level operations, their minimum altitudes have been reduced to below 500 feet (at about 400 feet). This allows them to use NOE low level tactics.
iii. For high performance interceptors, their minimum altitudes have been raised to above 10,000 feet. This allows the interceptors to CAP at higher altitudes, which is typical of their operations.
iv. For fighters used for point air defense, such as the F-5E and MiG-21, their minimum altitude have been lowered to 5,000 feet, allowing them to set up a low altitude CAP. The mixture of high and low minimum altitudes allows a high-low mix for CAPs and sweeps.
v. For helicopters, their cruise altitudes have been reduced from 5,000 feet to 200 feet, which is more typical of helicopter operations.
vi. For modern fighters such as F-15E and F-16C, their cruise altitude have been set to above 22,000 feet, which is typical of their operational ingress altitudes.

The changes made for each aircraft are shown in the table below:

Aircraft Type	Minimum Altitude (FL)		Maximum Altitude (FL)		Cruise Altitude (FL)	
	Original	RP	Original	RP	Original	RP
A-10	10	10	4500	250	200	120
A-50	350	300	350	350	300	330
AC-130U	30	50	150	250	200	140
AH-1	1	1	5	3	50	2
AH-64A	1	1	5	3	50	2
AH-64D	1	1	5	3	50	2
An-2	2	2	10	12	80	8
An-24	300	120	300	180	200	150
B-1B	5	4	200	350	300	320
B-52H	10	280	300	350	300	300
C-130H	300	10	300	250	200	180
CH-47	1	1	5	3	50	2
E-3	300	300	300	350	250	350
EA-6B	50	50	300	320	200	200
EF-111A	50	10	300	400	300	300
F-111	50	4	300	400	350	220
F-117	5	220	150	300	250	220
F-14B	100	150	350	450	300	350
F-15C	50	50	350	450	250	350
F-15E	10	4	200	350	250	240
F-16C	10	4	250	350	200	220

Aircraft Type	Minimum Altitude (FL)		Maximum Altitude (FL)		Cruise Altitude (FL)	
	Original	RP	Original	RP	Original	RP
F-22A	150	150	300	450	250	350
F-4E	10	15	250	320	250	220
F-4G	10	15	250	320	250	220
F-5E	10	15	250	280	300	150
F/A-18C	10	4	250	350	250	200
F/A-18D	10	4	250	350	250	200
Il-28	5	4	150	180	200	120
Il-76M	300	250	300	350	300	320
Il-78	300	200	300	350	250	220
J-5	5	4	300	250	200	180
J-7 III	5	10	300	350	250	250
Ka-50	1	1	5	3	50	2
KC-10	300	200	300	350	250	220
KC-130	250	150	250	250	200	180
KC-135R	300	200	300	350	250	220
MD-500	1	1	5	3	50	2
Mi-24	1	1	5	3	50	2
MiG-19	100	10	250	280	200	180
MiG-21	100	50	300	420	250	300
MiG-25	400	350	800	580	400	400
MiG-27	50	4	200	250	200	180
MiG-29A	100	100	300	350	200	250
MiG-29C	100	100	300	350	200	250
MiG-31	400	400	800	500	400	400
OH-58D	1	1	5	3	20	2
Su-25	10	10	150	180	200	120
Su-27	10	100	300	450	250	320
Su-30MKK	10	50	300	450	250	240
Tu-16	20	30	200	300	200	220
Tu-16N	300	180	300	350	250	220
Tu-95MS	20	120	200	250	200	180
UH-1N	1	1	5	3	50	2
UH-60L	1	1	5	3	50	2
Y-8	10	120	250	250	200	180

FIXING HELICOPTERS

The helicopters in Falcon 4 failed to function properly even in 1.08US. The helicopters were made to fire the anti-tank guided missiles (ATGM) in RP3, but kept flying towards the target in due process. As a result, the helicopters were often decimated by the air defense vehicles, such as the ZSU-23-4.

With Realism Patch version 5, the helicopters were improved. The changes include:

i. Helicopters will fire ATGM, air-to-air missiles, and rockets.
ii. The helicopters will now hover if they are within 60% of the ATGM's range (from the FALCON4.WCD entry), and more than 2,000 feet away from the target.
iii. The helicopters will only fire the ATGM if the target is within range and more than 2,000 feet away.
iv. If the targets are within 1,000 and 10,000 feet away, the helicopters will select rockets and then fire from a hover position.
v. The ATGMs will be fired at 15-second intervals.

vi. The helicopters will fly at the lowest possible altitude of 150 feet when they are within 36,000 feet of their targets. This allows the helicopters to fire from masked positions.

With the changes implemented, the helicopters are now more survivable in ground combat, and will be able to engage their targets outside the range of the typical SHORAD weapons. We have also seen numerous occasions of the AH-64 helicopters launching Hellfire missiles are targets from masked positions across hills.

THE ELECTRONIC BATTLEFIELD

Winning The Virtual War of Electrons
By "Hoola"

UNDERSTANDING HOW RADARS WORK IN FALCON 4.0

Sylvain Gagnon discovered the details of how the radars work and affect the AI. The explanations here on how the radar works in Falcon 4 is credited to Sylvain.

F4 models the radar in two forms in the game. For the human player, the radar scan volume obeys the bar scan, azimuth coverage and beamwidth stipulated in the FALCON4.RCD file. As such, the entire azimuth and elevation limit is not scanned, which is realistic and is how a real radar behaves. For the AI, the radar scan volume is the entire azimuth and elevation limit. This is something that is coded inside the game, and not easily hex editable as discovered by Sylvain. In actual fact, had the AI been modeled with an accurate radar, the FPS penalty would have been tremendous.

To do justice to the basics of radar operation, one would require a separate thesis rather than the coverage this short piece can allow. References (6), (7), and (8) will provide the basic knowledge for radar operations. Reference (5) is an invaluable source of information for understanding the mathematics and electronics behind radar operations, and was extensively used to compute some of the radar parameters.

What the RCD Floats Represent

RWR and RWR LOW Gain:

The RWR gain is used for normal RWR modes, while the RWR LOW gain is used for the RWR in the LOW mode. When the RWR detects that a target has spiked it, the slant range between the emitter and the target (the player) is calculated by taking the square root of the sum of the square of height difference and longitudinal range difference (Pythagoras' Theorem). The value is then divided by two times the range of the emitter radar. If the resultant value is less than 0.8, the RWR (or RWR LOW) gain is multiplied by the difference between 1 and this value. Else, the RWR gain is multiplied by 0.2. The net value will be a float between 0.2 and 1. The RCD float will control if the emitter symbol is placed inside the inner or outer ring.

Chaff:

This float controls the chaff susceptibility of the radar to chaff. The routine for maintaining a radar lock takes into account target range from the emitter, and the chaff susceptibility. When the target releases chaff, F4 performs some computation using two hard coded static arrays that is dependent on distance. The resultant float is then multiplied by the chaff susceptibility, to determine if the radar lock is maintained. As such, chaff susceptibility is also distance dependent. In general, the higher the float, the easier it will be to break radar lock, and chaff will remain effective even as the emitter closes in.

ECM, Beam Distance:

This controls the radar signal strength degradation that will occur when ECM is employed or when the target is beaming. For example, if a radar has a range of 32nm. against a target, and the ECM and beam multipliers are 0.1 and 0.2 respectively, then ECM will break the radar lock unless the target is within 3.2nm. of the radar. Similarly, the target can break the radar lock by beaming as long as the emitter is more than 6.4nm. away.

Range, Look Down Distance:

Range is the radar range in feet. The detection range for target is computed as follows:

Detection Range = Radar Cross Section × Radar Range

Look down distance is a radar signal strength multiplier, used when the target is more than 2.5 degrees below the emitter. This represents the look down performance of the radar. For example, for a radar with a range of 32nm. against the F-16, in a look down situation, if the Look Down multiplier is 0.5, then it will only detect the F-16 at 16nm..

Lock Time:

This is the time interval in milliseconds for the radar to refresh the target track. For example, for a sweep time of 3000, the radar will refresh the target track every 3 seconds to check if the target is still detected and locked.

All the other RCD floats are self explanatory.

The Falcon 4 Radar and Electronic Warfare Algorithm in Realism Patch

First things first. For a radar to lock onto a target in F4, it must first have a signal strength of 1 or more. The radar algorithm in F4 is as follows:

Radar Signal strength = (RCD radar range / Target Distance) X (Radar Cross Section)

The radar cross section does not work the same way as the actual radar equations do. In F4, this works more like a reflective value that is linear with range. Actual RCS affects radar detection range by an exponent of four. This is a good representation without the overhead of power computations, and we have modeled the RCS of vehicles taking this into account.

The height of the radar and the target is then subtracted, and if the difference is greater than the range to the target (in feet) multiplied by the tangent of 2.5 degrees, the radar range ratio is multiplied by the Look Down multiplier. This results in a smaller detection distance and lower signal strength in look-down situations for pulse doppler radars. For pure pulse radars, look-down performance is near impossible.

ECM from the target is then checked. If the target employs ECM, then the signal strength is multiplied by the ECM multiplier. Hence, ECM will decrease the range at which the target may be detected and tracked. Of course, this is provided the radar is inside the ECM coverage zones of the target.

The doppler filter is then checked, and if the target’s doppler velocity in feet/sec decreases below the doppler filter in the RCD entry for the radar, the range ratio is multiplied again by the beaming multiplier.

Once the resultant signal strength is greater than 1.0, the radar is now able to lock onto the target. The signal strength is boosted once the target is locked. Depending on what radar mode the radar is operating in, the multiplier for boosting the signal strength is different. For RWS, the signal strength of the lock is multiplied by 1.0. For VS mode, the signal strength is multiplied by 1.2, while STT mode multiplies the signal strength by 1.3. For TWS mode, the signal is multiplied by 0.9. All other radar modes do not modify the signal strength. This somewhat models the different track retention algorithm and scan pattern on real radars. With modes such as TWS, the radar can only spend a fraction of its time updating the locked target’s track file, in addition to tracking all other targets, and thus it becomes easier to break the lock as the radar is not paying full attention to it. For STT, the radar is dedicated to tracking this target, and all the radar processing capabilities are geared towards maintaining the lock. This is surprisingly accurate modeling on MPS’s part.

Hence, the greatest penalty against a radar is to fly low and either employ ECM, or beam the radar, or utilize a combination of all tactics including dispensing chaff.

If there is a radar lock and a missile is in flight with the radar supporting, it then checks to see if the target is dispensing chaff. The chaff algorithm is mechanized in the same way for SARH missiles compared to active radar guided missiles, though the chaff effectiveness is different. Chaff effectiveness is mechanized as a two dimensional array of distance versus effectiveness ratio.

For SARH missiles, the chaff effectiveness arrays are as follows:

[0 1500 3000 11250 18750 30000]
[0 0.1 0.5 0.5 0.2 0.1]

For ARH missiles, the chaff effectiveness arrays are as follows:

[0 12000 24000 48000 120000]
[0 0 0.75 0.75 0.0]

The first dimension of the array is the distance between the missile and the target in feet, and the second dimension (the lower row) is the chaff effectiveness quotient.

The chaff algorithm first checks the distance between the missile and the target, and then computes the chaff effectiveness quotient based on linear interpolation. For example, if the missile is 13,000 feet away from the target, the chaff effectiveness quotients will be:

*SARH Chaff Effectiveness Quotient = 0.5 – [{(13000-11250) / (18750-11250)} * (0.5-0.2)] = 0.43*

*ARH Chaff Effectiveness Quotient = 0.0 – [{(13000-12000) / (24000-12000)} * (0.0-0.75)] = 0.06*

The chaff effectiveness quotient is then multiplied by the chaff multiplier in the RCD entry for the particular radar, to determine the chances (in percentage probability) that the missile lock will be broken. This is then compared against a random number between 0 and 1, and if the random number is below the resultant number, the lock is lost and the missile misses.

As you can see, chaff effectiveness for SARH missiles is at its greatest between 3,000 feet (1/2nm.) and 11,250 feet (about 1.85nm.), and at distances greater than 11,250 feet and distances less than 3,000 feet, chaff effectiveness tapers off. For ARH missiles, chaff is most effective between 24,000 feet (about 3.95nm.) and 48,000 feet (about 7.9nm.), and effectiveness decreases beyond 48,000 feet and below 24,000 feet, and is totally ineffective under 12,000 feet (about 2nm.).

This variation of chaff effectiveness with missile range to target is a close approximation to how chaff affects radars. At longer ranges, the chaff bloom can be distinguished due to the rapidly decreasing velocity of the chaff cloud, thus making angular differences between the chaff cloud and the true target return more apparent. Both chaff and target are likely to stay within the missile seeker field of view for a considerable amount of time. This allows the missile to detect the presence of chaff and reject it after tracking both the chaff cloud and target for a while (target return still being inside the seeker FOV). At closer distances, the missile will switch lock to the chaff cloud as before, but being closer to the target, the target radar return has a higher chance of leaving the seeker FOV while the seeker is still tracking the chaff cloud, thus lowering the chances of missile reacquisition. At even closer ranges, the line of sight rate of the chaff cloud versus the target is higher, and this allows the missile to determine immediately the presence of chaff and reject it. Again, this aspect of chaff effectiveness modeling in F4 is surprisingly realistic.

For flares, the two dimensional arrays become:

[0 5500 11000 16500 27500]
[0 0.0 1.0 1.0 0.0]

The way flare susceptibility works is also the same as that of chaff. As you can see, flares are really only effective when the missile is between 5,500 feet and 27,500 feet. You may ask why should this be since some missiles have no IRCCM capabilities and should always be decoyed by flares. At closer distances, the flare will stay inside the seeker FOV for only a split second, and this very short duration may sometimes not be sufficient for the seeker to switch lock before it exits the seeker FOV, particularly if the line of sight rate at which the flare exits the seeker FOV is too high for the tracking system to follow. However, the mechanization isn't exactly quite accurate, and this aspect has been addressed as an overall holistic solution to improving IRCM combat in F4 (see earlier section titled "*Turning On The Heat*."

We will next discuss the RWR mechanization in F4. RWRs in real life have a specific antenna gain. This is similarly modeled in Realism Patch. The ability for the RWR to detect a radar transmission is controlled by the RWR gain. The distance at which a radar may be detected is simply as follows:

RWR Detection Distance = Radar RCD range x RWR gain in FALCON4.RWD entry

Thus, for example, if the radar range is 38nm., and the RWR gain is 0.5, then the radar can only be detected by this specific RWR at a range of 19nm..

The RWR symbology placement in F4 is mechanized as follows:

Slant Range between Emitter and Target = SQRT((Ground range) ^{2} *+ (elevation difference)* ^{2}*)*

The result is then divided by two times the range (in feet) of the emitter (i.e. the radar) to determine the range ratio. If the range ratio is less than 0.8, the RWR (or RWR LOW gain if LOW is selected) is multiplied by the difference between 1 and the range ratio. If not, the RWR gain is multiplied by 0.2. Hence, the RWR and RWR LOW coefficients for each radar acts as a pseudo lethality signal strength curve for the real RWR implementation, and determines if the threat emitter symbol should be displayed inside the inner threat ring.

While not entirely in conformance with actual radar equations, F4's way of modeling radar performance is adequate to simulate the appropriate radar characteristics without imposing an undue impact on graphics and FPS. Actual radar computations are very intensive and involve exponents, which will certainly drag the FPS down with little additional gain in simulation fidelity.

It is imperative that you understand how F4 handles the radars. With this understanding, you will be in a position to determine, as part of your mission planning, how best to employ your EW assets such as jammers, and how to interpret what your RWR is telling you. You will also be in a position to formulate tactics to counter each unique electronic threat. Understanding the threats are you are facing is a key component in surviving on the electronic battlefield, be it virtual or actual. with the Realism Patch, you will need to fly like real pilots do.

RADAR CHANGES MADE IN THE REALISM PATCH

Changes were made to all radars, based on public information available on Jane's Avionics, Jane's Radar and Electronic Warfare, and other sources such as the USN Radar and Electronic Warfare Handbook. Information was produced using radar equations as far as possible, before being used to modify the RCD floats. Radar performance data is, understandably, sensitive information and not publicly available. Hence, ECM performance was deduced by examining the state of the technology, and whatever information was available publicly. F4 does not model ECCM modes as they should be, and neither does F4 model the full effects of ECM. ECM in F4 will only result in the radar lock being broken, but will not result in false targets, etc.

You will find a big difference between different radars now. For example, you will not be able to detect targets with the F-5E or the MiG-19 and MiG-21 in a look down situation, as these aircraft are equipped with pulse radars that lack a look down capability. In addition, beaming will not be effective against such aircraft, as it does not utilize a doppler gate.

Chaff and ECM resistance is also changed, with older radars being more susceptible to ECM and chaff, and newer radars being more resistant. Beaming is also more effective now and closer to actual radar performance. Before this, beaming was largely ineffective in F4. We have also modeled monopulse radars in F4 (this will be discussed in later in more detail), and these are the radars used on AIM-120, AIM-54 and AA-12 missiles. These radars are extremely difficult to defeat through jamming or chaff employment, and we have implemented a HOJ (Home-On-Jam) mode on these radars.

