It is important to set the full details of the waypoint (the latlong can be taken from the F10 map).

PRACTICAL EXAMPLE

Setup: the F-14 is flying at 15,000ft, the waypoint was created over the small island of Arward, just a couple of kilometres from Tartus, in the Syria map.

Radar is set to Pulse Search, 1 Bar (see Chapter 6.2.1 for more information). If the INS is not completely off the chart, using the distance from the waypoint can be a useful tool to pre-set the antenna elevation angle at a meaningful angle. This helps the process as 1 Bar is quite narrow, depending on the range.

In this case, I used my in-game Kneeboard page to find the angle: the range from the waypoint is approximately 25nm, and the F-14 is flying at 15,000, so the angle is ~5.6°.

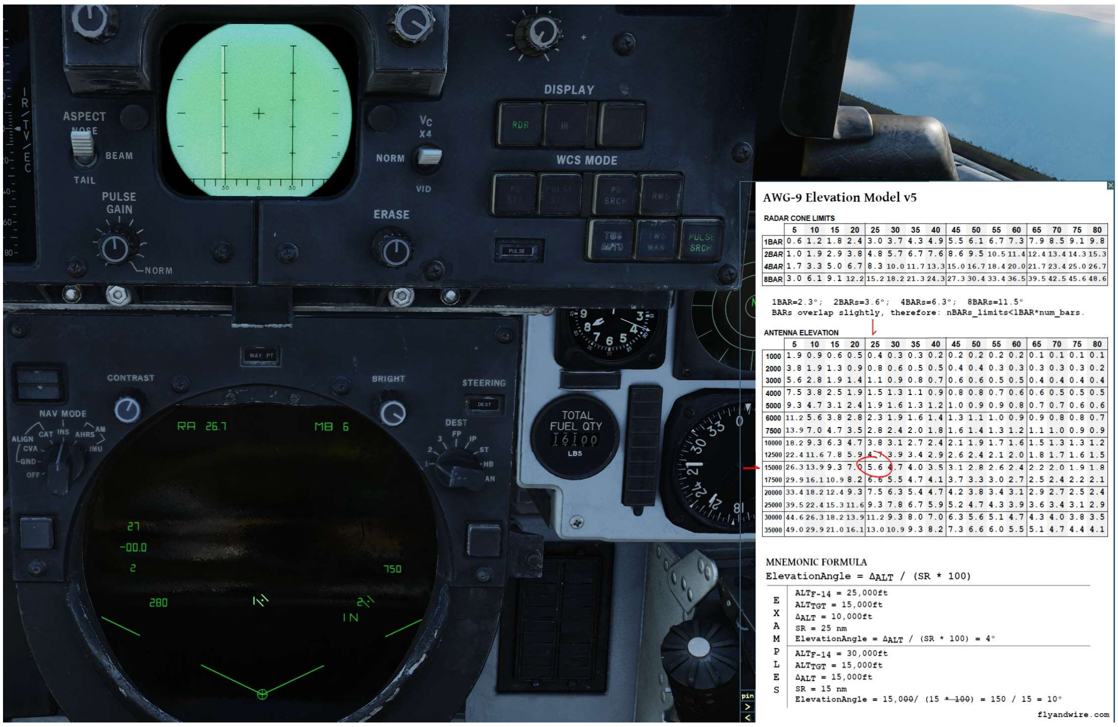


Figure 229: Radar fix update - setup.

Now we can slew the antenna and focus on the returns on the DDD.

Figure 230, shows the DDD in Pulse mode returning the coast. The little return under the HCU DDD-mode pointer is the island. Remember that the DDD provides a “bent” representation of the topography, in this case, the coasts. This makes working using hills or peaks much harder than islands or coast-line peculiar shapes.

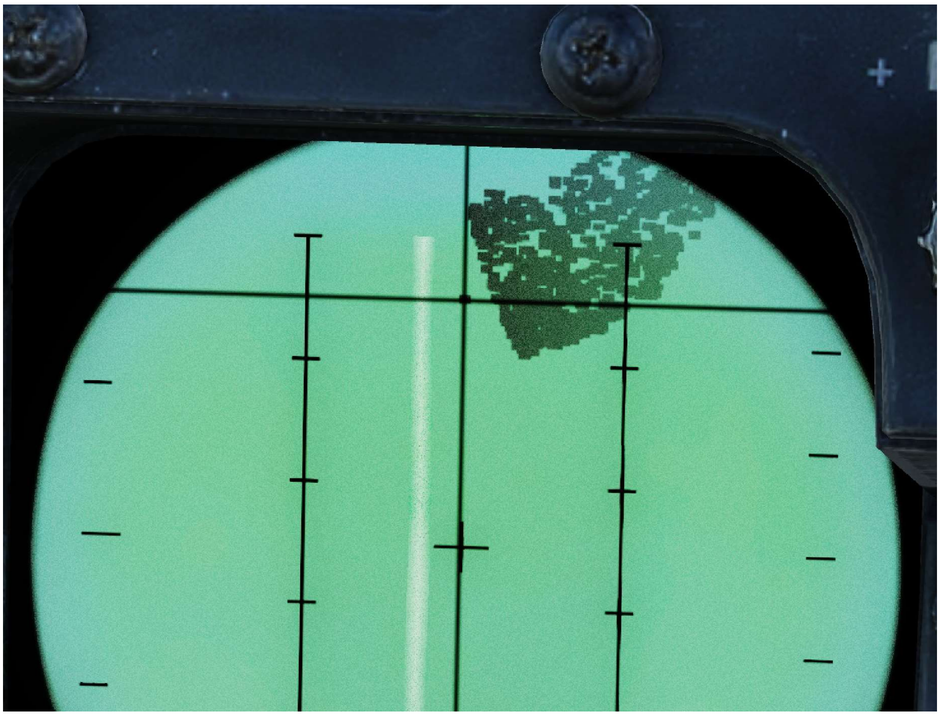


Figure 230: Radar fix update - DDD mode.

The next step is checking the delta:

- the left value is the ΔLATITUDE, it displays “LN” or “LS” depending on whether the delta is more to the North or South;
- the value on the right is the ΔLONGITUDE. Similarly to the ΔLATITUDE, it adjusts from the “side”, displaying “LE” and “LW”.

The closer the delta values are to zero, the less the INS has drifted. Figure 231 shows the deltas for this example.