If you need to understand electronic warfare and how radars work, we have used the following information sources. This is not an exhaustive list that we have used, but only a representative selection:

1. Jane's Avionics 1998-99
2. Jane's Radar and Electronic Warfare 1998-99
3. Jane's All The World Aircraft 1998-99
4. Jane's Aircraft Upgrade 1998-99
5. USN Electronic Warfare and Radar Engineering Handbook, available at http://ewhdbks.mugu.navy.mil
6. Journal of Electronic Defense, http://www.jedonline.com
7. AFP 51-45: Electronic Combat Principles, September 1987, available at http://www.wpafb.af.mil/cdpc/pubs/AF/Pamplets/p0051050.pdf
8. Avionics: The Story and Technology Of Aviation Electronics, Bill Gunston, published by Patrick Stephens Limited, 1990.

CORRECTING THE APG-68 RADAR IN REALISM PATCH

The original Falcon 4 implementation of the APG-68 radar scan volume is erroneous. You will often find situations where a radar contact may be within the altitude coverage of your scan pattern, but the radar fails to detect the target even though the target is not beaming nor jamming you. In addition, the altitude coverage for 2 bar, 3 bar, and 4 bar scan patterns are way too much for the APG-68 radar.

In Falcon 4 version 1.08, the radar altitude coverage are as follows:

1. At 20nm. in RWS mode, the altitude coverage is 9,000 feet in 1 bar scan; 18,000 feet in 2 bar scan; and 35,000 feet in 4 bar scan.
2. At 40nm. in RWS mode, the altitude coverage is 20,000 feet in 1 bar scan; 36,000 feet in 2 bar scan; and 70,000 feet in 4 bar scan.
3. At 20nm. in TWS mode, the altitude coverage is 30,000 feet in 3 bar scan; and 34,000 feet in 4 bar scan.
4. At 40nm. in TWS mode, the altitude coverage is 61,000 feet in 3 bar scan; and 66,000 feet in 4 bar scan.

In the actual APG-68 radar, the radar altitude coverage are as follows:

1. At 20nm. in RWS mode, the altitude coverage is 10,000 feet in 1 bar scan; 14,000 feet in 2 bar scan; and 24,000 feet in 4 bar scan.
2. At 40nm. in RWS mode, the altitude coverage is 20,000 feet in 1 bar scan; 28,000 feet in 2 bar scan; and 48,000 feet in 4 bar scan.

3. At 20nm. in TWS mode, the altitude coverage is 24,000 feet in 3 bar scan; and 30,000 feet in 4 bar scan.
4. At 40nm. in TWS mode, the altitude coverage is 48,000 feet in 3 bar scan; and 60,000 feet in 4 bar scan.

Now, the radar algorithm in Falcon 4 steps the antenna in 2° in elevation for each bar in the scan pattern (this is also known as the bar step). For example, with the radar centered on the airplane's centerline, and set to a 4 bar RWS scan pattern, the antenna will tilt to 3° above the centerline for the first bar, and then tilt downwards by 2°, to a position that is 1° above the centerline for the second bar. It then tilts to 1° below the centerline for the third bar, and 3° below the centerline for the fourth bar. With a beam width of 4.6°, and the antenna step of 2°, the total elevation coverage of the radar implementation is thus 10.6°. In the real APG-68, the antenna moves in steps of 2.2° in RWS, and an average of 3.25° in TWS (the exact antenna step is dependent on the MFD radar range). The implementation of the scan pattern in Falcon 4 is surprisingly accurate for the RWS mode, but too narrow for the TWS mode.

However, from the altitude covered by the radar cursors, the RWS 4 bar scan results in an elevation coverage of 17.2°. We thus have a situation where the radar code is implementing the scan pattern correctly, but the MFD code is displaying the altitude coverage erroneously ! You can thus tilt the antenna to cover the altitude of interest, and yet not detect the target at all if the target is flying at an altitude that is close to the upper or lower limit of the cursor altitude coverage ! This is so because the radar isn't scanning that particular area in the sky, even though the MFD radar cursor is displaying it as such.

Sylvain investigated the implementation of the radar and the MFD codes in the assembler, and discovered that the equations for determining the MFD radar cursor altitude coverage is as follows:

Cursor Altitude Coverage = (sin ((No. of Bars – 1) × Bar Step) + (2 × Half Beam Width)) × Range

This equation is actually wrong. For example, in a 4 bar scan, this is equivalent to having the first bar scan at 4° above the centerline, and the second bar at 2° above the centerline. The third and fourth bar will scan at 2° and 4° below the centerline respectively. However, the antenna step between the second and third bar is 4° instead of 2° ! This results in the mismatch between the actual radar scan volume and the MFD displayed scan volume.

With the Realism Patch, the cursor altitude coverage is now as follows:

Cursor Altitude Coverage = (sin (((No. of Bars – 1) × Bar Step) + (2 × Half Beam Width))) / 2) × Range

This addresses the discrepancy between the radar cursor altitude coverage and the actual radar coverage. In addition, the antenna step (or bar step) is increased from 2° in RWS, to 2.2°, and increased from 2.6° in TWS, to 3.25°. The radar scan volume in RWS and TWS modes are now correct.

The other small change in the radar mechanisation is the antenna elevation step when you command the radar antenna to tilt up or down. The antenna will tilt in 4.6° increments previously, and this is far too coarse for antenna movement, as it corresponds to about 10,000 feet of altitude coverage at 20nm.. With the Realism Patch, this has now been adjusted to 2.5° steps in elevation, corresponding to approximately 4,000 feet of altitude coverage at 20nm..

REVAMPING NON-COOPERATIVE TARGET RECOGNITION (NCTR) IN REALISM PATCH

One of the most glaring mistakes in the radar mechanization of Falcon 4 is in the Non Cooperative Target Recognition (NCTR) feature. The Falcon 4 way of implementing NCTR is to represent the target ID with a bar. The bar will extend to the left if the target is hostile, and to the right if the target is friendly. The length of the bar is dependent on the range to the target, and not whether the radar is certain of the ID or not.

We have made some extensive research into NCTR, based on publicly available material. NCTR works by comparing the radar return signature of the target. Each airplane has a unique radar signature, and this signature varies with the target aspect, altitude differences, and the ordnance that it carries. When viewed directly from the front and rear, the engine fan and turbine disks are visible, and generate a characteristic radar return. When viewed in the beam or off to the sides, the airframe generates its own characteristic radar return. The engine compressor and its air intake will generate the most characteristic radar signature, as the radar signature of other locations of the airframe will change with any external ordnance being carried. Our understanding is that the current implementation of NCTR relies on the jet engine modulation (JEM) technique.

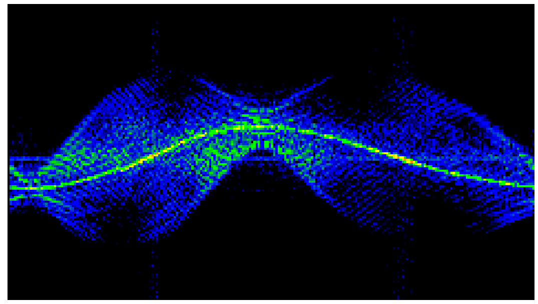

Figure 165: Computerized visualization of JEM radar returns, showing the amplitude modulations on the base carrier frequency. (Picture credit of US Naval Air Warfare Center – Aircraft Division)

Jet Engine Modulation (JEM) of radar returns is a commonly observed phenomenon in the radar observation of jet aircraft. All moving targets will impart Doppler shifts to the radar return. The amount of Doppler shift is a function of the radar's carrier frequency and the relative speed of the radar and the target. Moving or rotating surfaces on the target (such as propellers and jet engines) will have the same Doppler shift as the target, but will also impose amplitude modulation (AM) on the doppler shifted return. The radar reflections are characterized by both positive and negative Doppler sidebands corresponding to the blades moving towards and away from the radar respectively.

The harmonics within the sidebands are a function of the PRF of the blade chopping action and its amplitude is dependent on the target aspect. The periodic modulation of the radar signal is unique to engine and intake types, and is useful for target identification. In most implementations on fighter radars, the approach to JEM target identification taken has been to use either periodogram estimates of the JEM power spectral density or the cepstrum of the JEM return to form a set of features for use in a pattern recognition algorithm.

The JEM phenomenon is only observable when the radar is observing the jet airplane at an aspect angle that allows the electromagnetic radiation to be backscattered from the moving parts of the jet engine's compressor and blade assembly. JEM has been observed at angles as great as 60° (from a nose-on aspect) between the radar and the observed aircraft. Such high aspect angles occur for aircraft with relatively short intake ducts, where the engines are not as buried in the aircraft, for example, commercial jet airliners. For most fighters, the observable aspect angles are much more restricted, and generally limited to less than 30° off the nose.

The other target recognition techniques include shape estimation and downrange target profiling, both of which have practical technical limitations currently and are not being used. One of the main technical hurdles is the changes in the radar scintillation that will result from external stores carriage. This makes target shape estimation and profiling a lot more difficult, as the resultant radar threat library will need to be expanded greatly since the signature of the target will be unique depending on the external stores that are carried. We also understand that there is considerable research into both techniques, including the analysis of radar scintillation pattern changes with time to derive target shape data. For more information on the current state-of-the-art research into NCTR techniques, as well as some background information on the JEM technique, you can refer to the following reference sources:

1. "*Radar-Based Target Identification*," Dr. Brett H. Borden, Naval Air Warfare Center Weapons Division, available at http://www.nawcwpns.navy.mil/hybrid/rbti.html.
2. "*A Likelihood-Based Approach to Joint Target Tracking and Identification*," J. O'Sullivan, Steven P. Jacobs, Michael I. Miller, and Donald L. Synder, conference record of the 27th Asilomar Conference on Signals, Systems & Computers, Volume 1, November 1993, pages 290 – 294.
3. "*High Resolution Radar Models for Joint Tracking and Recognition*," Steven Jacobs, Joseph A. O'Sullivan, Proceedings of the 1997 IEEE National Radar Conference, May 1997, pages 99 – 104.
4. "*Modeling of Jet Engine Modulated Radar Signal Returns for Target Identification*," Mark R. Bell and Robert A. Grubbs, IEEE Transactions on Aerospace and Electronic Systems, Volume 29, No. 1, January 1993, pages 73 – 87.
5. USN Electronic Warfare and Radar Engineering Handbook, available at http://ewhdbks.mugu.navy.mil

The JEM characteristics are programmed into a RCS characteristics library, and loaded into the radar processor. Using pattern recognition algorithm, the radar will guess the target ID based on how well it matches its library, and then displays its best guess. As such, it is not possible for the radar to determine if the target is hostile or friendly, as a hostile MiG-29 will look the same to the radar as a friendly MiG-29.

Due to the unique combination of air intakes and engines, a target carrying external ordnance can be identified as positively as a target without any external ordnance. However, airplanes with similar combinations of air intakes and engines cannot be distinguished from one another. It is hence impossible to distinguish sub-variant differences, such as a MiG-29 Fulcrum-A and a MiG-29 Fulcrum C, or distinguishing between F/A-18C and F/A-18D, unless there are big differences in the engine and air intake RCS characteristics. It is important to know that even though the sub-variants may be equipped with sub-models of certain engines (for example, the F110-GE-100 engine on the Block 40 F-16 and the F110-GE-129 on the Block 50 F-16), the RCS characteristics may not vary significantly to allow positive identification between the two. JEM is heavily dependent on aspect, and fairly susceptible to jamming. As such, this limits the NCTR capability to aspect angles that allow the radar to see the target's air intakes and engine compressor blades (usually ±15° to ±25° for fighter aircraft).

With Marco Formato's help, the Realism Patch has revised the NCTR to reflect this understanding of how this technology works. The NCTR bar has been replaced with a four-character ID string. The implementation is as follows:

1. If the target is in STT or TWS, and the resultant radar return strength is less than 2.5, then the radar MFD will display the mnemonics "WAIT," to indicate that the radar is analyzing the signal returns and attempting to identify the target.
2. If the radar signal return is 2.5 or greater, the "WAIT" mnemonic will be replaced by the following:
    a. "UNKN" if you are not within a ±25° cone centered on the target's nose, i.e. you must be within ±25° in azimuth and elevation of the target. This indicates that the radar is unable to determine the target's ID.
    b. Target's NCTR ID if you are within a ±25° cone centered on the target's nose.

We have decided to use the aspect limit of ±25°, as this is more representative of fighter aircraft, which are present in more abundance in the virtual skies of Falcon 4. Although we understand that the JEM signature may be observable up to greater aspect angles for transport aircraft and fighter aircraft with very short intake ducts (for example, the AV-8B Harrier), we deem this a reasonable tradeoff to model most of the aircraft in greater fidelity.

The FALCON4.VCD file was modified to support the implementation of NCTR ID. The original name field for each vehicle consists of 20 bytes. This is more than enough for any vehicle name, and byte 11 through 14 is used to store NCTR ID instead.

Due to the different signal multipliers for STT and TWS modes (this was implemented to represent the different processing algorithm and capabilities of each mode), NCTR ID is obtained much earlier in STT mode. If you are in TWS mode, the NCTR ID can only be obtained at 70% of the STT range.

The implementation of NCTR in the Realism Patch is corroborated by the shoot-down account of a Serbian MiG-29 Kosovo during Operation Allied Force. In this account, the F-15C pilot claimed that NCTR ID was obtained at about 30nm.. The account provided anecdotal evidence that the NCTR modeling is correct, as the NCTR ID on a MiG-29 will be obtained at approximately 30nm. on the APG-70 radar in the Realism Patch.

VARYING RADAR PERFORMANCE WITH TARGET ASPECT IN REALISM PATCH

With Realism Patch 5, the radar modeling has increased in fidelity. The detection performance of all radars are dependent on the target radar cross section, and the relative doppler velocities (for pulse doppler radars), amongst other things. All versions of the Falcon 4 executable assumes that the radar cross section of the target remains the same regardless of the target aspect, and that the radar's performance remains the same regardless of the relative doppler differences.

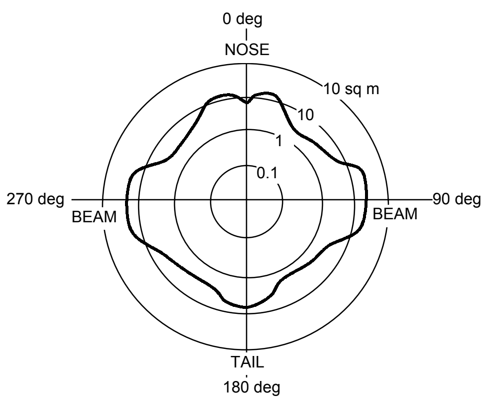

Figure 166: Typical Radar Cross Section of Aircraft

The typical radar cross section of an aircraft is at its beam, due to the large physical area observed by the radar and the perpendicular aspect (increased reflectivity). The next highest RCS area is in the nose area, due to the reflections off the engine compressor/propellers. For pulse doppler radars, targets in the beam will result in a reduction in the doppler velocities, and hence, even though the RCS is at its largest, the radar will still have difficulty detecting it due to the lower doppler velocity.

For head-on targets, the doppler velocity is at its highest. For tail-on targets, the doppler velocity is much lower. For targets in the beam, the relative doppler velocity is even lower. The variation in the doppler velocity results in a variation in the radar's detection performance, and the difference in RCS will also contribute to it. Phase differences, polarization, surface imperfections, and material type will affect the results greatly. These differences typically result in tail-on detection ranges being lower than head-on, and beam-on detection ranges being in between for pulse doppler radars.

The effects of RCS variation and doppler velocity variations have been combined in the Realism Patch. The radar signal strength is dependent on the target aspect, and reduces linearly from a multiplier factor of 1 at the nose-on target aspect, to a multiplier factor of 0.75 for the tail-on aspect. While it is possible to differentiate between the two effects by tuning the doppler radar notch, it will require a six-point interpolation scheme instead of the current two-point interpolation scheme in order to implement. This would have increased the computational and memory requirements significantly. The current two-point interpolation scheme produces an adequate level of fidelity, and introduces more uncertainty into radar performance. Such variations are typical in real radars, and the effects are now captured with the Realism Patch.

Unfortunately, due to the underlying architecture of Falcon 4, the radar cross section of external stores is not modeled. This does not allow us to model the RCS changes that will result from ordnance carriage.

MAKING ECM WORK IN REALISM PATCH

The debate of whether ECM works or not in F4 has been a point of contention since the release of the game. With the work done by Sylvain Gagnon, this debate is set to end once and for all. Well, the answer is that ECM works and does not work! This write-up is an adaptation from Sylvain's README, and includes some of the historical design considerations taken into account during the development of the patch.

The problem lies in the way F4 mechanizes the radars. This has to do with the way F4 handles the fading of the radar signal. If you turn on the ECM before the radar has a lock, ECM will work until you enter the burn-through range, after which the radar will re-acquire lock. The problem lies on turning the ECM on **after** the radar has locked onto you. When this is the situation, the ECM is supposed to degrade the radar signal. When this decreases below the detectable threshold (be it due to ECM or beaming, or the target going into the ground clutter, or the target getting out of range), the lock should be lost after a specific time specified in the RCD (the "Lock Time" entry, which is in milliseconds). In F4, this fading of signal is never applied, and as a result, the AI radar never loses the radar lock. The ECM patch developed by Sylvain changes this, and in addition to this, enables the AI plane to check whether it's own radar has a lock first before launching a radar guided missile (F4 does not do this check and will result in wasted missiles as the AI will launch without a valid radar lock).