Figure 231: Radar fix update - Delta values.

When the suggested delta is deemed satisfactory, pressing FIX ENABLE updates the INS and the position of the F-14 is updated.

Compared to other INS Fix Update techniques, this is one of the less precise. However, if nothing else is available, then it is still a valid solution.

Unfortunately, due to how the Pulse radar works and the lack of a proper air-to-ground radar, finding a recognisable point may not be an easy task. Luckily, water tends to not providing any return, so it is very easy to highlight a lonely island, a coastal feature (or even a ship!) in Pulse Search.

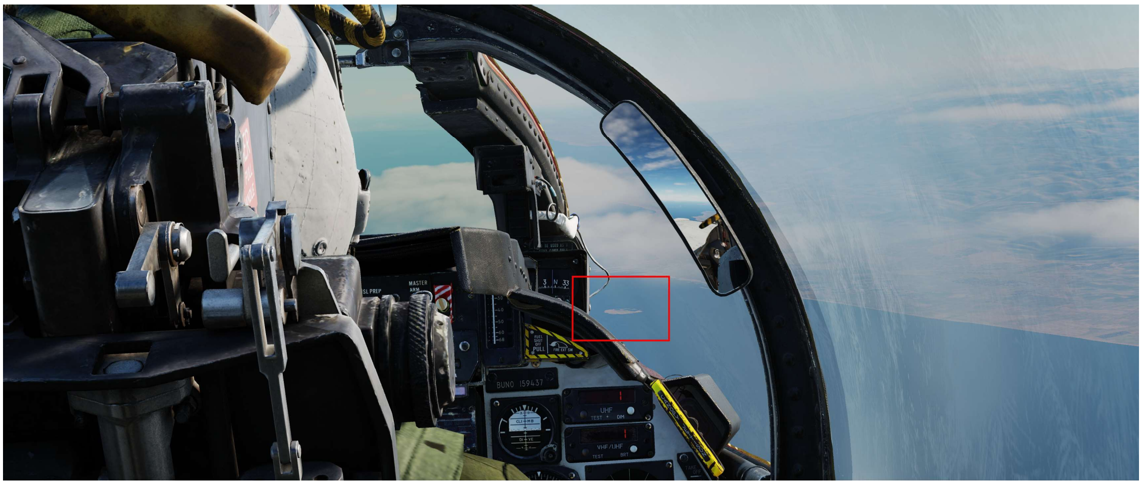


Figure 232: Radar fix update - The geographical reference point.

6.14.5 "UNORTHODOX" METHODS

The following are three methods to update the INS that probably no one ever used in real life. However, if necessity calls, they can be used and solve an turn a forced RTB into an ongoing mission.

Unorthodox method I: LANTIRN

The LANTIRN pod has its own independent GPS and its reading can be used to obtain a constant and precise indication of the position of the aircraft. The RIO simply has to input such data in the CAP, Own Aircraft, and confirm the new set of coordinates.

Since the F-14 is moving, the latlong values must be set according to the future position of the F-14 and ENTER must be pressed as soon as the values match.

If well timed and coordinated with the pilot, this method allows to correct the F-14 position in no longer than a few seconds.

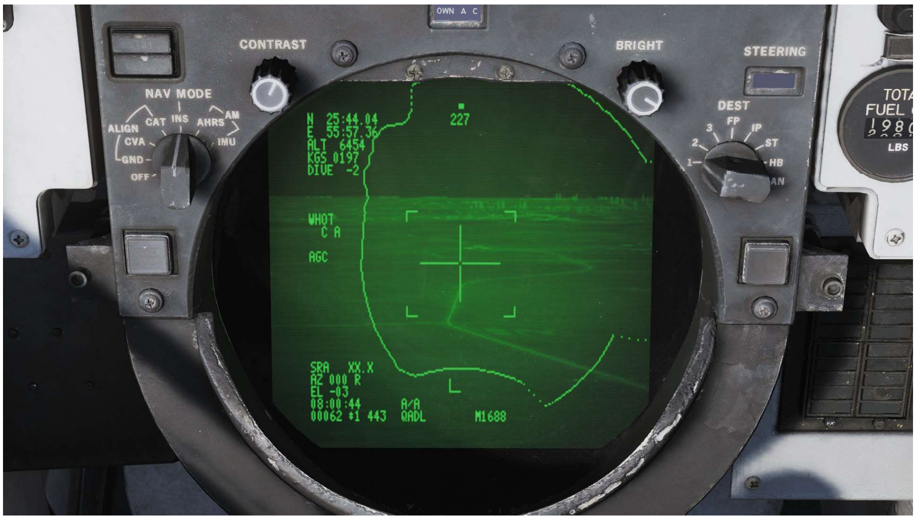


Figure 233: Figure 61: View of the LANTIRN pod. The latlong of the F-14 are in the top-left corner.

Unorthodox method II: LINK4A DL and CV

The Carrier appears as a Datalinked Homebase Waypoint on the TID when the Datalink is tuned to the CV's frequency. Since the CV is a TCN station as well, my first idea was using the TCN fix procedure along with the CV DL HB WP as the TCN station WP but unfortunately it doesn't work.

The waypoint can still be used in two ways, although none of them is as precise as my initial idea would have been. The procedure is simple: another WP can be created over the position of the CV and quickly used to perform either Visual or TCN update. Considering the intrinsic imprecision of the analog INS of the F-14 and the fact that the CV doesn't move fast at all (the movement can be compensated by placing the WP at a distance proportional to the speed of the CV, if necessary), this method can be used to achieve decent results, especially in the case of heavily degraded INS, and if no standard methods are applicable.