What this means for the player is that if ECM is turned on **before** the hostile emitter has a lock, the signal can be degraded such that a lock cannot be obtained, and you can prevent a launch. If you turn on the ECM **after** a launch, then as long as the radar is still outside the ECM burn-through range, its lock will be degraded and broken, and you will defeat the missile.

The ECM patch also activates the effect of internal jammers. Without the patch, internal jammers are cosmetic in nature, and though it will display the jamming "X" symbol, the jammer will never be able to break a radar lock.

For SAM crews, there is also a random factor thrown in, and SAM crews will sometimes launch unguided missiles. This is skill level related, with recruits being more likely to launch unguided than veterans. Ace SAM crews will always wait for a valid lock prior to launch. With a mixed crew, you can expect to see some unguided launches every now and then.

Another big change in the implementation of ECM is the coverage zones. In F4, ECM is assumed to give full spherical coverage. All ECM systems are designed with specific coverage zones, and ECM transmitting and reception antenna do have their coverage zones. In addition, the antenna pattern varies, and hence the strength of the jamming signal is dependent on the location of the threat emitter vis-à-vis the boresight of the antenna main lobe. This also means that if a threat is outside the ECM antenna coverage zone, it will never be jammed.

With Realism Patch, a generic coverage zone has been defined and implemented (by contrast in reality all ECM systems have distinct coverage zones of their own). The coverage zone is defined as ±60° in azimuth (measured from aircraft centerline), and elevation of +15° (upwards) to –30° (downwards), and is a generic representation of the 3 dB jamming beamwidth. Within this coverage zone, the main lobe of the jamming beam is defined as ±30° in azimuth, and elevation from +5° to –20°. Between azimuth of +30° to +60° (and also –30° to –60°), the ECM effect falls off logarithmically with an exponent of 0.5 (gradually first, then more and more abrupt). This applies to elevation coverage as well, with effectiveness falling off from elevation of +5° to +15°, and from –20° to –30°. Outside the effective coverage zones, ECM remains totally ineffective. The generic coverage zones were devised after examining photographs of many podded and internal ECM systems to estimate they antenna coverage.

One important change to ECM affects the AI. ECM leaves behind visible traces of its usage on the target radar display. For a raw video display, this can be snowing on the radar display, or a vertical noise strobe at the angular position. For synthetic displays, this can be synthetic symbologies indicating that the radar sees some jamming signal. The radar may also be able to determine the angular position of the jamming signal, and indicate it on the scope. Hence this allows the pilot to determine the approximate azimuth location of the jammer, even though a valid radar lock is denied, and normal tracking information such as velocity and range measurements are not possible. This also means that even though the pilot has been denied a firing solution, he is still able to maneuver and close in on the jammer in an attempt to get inside the burn-through range.

The RP ECM changes implemented by Sylvain will allow the AI to know where the jammer source is, though a valid radar lock is denied (hence denying a shot). As such, usage of ECM **will attract** the attention of the AI pilots if you are inside their radar coverage cones. In addition, for monopulse radars with Home-On-Jam (HOJ) capabilities, such as the AIM-120, AIM-54 and AA-12, turning on the jammer will result in the missile radar seekers transiting into interleaved HOJ/pinging mode. For these missiles, the one-way monostatic radar transmission effectively acts as a beacon to attract the missile. This implementation is more realistic, and the players have to be aware of the effects of using ECM. Understanding its usage will go a long way in surviving the electronic virtual battlefield in Falcon 4.

The last change incorporated in the ECM model is the ability to vary the effectiveness of different ECM systems on different aircraft. ECM systems equipping fighter aircraft are often limited in their power output, whereas ECM systems equipping bomber aircraft such as the B-1 and the B-52 have much higher power output and processing capability. The default Falcon 4 ECM model does not allow the different ECM systems to be differentiated. With the Realism Patch, this has now been implemented. A data field is created at byte 14 of the VCD name field for the aircraft, and this is used to store the multiplier effect of the ECM system equipping the aircraft. The effectiveness of the ECM can now be varied to model the different ECM systems in higher fidelity.

MAKING TRACK-VIA-MISSILE GUIDANCE WORK PROPERLY IN REALISM PATCH

The only missiles in the Falcon 4 world that uses the Track-Via-Missile (TVM) mode of guidance are the Patriot PAC-2 and the SA-10 (S-300PMU1) “Grumble.” These missiles have always been modeled as semi-active radar homing, and the launch of these missiles will always trigger a RWR launch warning.

We received some unclassified background information on the TVM mode of guidance from an experienced Patriot and Nike operator, indicating that the launch of a TVM guided missile will not trigger a RWR launch warning. The target will never be notified electronically that he has been targeted, and there will be no RWR indication other than the pilot being able to see a Patriot or SA-10 radar in search mode.

The TVM mode of guidance relies on two links. The radar continually paints the target normally, as it would track any airborne target, and directs the missile to look in the target’s direction through a separate uplink. The missile will receive the reflected RF energy from the target, and as it closes it, will begin to intercept the increasingly precise returns. The missile will re-transmit the target data that it receives back to the guidance radar, which will then use this information to generate guidance instructions. The instructions are then passed back to the missile using the radar-to-missile uplink. The missile does not emit any RF energy of its own, unlike active radar guided missiles.

Throughout the entire engagement, there is no perceptible change in the radar pulse form and PRF, thus making it impossible for an RWR to determine if the guidance radar is in search and track mode, or in fire control mode. The active electronically scanned array radar is also capable of multiple mixed mode operations, making any attempts of jamming it rather futile. Chaff is also almost useless against this mode of guidance, thus making these SAMs one of the most formidable threats.

We have modified the Patriot and SA-10 radars and missile model, such that the launch of these missiles will not trigger an RWR launch warning. You will only see the Patriot and SA-10 radar on the RWR in search mode, and possible when it locks onto you, but you will never know if a missile has been launched. Even when the missile arrives at the target, the only way to know it is to spot the inbound missile, as the RWR will not be able to give any indication of the inbound missile.

MAKING ACTIVE RADAR GUIDED MISSILES WORK PROPERLY IN REALISM PATCH

Active radar homing (ARH) missiles have always somewhat worked in Falcon 4, but not to their fullest extent. We have made significant changes to the underlying algorithm (thanks to Sylvain Gagnon), and modeled the ARH missile seekers with a lot greater accuracy compared to RP3 and before.

From RP4 onwards, the ARH missiles now have a pseudo COAST mode. Missiles such as the AIM-120, AIM-54 and AA-12 have an inertial guidance mode. In this mode the missile will make course corrections, using periodic datalink updates on the target's spatial location, provided that the launching aircraft maintains a valid radar lock throughout this phase. Once at the pre-determined location (defined as 13 seconds of flight time from the target), the missile goes active and autonomous, and will first search the extrapolated position of the target to see if it is present.

In 1.08US or 1.08i2, if the parent aircraft breaks the radar lock, when the missile turns autonomous, it will search only directly ahead. This does not simulate a proper inertial mode where the missile extrapolates the target location based on the last known velocity vector prior to the loss of datalink information.

From RP4 onwards, the ARH missiles are mechanized such that when the missile turns autonomous, it will snap look at the last known position of the target, to determine if the target is within its beamwidth. If the target is detected, it will guide towards it. If the target is not within its FOV, but there are other airplanes within 10nm. of it (the ARH missile search distance), it will lock on to the closest target. This means that the missile is indeed a rabid dog once it turns autonomous. The only way to ensure that you will not commit fratricide is to ensure that you support the missile via datalink until it turns autonomous. Failure to do so may result in the missile not acquiring the target when it turns autonomous, especially if the target maneuvers violently and way out of plane to avoid being caught when the missile goes active. Worst still, if this happen, the missile may lock onto any target within its search distance, including friendlies.

ARH missile seekers also operate in a mixed mode for initial acquisition. These seekers typically operate initially in a high PRF (HPRF) mode to maximize detection range (while sacrificing some range resolution accuracy) when they turns autonomous. Once a target is detected, they will normally transit to medium PRF (MPRF) modes for better range measurement to plot the intercept trajectory. In 1.08US and 1.08i2, the ARH missiles are programmed to search out to 8nm., and any target inside 8nm. will be considered for targeting. This does not model the initial HPRF mode quite as accurately, and has been amended to 10nm. from RP4 onwards.

Modeling the ARH Missile Seekers (Monopulse with Home-On-Jam)

A problem arose in RP3, where the ARH missile seekers were modeled as conventional radars. This made the ARH missiles very susceptible to chaff, ECM, and beaming, especially in high clutter, look-down scenarios. The problem was masked by the less than competent AI missile evasion tactics (now altered and much improved from RP4 onwards), but was revealed in the F4 ladder competitions during human-to-human BVR fights. A lot of research was poured into identifying the problem, and improving the accuracy of the ARH seeker modeling, when we managed to replicate the scenario and identify the specific engagement geometries.

Our additional research revealed that the ARH missile seekers are monopulse seekers. I will discuss about monopulse seekers and their mechanization first, to lay the ground work for understanding why the ARH missiles are now modeled as such in the Realism Patch. All materials presented here are publicly available, though much of this information is difficult to locate and must be paid for.

Unlike conventional radars that derive tracking information by comparing the characteristics of a series of pulse returns (measurement of pulse-to-pulse amplitude variations), monopulse radars derive its tracking information (in azimuth and elevation) from every return pulse that is received. Monopulse radars have four separate receivers to receive the return pulses. Every return radar pulse is received by all four receivers. By comparing the relative pulse amplitudes received on all four antennas, the azimuth and elevation correction signals can be generated to center the target on the tracking antenna.

The distinct advantage of a monopulse radar is that the pulse-to-pulse amplitude variations caused by noise or deliberate use of ECM will not affect its tracking ability, and error signals are updated at a much higher rate since a new position is generated for every pulse transmitted. The flip side of the coin is that monopulse radars are capable of tracking only single targets.

The established method of defeating monopulse tracking is through using the radar resolution cell, or other methods. The former can be achieved by having a stand-off jammer within half of the radar's pulse width from the target. This is however not practical against ARH missiles as the ranges are too close. Another technique involves using two airplanes equipped with blinking jammers, all within the radar resolution cell of the monopulse tracker, with the jammers blink alternatively on and off at a rate close to the radar's guidance servo bandwidth (typically 0.1 to 10 Hz), and attempt to cause resonance in the tracking response so as to throw off the antenna, resulting in overshoots.

Other techniques include terrain bounce (bouncing the jamming signal off the ground to reflect towards the monopulse tracker), skirt jamming, and image jamming. These techniques, however, require a lot of jamming power that is usually not achievable on self protection jammer systems. Cross polarization jamming may also be used, though this technique can be easily defeated by the monopulse tracker through the use of a polarization screen, and we have assumed that the ARH missiles are all equipped as such.

The last two methods of jamming monopulse radars include coherent jamming and cross eye jamming. The former requires the usage of two jammers that provide coherent transmissions (usually very difficult to achieve due to electrical phasing), while the latter relies on a pair of coherent repeater loops. The latter is equally difficult due to the difficulty in maintaining closely matched electrical paths between the two repeater loops. A very high jamming power is also required to overwhelm the signals on the monopulse tracker.

The current ways to defeat the monopulse tracker include using towed decoys operating on repeater mode, and activated at sufficiently far distance such that the towed decoy is inside the same radar resolution cell as the aircraft. With properly timed repeater signals, the repeater signal can be injected into the tracking gate, and as the missile closes in, it makes it more difficult for the missile to distinguish between the towed decoy repeater signal and the parent aircraft skin return. Hopefully, the missile will track the towed decoy if the repeater signal is stronger than the skin return from the aircraft.

As such, conventional self protection jammers have little ability to defeat a monopulse radar. The normal deception and noise tactics do not work well, as even if it denies the monopulse tracker with certain tracking information such as velocity or range, the radar can still track in angular position, and this is sufficient to plot a coarse path towards the target and close in for the onboard monopulse radar to burn through and re-acquire the target.

The usage of chaff is also largely ineffective, as the chaff bloom is fairly ineffective in the HPRF initial acquisition mode. However, chaff will still be effective at longer ranges, when the missile just turns autonomous and has yet to lock onto the target, though the effectiveness is marginal. Once locked on, the chaff bloom is easily distinguished from the target return.

In addition, the ARH seekers are equipped with Home-On-Jam (HOJ) capabilities. Activation of jamming will often cause the missile to transit into tracking modes that interleave the passive HOJ mode with active transmission mode. HOJ allows the radar to obtain angular information about the jamming source, and this is sufficient for the radar to plot an approximate course of intercept through proportional navigation. Since the jamming transmission is one-way, this in effect acts as a beacon for the missile to home onto, even though the missile seeker's signal-to-noise ratio is degraded under jamming, and we have modeled the seekers as such. The way the seeker is modeled is that it will simulate the missile seeker plotting an initial proportional navigation course to the target using HOJ mode, while interleaving active radar transmission to attempt a burn-through. Once inside burn-through range, the missile will transit to full active homing for terminal guidance.

While it is true that HOJ modes do not provide sufficient targeting information for an accurate intercept, and will often decrease the missile Pk through the missile plotting a sub-optimal intercept course, thus wasting energy, it is not possible to simulate the full effects of jamming on the guidance system and missile Pk within the confines of Falcon 4.

One thing that any radar will not be able to overcome is the ground clutter in look-down scenarios. This raises the noise threshold that will mask the skin returns in look-down situations. This aspect has also been modeled in the ARH seekers, though the monopulse seekers are slightly less susceptible due to the inertial mode and datalink capabilities, enabling the seeker to look at the last known good position of the target and attempt to acquire the target.

Removing the ARH Missile Launch Warning

In 1.08US and 1.08i2, whenever an ARH air-to-air missile is launched, the RWR launch warning light and audio tone will always be triggered. Strictly speaking, this is not correct, as ARH missiles guide by inertial mode in the initial phase, while receiving datalink information to update the target location.

Semi-active radar homing (SARH) missiles rely on continuous wave (CW) radar illumination to guide. The launching aircraft has to activate a CW illuminator (CWI) to "paint" the target, and the SARH missile will guide on the reflected CW energy. This CW waveform is a continuous sinusoidal waveform, unlike normal pulse or pulse doppler transmissions, and can be very easily distinguished. Whenever SARH missiles are launched, the CWI is turned on automatically, and this will trigger the launch warning light and audio tone on the RWR. For command guided missiles (such as SA-2, SA-3, and SA-8), the command guidance transmissions from the missile guidance radar can be easily detected and distinguished from the normal search and track radar transmission. Detection of the command guidance transmission will similarly trigger the RWR launch warning.

Conversely, when ARH missiles are launched, the radar does not need to provide target illumination. In terms of radar transmission, it is still as per normal for the particular radar operating mode. Since there is no change in the radar pulse-form received by the RWR, it will not trigger the launch warning. When the missile turns autonomous, the transmission from the monopulse seeker also resembles that of a normal airborne radar in the I/J band, as the RF waveforms are pulse doppler signals. This will similarly not trigger the RWR launch warning. As such, the only time the RWR will detect the presence of an ARH missile is when the missile goes autonomous, and the missile symbology appears on the RWR display. With the Realism Patch, this is now implemented.

REVAMPING THE RADAR WARNING RECEIVER IN REALISM PATCH

One of the most vexing problems with Falcon 4 is the implementation of the radar warning receiver. The RWR will continue to display the threat symbol and play the audio tone even long after the threat emitter has lost radar lock, or exceeded its radar gimbal limits. For example, the "M" symbol of the AIM-120 as well as its RWR tone will continue to be displayed and played back long after missile impact, for a duration as long as 10 seconds or even more. In addition, the "HANDOFF" function did not function properly, as the depression of the "HANDOFF" button will often not play back the audio tone of the corresponding threat.

With the help of Sylvain Gagnon, the implementation of the RWR has been changed and fixed in the Realism Patch. Before we discuss about the changes made, you should first familiarize yourselves with the workings of a radar warning receiver. This is covered in detail in the section titled "*RWR Management*," in user's manual.

Original RWR Implementation

In the original implementation of the RWR in Falcon 4, depression of the HANDOFF button will not result in the audio tone of the new priority threat being heard, although the next highest priority threat symbol will be selected. The threat priority is sorted by the relative lethality of each emitter detected, regardless of whether the emitter is in search mode or lock-on mode. The RWR routine will also check if the emitter's orientation to see if the contact is within the radar coverage. If the emitter is not locked onto the target, the coverage is assumed to be the entire radar azimuth and elevation volume (this is the radar scan volume for all AI controlled airplanes). If the emitter is locked onto the target, the coverage is changed to the beamwidth of the emitter. However, the RWR routine does not take into account the position of the emitter, and as such, does not determine if the emitter can see the contact. The RWR routine does not check if the target is outside radar gimbal coverage, and if the target's signal strength is too low for it to detect. The RWR coverage zones are also not checked. The RWR routine is written such that the emitter's audio tone is played automatically every 12 seconds, regardless of what happens.