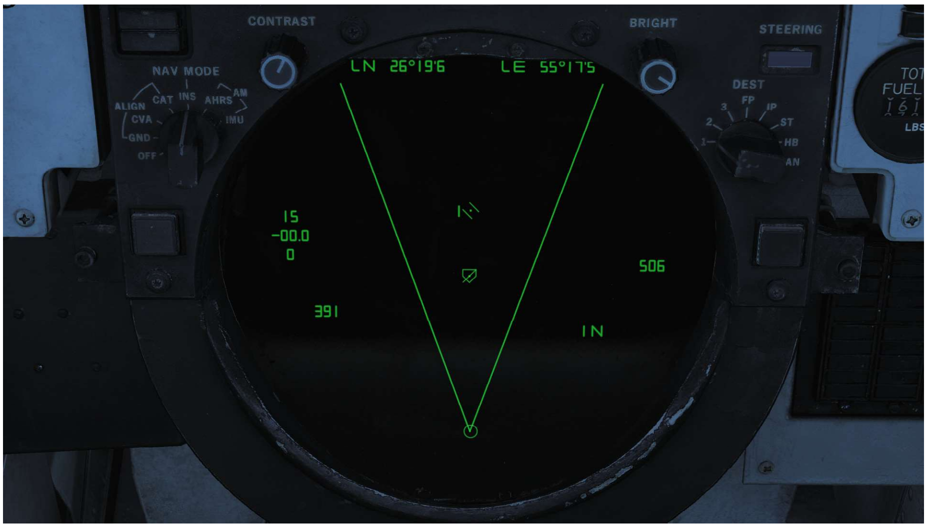


Figure 234: The position of the Carrier, marked by a Datalink waypoint.

Unorthodox method III: NS 430

I bought the NS 430 module during a sales back when it was available only for the Mi-8. It is now available for almost any module, in a couple of which in its original 3D version, as a 2D overlay for the others (warning, the 2D overlay had or still has issues with VR, as far as I know).

You have probably understood already where I'm going, after the discussion about the LANTIRN: the plan is using the GPS data from the NS430 to update the F-14 position.

Figure 235: The NS 430 GPS.

On top of that, the NS 430 is a useful navigation tool, it provides a moving map and other information and functions. I don't feel the need of it between TCN and INS, but it can be a handy backup tool indeed.

The NS 430 is discussed in more detail in Chapter 21.3.

6.15 ***F-14 TOMCAT AND ELECTRONIC COUNTERMEASURES

> **Note:**
> Heatblur is still working on the implementation of the effects of ECM on the F-14 Tomcat. The manual offers a glimpse of the features and the new tools the Radar Intercept Officer will, hopefully, be able to play with when the new effects are introduced.

For us Prowler ECMOs the AWG-9 was one hard radar to jam. But more important than the gadget itself was the knob-twisting RIO you were dealing with.

PARSONS, DAVE; HALL, GEORGE; LAWSON, BOB. GRUMMAN F-14 TOMCAT: BYE-BYE, BABY..! (P. 228).

According to many sources, the F-14 Tomcat was, at the time of its introduction and for several years, a really tough costumer when it came to jamming it.
From the first tests conducted versus noise jamming targets (notable the one conducted on the 12th of April 1973 – See chapter 7.4.2), to the Iran vs Iraq war and the exercises against the EA-6 Prowlers, the ability of the F-14 and its crew to break the hostile electronic countermeasures.

> *"During the whole war, I never heard of the AWG-9 radar being successfully jammed. There were a handful of cases of radar lock-on being broken by close-range manoeuvring or by MiG-25s using their high speed to outrun an F-14, but the Iraqis (using French equipment) and the Soviets never managed to jam our radars. They expended considerable effort trying to do so, using different systems."*
> *"They tried deception, barrage, spot and overload jamming, but they weren't successful. Our radars had a high basic working frequency and excellent frequency agility, so it was easy to move the radar away from the jamming signals and reject those which didn't match the precise search form pattern of our AWG-9. On several occasions, they tried overwhelming us by combining all these methods. I once detected 11 jets closing simultaneously on me using jamming, but this posed no great problem, as my AWG-9 could handle twice as many targets simultaneously. And my RIO and I solved the jamming within seconds."*

TOM COOPER, FARZAD BISHOP – IRANIAN F-14 IN COMBAT. PAGE 83-84.

6.16 ***RECONNAISSANCE TOMCAT

Note:
The main instrument the Tomcat can use to operate as a reconnaissance asset is the TARPS pod. However, this is not available yet in DCS. Thus, this Chapter is a placeholder and the discussion will be expanded as the pod will become available.

> *[..] Norman Schwarzkopf was determined his air forces would prevail. Since dawn that 17 January, his F-14 Tomcats equipped with TARPS - Tactical Air Reconnaissance Pod System - had been surveyed the targets hit during the night.*
> *They came back with hundreds of pictures of the extensive damage caused during the first wave.*

JOHN NICHOL – TORNADO, IN THE EYE OF THE STORM, PAGE 175.

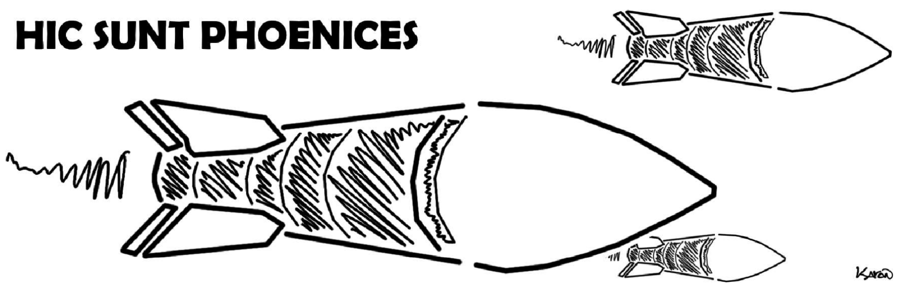
One of the F-14's greatest tools was the TARPS. The Tactical Airborne Reconnaissance Pod System allowed the Tomcat to perform reconnaissance missions, using the camera hosted in the TARPS pod.
The real TARPS is huge, more than 5m long and weighting almost 850 kg, and very sophisticated, sporting a number of high-resolution cameras. Its controls are interfaced with the F-14's avionics.

Heatblur has not introduced the TARPS in DCS yet, but the devs have stated that it will be a simplified integration, probably due to how poorly the recon / intelligence aspect is developed in DCS. However, even the simple ability of augmenting the navigation instruments and taking high-res screenshots framed in a particular way would create a new niche and add even more value to the F-14s.

7. WEAPONS I: AIR TO AIR

The primary role of the F-14 has been, for the majority of its life, related to the sky.

The F-14 was introduced in 1974 and flew in Vietnam in the very last few moments of the war in April 1975. Back then, and for the next 20-odd years, the US Navy fielded a variety of aircraft along the Tomcat dedicated or more effective air-to-ground aircraft, although the F-14 was always capable to perform air-to-ground basic duties. Some were later decommissioned and others were introduced along the way, such as the A-6 Intruder (recently announced by Heatblur) and the A-7 Corsair II (being developed by FlyingIron Simulations) or the F/A-18.