The RWR routine will also retain every emitter contact for up to a period of 30 seconds. While this is acceptable for the AI, as an implementation of pseudo memory, it creates an extremely unrealistic behavior on the player's RWR, since the RWR symbol will continue to be displayed long after the emitter loses radar lock. The audio tone will also continue to play. The RWR routine will also update the "Last Repaint" timer of the radar each time the radar loses lock, when it should only update each time the radar pings on the target. This results in a track refresh even though the radar has lost lock on the target.

The most irritating aspect of the original RWR implementation is the constant "New Guy" beeping tone. The RWR will display up to 16 targets at any one time. In the original implementation, before the RWR adds a new contact when it detects a radar painting it, it will check to see if the emitter is already in its list of contacts. If it is not, the RWR then plays the "New Guy" audio tone, and attempts to add the contact to its list. However, the "Add Contact" routine in the RWR code may not add the contact if its signal strength is too low to be considered a threat, or if the target list is full. Hence, every time the RWR code goes through its target list, it will play the "New Guy" audio even though the target is not added.

The launch warning on the RWR was mechanized to sound upon missile launch. However, the launch warning is affected by the launch guidance delay of the missile. For missiles such as the SA-5, missile guidance will only commence 15 seconds after launch, but the missile control radar will begin transmitting immediately upon missile launch. Hence, the launch warning should sound immediately upon missile launch, whether the missile has commenced guidance or not.

There is also a problem of the launch warning light being lit, and the launch warning tone not being sounded. When a missile is being fired at the player (be it in a single or multiplayer environment), a message is sent to the player that a missile has been launched. The player's computer receives this message event and checks if the "Missile Activity" flag on this RWR contact has been set to 1. If it is not, the launch warning tone is sounded. This message event is sent once for each missile fired, and hence, the launch warning tone cannot be sounded more than once per missile fired. In the player's RWR mechanization, the "Missile Activity" flag of each RWR contact is tested and if any of the contact has it set to 1, the launch warning light will be lit. Hence, it is possible that the contact has fired at someone else, and the launch warning light triggers. Since the contact has not fired at the player, the "missile fired" message is not sent to the player, and hence, the RWR launch warning tone does not sound.

Realism Patch Implementation

In the Realism Patch, the RWR behavior is modified to correct these inaccuracies and deficiencies. The changes are made only to the player's RWR, as the AI lacks memory. Implementation of such changes to the AI's RWR will result in unrealistic AI behavior as the AI will forget about a contact and cease to react to it, whereas a human will not.

All RWR creates emitter track files each time it detects a new emitter. This track file is updated each time the emitter pings the RWR. The purpose of track file retention is to prevent the creation of extraneous RWR contacts each time the emitter pings the RWR, as the signal will be correlated with the track file to determine if it is the same contact. If this is so, the track file is updated, and a new symbol is not created. However, the RWR will not retain the track file indefinitely, and will drop the track if the emitter fails to repaint it at regular intervals. The track file retention duration is decided as follows:

We assumed an emitter radar in a 60° azimuth, 4-bar search scan. Assuming a beamwidth overlap of 2.2°, and a beamwidth of 4.6°, and assuming that the target is detected by the radar in 2 of the 4 scan bars, at the extreme azimuth limit of 60°, the target's RWR will not be refreshed during the remaining 2 scan bars coverage 60° azimuth. Taking a typical antenna scan rate of about 60°/sec, the remaining two scan bars will be covered in approximately 4 seconds. When the radar returns to the first scan bar, it will have to traverse across from 60° on one end, to the opposing end where the target is located. This will take another 2 seconds. As such, the target's RWR will be painted every 6 seconds in the search mode, and the RWR track file will be updated every 6 seconds. For any scan interval beyond this, the track will be dropped and the radar sweep will lead to the creation of a new track file.

1. The HANDOFF button will now select the next highest priority threat symbol, and play its audio tone. The audio tone that is played will depend on the radar mode that the emitter is in. If the emitter is in search mode, then the audio tone will only be heard each time the emitter sweeps its radar beam pass the RWR. If the emitter is locked onto the target, the audio tone will be heard continuously.
2. The threat priority is now sorted by lethality and emitter status. Each depression of the "HANDOFF" button will step the RWR through to emitters of lesser priority. The emitters are sorted as follows, in decreasing order of threat priority:
    - Emitters inside the lethal inner ring of the RWR display, and is locked onto the target.
    - Emitters outside the lethal inner ring of the RWR display, and is locked onto the target.
    - Emitters inside the lethal inner ring of the RWR display, but is in search mode and not locked onto the target.
    - Emitters outside the lethal inner ring of the RWR display, but is in search mode and not locked onto the target.
3. The RWR routine now checks if the emitter is able to see the target, and obeys the gimbal limits as well as radar transmission signal strength. The audio tone will not be heard if the emitter is not painting the RWR, even though the symbol may be displayed due to track retention.
4. The "Last Repaint" time of the radar will no longer be refreshed when the radar loses lock. This timer is only refreshed each time the radar repaints the target.
5. The RWR will no longer retain an emitter track for 30 seconds after the emitter last ping it. The RWR will drop the track if the emitter fails to ping it every 6 seconds. This means that the RWR will retain an old emitter track up to 6 seconds before discarding it. The symbol will disappear. The design rationale of this 6 second track file duration is elaborated in the paragraph above, and is based on the typical scan interval of an airborne interception radar.

6. The “New Guy” audio tone is only played when a newly detected emitter is added to the RWR’s contact list (16 contacts in normal operation, and 5 contacts in PRIORITY mode).
7. The launch warning aural tone will sound immediately when a missile is launched at the player. If the missile is not decoyed, and the emitter remains in the fire control and missile guidance mode, the launch warning is sounded again at an interval of 15 seconds. If the missile is successfully decoyed, or the hostile radar is destroyed, the launch warning will not sound again. The launch warning light will remain lit throughout.

With the Realism Patch, the RWR symbols will now be purged 6 seconds after the emitter loses contact. You will now be able to interpret the RWR data accurately, as a contact that does not give an audio tone will mean that it is not painting you, and you are now in a position to determine which emitter has lost track of you.

Creating Individual RWRs

Prior to the Realism Patch, all aircraft in the Falcon 4 world share the same RWR model (the RWR characteristics are found in the FALCON4.RWD file (this is found in the terrdata\objects directory). There are 5 parameters contained in each RWD entry:

Range :
This is the RWR gain, used to determine the range at which radar emissions can be detected by the RWR. The range of the target emitter (obtained from the FALCON4.RCD file) is multiplied by this gain, to obtain the range at which the emitter can be detected.

Left / Right :
This determines the azimuth angular coverage limits of the RWR. For most RWRs, it is ±180°, indicating full azimuth coverage.

Top / Bottom :
This determines the elevation angular coverage limits of the RWR.

Most if not all RWRs use spiral antennas. These antennas have specific sensitivity zones, and their angular coverage is a ±45° cone centered on the antenna boresight. Since the RWR antennas are usually placed at 4 separate corners of an airplane, each spiral antenna provides coverage for a 90° quadrant in azimuth. With a set of 4 antennas, total azimuth coverage is obtained. The elevation coverage is however not complete, due to the sensitivity zone of the spiral antenna. For most Western RWRs, the elevation angular coverage is ±45°, while most Russian systems have elevation angular coverage of ±30°.

The Realism Patch models the elevation coverage of individual RWRs, as well as the sensitivity characteristics of each RWR type. Prior to the Realism Patch, all RWRs have the same gain, and provide complete spherical coverage. RWR sensitivity is dependent on the receiver type, with simple crystal video receivers being far less sensitive than the new super-heterodyne receivers are. Since RWR systems often use a receiver system that scans across different frequency bands instead of listening to all frequency bands simultaneously, there is some degree of degradation in detection range. Crystal video receiver based RWRs often pick up the radar emissions at ranges that are close to or inside the weapon engagement envelope of the hostile emitter, and as such, provides far less reaction time to the user. Super-heterodyne receivers based RWRs are far more sensitive, and will detect the hostile radar emissions at ranges outside the weapon engagement envelope. This is now modeled in detail in the Realism Patch.

RWR Symbologies and Aural Tone Assignment

The RWR symbols in 1.08US are assigned as follows:

Symbol S/Number	RWR Symbol
1	U
2	Advanced Plane symbol
3	Old Plane symbol
4	M
5	H
6	P
7	2
8	3
9	4
10	5
11	6
12	8
13	9
14	10
15	13
16	A
17	S
18	Ship symbol
19	C
20	15
21	N

With RP5, the RWR symbology library has been totally revamped and revised. Modern RWRs can be programmed to display sophisticated symbols. While the RWR symbologies in 1.08US are somewhat correct, RWR systems have been updated with new symbologies. The expanded RWR symbology library in RP5 will allow different RWR systems to be modeled, by changing the RWR symbols associated with each radar. The expanded symbol set allows for RWRs of the ALR-56M and ALR-67 generation, as well as the older ALR-45 and ALR-69 generation to be modeled. The expanded Realism Patch RWR symbol table are optimized for SAMs and AAA threats, as well as airborne radars.

The RWR aural warning tone assignment are as follows. The WAV files are located in the sounds/twi directory, and the sound serial number correspond to the RCD sound entry.

Sound S/Number	WAV File
37	mig21.wav
41	mig23.wav
52	mig25.wav
53	mig31.wav
73	a50.wav
74	chaparal.wav
75	f5.wav
76	f22.wav
77	2s6.wav
78	adats.wav
79	ah66.wav
80	av8b.wav
81	e2c.wav
82	e3.wav
83	f4.wav
84	f14.wav
85	f15.wav
86	hawk.wav
87	hercules.wav
88	j5.wav

89	j7.wav
92	patriot.wav
93	sa2.wav
94	sa3.wav
95	sa4.wav
96	sa5.wav
97	sa6.wav
98	sa8.wav
99	sa9.wav
100	sa10.wav
101	sa13.wav
102	slotback.wav
103	su15.wav
152	barlock.wav
153	firecan.wav
154	flatface.wav
155	longtrak.wav
156	lowblow.wav
157	mpq54.wav
158	msq48.wav
159	msq50.wav
160	spoonrst.wav
161	tps63.wav
162	f16.wav
163	spy1a.wav
164	gundish.wav
165	amraam.wav
166	phoenix.wav

RADAR LINE-OF-SIGHT IN FALCON 4

During the course of the development of Realism Patch, we discovered that a basic radar line-of-sight (LOS) model is included in Falcon 4. For example, when testing the SA-10 missile, our tester sited the SA-10 SAM site on flat ground, amidst some hilly terrain. With a minimum engagement altitude of 512 feet AGL, our tester mapped out the SA-10 firing range vis-à-vis ingress altitude:

Ingress Altitude	SA-10 Firing Range
20,000 ft	40nm.
15,000 ft	35nm.
4,000 ft	20nm.
1,500 ft	11nm.
700 ft	4nm.

When the SA-10 SAM site is located on flat ground near the sea, it engaged targets ingressing at 800 feet AGL from as far out as 30nm.. When the SA-10 is sited behind a hill, the SAM site will never fire at a target unless the target is almost on top of it, or is approaching it from the same side of the hill that the SAM site is located.

In another set of testing, we tested the SA-2 by siting it in an urban environment, next to a building. By flying around in circles around the Fan Song radar, the RWR symbol and aural tone were observed. When the Fan Song has a clear line of sight to the target, the RWR symbol is displayed at the appropriate azimuth location, and the aural tone indicated that the Fan Song has a lock on the target. When the target flies to a location such that the building is between the Fan Song and the target, the Fan Song's RWR tone stopped abruptly. If the building continues to block the Fan Song's line of sight to the target, the Fan Song's RWR symbol will be dropped 6 seconds after losing contact.

The testing observations confirmed that a basic radar line-of-sight model is present in Falcon 4. This allows terrain masking tactics to be used against SAM sites and other targets, and it is even more important to know how to interpret the RWR data accurately.

IMPROVING THE F-16 AVIONICS SETUP IN REALISM PATCH

The HUD dogfight symbology has also been modified. In the actual Block 50/52 F-16, the HUD is de-cluttered in dogfight mode, and all extraneous symbologies are removed to aid heads-out fighting and minimize information overload. The default 1.08US HUD contains extraneous symbologies, and these include:

i. Flight path marker
ii. Pitch ladder
iii. Altitude scale
iv. Airspeed scale

The extraneous symbologies have been removed in the Realism Patch, and the HUD display is now a correct representation of the actual F-16C HUD in dogfight mode. The RPM reading has also been removed from the HUD, as the real F-16 HUD symbology does not display RPM.

We have also consulted several F-16 pilots who specialized in air-to-ground missions on the most commonly used avionics settings for air-to-ground weapon delivery. The avionics settings used in the Realism Patch are modeled closely after these settings used in the USAF:

1. The default A/G weapon delivery master mode is CCRP, with the radar defaulting to STPT mode in GM.
2. The bomb spacing is set to 125 feet, which is the most commonly used setting, instead of 50 feet.

GROUND CONTROL INTERCEPT, INTEGRATED AIR DEFENSE SYSTEM, AND AWACS IN FALCON 4

One of the most important elements of a modern air battlefield is the presence of GCI (Ground Control Intercept) and AWACS. In our early attempts to create a GCI/AWACS environment in Falcon 4, we discovered the following things about the 1.08i2 version of Falcon 4:

1. In the 2D world, GCI and AWACS coverage is present and active. By activating the threat circles for low and high altitude radar coverage, we can see enemy fighters being vectored towards friendly fighters if the friendly fighters are inside the enemy's radar coverage zones. This is despite the friendly fighters being outside the radar detection range of the enemy fighters. When the friendly fighters are not inside the radar coverage, the enemy fighters will not be vectored.
2. Radar sites in Falcon 4 can detect you electronically and visually. Visual detection is dependent on the time of the day and the movement type of the target. For a radar vehicle whose radar coverage is fully overlapped by another radar vehicle, the vehicle will turn off its radar, and only turn it on when the other radar vehicle is destroyed. This does not happen regularly, and only occurs at 15-minute intervals. The visual detection ranges of the radar sites are coded in the FALCON4.OCD file (for objectives). For daytime, the detection ranges are as is in the OCD entry. For nighttime, the detection range is modified by first adding 3 to the OCD entries, and then dividing the result by 4. At dawn and dusk, the detection range is obtained by first adding the OCD entry by 1, and then dividing by 2.
3. Many radar sites are named wrongly. There are many objectives named as radar sites, but they do not contain any radars. These are often TV stations and radio towers, and do not have

any search radars mounted. As such, these supposed EW radar sites are cosmetic and non-functional, and since these radars are non-functional, they cannot be targeted by anti-radiation missiles as part of a SEAD campaign.

4. Microprose had coded such that flights/airplanes are detected/spotted only if they are within a certain detection range around a unit. The detection boundary is a cylinder around the unit. For a flight in 3D, it is automatically marked as spotted. Because of this, 3D GCI cannot work because any deaggregated airplane would automatically be spotted. Similarly, 2D GCI will not work properly since the detection volume is a cylinder encompassing a unit (such as a radar station), and not a hemisphere. The targeting flight also has 360 degrees coverage.

Implementation in the Realism Patch

In order to make GCI/AWACS work in Falcon 4, the Realism Patch GCI is designed such that a flight has to be detected in 2D world before it can be detected in the 3D world. If all this sounds really confusing, it is ! We needed a long time to figure out the GCI implementation as well. There are some terminologies that we will use here:

Detected
When a targeting entity (such as an interceptor flight) has detected an enemy flight, the enemy flight can be considered as a potential target. The targeting entity cannot consider a flight that it has not detected as a target. Aggregated and deaggregated entities will detect both aggregated and deaggregated entities. A detected target does not equate to the target being spotted. It just means that the physical conditions permit the targeting entity to see the target (such as no LOS blockage, and the target being within the detection range), and can be a candidate for initiating combat.

In Range
This means that the targeting entity is within firing parameters. The targeting entity will check to make sure that its best weapon can reach the target. The orientation of the airplanes in the 2D world is not considered, and range of the weapon is the only factor. This is used only by aggregated targeting entities. Deaggregated targeting entities have their own AI logic, and will engage the target as they deem fit.

Spotted
When a flight has been spotted, it means that it has been detected by the enemy’s GCI infrastructure.

The distinction between “Detected” and “Spotted” means that a certain target may be “spotted” by a GCI radar (as in, the GCI radar physically sees the target on its radar screen), and yet not be seen by a pair of interceptors. However, since the GCI radar controls the interceptors, the target is considered to be “detected” by the interceptors as well, as the GCI passes the target’s information to the interceptors. The interceptors can then initiate an intercept, while at the same time attempt to “spot” the target using its own sensors for fire control purposes. The interceptors cannot shoot at the target until it has “spotted” the target on its own sensors. This makes the distinction between GCI guidance, and fire control guidance. For former can only guide fighters to their targets, while the latter is required for the fighters to shoot at the targets.

An aggregated entity can only spot other aggregated entities, while deaggregated entities can spot both aggregated and deaggregated entities. An aggregated entity will consider an aggregated target as detected if the target is within the targeting entity’s "Detect" range for the target’s movement type. Objectives are also capable of detecting targets. If the targeting entity is a battalion, it will also use the detection range and the range/azimuth coverage of the nearest objective. If the targeting entity is a flight (a flight is an aggregated entity, while an airplane is a deaggregated entity) and the target is also a flight, the targeting entity will use the radar azimuth coverage of the first vehicle in the flight. If the target is outside the radar coverage, it will use a generic visual detection routine. This allows AWACS assets to have 360° coverage.

3D entities are limited to using their own onboard real sensors for spotting targets. Since the spotting code is shared by both the 2D and 3D combat, and sent on the network to the other players, targets spotting in 2D will affect what the 3D entities sees, and vice versa. If a flight is not spotted in the 2D world, it will not be seen in the 3D world as well. Once a target is spotted, the 2D and 3D code has the target automatically detected but not necessarily spotted. A spotted target can hence disappear over time if there are no longer any units in the F4 world that is able to see it.

We need to spend some time to explain the data fields in Falcon 4, as this determines how 2D combat is resolved. Every weapon in Falcon 4 has range and "Hit Chances" value, used to resolve statistical combat. These values are different depending on the target type. The following target types are defined:

1. Static
2. Foot
3. Wheeled
4. Tracked
5. LowAir
6. Air
7. Naval
8. Rail

Similarly, every vehicle and unit in Falcon 4 has a table in which targets are paired with different actions, as follows:

	To Hit	Strength	Range	Detect
vs Static				
vs Foot				
vs Wheeled				
vs Tracked				
vs LowAir				
vs Air				
vs Naval				
vs Rail				

For units/vehicles, the "Range" field specifies the range (in kilometers) that combat should be initiated while the "Detect" field specifies if a target should be engaged. In 2D combat the “Range” of the unit is first checked. If within the target is within the range corresponding to its target type, Falcon 4 checks the "Range" field of the vehicles that make up the unit. This is more useful for ground units where each vehicle has a different range, since ground units are composed of different vehicle types. The best weapon is then used, and 2D combat is resolved using the "Hit Chances" values for the selected weapon, and the target is engaged at the appropriate range of the selected weapon.

For the detection algorithm, the following time-of-the-day is used to define daylight, night, dawn, and dusk:

i. From 2100hrs to 0500 hrs, it is defined as night.
ii. From 0500 hrs to 0700 hrs, it is defined as dawn.
iii. From 0700 hrs to 1900 hrs, it is defined as day.
iv. From 1900 hrs to 2100 hrs, it is defined as dusk.

As you can see this is all very complicated. The complex computation and selection is made even in 2D combat. You can see this in action if you run a TE or campaign at normal time or low rates of time acceleration, and observe the way weapons are being expended. You will find that the best and the longest-range weapons are used first, before other weapons are used. For example, the AIM-120B will be first used, and only when the missiles are expended, will the AIM-9 then be used. You will also find that the ordnance load in 2D war correspond exactly to the ordnance load of the same unit/vehicle in the 3D war.

The key parts of the Realism Patch GCI/IADS/AWACS changes are as follows:

1. The radar coverage on 2D map is made dynamic. You can see the low altitude and high altitude radar coverage on the 2D map (by activating the radar coverage circles in the 2D map), and the radar coverage circles will indicate the radar coverage zones at that instance. If radar stations are destroyed, the gap in radar coverage will be reflected on the 2D map. This does not happen constantly, but occurs at a regular time interval of about 15 minutes. As such, you can see a real-time air picture as you destroy the enemy's IADS, and use this as a mission planning tool to select ingress routes for your strike aircraft.
2. The threat circles on the 2D map are made dynamic to reflect the threat situation based on the current intelligence. For every detected unit that is capable of engaging air targets, a threat circle will be drawn for its engagement range at low and high altitudes. These units need not be SAM/AAA units, and need not have functional radars. As long as they can pose a threat to aircraft, they are considered a threat, and the threat circle will be displayed. For undetected units, their threat circles cannot be displayed. This simulates the fog of war due to incomplete intelligence information.
3. The 2D map will now only show aircraft that have been detected by any component of the IADS. For example, if an enemy flight is not being detected by any of your IADS/GCI/AWACS assets, and has not been detected by any of your fighters, they will not appear on the 2D map, and you will not be aware of its presence. The IADS/GCI/AWACS assets include aircraft, AWACS, early warning radar sites, air bases with radars, and SAM sites and battalions.
4. Low level tactics are now possible in 2D and 3D combat. You (and the AI) can now fly in 2D or 3D at low altitudes, and not be detected at all if the flight route does not take the aircraft over any enemy IADS assets. Even if an aircraft overflies an IADS asset, the enemy will only be able to detect you as long you stay in inside its coverage area (such as visual or radar detection range). This means that if the enemy has gaps in its radar coverage, even if you have been detected, if you fly into areas that are not covered by radar or any other visual sensors, the enemy will lose you. This allows you to sneak away as the IADS will not have sufficient reaction time to direct fighters against you.
5. All aircraft in 2D will now use their radar and visual sensors to detect and spot targets. The original Falcon 4 implementation has the aircraft seeing everything around it that is within a 128 km radius (approximately 71nm.).
6. In 2D combat (which also occurs during 3D combat), the EW and SAM radar sites are interlinked. When the radar coverage of SAM radars are overlapping, the SAM radars with lower range will shut down, and will rely on other SAM radars on the IADS network for detection and targeting purposes. As active radars are destroyed, these "dormant" radars will become active to take over the air defense radar coverage.
7. When in 2D combat, all components of the IADS can detect and send information about the targets that they have detected to friendly aircraft that are nearby. For example, enemy AWACS, fighter aircraft, SAM radars, and EW radars can now pass the information on a detected target to other enemy fighters, and if the enemy fighters are within range, they will be vectored to intercept the target.
8. In 3D combat, IADS assets such as aircraft, AWACS, SAM sites/battalions, air base radars, and early warning radar sites/stations can and will detect targets, and send the information to other friendly interceptors/fighters nearby. If the interceptors/fighters are within range, they will commence an intercept.
9. In the 3D world, IADS information can be passed on to other IADS assets by air defense units. IADS information can also be passed on to, and made used of, by aircraft that are crewed by

aces or veterans that are within range of the target, provided that their morale is not broken. Since the 2D IADS detection code is also used in 3D, targets detected by 2D GCI assets can also be seen by airplanes in the 3D world. This allows ace and veteran pilots to be guided by GCI information for vectored intercepts. Pilots of lower skills can sometimes act on GCI data, but this is based on a random generation. For AWACS, they can detect targets when they are aggregated as well as deaggregated.

10. In the 2D world, IADS information can be passed on by any air defense unit (AAA or SAM), early warning radar sites, airbase radars, and AWACS. Fighter and fighter bomber aircraft that are tasked for missions other than air-to-ground, and crewed by ace or veteran pilots whose morale are not broken can also pass on IADS information, and make use of such information for vectored intercept. Pilots of lower skills can sometimes act on GCI data, but this is based on a random generation. Aircraft flying at low altitudes (less than 500 feet AGL) can also escape detection from high flying CAP, although they can still be detected if they overfly EW radar sites, or SAM/AAA battalions.

11. The visual detection envelope of 2D airplanes is limited to ±175° in azimuth, and –30° to +90° in elevation. The visual detection envelop of 2D IADS combat units (such as SAM/AAA battalions), as well as 2D IADS objectives (such as airbases) is ±180° in azimuth. The visual detection range is dependent on the time of the day, and ranges from 16 km in daytime (about 8.9nm.), 8 km at dawn and dusk (about 4.5nm.), and 4 km at night (about 2.3nm.). The detection ranges are the same for airplanes, objectives, and combat units.

12. For 2D airplanes, there is an additional condition for visual detection of enemy airplanes. If an enemy airplane is within a circle of 1nm. radius around the airplane, and has not been detected by it (for whatever reasons, such as the enemy being outside the visual detection envelope), the enemy airplane will automatically be detected if it is flying above the altitude of the airplane. If the enemy is flying below the airplane, it will be automatically detected if the altitude separation is less than 5,000 feet, else the enemy will remain undetected. For NOE enemy airplane flying at altitudes below 500 feet AGL, they cannot be detected if the vertical separation between the enemy airplanes and the friendly airplanes exceeds 2,000 feet

13. For 2D radar detection of enemy airplanes by AWACS or friendly interceptors, the radar azimuth coverage of the first airplane in the unit is used. For targets flying above an altitude of 10,000 feet, the detection range is the “Air” value in the “Detect” field for the unit. For targets flying at an altitude between 500 feet and 10,000 feet, the detection range is the “Low Air” value in the “Detect” field for the unit. For targets flying at altitudes below 500 feet AGL, they can only be detected if the AWACS or friendly interceptors are flying below 2,000 feet themselves. The 2D radar elevation coverage is ±60°. There is a 2D doppler notch mechanized, at ±10° off the boresight. Any targets flying inside the 2D notch will not be detected.

14. For 2D radar detection of enemy airplanes by AAA/SAM units as well as objectives equipped with a functional radar feature, the azimuth limit of the detection envelope is specified in octants of 22.5°. For targets flying at altitudes above 10,000 feet, the detection range is the “Air” value in the “Detect” field for the unit/objective. If the target is flying at altitudes between 0 feet and 10,000 feet, the detection range is dependent on the “Low Air” value in the “Detect” field for unit/objective, as well as the target’s altitude. Each objective and 2D unit has a radar array that specifies how far its radar can see at various octants. The range may vary from octant to octant, thus creating blind zones in coverage. These values are stored in the campaign CAM files for each objective. The detection range of an air target is the relative altitude of the air target compared to the objective, divided by the radar array element at the corresponding octant. The result is in feet. If the “Low Air” value for the objective/unit is larger than the resultant detection range, then the detection range remains as is. If the “Low Air” value is smaller than the detection range, then the detection range is capped at the range specified in the “Low Air” value. For example, if a target is flying at a bearing of 30° from a radar equipped objective, at an altitude of 2,700 feet. The altitude of the objective is 2,300 feet, and the relative altitude difference is 400 feet. If the radar array element for the 22.5° to

45° octant of the objective is 0.022 (for example), the detection range is 400 divided by 0.022, giving 18,181 feet (about 3nm.). If the "Low Air" value of the objective is 10 (this is in kilometers, and equates to about 5.5nm.), the target will be detected only at 3nm.. If the "Low Air" value of the objective is 5 (equating to 2.7nm.), then the target can only be detected at 2.7nm.. In essence, it makes it impossible for IADS radars to detect targets flying below their altitude.

15. The detection range of long range EW/GCI radars and AWACS have been altered. This is set to kilometers, and the longest available range is only 255 km. For AWACS and EW/GCI radars, this limitation to their detection range is not realistic, as AWACS can detect targets much further than 255 km (about 142nm.). For ranges at 250 or below, the detection range is as specified. For example, if the range is 250, it remains as is. Every one unit increment above 250 increases the range by 50 km. For example, if the detection value is 251, the detection range becomes 300 km. For the detection value of 255, this equates to a detection range of 500 km (about 278nm.). This change creates a more functional AWACS, and simulates the capabilities of modern C^3I facilities better.
16. The detection range of stealth aircraft in 2D is also changed. In 1.08US, the detection ranges of stealth aircraft are halved as compared to normal aircraft. This is however unrealistic, and has been changed to 1/20th of normal aircraft in the Realism Patch.

The IADS modifications in the Realism Patch now makes it possible to progressively destroy the IADS and gain air dominance over the enemy, by targeting its EW radar sites, SAM/AAA sites, as well as AWACS assets. As the IADS assets are destroyed, you will find that the low and medium/high altitude radar coverage zones will progressively shrink, and gaps in radar coverage will be created. The air picture is a lot more dynamic and uncertain, as the campaign map will no longer show all the enemy targets, but will only show targets that have been detected by your own IADS assets. Since EW radars can be targeted, you will need to participate actively in the selection of targets for SEAD strikes and SEAD escorts, and make it a priority to destroy the IADS EW radar sites. With the destruction of such sites, you will reduce the air engagements to localized engagements, where the enemy fighters will have to rely solely on their own onboard sensors for detection.

STAND-OFF JAMMERS IN THE REALISM PATCH

One of the major components in an air campaign is the usage of tactical jamming assets, such as stand-off jammers, to disrupt the enemy's integrated air defense system. The usage of tactical stand-off jammers will prevent enemy IADS assets such as EW radars and SAM radars, from detecting your own strike packages, and engaging them. This aspect was never implemented in Falcon 4, and constitutes one of the most glaring omissions from an otherwise well designed air campaign engine.

Stand-off jamming targets the communication links, as well as detection and early warning radars in an air defense environment. Most modern SAM fire control systems require some amount of initial targeting information in order to initiate a fire control solution that will lead to an engagement of the enemy airplanes. Enemy interceptors will also rely on targeting information from early warning radar sites, so that they can be vectored to the correct location to intercept the intruders. Stand-off jammers targets the early warning radars that supply the information to the SAM batteries and interceptors, and forces them to detect the targets using their own onboard sensors.

SOJs are primarily noise jammers, putting out white noise at the frequency of the victim radars. For a radar to be susceptible to jamming, the jamming signal must be close to the victim's radar frequency. The distance that it needs to be at depends on the antenna design of the victim's radar, as well as its characteristics. Most modern radar receivers have some form of AGC (automatic gain control) logic implemented in their radar receiver. Radar returns are very much weaker than the radar transmissions, and hence radar receivers are designed to be very sensitive so they can listen out for the echoes. If the returning RF pulse is of a high signal strength, it can potentially saturate or burn out the receiver, due to the receiver's high sensitivity. The gain control logic will reduce the receiver gain, so that the returning RF pulses do not saturate or burn out the receiver. If there is a legitimate target return, and the receiver gain has been reduced, the receiver may no longer be able to detect the legitimate target return simply because the signal strength of the target is below the detectable threshold. Now, if there is a legitimate target return, but there is a lot of RF white noise, the signal strength of the white noise may be higher than that of the target return. Under such circumstances, the target can no longer be detected since its return has been "drowned out" by the background noise.

What an SOJ does is to achieve these effects. It introduces white noise to the receivers of the victim radar. This "drowns out" legitimate target returns, unless the target is sufficiently close to the victim radar such that its returns have a higher signal strength than the white noise. The high signal strength of the white noise will also cause the victim radar receiver to reduce its gain, thus making it even less sensitive to weak target returns. The detection range of the victim radar will be reduced. It is possible to jam a GCI radar through its side lobe, in addition to jamming it through its main lobe.

Stand-off jammers are now implemented in the Realism Patch. If an ECM squadron is available in TE, such as the EA-6B, the SOJ flights can be assigned to provide stand-off jamming protection to other flights in the same package as the jammers. The SOJ has been implemented in 2D and 3D combat, and its effectiveness is dependent on the range at which the SOJ is flying from its victim radar. If ECM squadrons are available in campaign, the ATO engine will task them for jamming missions.

If the SOJ is within 1.5 times the nominal 2D radar range of a radar equipped SAM unit, a radar equipped objective, or an AWACS, the detection range of the SAM unit's 2D radar is reduced by a power of 2 on the square of its detection range. The mathematical relationship is as follows:

$$(\text{Effective Victim's Radar Range})^2 = (\text{Victim's Radar Range})^2 \times ((\text{Jammer's Range from Victim})^2 / (\text{Victim's Radar Range} \times 1.5)^2)^2$$

This is best illustrated by some examples. Assuming that the radar has a detection range of 200nm..

1. If the SOJ is flying at a range of 300nm. or more from the radar, the radar's range is unaffected.
2. If the SOJ is flying at a range of 290nm. from the radar, the radar's range is 187nm..
3. If the SOJ is flying at a range of 200nm. from the radar, the radar's range is 89nm..
4. If the SOJ is flying at a range of 100nm. from the radar, the radar's range is 22nm..
5. If the SOJ is flying at a range of 50nm. from the radar, the radar's range is 6nm..

For 3D implementation of SOJ, the implementation is the same as in 2D. The effective range of the victim radar is first determined from the relationship above, and the effective radar range is then used to determine the radar signal strength, through the normal radar detection routine (see the details of this in the earlier sub-section titled "*Understanding How Radars Work In Falcon 4.0*."

As you can see, the high output power of the SOJ totally saturates the receiver system on the victim radar, and practically shuts down the radar the closer it is to the victim. The jamming power drowns out all other radar contacts and de-sensitizes the victim radar. Unless the radar contact is inside the effective range, the contact cannot be detected.

MISSILES GALORE

Technical Notes On Missile Modeling in Falcon 4
By "Hoola"

BASICS OF HOW MISSILES WORK

Before all the fun can begin, it pays to understand how missiles work. With a basic understanding of the underlying mechanism of missiles, you will be able to identify how the changes made to the F4 files will affect final missile performance, and identify any anomalies that may arise.

Basic Layout

The basic layout of the missile consists of 4 sections:

Guidance section
Warhead and fusing section
Control section
Propulsive section

The propulsive section may consist of either a turbojet with a fuel tank, like the AGM-130, and AGM-84, or a solid rocket motor. The weight of the propellant depends on the missile type, and more often than not, is about 30-50% of the total missile weight.

Rocket Motor Properties

Most missiles equipped with solid rocket motors do not have a long burn time due to the burn characteristics of such motors. Solid rocket motors may have two different thrust profiles, a pure boost profile which will give a very short burn time but a very high thrust to accelerate the missile to the maximum velocity at burnout, and a boost-sustain profile, which is a compromise. The boost-sustain profile consists of a short boost phase of high thrust (still lower boost thrust than a pure boost profile), where the missile is accelerated to its maximum velocity (Vmax), and a longer sustain phase with lower thrust to maintain Vmax while the motor is burning.