"Here be Phoenixes"

PARENTHESIS: EL CLÁSICO IN DCS – F-15 VS F-14

The F-15 Eagle and the F-14 Tomcat are always compared, and the debate on which one is “better” never settles. However, this comparison dues not bring justice to any of the two. When it comes to DCS, in fact, the two aircraft works best together, each providing what the other aircraft can’t.

F-14 and F-15 were introduced in the same period, around the mid 70s, but are drastically different. The F-15 is a land-based fighter, born and raised for only one task: air superiority. It uses more modern technologies than the F-14 and, although affected by a few initial issues, it was later upgraded into one of the most successful aircraft ever produced.

The F-14 has a different story. In order to be both fast but able to perform safe carrier landings, it was designed with variable geometry. Such capability requires a more rugged airframe and landing gear, eventually increasing the weight, a non-ideal feature considering how underpowered its TF30s were.

Somewhat similarly to the A-10 and its GAU-8, the F-14 was conceived around the requirement of a long-range bomber interceptor and air superiority fighter. The AN/AWG-9, developed in the 50s and operative since the 1962, was able to engage up to 6 targets at the same time at unthinkable ranges when compared to the main contemporary air-to-air missile of the period: the AIM-7 Sparrow. Moreover, thanks to the active radar mounted in the AIM-54 Phoenix, the F-14 was able to execute launch-and-leave tactics if required (although not common. Moreover, the Phoenix was not a cleared for employment vs fighters until mid/late ‘80s).
The F-15, despite being more advanced, was unable to engage multiple aircraft at the same time until the AIM-120 Advanced Medium Range Air-to-Air Missile (AMRAAM) was introduced *seventeen years later*, in 1991, due to the lack of an active radar in the AIM-7 Sparrow.

The F-15 can be considered a true 4th generation fighter. The F-14 instead can be disputed, and it can be more reasonably considered a 3.5 or a very early 4th gen, somewhat in-between the old conception of fighter jet of the 3rd generation, and the digital fest of the 4th generation, something that the F-14 did not fully see (albeit in limited numbers) until the introduction of the F-14D.

Another aspect not often discussed but very relevant, especially during short range exercises, is the weight. The F-14 is a carrier-based aircraft, requiring an especially sturdy landing gear and other measures. These, on top of the additional weight of the second seat, the avionics and design choices lead to a considerable total weight.
The following tables shows the weights of the aircraft available in DCS:

AIRCRAFT	WEIGHT	ENGINES
F-14A-135-GR	42086 lbs	Pratt & Whitney TF30
F-14B	44040 lbs	General Electric F110
F-15C	29498 lbs	Pratt & Whitney F100
F-15E (AI)	37637 lbs	General Electric F110

Unfortunately no high-fidelity F-15A is available in DCS, and the C is only FC3-level. The closest version under development is the F-15E, from RAZBAM. Although similar and based on the same aircraft, there are still differences. It looks like that El Clásico in DCS has to way to another valiant third party dev!

7.1.1 F-14 TOMCAT: AIR-TO-AIR WEAPONS

The F-14 carries three main Air-to-Air weapons:

1. AIM-9 “Sidewinder”: IR homing missile (“FOX-2”);
2. AIM-7 “Sparrow”: Semi-Active Radar Homing Missile (SARH - “FOX-1”);
3. AIM-54 “Phoenix”: Active Radar Homing Missile (ARH - “FOX-3”).

Each of them has different seeker type, guidance, range and it is used in scenarios.

The following Chapters go into the details of each weapon, covering the usage in DCS along the technical details (most of the information are taken from the P-825/02).

7.2 AIM-9 “SIDEWINDER”

> *“The AIM-9 Sidewinder is a short-range, all-aspect, heat-seeking missile. The Sidewinder has proven itself to be the weapon of choice because of its simplicity, reliability, and high probability of kill. Throughout its history, the Sidewinder has seen vast improvements in its basic design. However, it remains limited to the in-close, visual combat arena.”*
>
> **P-825/02 P.97**

The AIM-9 Sidewinder is one of the oldest missiles still in service, since the AIM-7 is being phased out, and the AIM-54 have been decommissioned. It achieved its first kill in 1958, when a Taiwanese (Chinese Nationalist back then) used it in the Formosa Straits conflict against a Communist Chinese.

On 28/09/1958, during the same conflict, an AIM-9 hit its target (a MiG-17) but did not explode, became lodged there and was later recovered and sent to the Soviets, which used it to develop their Vympel K-13 (AA-2 “Atoll”)[52].

Through the years, the Sidewinder receiver numerous upgrades, such as a new seeker head, warhead combination and achieved all-aspect capability.