The disadvantage of a pure boost motor profile is the quick acceleration. This often increases aerodynamic heating and drag due to the high Mach, and once the motor has burnt out, the missile will begin to decelerate rapidly even when not maneuvering. If the missile maneuvers, the higher drag will slow the missile down even more. Kinematic range is thus shorter for pure boost rockets. The upside of a pure boost rocket is that the missile can prosecute the target more rapidly than a missile with a boost-sustain rocket, while the rocket is still burning. The maneuvering potential is also higher during rocket firing, though the disadvantages outweigh the benefits once the rocket has burnt out. Most new missiles are equipped with boost-sustain rockets these days. Pure boost profiles are used in missiles like the AIM-9P and PL-7.

Proportional Navigation

Almost all modern missiles guide themselves to the target using proportional navigation. The target line of sight (LOS) is used as an input to the guidance system, to compute a collision course. This involves turning the missile until a heading is found which stops the target's apparent LOS drift rate. By maintaining this lead angle, the missile will theoretically fly a straight path to intercept a non-maneuvering target. The lead required to stop the drift rate is dependent on target speed and aspect, as well as missile speed, but *not* range. This mode of guidance is what results in the characteristic wriggle of the missile as it corrects for LOS drift.

Missile Range and Kinematics

Missile ranges are described in various different definitions. The common definitions used by the USAF are as follows:

Rmax1 - The maximum range at which the missile may be launched at a 1g non-maneuvering target, and either achieve a direct hit or pass within lethal distance of the warhead.

Rmax2 - The maximum range at which the missile may be launched at a target that performs a constant speed 6g turn to 0° aspect at the point of launch, and then accelerate at a rate of 1g to an airspeed that is 300 knots above the starting airspeed.

Rmin1 -The minimum range at which the missile may be launched at a 1g non-maneuvering target, and arm the fuse.

Rmin2 - The minimum range at which the missile may be launched at a target that performs a constant speed 6g turn to 180° aspect, and thereafter heads directly towards the launch aircraft, and still achieve either a direct hit or pass within lethal distance of the warhead and result in warhead detonation.

The weapon employment envelope encompassed by Rmin2 and Rmax2 is sometimes known as the no escape zone. In most cases, missiles may be launched between Rmax1 and Rmax2. The difference between Rmax1 and Rmax2 can be significant, and sometimes up to 3 times in difference.

The reason for the difference is primarily due to missile aerodynamics. Missile drag increases drastically the moment the missile angle of attack is increased due to maneuvering. Since the missile motor does not burn for long and the missile is in coast most of the time, any maneuvering will result in energy loss. The maximum maneuvering potential is thus realized only at the point of motor burnout, and the more the missile has to correct its trajectory to pursue the target, the more limited the maneuvering potential towards the end of its flight.

Missile kinematics refers to the missile aerodynamic performance, such as acceleration rate during rocket motor burn, deceleration rate after burnout and during maneuvers, and g capability with missile speed. It generally governs to the missile range, without accounting for seeker performance.

IR Guidance System

IR guided missiles are normally tail chasers during end game. The only information available to the guidance system is the seeker LOS and drift rate. Thus, end game is usually tail chase, and the missile is limited in the amount of lead that it can achieve.

Semi Active Radar Guidance System

Semi active radar guidance relies on the host aircraft's radar to perform the guidance. The radar seeker will home onto the reflected signals that the missile is tuned to recognize. Range and drift rate is thus available to the missile, as are target velocity and direction. The missile can thus potentially pull more lead during intercept.

Active Radar Guidance System

When active radar missiles are fired, they are usually guided inertially in the initial stage. At the point of firing, the missile is usually given a predicted location of the target based on the target track, and a point in the sky to turn on the onboard radar. However, since missile flight time can exceed 20-30 seconds, the possible target location is actually an uncertainty zone. The missile seeker FOV is usually much smaller than this uncertainty zone, and the probability of the missile finding the target within its FOV at the point of onboard radar activation is thus lower.

If the launch aircraft maintains target track, it is then able to update the missile periodically with the target information, and the missile will adjust its inertial flight path accordingly, as well as the activation point. The missile is usually updated through a datalink, and the effect of the datalink is to progressively shrink the uncertainty zone. The probability of the missile finding the target within its seeker FOV at the point of activation is thus higher, increasing the probability of kill (Pk) of the missile.

This is the same for active guided radar missiles such as AA-12, AIM-54, and AIM-120. The onboard missile seeker will obtain range, velocity, LOS, and drift rate for determining the intercept course. Active missiles are thus able to pull more lead during the inertial phase as well as the final guidance phase.

Missiles like AA-12 and AIM-120 have a limited close in capability as the minimum range is constrained by fusing and missile aerodynamics.

Fusing and Arming

All missiles are armed only after some flight time. The arming of the fuse and warhead is usually due to onboard gas generator pressure, or inertial switches triggered by missile axial acceleration. This arming time and distance is one of the constraints on the minimum range at which the missile can be launched, together with the servo lockout time designed to prevent the missile from maneuvering within close proximity of the launch aircraft.

Even though the missile may be able to maneuver and strike the target at closer range than the Rmin, the warhead may not be armed. This process is not modeled in Falcon 4, and missiles can still successfully destroy targets at very close ranges of up to 1500 ft or so, which is well within gun range.

FALCON 4.0 MISSILE MODELING

Missile Modeling Files

The files used for modeling the missiles are as follows. The files with extensions DAT and VEH are ASCII files, while the FALCON4.SWD, FALCON4.ICD and FALCON4.WCD files are binary files. Descriptions of the binary files are based on Julian Onions' F4browse utility.

.DAT - In sim/misdata directory. This contains the missile seeker information, as well as motor burn time, missile aerodynamic coefficients for flight modeling, and range information for the AI.

.VEH - In sim/vehdef directory. Contains the missile vehicular information, such as weight, drag factor, name, and weapon type.

FALCON4.SWD - In terrdata/objects. Contains the simulations weapons data, which includes the missile pointer and the type of the weapon. The missile pointer indicates the corresponding entry in the mistypes.lst in the sim/misdata directory. The entry in the mistypes.lst file then refers Falcon4 to the appropriate DAT file.

FALCON4.WCD - In terrdata/objects directory. Contains the weapon data, such as weight, blast radius, drag (in counts), guidance type, damage, and the onboard seeker radar type (if any). For SAMs, the maximum and minimum engagement altitudes, as well as engagement range, is included in this file, and is not controlled by the SAM kinematic model data files.

FALCON4.ICD - In terrdata/objects directory. Contains the missile IR seeker properties, similar to the .IRS file. The information includes nominal range, seeker field of regard, seeker field of view, flare chance, and ground factor. I suspect that the information presented here supercedes that in the .IRS file.

FALCON4.RWD - In terrdata/objects directory. Contains the anti-radiation missile seeker properties, in addition to the RWR characteristics. The information includes acquisition sensitivity, field of view in azimuth, and field of view in elevation.

FALCON4.VSD - In terrdata/objects directory. Contains the TV seeker properties, in addition to the visual seeker characteristics (such as Mk-1 eyeball). The information includes acquisition range, field of view in azimuth, and field of view in elevation.

Missile Flight Modeling

The missile model in Falcon 4 mimics that of the actual missile range computation algorithm in the fire control computer of modern aircraft. The missile range modeling is a three-degree of freedom simulation, mechanized as follows:

Missile aerodynamics is resolved using trigonometry, through two tables, one containing the normal force coefficient Cx (perpendicular to the x axis of the missile), and the axial force Cz (along the missile x axis). The missile lift and drag force relative to its flight path is resolved based on the angle of attack, as follows:

Lift = {Cz * Reference Area x cos (missile AOA)} + {Cx * Reference Area x sin (missile AOA)}
Drag = {Cx * Reference Area x cos (missile AOA)} + {Cz * Reference Area x sin (missile AOA)}

Missile thrust is computed from the motor time history. Flight trajectory is computed by resolving the lift, drag, and thrust, as well as the missile weight. Missile guidance is affected by a proportional gain factor, which controls directly how much the missile leads the target in the pursuit

Warhead effectiveness is controlled not by the data files, but by the FALCON4.WCD file, which contains the weapon warhead data and damage potential.

Interpreting DAT File Data Fields

Final Time (sec) - This controls the total guidance time of the missile. In actual fact, this is the life of the thermal battery onboard the missile, which provide electrical power to the guidance package. Some missiles will self-destruct at this time. Falcon 4 will command a self-destruct for the missile.

Pk - The probability of kill, assuming that the missile is fired at a non-maneuvering target that does not evade nor employ IRCCM/ECM. This may or may not be one. I have not found any effect of this at all.

Weight of missile (lb.) - Missile weight at launch, in pounds.

Weight of propellant (lb.) - Weight of missile rocket motor. This weight is burned off from the missile weight linearly throughout the life of the missile motor burn time.

Motor Impulse (lb-sec) - The missile rocket motor impulse, in lb-sec. This is the integral of the motor thrust time history. I have not found any part that this number will play in Falcon 4, other than being there for information. For most missiles, this number is left unchanged or at some arbitrary figure.

*Missile Reference Area (ft*ft)* - The missile reference area in square feet, usually defined as the cross section of the missile body.

*Nozzle Exit Area (ft*ft)* - The missile rocket motor nozzle exit area. This number has no game function and is usually for reference.

Length (ft) - Missile length. This number has no game function.

AOA min, AOA max, Beta min, Beta max (deg) - The maximum allowable angle of attack and angle of sideslip for the missile, in degrees. For a missile, both angles are the same since missiles are symmetric about the pitch and yaw axis. The default values in Falcon 4 are way too high for most missiles, at 25°. The more appropriate AOA and sideslip for conventionally steered missiles (i.e. non thrust vectoring missiles) is about 15-19°, with AA-11 going up to maybe about 25-35°. Exceeding this will usually result in the missile stalling and losing lift, which is not modeled in Falcon 4.

Velocity min (ft/sec) - The minimum missile velocity. The missile will self-destruct when its velocity falls below this limit. The unit is actually not in ft/sec, but rather, in nm./hr.

Gimbal Angle Limit (deg) - The missile seeker gimbal angle limit, in degrees, with reference to the missile x body axis. This is way too high for most missiles. This number does not control IR seeker gimbals, which are controlled by the FALCON4.ICD file.

Gimbl Ang Rate Lim (deg/sec) - The missile seeker gimbal angular rate limit. In actual missiles, the performance is determined by the smaller of either the gimbal angular rate limit or the tracking rate limit. Since Falcon 4 missile modeling is simple, this figure actually corresponds to the tracking rate, and defines how fast (in degrees per second) the target can traverse across the seeker. The higher the number, the better the missile is at keeping track of a high crossing rate target. This number is way too high on all the missiles.

Field of view (deg) - The missile seeker field of view in degrees. This number does not control IR missiles, for which seeker data is embedded in the FALCON4.ICD file.

Guidance Delay - The time in seconds between missile launch and commencement of missile guidance. The times for most A/A missiles are something like 0.2 to 0.5 seconds, and about 2-5 seconds for SAMs. It prevents the missile from maneuvering while in close proximity to the launch aircraft. This is not the safe and arming time. However, since Falcon 4 does not model safe and arming, the guidance delay can be used to simulate this to increase Rmin. The downside of using guidance delay is that if you are shooting close to the gimbal limit, the guidance delay may result in the target exiting the seeker gimbal limits and losing lock. This may not necessarily happen with the real missile.

Lofting bias - This controls how much the missile will loft once fired. The higher the number, the greater the lofting upon launch.

Proportional Nav gain - This number controls how much lead the missile guidance will perform. By lowering the number, the missile end game will usually result in a tail chase. Raising the number will lead to a shorter intercept time since the missile will pull a lot of lead to perform the quickest intercept. The number is also way too high in all the missiles.

Autopilot Bandwidth - This is the autopilot guidance system bandwidth for active missiles only. I haven't found the exact effect of changing this.

Time to go active (sec) - The time that the missile will go active, for an active radar guided missile. For a passive sensor, this is set to -1.

Seeker Type, Version - The seeker type and version. Version for IR missiles pertains to the appropriate entry in the FALCON4.ICD file.

Type
0 Infra-red homing
1 Active radar homing
2 Anti radiation radar homing
3 Optically guided
6 Semi active radar homing

Display - This number indicate whether the missile displays any picture on the aircraft MFD (I guess).

0 No picture
1 Optical picture (normal optics)
2 Imaging Infrared picture
4 HARM Targeting Display

Missile Aerodynamic Data - The data here is presented in an entire block. The data grid is divided into Mach and Alpha (angle of attack), for the pertinent aerodynamic coefficients, Cz (normal force) and Cx (axial force).

The coefficients are presented in a matrix for each Mach number breakpoint, with a normal or axial multiplier factor. The multiplier allows Microprose to use the same aerodynamic data for different missiles, and scale them according to the missile weight. The multiplier is applied to all data points within the data grid. All Cx and Cz data are given as negative, since this is the normal convention for missile or aircraft aerodynamics. When resolved accordingly, the negative sign will produce drag accordingly. The data for Cz is not aerodynamically representative, and I have applied some engineering judgment to re-create typical drag data for missiles.

Mach - This states the number of Mach breakpoints in the data grid

Alpha - This states the number of angle of attack breakpoints in the data grid

Normal Multiplier - The multiplier factor used to alter all the data points in the normal force coefficient matrix.

Axial Multiplier - The multiplier factor used to alter all the data points in the axial force coefficient matrix.

Engine Data - The rocket motor data is given as a thrust profile, with respect to time, in pounds. The first number under the BRNTIM entry is the number of breakpoints in the rocket motor burn time history, followed by a data block with the corresponding time breakpoints.
The second data block is the motor thrust in pounds, corresponding to the individual time breakpoints.

Range Data - This gives the missile engagement range in Rmax2, for the AI. The descriptions are as follows:

Table Multiplier - The multiplier factor for the range data

Altitude Breakpoints - This shows the number of different altitude bands, and breakdown of each altitude in feet.

Velocity Breakpoints - This gives the number of velocity breakpoints, and a breakdown of each velocity. The velocity seems to be in knots, and appears to pertain to launch aircraft velocity.

Aspect Breakpoints - This gives the engagement range data for the different target aspects. Range data is given as a block for all three aspects for each mach and altitude combination. It is possible to create rear aspect missiles and prevent the AI from firing it all aspect, by limiting the aspect breakpoints to angles behind the 3-9 line.

The range is given in feet, and aspect angle is given in radians (1.57 is pi radians, and gives 90 degrees).

The range breakpoints for A/A missiles will determine the range envelope, as well as the HUD DLZ cues. For example, to determine the firing range against a target closing at 800 knots, at 16,000 feet, 20 degrees off the nose, you will need to first interpolate between the range breakpoints for aspect of

0 and 1.5708 for both 15000 and 20000 feet, for both 0 knots and 1181.49 knots to obtain the firing range for closure of 0 knots and 1181.49 at 15000 and 20000 feet at 20 degrees angle off. You then interpolate the two closure speeds to obtain the firing range for a closure speed of 800 knots for both 15000 and 20000 feet, and finally interpolate between the altitude to obtain 16000 feet.

For SAMs, the range breakpoints in the DAT file are for reference only, and not actually used. The firing ranges and altitudes are encoded in the FALCON4.WCD file, in the fields labeled as RANGE, AIR BLAST, and AIR HIT, by Julian Onions' F4Browse utility. There may be other data fields involved. The relationships between these data fields are currently not entirely known, though the SAMs have been tweaked to achieve realistic firing altitudes and ranges.

General Notes

It is possible to include more breakpoints in modeling the missile aerodynamics. However, Falcon 4 interpolates linearly between breakpoints, and introduction of more breakpoints to more accurately model missile performance will only incur additional CPU cycles and memory for processing.

Modeling Rmin – In the Realism Patch, warhead arming time is now modeled (see section titled "*The Long And Short Of Fuses*" in the Designer's Notes). The default implementation of Falcon 4 does not model Rmin properly. The AIM-120 model can actually be fired at targets well within 1nm. of range head on, and still obtain a hit. The safe and arming time for missiles play a very important role in constraining the Rmin for missiles. Besides the safe and arming time for missiles, there is also guidance delay to consider. All missile guidance systems are programmed with a guidance delay, to allow the missile to fly out ballistically so that any autopilot failure will not cause the missile to crash into the parent aircraft. If the missile is launched close to the gimbal limits, the delay may result in the target exiting the limits. Safe and arming usually occurs within 300-400 meters from the launch aircraft, which corresponds to about 900-1500 feet.

Interpreting Missile Range – Before any one screams about the AIM-120 or any other BVR missiles hitting targets when launched at 0.5nm from the target being totally unrealistic, and BVR missiles not being able to hit anything beyond 12nm., you need to consider the firing geometry.

Missile ranges are often quoted in reputable journals and publications. These ranges are however often quoted without the firing conditions and geometry. Firing geometry and target maneuver will influence range considerably. Consider the AIM-7, when fired head-on at a non-maneuvering target, its range is approximately 3 times farther then when fired at a maneuvering target in a constant 5g turn. In the latter case, the AIM-7 is barely even BVR. As another example, the AMRAAM is often quoted with a 50 km range. This figure would be for a head-on engagement against a non-maneuvering target.

The general rules of thumb are as follows:

Rmin is smallest when firing head-on at high closure. The higher the closure, the larger Rmin becomes.

Rmin in tail-on engagements is closer than Rmin in head-on engagements. This is only to be expected since the missile needs to maneuver less. Head-on shots often have high LOS drift rates and may thus exceed the missile's maneuvering capability.

Rmax for a non-maneuvering target is also about 2-3 times more than for a maneuvering target. Head-on engagement range is greater than tail-on. This is plain kinematics. However, head-on range for IR missiles is limited by seeker performance. Thus, IR missile head-on ranges are less than tail-on ranges.

Newer IR missiles generally have greater seeker acquisition range in the rear aspect than its kinematic range. Kinematic range will however exceed seeker acquisition range in the front aspect.

When the missile is made to maneuver, it will lose energy rapidly. Prior to motor burnout, the missile can maneuver without losing much energy. Once the motor has burned out, you should expect the missile to lose energy fairly quickly even when not maneuvering. Missile drag at high supersonic Mach numbers is considerable.

Creating an Accurate Missile Model in Falcon 4

The following factors have the greatest influence over missile performance in Falcon 4. These changes must be applied together to obtain the correct behavior:

1. Seeker gimbal limit
2. Seeker angular rate
3. Missile Cx (normal force) and Cz (axial force)
4. Cx and Cz multiplier
5. Motor thrust history
6. Reference area
7. Missile weight and propellant weight

Most hex editors only concern themselves with changing blast distance, warhead damage figures, seeker characteristics (gimbal limit, angular rate, and seeker range), and missile mass properties. Some will also change the motor burn time to affect range. Some have also adjusted the maximum AOA and sideslip to limit maneuverability. However, the most important changes of all are the missile aerodynamics, which many leave unchanged.

Without changing missile aerodynamics, it is impossible to properly model motor burnout effects, and vary the missile maneuvering capability with missile speed. The default Falcon 4 missile model loses energy at an incredibly slow rate after burnout, even when maneuvering. This gives the missile impossibly high maneuverability throughout the entire engagement range.

The Realism Patch models the missile aerodynamics as follows:

1. Leave the maximum and minimum AOA and sideslip at realistically high values such as 15-20°. Make sure that missile mass properties and reference area are correct.
2. Adjust normal force to aerodynamically representative values. This should decrease slightly with Mach.
3. Reduce normal force multiplier slightly to reduce missile maneuverability. The overall effect of this change, together with (1) and (2), will make the missile more maneuverable at higher Mach due to the higher normal force, though missile AOA required to achieve the g will be less. At lower Mach, the missile has the ability to use higher AOA to complete the intercept, though normal force will be lower, and missile g may be lower.
4. Adjust axial force to model higher energy loss at higher AOA, and also increase missile drag at 0° AOA to increase the nominal energy bleed rate. Missile drag increases with Mach, and this has to be reflected. Hence, the missile energy bleed rate is higher at higher Mach, and decreases as Mach decreases.
5. Increase axial force multiplier to increase missile drag. The overall effect of (4) and (5) is to simulate increased missile energy loss rate under g, due to increased missile drag.

ACMI recordings are also invaluable for diagnosing missile problems. It is important to determine firing geometry as well as ranges, and target maneuvering history, in order to interpret the test results properly. The satellite and isometric view is also good for working out target g as well as estimating missile speed and g. You should also utilize standard fixed firing profiles and engagement geometries to tweak the missile. That way, you will always have a consistent baseline for comparison.

Fine Tuning Surface-to-Air Missiles In Falcon 4

One of the biggest problems with modeling SAMs in Falcon 4 is the inability to control SAM launch range and altitudes with the missile kinematic model (the missile data files in the sim\misdata directory). SAM launch range and altitudes are controlled by the following parameters:

1. *Range* field in the FALCON4.WCD file in the terrdata\objects directory. This is the nominal SAM launch range in kilometers.
2. *Max Alt* field in the FALCON4.WCD file in the terrdata\objects directory. This is the maximum target altitude at which the SAM will be launched.
3. *LowAirRangeModifier* factor in the FALCON4.AII file (in the campaign\save directory). This is a percentage factor.

For target at altitudes below 10,000 feet, the SAM launch range is the *Range* field multiplied by the *LowAirRangeModifier* factor in percentage. For example, if the former is set to 23, and the latter is set to 66, then, the SAM will launch at 12.8nm. when the target is flying at 10,000 feet and above, and 8.4nm. when the target is flying below 10,000 feet. This is the same regardless of the target velocity. As such, we cannot tailor the SAM engagement envelope to suit various target velocity and altitude profiles.

The minimum launch altitude of all SAMs is also hardcoded in the executable, at 1,500 feet. This is applied to all SAMs, and allows targets flying below 1,500 feet altitude to penetrate heavily defended airspace with impunity. SHORAD systems such as the SA-7 and Stinger have much lower engagement altitudes than 1,500 feet, and this does not allow a layered air defense to be modeled. We can only surmise that Microprose/Infogrames has chosen this approach to simulate some kind of terrain masking and line-of-sight constraints.

With the help of Sylvain Gagnon, we have modified each SAM to tailor their minimum launch altitude. Byte 18 of the FALCON4.WCD file was modified to support the *Min Alt* field to indicate the minimum launch altitude. As such, we are now able to create a layered air defense system, with overlapping altitude and range coverage. Medium and high altitude SAMs will cease firing at higher altitudes, while the low altitude attackers will be attacked by short and medium range systems. For example, targets that managed to escape engagement by HAWK batteries will now be engaged by Stinger SHORAD batteries, and the air defense system no longer shuts off abruptly when the target is flying below 1,500 feet altitude. Instead, the targets will be engaged at altitudes as low as 50 feet above ground level.

We have also tested for the existence of a line-of-sight (LOS) model in Falcon 4, and discovered that Microprose/Infogrames has created a rudimentary but effective model. This allows for meaningful terrain masking tactics to be used, as the minimum launch altitude is designed such that it is the target's altitude above ground instead of barometric altitude. For example, in some of our testing with the SA-10 missile (minimum engagement altitude of 512 feet), we obtained the following results that demonstrated the existence of a LOS model in Falcon 4:

Ingress Altitude (feet)	SA-10 Engagement
20,000	40nm.
15,000	35nm.
4,000	20nm.
1,500	11nm.
700	4nm.

The results clearly demonstrated the existence of a line-of-sight model, as the engagement range is also heavily dependent on the terrain type. The engagement range increases when the target is flying over water, and decreases when the target is flying at the same altitude AGL over mountainous terrain.

Fixing The Exploding Air-to-Ground Missiles

One of the problems existing in Falcon 4 since version 1.08US was inexplicable mid-air explosion of Maverick missiles fired by the AI. In most cases, the first missile fired by the AI pilot will always explode in mid-air. In some cases, most if not all of the AI's missiles will explode. Missiles will explode in mid-air primarily due to two reasons. The first, when the time-of-flight of the missile has expired, and the second, when the velocity of the missile has reached a minimum threshold. When the bug manifests, the missile is well within the limit of the time-of-flight, and the missile velocity is always higher than the minimum threshold.

With the help of Sylvain Gagnon, this infamous bug that was noticed since Realism Patch version 4 was finally found. There was a programming error where the local structure containing the range, azimuth, elevation, etc. of the missile target was not set for Mavericks (and other TV and FLIR guided missiles) when they are configured for firing by the AI. With RP5, the current range is checked to see if it is zero upon being configured for firing by the AI. This should only happen when the missile local structure has just been initialized but not calculated. If the check finds that the current range is zero, the standard geometric calculation is then performed to set this variable to the correct value.

The exploding missile phenomenon was due to an interaction between the sensor coverage and the missile range. If the local structure (i.e. elevation and azimuth) are set to zero, and the missile is looking down (as it usually will be prior to launch), the missile will lose the target immediately upon launch if the elevation field of regard is small. Since the range is also set to zero, the missile will assume that it is right over the target. However, Falcon 4 was coded such that the missile will wait for 15 seconds first prior to detonating, probably due to the programmer not being able to figure out what was wrong to begin with. With the bug fix in Realism Patch, the mystery of exploding missiles is now solved.

THE LONG AND SHORT OF FUSES

Modeling Warhead Arming Delay in The Realism Patch
By “Hoola”

In the Microprose implementation of Falcon 4, missile and bomb detonation is triggered by the collision of 3D objects. When a missile passes close to an aircraft, if the aircraft is situated within its blast radius, the missile is detonated. The moment any object becomes placed in the 3D world, object collision detection is enabled.

While this is acceptable under most circumstances, the side effect is that the warhead on missiles and bombs will become active immediately upon launch/release. In reality, all warheads on missiles and bombs are mechanized with a time delay for the fuse to arm. For missiles, this requirement exists to protect the launch aircraft against any premature detonation or malfunction of the warhead. The arming time is often set such that the missile will be sufficiently far away that the warhead will not cause any damage to the parent aircraft if it is detonated. For bombs, this delay is often to allow the ordnance to separate from the aircraft, and inhibit any detonation that may result from collision between bombs. For medium and long range SAMs, the arming time often correspond to booster separation or burnout.

The time required to arm the fuse plays an important role in determining the minimum launch range of a missile, and minimum release altitude for bombs. While an air-to-air missile may guide perfectly even when launched at extremely close ranges, the need for fuse arming means that even if the missile guides to its target, the warhead will not detonate and the shot is wasted. This important aspect was never captured in Falcon 4, and it was possible to launch missiles at extremely close ranges and still score a kill.

MECHANIZATION OF WARHEAD ARMING DELAY

With Realism Patch, the situation is now changed. Warhead arming is now part of Falcon 4. This makes use of the “Bullet TTL” parameter in the FALCON4.WCD file for each weapon. This parameter was originally created by Sylvain Gagnon for tweaking the guns and tracer rounds. With the help of Marco Formato, this parameter is adapted for use as warhead arming time delay.

The “Bullet TTL” parameter takes an integer from 0 to 7, representing different time delays options. The time delay corresponding to the parameter are as follows:

Bullet TTL	Arming Delay
0	0 seconds
1	1 second
2	2 seconds
3	3 seconds
4	4 seconds
5	10 seconds
6	12 seconds
7	14 seconds

Object collision detection for the weapon is inhibited if the time duration that the object exist in the 3D world is less than the arming delay. The parameter values of 0 through 4 allow arming time delays for bombs, A/A and A/G missiles, as well as short range SAMs to be simulated, while the parameter values of 5 through 7 allow arming time delay of medium and long range SAMs to be simulated.

From version 5 of the Realism Patch onwards, all missiles and bombs now have arming delays, and this is an important factor to consider during missile launch and bomb deliveries.

ALL THINGS LASER

Re-Modeling the Laser Guided Bombs in The Realism Patch
By "Hoola"

The mechanization of laser guided bombs (LGBs) has always been wrong in Falcon 4. Laser guided bombs can be released while you are doing a barrel roll, and still hit the target. You can also break the lock of the LANTIRN pod immediately upon releasing the bomb, and the LGB will still guide perfectly. Similarly, if you maneuver such that the target is outside the gimbal limits of the LANTIRN pod, the laser guided bomb will still guide.

These bugs make the laser guided bomb guaranteed to hit, and makes the delivery of laser guided bombs extremely easy. It is difficult to deliver LGBs in real life, as extensive planning and preparations are required. It also requires flying the delivery profile accurately, to avoid exceeding the gimbal limits of the laser designator. This aspect of LGB delivery was never captured accurately in Falcon 4.

MECHANIZATION OF LGB IN THE REALISM PATCH

The most important fix in the Realism Patch is the mechanization of the LGB guidance mode. Laser guided bombs guide by homing onto the laser reflections from a laser target designator. In the case of the F-16, the source of the laser is the LANTIRN targeting pod, which contains a FLIR camera, as well as a boresighted laser designator. The laser spot must be kept on the target, and must remain visible to the LGB seeker throughout the entire flight of the bomb, in order for the bomb to guide.

The firing of the laser is automatic in Falcon 4. As long as the targeting pod remains locked onto the target, the laser will continue firing, and the LGB will continue to guide. If the lock is broken before the LGB impacts the target, the LGB will no longer guide, and will go ballistic. The miss distance is dependent on the LGB type, as well as the range at which the LGB is from the target at the point of breaking lock. The further the LGB is at the point of breaking lock, the greater the miss distance. You must now keep the targeting pod locked onto the target to ensure that you are providing guidance to the LGB throughout its flight.

The other difference is the flight profile between second generation LGBs (the American Paveway II series and the Russian KAB series), and the third generation LGBs (the American Paveway III series). Second generation LGBs use a control logic known as the "bang-bang" guidance logic. The control fins will move to their maximum deflections every time a guidance command is received to alter the bomb flight path. The LGB will always oversteer and understeer about its flight path, and its flight path to the target resembles a snake. Third generation LGBs will deflect the control fins proportionately, according to the amount of steering required.

The most important fix in the Realism Patch is the mechanization of the LGB guidance mode. Laser guided bombs guide by homing onto the laser reflections from a laser target designator. The difference will show up in the impact point of the LGBs if the lock on the target is broken prematurely. For a second generation LGB, the control fins will be at either end of their maximum travel, and the bomb will immediately perform a hard-over maneuver, and either fall way short of the target, or way long. For a third generation LGB, the control fins will remain at their previous positions, which is usually by much less than the maximum fin travel. Hence, the bomb will not miss as much. This distinct difference in the miss distance between second and third generation LGBs is captured in the Realism Patch. Third generation LGBs are identified by the checking of the "0x40" flag in their entry in the FALCON4.WCD data file.

MECHANIZATION OF THE LANTIRN TARGETING POD IN THE REALISM PATCH

The current LANTIRN targeting pod (as with other targeting pods in the same generation) uses a flashing xenon lamp to produce the laser. Operation of the xenon lamp at altitudes above 25,000 feet will often result in electrical arcing inside the lamp, due to the reduced air density. As such, the laser will be inhibited from firing above a barometric altitude of 25,000 feet, even though the pod can lock onto the target, and the pilot can release the bomb. This is now captured in the Realism Patch. The LGB will miss if it is released above 25,000 feet, even with the targeting pod locked onto the target, as the Realism Patch simulates the inhibition on the firing of the laser above this altitude.

If the LGB is released above 25,000 feet, its trajectory will be ballistic and similar to an unguided bomb. If the aircraft descends below this altitude prior to bomb impact, the LGB will begin to guide. If the aircraft ascends above this altitude again, guidance will be lost, and the LGB will behave as if it has lost lock.

The LANTIRN pod has a gimbaled head with a FLIR camera and a laser target designator that is correlated to the boresight of the FLIR camera. The gimbals have a physical limit of ±150°, and can be rotated through 360° about the x-axis of the pod. However, even though the pod is capable of looking almost all around, there will be locations where the FLIR camera (and the laser designator) will be looking directly at the airframe structure. The silhouette of the airframe is programmed into the pod. The laser that is used for LGB target designation is not eye-safe, and can cause permanent damage and blindness. If the laser is fired while the targeting pod is looking at part of the airframe structure, the laser will reflect off the airframe. This poses a potential health hazard to the pilot, as well as pilots of other aircraft flying in the vicinity. As such, the targeting pod will automatically inhibit the laser designator from firing if it detects that it is looking at part of the airframe structure. This will occur even if the physical gimbal limits of the targeting pod has not been reached. The laser is said to be “masked” when this happens. Since the targeting pod knows the position of its gimbaled head (in azimuth and elevation), the co-ordinates of the gimbal head that will result in the laser designator firing into the airframe is programmed into the pod as the “laser masking zone.”

The exact laser masking zone is impossible if to model to any degree of accuracy in Falcon 4. This has been abstracted in the Realism Patch, and the limit of the field-of-regard of the laser designator is shown in Figure 43 and Figure 44. This implementation is an adequate approximation of the masking zone on the F-16.

THINGS THAT FALL FROM THE SKY

Fixing Bomb Ballistics in The Realism Patch
By "Hoola"

Ever since the first version of Falcon 4 was released, the ballistics of the bombs has not been correct. This affects the low drag bombs such as Mk-82 and Mk-84, cluster bombs such as the CBU-87/B, and laser guided bombs such as the GBU-12. The bombs were flying further than they should be upon release, and did not appear to be affected by drag. With the help and work of Sylvain Gagnon, the bomb ballistics have been adjusted in the Realism Patch.

MECHANIZATION OF BOMB BALLISTICS

At bomb release, the bomb is given the velocity vector of the parent aircraft. Falcon 4 computes the ground distance covered by resolving the x and y velocity vectors (where x and y represents the longitude and latitude). The z velocity vector acts vertically downwards, and the altitude lost by the bomb every second is also computed at the point of bomb release.