52 Source – Wikipedia: K-13 (missile) and P-825/02 p.97.

7.2.1 PHYSICAL CHARACTERISTICS[53]

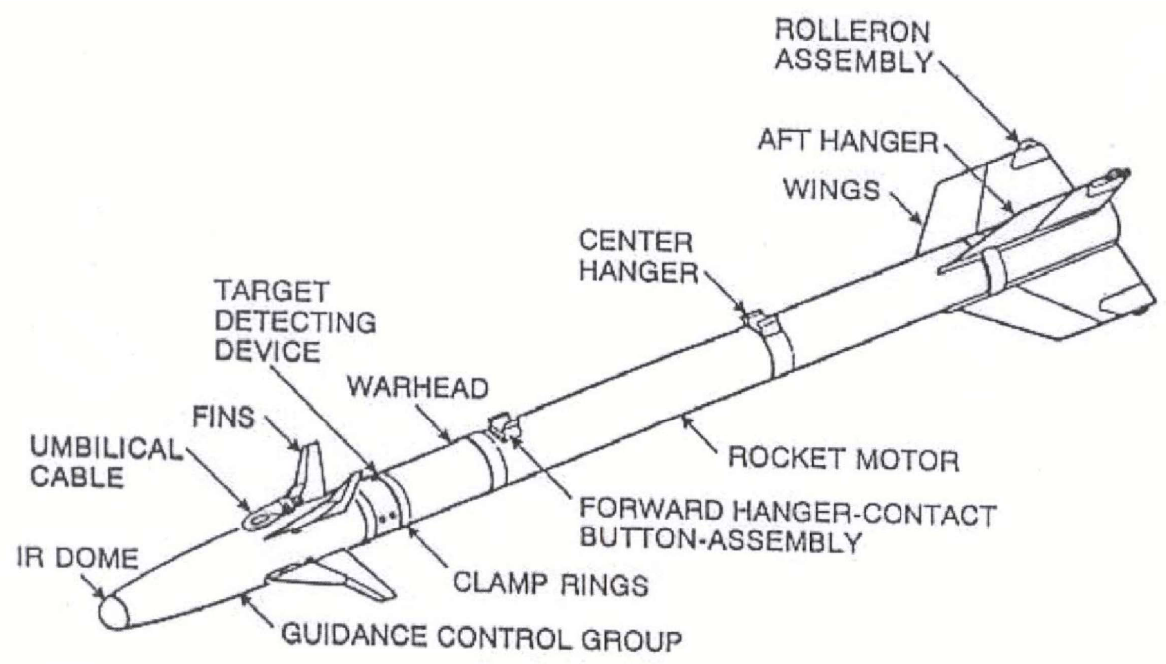


Plate 7: AIM-9 Sidewinder Missile [Source: P-825/02]

Minimum Range	1000 ft	Diameter	5”
Gyro tracking	24° / s	Weight	185 lbs
Thrust	2880 lbs	Length	9’5”
Velocity	2.0+ Mach	Turning	45 G’s
Seeker FOV	3.5°	Gimbal Limits	±40°

Fuse	Contact and Proximity.
Guidance	Infrared (IR) cooled by compressed nitrogen and contains indium antimonide (InSb), which makes it very sensitive to IR emissions.
Control	The missile is guided by the deflection of the 4 forward fins that are pneumatically controlled by a gas generator ignited at launch. A thermal battery provides power for 60 seconds time of flight.
Warhead	Annular blast fragmentation (ABF) warhead, consisting of high explosive encased by titanium rods and a zirconium disk. The titanium rods penetrate an aircraft's skin and the zirconium disk fragments will set fire to any combustible material.
Rocket Motor	Mk-36 rocket motor producing 2880 punds of thrust for a 5” burn time, capable of accelerating the AIM-9 to 2.0 Mach. The "smokeless" motor is actually 95% smoke free, leaving only a thin wisp of smoke in its trail, which would be imperceptible to the enemy.

53 For AIM-9M.

AIM-9 SIDEWINDER IN DCS

The F-14 Tomcat is able to employ a variety of versions of the AIM-9 Sidewinder, some of them are not implemented in the game yet, such as the AIM-9D.

- **AIM-9P**: mid-70s version with improved rocket motor, it derives from the AIM-9J/N. Later versions of the AIM-9P had limited all-aspect capability.
  Also by the Iranians F-14s, it is not yet available in-game for the Tomcat;
- **AIM-9L**: introduced in 1977, it takes full advantage of the Sidewinder Expanded Acquisition Mode (SEAM) introduced with the AIM-9G.
  It was the first all-aspect AIM-9.
- **AIM-9M**: introduced in 1982, is an overall improvement over the AIM-9L. Although very similar, it features a new "smokeless" motor and better countermeasure resistance.
  The AIM-9M is the responsible for all the 10 kills scored with Sidewinders in the Gulf War[54].

In DCS, up to four AIM-9 Sidewinders can be carried: two on pylon 8, two on pylon 1. On pylon 8A and 1A, the AIM-9 is mounted on the LAU-138, discussed in Chapter 6.7.1 . Pylon 8B and 1B use the LAU-7 missile rail launcher[55].

The AIM-9 is competence of the Pilot only, the RIO cannot launch it from the rear seat.

7.3 AIM-7 "SPARROW"

> *"The AIM-7 Sparrow is a medium range, all-aspect, all-weather, semi-active radar guided missile. In addition to its air intercept role, Sparrow variants have been utilized as air-to-surface and surface-to-air weapons since the missile's inception in 1946. Unlike many of its predecessors, the current Sparrow (AIM-7M) is a reliable and highly lethal weapon."*
>
> **P-825/02 P.101**

The AIM-7 Sparrow had a long and complex history. Developed as a beam-rider, it was meant to be used primarily against bombers, a target rarely seen in the skies of the Vietnam. This and other reasons (such as the climate conditions), earning it a bad reputation.

Later developments greatly improved the performance and the effectiveness of the missile. For example, the AIM-7M entered service in 1982 and scored a hit rate of 68.2%, with a kill

54 Source: Air Power Australia – The Sidewinder Story.
55 More information about the LAU-7, here.

rate of 59.1%, in the 1991 Gulf War. The AIM-7D/E/E-2 in Vietnam, instead, achieved a hit rate of 15.8%, with a kill rate of 9.2%[56].

> *While the AIM-9 Sidewinder is usually described as the best short-range air-to-air missile of the war, Iranian experience with the AIM-7 matched that of US pilots in Vietnam, who found that the weapon sometimes functioned well, but on other occasions was totally useless. But unlike American pilots, the Iranians never used the AIM-7 in dogfights. It was employed exclusively in medium-range engagements, being fired from a forward aspect at a range of 12 km (seven miles). While most pilots remained unimpressed with the AIM-7, careful handling and precise pre-flight checks assured a kill probability of more than 20 per cent - twice that achieved in Vietnam.*
>
> **TOM COOPER, FARZAD BISHOP - IRANIAN F-14 IN COMBAT. PAGE 80.**