For the first second of flight, drag is not applied to the bomb, and gravity is the only factor affecting bomb trajectory. The drag is then applied as follows:

Drag Factor = Weapon Drag × 1.4	(if weapon drag is less than 1.0)
Drag Factor = 1.4	(if weapon is a Durandal)
Drag Factor = 1.26	(if weapon drag exceeds 1.0)

The drag factor is the velocity reduction The weapon drag is found in the corresponding entry for the weapon in the FALCON4.SWD hex file. The rate at which the x and y velocity changes is resolved by first dividing the x and y velocity (in feet per second) by the ground distance traveled per second, and then multiplied by the drag factor. The resultant is then added to the x and y velocities. For z velocity, the effect of gravity is applied to the weapon. If the weapon is a Durandal, the effect of gravity is multiplied by 0.65 to simulate the drag chute. Drag is not modeled otherwise. This process is repeated every second until bomb impact.

Taking an example where the aircraft is moving only along the x-axis at 450 knots TAS. The velocity is 760 feet per second along the x-axis, and 0 along the y-axis. The drag factor of a Mk-82 is 0.2. For a Mk-82 that is released, the x velocity will be reduced by 0.28 for every second after its release. It will thus take 2,714 seconds for the drag to stop the bomb. This is obviously wrong, as the drag is too low.

The drag computation has been changed in the Realism Patch, and the drag factor increased by 100. With this change, the drag factors of the bombs were also changed in the FALCON4.SWD to reflect the updated drag. The bomb fall distance for low drag bombs, CBUs, and LGBs are now correct and within 5 to 10% of their real world counterparts.

THUNDERBIRDS AND BLUE ANGLES

Flight Formation Adjustments in The Realism Patch
By "Hoola"

The different flight formations available in Falcon 4 include wedge, fluid four, spread, trail, ladder, stack, resolution cell, and arrowhead. The default formations do not reflect the actual tactical formations used, and resulted in quirks such as the number four AI wingman missing with his bombs when the flight adopts a trail formation (due the an interaction with the player's bubble). With the Realism Patch, we have now researched the formations used tactically by fighter pilots, and amended the flight formations in the game. The formations had been edited with reference to *USAF Multi-Command Handbook 11-F16, Volume 5, F-16 Combat Aircraft Fundamentals*, available at http://www.fas.org/man/dod-101/sys/ac/docs/16v5.pdf, and we have also obtained valuable inputs from an ex-USN BFM and air combat instructor.

FORMATION CHANGES

Trail Formation

The default Falcon 4 trail formation is shown on page 23-10 of the Falcon 4 game manual. This formation is not correct, and the actual trail formation is closer to a straight line. The spacing between each member of the flight is tuned to provide approximately 6 seconds of separation between each member, at a typical combat speed of 500 KTAS. The entire four-ship formation will transit through the target area in 18 seconds, as compared to 40 seconds with the default formation.

For a four-ship air-to-ground attack, the trail formation in the Realism Patch also gave better air-to-ground score, and a slightly faster rejoin. From a spread formation, the AI requires only 12 seconds at typical combat speeds, to transit into a trail formation. The second element will also not execute a 360° turn in order to formate on the leading element.

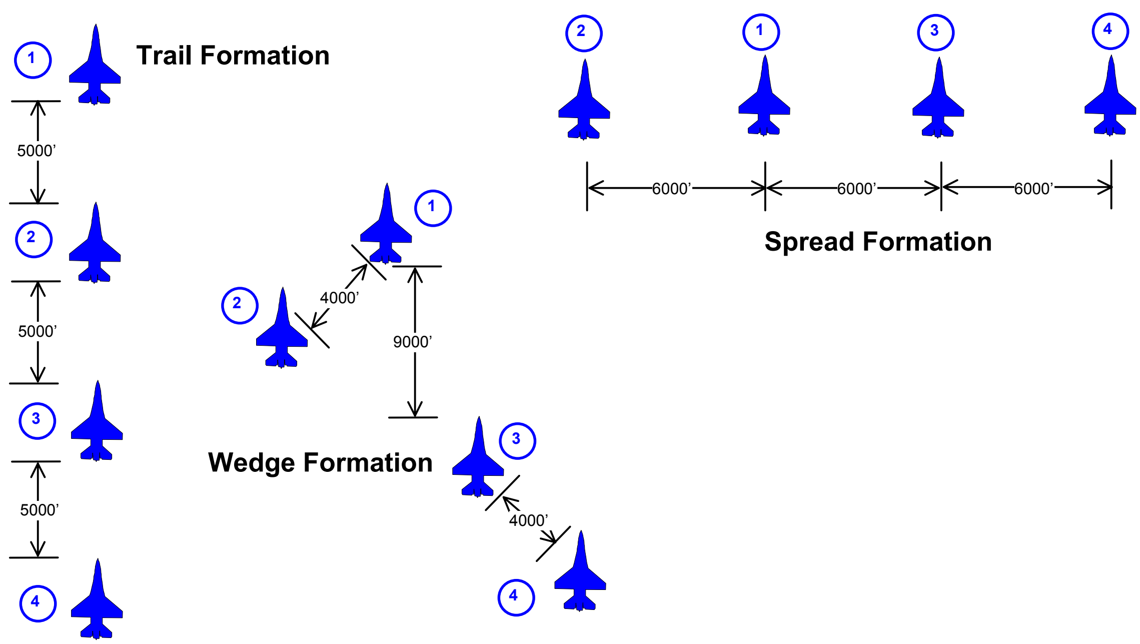

Figure 167: Corrected Formations in the Realism Patch

Wedge Formation

The default Falcon 4 wedge formation is shown on page 23-10 of the Falcon 4 game manual. This formation is incorrect, as the separation between the lead and the wingman within each element is only 990 feet. The actual separation should be between 3,000 to 6,000 feet, and we have chosen 4,000 feet for the ease of AI management. The separation between the two elements has also been increased from 1nm. to 1.5nm. (9,000 feet). This makes the second element more useful tactically, as the second element trails further back, at approximately 75° swept back from the leading element (the original Falcon 4 formation has the second element at 45° swept). This formation is closer to the formation used by F-16 pilots. The wingman of each element has been moved out to 4,000 feet away, making them tactically useful. The original 990 feet separation limits the amount of maneuvering that can be made.

Spread Formation

The default Falcon 4 spread formation is shown on page 23-8 of the Falcon 4 game manual. This formation has the wingman of each element placed at 3,000 feet away from the lead. The actual separation should be approximately 6,000 feet between the wingman and the lead, and 6,000 feet between the lead of each element. The separation between the two elements has been left unchanged at 1nm., although the separation can range from 1 to 1.5nm.. All the flight members will be separated by a lateral distance of 6,000 feet. The increased distance between the element lead and the wingman also increased to tactical flexibility and usefulness, giving each flight member more maneuvering space.

THE FUNKY CHICKEN

Truths and Myths Of Aircraft Damage
By "Hoola"

Ever since the release of Falcon 4, there have been numerous complaints about the "funky chicken dance" that the airplane will perform whenever it sustains damage. There have been various explanations and attempts to "model" damage better, some of which are correct, but many of which are totally unrealistic and wrong, if not more so than the "funky chicken dance." Damage modeling was not changed in the Realism Patch, as the bulk of the efforts are geared towards developing structural changes to the tactics, avionics, and war making engine. The purpose of this article is to dispel some of the myths, and explain the situation better.

FALCON'S DAMAGE MODEL

Falcon 4 models different kinds of battle damage. One of the biggest gripes is the wobbly way that the aircraft flies whenever it sustains damage, making flight impossible. Mechanical damage to airframe can result in various effects, ranging from total loss of the aircraft, to the loss of control or lift generating. In most cases, airframe battle damage will probably damage a control surface, or result in the loss of part of a tail or wing.

With such damage, the aircraft will develop a constant tendency to roll or yaw (where it rolls or yaws depends on the nature of the damage). It may also develop a pitching tendency if the damage is sustained at the tail. The flying qualities are often severely degraded, and precise flight path control becomes very difficult, if not impossible. The lack of precise flight path control is what Microprose's "funky chicken dance" tries to portray, albeit somewhat poorly. The roll/yaw/pitch tendency following battle damage is not modeled even though it is one of the most likely consequences.

Another fallacy concerns the re-start of engines following battle damage. Modern jet engines are extremely reliable, and exceedingly difficult to stall (unless you intentionally mis-handle it). Most compressor stalls are caused by departure from controlled flight, or engine mis-handling. If battle damage or FOD ingestion results in an engine flameout, or an engine running roughly, the engine will be shut-down and in most cases, cannot be re-started. The engine would have been damaged considerably for it to shut-down, and re-lights will not be possible since the engine is already incapable of sustaining operation. The ability to re-light an engine following battle damage is thus not realistic and bogus.

The other forms of damage modeled in Falcon 4 include avionics and SMS damage. This is possible due to equipment being hit by shrapnel, or connectors being jolted loose by the impact or detonation of missiles. This aspect of battle damage is reasonably accurate, although it does not capture the random equipment failure due to reliability problems. The latter is common in modern military aviation, especially when the aircraft ages.

DAMAGE DUE TO EXCEEDING FLIGHT LIMITS

All air vehicles are designed with specific operating limits. This includes g limit, airspeed/Mach limits, and weapon release limits. These operating limits define the conditions within which the aircraft may be operated safely without the fear of structural failure. For example, when bombs are carried on the F-16, the aircraft is typically limited to 5.5g and 550 KCAS, 0.95 Mach.

The airspeed/Mach limit is usually determined by the structural divergence limit, or flutter limit. Fluid-structural interaction (to put this is layman's terms, interaction between the airflow and the airframe) will often bring about a structural divergence when the airspeed/Mach increases to the point where the inherent structural damping becomes negative. For aircraft such as the F-16 and the F-18, they are affected by a slightly different form of structural vibration problem known as limit cycle oscillation. The fluid-structural interaction produces a vibration throughout the airframe, and the vibrations usually increase with airspeed. The vibrations will grow in magnitude, but is usually not divergent. The limit airspeed/Mach is usually the airspeed at which the structural vibrations become too much for the pilot to handle, such that the pilot can no longer perform his mission effectively. The airframe will not be harmed by these vibrations.

In the former situation, the limit airspeed is usually set to a value that is at least 15% lower than the actual airspeed when structural divergence will manifest. This gives a considerable amount of protection against over-speed. Exceeding the speed limit by a little will usually not cause any damage to the aircraft at all.

In the latter situation (which is the case for the F-16), exceeding the airspeed limit will only increase the structural vibrations to an intolerable extent for the pilot. The pilot will usually reduce the airspeed automatically due to the discomfort, but the airframe will not be damaged. In many cases, the limit is set to whatever that aircraft was actually tested to. Even though the aircraft may be capable of higher airspeeds, budget and manpower limitations will often prevent further effort from being expended to increase the airspeed limit, especially when the achieved limit is sufficient to meet operational requirements. It is complicated if not impossible to model the effects of such vibrations in a PC flight simulator, but it is equally unrealistic to model any airframe damage that will result from minor over-speeding.

The g limit of an aircraft is determined by the structural loads which the airframe is subjected. All airframe components are designed to a specific structural limit. For normal operations, this g limit will result in the structural loads reaching 100% of the material elastic structural strength. The airframe structure behaves elastically up to the g limit. When the g limit is exceeded, some of the components may become permanently deformed, but as long as the g load does not exceed 1.5 times the g limit, the airframe will not break into pieces. It is a mandatory requirement for most if not all aircraft to be designed such that they will not break into pieces until the g limit reaches 150% of the limit.

Even if the airframe is severely over-stressed due to g limit exceedance, this usually results in some bent panels and warped wings. It is rare if not unheard of for the stores management system and pylons to become damaged, as these components are often subjected to greater loads during ordnance release. It is hence not correct to model hardpoint and SMS damage due to over-g, as this rarely if ever happens in real life. The author (and several other more qualified members in the RPG, including former and serving military pilots and aerospace specialists/engineers) has seen aircraft over-stressed by 33% of their g limit during air combat, suffering from nothing other than a few warped panels and a bent wing (not counting the pilot's badly bruised ego after a severe dressing down by his superiors, but he still had the last laugh since he won the fight).

PC pilots are not subjected to the same constraints as real pilots are, and they have to constantly be aware of the operating limitations of their aircraft, even though their aircraft may have the performance to exceed these limits. The real pilot also have other sensory perceptions to assist him and staying within the limits, such as the perception of the g force, and these peripheral sensory perceptions are not present in a PC flight simulator. While it is acceptable to incorporate some elements of this into a PC flight simulator, to simulate the constraints that a real fighter pilot will have to face, modeling aircraft SMS damage and hung ordnance is totally unrealistic. A more graduated approach to model progressive structural damage depending on the extent of airspeed or g limit exceedance, selected unavailability of the aircraft due to the maintenance downtime, plus a demotion in rank or status and grounding, will capture the effect realistically. It is unfortunate that some quarters of the Falcon 4 community has incorporated such unrealistic damage modeling into other Falcon 4 executables, even after being advised against doing so by qualified personnel (within their own ranks) who have spent many years working on and flying military aircraft, on the basis that too much efforts have been expended to justify the removal of the "feature."

BUG HUNTING SEASON

Solving the Niggling Bugs in Falcon 4
By "Hoola"

There are numerous bugs in Falcon 4, many of which have existed since the first version of the game. During the course of development, several of these bugs were investigated by Alex Easton, who fingered the problem, and Sylvain Gagnon provided the executable patches. A brief description of each bug is written here, together with the solution in the Realism Patch. The credit of the investigation and solution goes to Alex Easton and Sylvain Gagnon.

C-130 TAXIING PROBLEM

This problem affects all AI aircraft when the landing airbase is different from the airbase that the aircraft took of. The problem is especially bad with the C-130, as the airlift mission will produce a flight plan that has a different landing base from the takeoff base. The problem lies in the taxiing data for the landing being loaded up for both bases, and as a result, the AI will taxi all the way to the landing base. Once the correct data is loaded for each base, the problem was resolved.

ILS GLIDESCOPE AND COURSE DEVIATION BAR

The ILS glidescope deviation bar was not accurate for airbases with elevation that are well above the mean sea level. The ILS routine uses the MSL elevation, and as such, will guide the aircraft to land short. This was fixed by ensuring that the correct airfield elevation is used by the ILS routine.

The ILS course deviation bar also gave erroneous approach vector. The ILS routine truncated the runway heading by two significant figures, and this round up the runway heading to the nearest multiple of 10. For airfields that have runway headings that are not an even multiple of 10, this results in erroneous heading information being shown on the course deviation bar. By including an extra significant figure in the ILS routine, the runway heading is not correct to the nearest 0.5 degrees.

AIRBASE RELOCATION

In the original implementation of the airbase relocation patch, the squadrons will relocate instantaneously when the activity is triggered. This "teleportation" of the entire squadron and its logistical train is unrealistic. The behavior has now been modified in the Realism Patch (within the confines of the executable), and the squadrons that have been relocated can only be tasked for flights after one day. This simulates the effect of the squadron transiting to the new airbase, and setting up the logistical support operations.

Supply And Demand

Logistics Support in the Realism Patch
By "Hoola"

One of the beauties of Falcon 4 is the modeling of the effect of logistical supplies on the war waging capacity in the campaign. Airlift missions are generated by the campaign engine to resupply the combat units, and industrial facilities will contribute to the war waging capability of the country. Sylvain Gagnon discovered the effects of supply on the campaign, and several changes were made in the Realism Patch to model the effects better.

Implementation in Falcon 4

Airlift missions are generated by the ATO engine. Whenever a transport airplane (C-130 or equivalent) lands at its destination, the team that the transport airplane belongs to gets a total of 20 "supply points", 2 "fuel points", and 2 "replacement points". This simulates the logistical effort required to sustain the war.

Factories produce supplies in Falcon 4, while oil refineries produce fuel. The DATA field in the FALCON4.OCD hex file corresponds to the supply or fuel points that the factory or refinery can produce over a period of 24 hours. For example, if the DATA field is 100 for the refinery, then the refinery will produce 100 "fuel points" every 24 hours.

Supplies and fuel are produced at the 50th minute of every hour. If the factory or refinery is damaged, the production capacity is reduced accordingly. For example, if the factory is capable of producing 100 "supply points" every 24 hours, and is 50% damaged, then it is only able to produce 50 "supply points" every 24 hours.

Although factories and refineries require electrical power to function, this is however not modeled in Falcon 4. Destruction of power stations and nuclear plants will not affect the functioning of the industrial complex.

Implementation in The Realism Patch

In the Realism Patch, power stations and nuclear plants will now affect the production capacity of factories and oil refineries. The electrical power used by factories and refineries will be provided by the nearest power or nuclear plant. The production capacity is relative to the status of the power or nuclear plant. The takeoff and landing rate of airbases are also affected by the operating status of the nearest power station or nuclear plant.

For example, a factory is capable of producing 100 "supply points" every 24 hours, and its electrical power is supplied by a nearby power station. If the power station is 100% operational, the factory will produce 100 "supply points" every 24 hours. If the power station is 80% operational, then the factory's output will be reduced to 80 "supply points" every 24 hours. If the factory is damaged and its production capacity is reduced to 80%, then its production capacity will be further reduced to 64 "supply points" every 24 hours.

With the changes made in the Realism Patch, destruction of enemy power stations and nuclear plants will now have an impact on the war waging capacity of the opposing team. This allows for a realistic air campaign to be modeled, and strategic strikes against the enemy's industrial complex will affect the outcome of the war.