7.3.1 PHYSICAL CHARACTERISTICS[57]

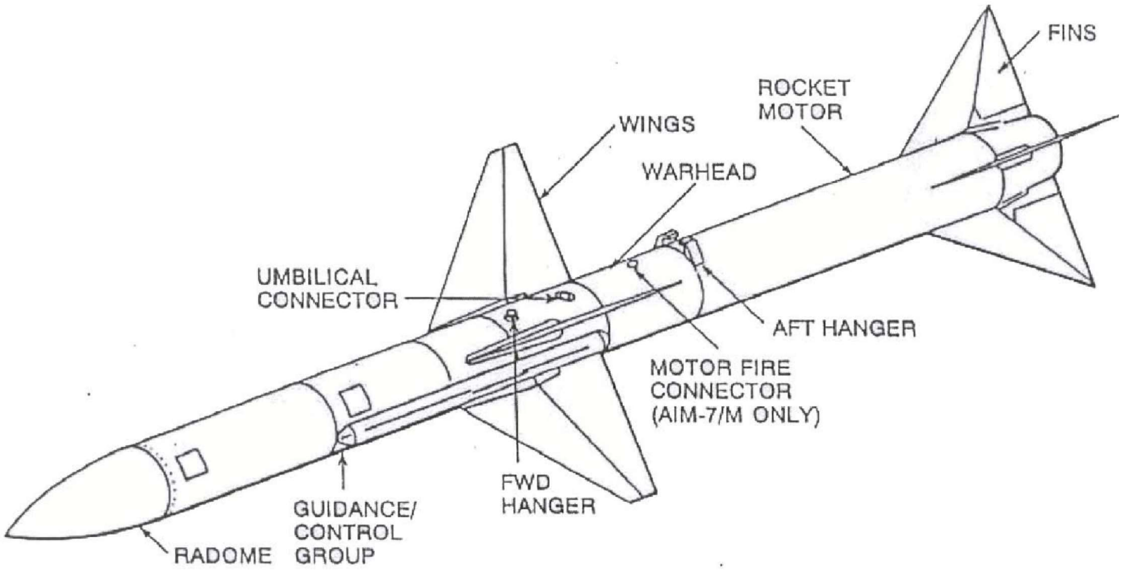


Plate 8: AIM-7 Sparrow Missile [Source: P-825/02]

Length	12 ft	Diameter	8”
Wingspan	40”	Weight	510 lbs
Motor Burn Time	3.5” / 12.5”	Warhead	85 lbs
Kill Radius	40 ft	Kill Radius	25 G’s
Minimum Range	1000 ft	Velocity	2.5 Mach
Max. Target	89,000 ft	Launch time	1.5”

56 Source: Wikipedia – AIM-7 Sparrow.
57 For the AIM-7M.

Altitude	
Fuse	Contact and Proximity.
Guidance	Semi-Active Radar Homing. The AIM-7 guides on the reflected energy of the target using a forward-looking planar-array antenna. It receives guidance information via a rear facing antenna on the end of the missile.
Control	The forward wings are controlled by an open-loop hydraulic system that is pressurized upon trigger squeeze. Once the hydraulic fluid is used, it is vented out of the missile. When the fluid has been exhausted, the missile can no longer manoeuvrer.
Warhead	85 lbs annular blast fragmentation, exploding in a thousand of steel fragments. The hot gases propelling these fragments also serve to ignite all combustible material.
Rocket Motor	Mk-56 solid propellant rocket motor. The initial boost lasts 3.5”, propelling the missile to its cruising speed of 2.5 Mach over the launch aircraft’s speed, then sustains the thrust for an attritional 12.5”.

AIM-7 SPARROW IN DCS

The AIM-7 is considered a poor missile, as players are used to the performance of the AIM-54 and the AIM-120 (or non-NATO equivalents) in non-realistic or non restricted servers.

In the appropriate time-frame instead, is still a valid missile, although inferior to similar non-NATO solutions.

The Sparrow implemented for the F-14 has been for a prolonged period different from the version used in other modules made by Eagle Dynamics. Recently, some technical blockers have been solved[58], and the F-14 is using the same implementations used by the Hornet and the F-15.

Since the F-14 has been operative for over 30 years, its AIM-7s have seen several upgrades. The versions available in DCS are:

- **AIM-7E-4**: supported by the F-14, but not available in-game yet (22/06/2022).
- **AIM-7F**: entered service in 1976, it had a dual-stage rocket motor, solid-state electronics and larger warhead. It has a much better effective range than the AIM-7E and it is the first AIM-7 to support Pulse Doppler guidance;
- **AIM-7M**: entered service in 1982 with a new monopulse seeker, better EMC resistance and other features. Its combat record during the Gulf War drastically changed how the AIM-7 was perceived by the general public and military enthusiasts;

58 Source: Cobra – ED Forum.

- **AIM-7MH**: similar to the AIM-7, it features several improvements such as Home-On-Jam (HOJ)[59].
- **AIM-7P**: recently added[60], the AIM-7P is a late variant, featuring a new radar fuse and improved guidance, on top of a new uplink for mid-course guidance.
  The AIM-7P was produced since 1987.

The AIM-7 is often launched by the Radar Intercept Officer in Beyond Visual Range scenarios. At closer ranges, when tally or dogfighting, it is employed by the Pilot[61].

AIM-7 SPARROW GUIDANCE

The AIM-7 Sparrow can be boresighted or launched in STT mode, both PSTT and PDSTT.

The default launch method uses a Continuous Wave antenna to guide the missile (for both boresight and STT). Since the introduction of the AIM-7F, the Sparrow can be guided using the Pulse Doppler illumination, hence increasing its potential range and reliability against Chaffs (in theory, in DCS it is another matter), whilst introducing two weak points in the form of notching (MLC) and absence of Doppler shift (ZDF).
To select PD guidance, the RIO actions the **MSL OPTIONS** switch show in Figure 236, selecting "*SP PD*".

When the AIM-7 Sparrow is employed in boresight, the CW antenna is used and the missile homes on the strongest target return in the flood area.

> **Important!**
> Unfortunately, the switch, presently, is not fully implemented. The reason is the missile guidance logic in DCS. In fact, tracking or not works as a flag: as long as the F-14 tells the game that a target is being tracked, then the missile is guiding[62].
> Therefore, **there is no point in using that part of the MSL OPTIONS switch right now, as it has to effect on the guidance**.
> However, since the tracking depends on having a radar lock, the player is left with the option of choosing between PSTT and PDSTT. Since Pulse can be effortlessly used even in look-down situations and PDSTT suffers from ZDF, Pulse mode seems like the most efficient radar mode at the moment.

59 In DCS, the missile home automatically on the source of the jamming.
60 DCS Open Beta patch 22/06/2022, v. 2.7.15.25026. Patch notes.
61 Subject to crew contracts. See Chapter 1.2.
62 Source: a chat with Naquaii, Heatblur dev, 10/06/2022 – thanks mate!

Figure 236: Missile Options switch.

7.4 AIM-54 "PHOENIX"

> *"The AIM-54 Phoenix is a medium to long range, all aspect, all weather missile, with both semi-active and active radar guidance systems. The Phoenix was designed primarily for long range battlegroup defense against bomber-sized aircraft, but has also proven effective against cruise missiles and fighter-sized aircraft."*
>
> **P-825/02 P.103**

The AIM-54 Phoenix is a huge, 1000 lbs missile, capable of reaching and destroying targets over 100 nautical miles distant. It is a powerful but flexible weapon, effective even a short range although this is where, doctrinal and historically, the AIM-7 was employed.

Initially, the usage of the Phoenix was reserved to bombers and other high-priority targets. From mid to late 1980s[63], it was cleared for usage against fighters.

The Iranian F-14 employed the AIM-54A regularly, with great results, although those reports are sometimes contested out of the Persian country.

Similar to the AIM-7, the AIM-54 Phoenix is usually competence of the Radar Intercept Officer[64].

> *I always thought of the Phoenix as a crazed little Kamikaze hanging under your belly. Or six of them.*
>
> **PARSONS, DAVE; HALL, GEORGE; LAWSON, BOB. GRUMMAN F-14 TOMCAT: BYE-BYE, BABY..! (P. 113).**

63 Source: Grim Reapers' interview to Dave "Bio" Baranek. Timestamp (16'10").

64 Subject to crew contracts. See Chapter Error: Reference source not found.

7.4.1 PHYSICAL CHARACTERISTICS[65]

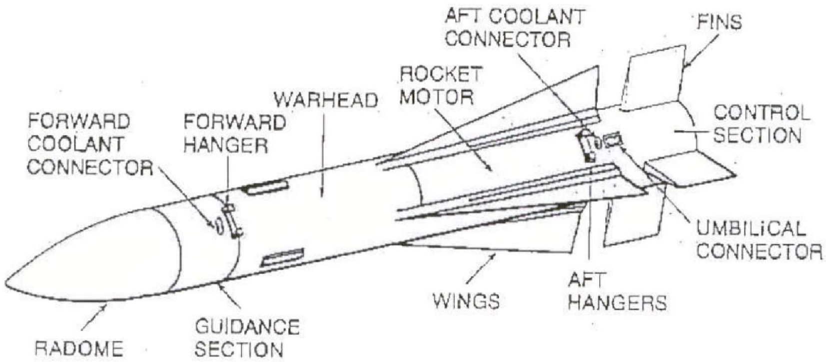


Plate 9: AIM-54 Phoenix Missile [Source: P-825/02]

Length	13 ft	Diameter	15”
Wingspan	36 in	Weight	985 lbs
Motor Burn Time	27”	Warhead	133 lbs
Kill Radius	50 ft	Launch time[66]	3”

Fuse	Contact and proximity.
Guidance	Active and Semi-Active Radar Homing (ARH, SARH). In ARH, it follows the radar illuminating the target in TWS. Once launched, it goes through an initial and midcourse guidance similar to that of an AIM-7. Terminal guidance is provided by the AIM-54’s active radar illuminating the target before impact.
Control	Relies on hydraulics for control of the flight control surfaces, but the system is a closed loop. Therefore, operational time is limited only by the operational time of the battery.
Warhead	133 lbs, continuous-rod, high explosive. Produces a ring of steel lethal at 50 ft, designed to cut off pieces of the target such as the wings of the tail.
Rocket Motor	Solid propellant, single stage motor with burn time of 47”.

65 For the AIM-54 Mk47.

66 Depends on the employment method (such as PSTT vs PDSTT). This topic will be thoroughly discussed later.

7.4.2 AIM-54 & AWG-9 – DEVELOPMENT TIMELINE AND TESTS

The following is a condensed timeline, from "*An Outsider's View on the Phoenix AWG-9 Weapon System*", written in 1977 by Stephen Thornton Long. The same source is used in Chapter 7.4.3).

It gives an overview of the main development steps and tests of the AIM-54 Phoenix and AWG-9 Weapons Control System.

NOVEMBER 1966	First live separation test from an F-111B.
17 MARCH 1967	The Phoenix hits its target in its first guided launch from an F-111B.
DECEMBER 1968	F-111B program is cancelled by the US Navy.
JANUARY 1969	The capabilities of the Hughes AWG-9 WCS are to be expanded to include the AIM-7 Sparrow, late AIM-9 Sidewinder and fixed gun.
MARCH 1969	Two drones successfully attacked at the same time by a F-111B.
OCTOBER 1971	F-14A No.4 arrives at the facilities to be outfitted with the AWG-9 and Phoenix system.
JUNE 1972	First launch of the Phoenix from an F-14A. The target was flying above 70,000ft; the F-14 at 40,000ft at a speed of Mach 1.2. The Phoenix, launched at a distance between 35 and 40 nm, passed 20ft from the target (within Phoenix's warhead radius). "Look-down" capability was tested as well, when a Phoenix launched from 10,000ft hit a target flying at 800ft.
OCTOBER 1972	The F-14 enters Navy service.
20 DECEMBER 1972	The F-14 successfully hits four drones at the same time. The F-14 was at 30,000ft, the five drones between 20,000ft and 25,000ft. The AWG-9 detected them farther than 60nm, and the six Phoenixes were launched from about 30nm in the span of 45 seconds.

APRIL 1973	So far, the overall success of the Phoenix in testing environments is 76%, with a success ratio of 86% of the F-14 Tomcat.
12 APRIL 1973	Scored the longest known air-to-air guided missile intercept. The F-14 intercepted a simulated Tupolev T-22 Backfire. The target was flying at 52,000ft at a speed of Mach 1.55; the F-14 at Mach 1.45 at 45,000ft. The AWG-9 detected the Tupolev in Track-While-Scan at 132nm. The Phoenix was launched at 110 nm, the missile reached an altitude of 103,500ft (~31.5km), before passing 5ft from the target (!) at 75nm. The simulated bomber was also using an on-off blinking noise jammer but failed to jam the AIM-54 Phoenix.
21 NOVEMBER 1973	Six AIM-54 Phoenix are launched near-simultaneously at drones flying at a range in excess of 50nm. One missile suffered a hardware failure.
DECEMBER 1974	In a test, a drone pulled a 6g, 174° turn in four seconds in an attempt to break the radar lock of the Phoenix and the AWG-9 WCS. The AIM-54A responded with a 16g manoeuvre and scored a lethal hit (see Figure 237). Out of the first 76 Phoenix launched by the F-14, the success ratio was 88%.
NOVEMBER 1975	Out of 124 Phoenix missiles fire in tests, 80 were launched by the F-14, with a success rate of 85%.

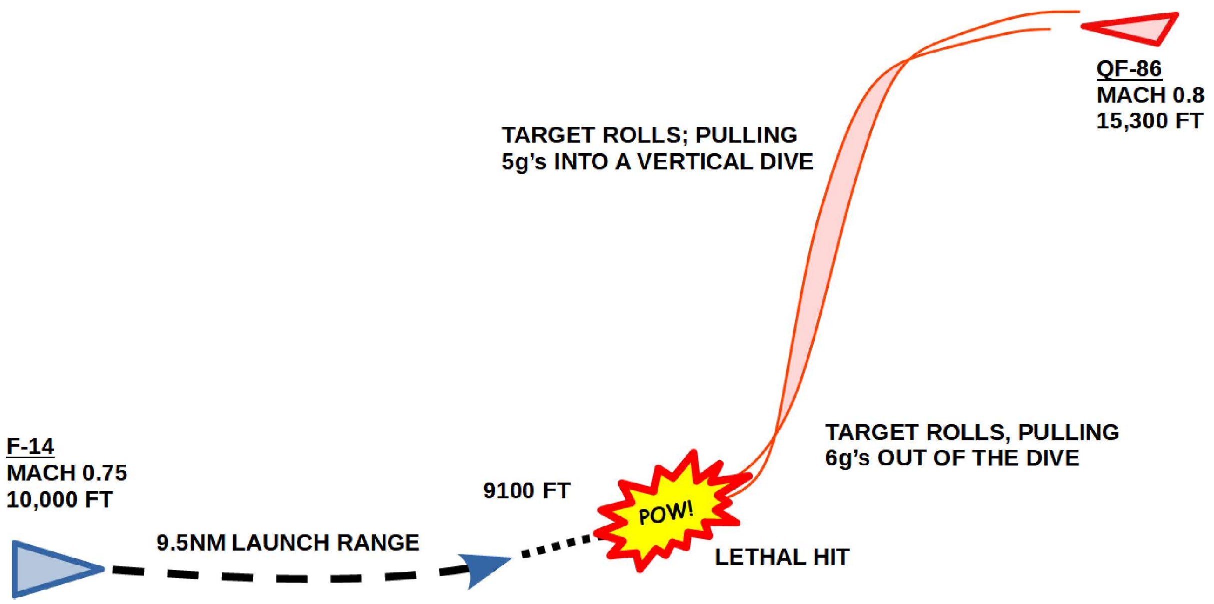


Figure 237: Very realistic representation of the December 1974 AIM-54 test.

The caption of the original image reproduced in Figure 237 reads:

> *While not intended as a dogfight missile, Phoenix has greater capability against maneuvering targets than any other air-to-air missile.*
> *For example, in the illustrated launch mission, a QF-86 drone attempted to break AWG-9 and Phoenix track by violently maneuvering in the vertical plane 16 seconds after missile launch. The drone pulled 5g's going into a 6200 foot dive and 6g's coming out. Phoenix scored a lethal hit on the drone just as it pulled out of the dive. In other evasively maneuvering target launches, Phoenix has pulled as many as 16g's to hit the target.*
>
> **HUGHES AIRCRAFT COMPANY**

7.4.3 AIM-54 PHOENIX MODES OF OPERATION

The AIM-54 has four modes of operation:

1. sample data semi-active;
2. continuous semi-active;
3. active;
4. home-on-jam.

SAMPLE DATA SEMI-ACTIVE

Mode used by Track-While-Scan to support the Phoenix. Up to six Phoenix can be launched and independently guided in this mode.
There are three guidance phases in this mode:

1. Programmed guidance: the AIM-54 performs a timed vertical manoeuvre in response to pre-launch commands. Two effects:
   - the manoeuvre allows the missile to avoid the main beam of the radar;
   - it provides the trajectory shaping that increase the missile's aerodynamic range.
2. Mid-Course guidance: the WCS sends information directly to the missile. It then directs its antenna and controls its receiver to receive the semi-active signal and target echo from a designated target as the radar scans it. The Phoenix then derives guidance commands from the sampled return and guides on the target with fixed guidance gain.
3. Terminal Active Guidance: the receiver transfers to a different frequency, commanded by the WCS, evaluates the spectrum to avoid interfering signals, radiates its own RF signal to illuminate the target, continually tracking the target echoes and guides with proportional guidance gain to intercept the target.

Note: according to the source, the switch from mid-course to terminal guidance occurs about 10nm (16 km) from the target. Maybe this is where HB found the initial implementation of the A-Pole, later changed as a function of the position of Size switch, after being suggested by their SME.

CONTINUOUS SEMI-ACTIVE MODE

This guidance mode also comprises three phases:

1. Programmed guidance: same as in the Sampled data semi-active mode;
2. Mid-Course guidance: the Phoenix receives more messages from the WCS than in Sampled data semi-active mode. The AIM-54 uses the content of the messages to position the antenna and turn the received on, continuously tracking semi-active target echoes with the receiver except during message transmission, deriving continuous guidance signals and guiding with fixed guidance gain,
3. Terminal guidance: the missile continuously tracks the target as in the mid-course phase, but uses proportional guidance. In this mode one missile is fired optimally but up to six missiles can be fired at the same target.

ACTIVE MODE

In this mode, the Phoenix is launched with its receiver commanded in active mode, but it receives prelaunch commands when available. The missile transmitter is radiating shortly after launch.
The missile guidance uses angle-rate memory technique, where the average of the steering signals developed during a clear period are used for tracking and guidance during the following eclipse periods.
The aircraft can launch and leave the missile in this mode.

HOME-ON-JAM MODE

Home-on-jamming allows the Phoenix to passively track noisy electronic countermeasures (ECM) targets on both its active and semi-active frequencies.
The missile guidance locks on the jamming noise. When the jamming is turned off, the missile attempts to reacquire the target in either its active or semi-active modes.

> *The crews of the two F-14As which covered Dowran's last raid into Iraq had been ordered to remain on the Iranian side of the border, but when the F-4E flown by Dowran's wingman, Maj Mahmoud Eskandari – which had been damaged by a 57 mm shell hit near the cockpit – was almost cut off by two flights of Iraqi interceptors, the Tomcat pilots could not hold back. Disobeying their orders, they raced into Iraq and shot down three fighters with two AIM-54s fired from more than 50 miles away.*
>
> **BISHOP, FARZAD; COOPER, TOM. IRANIAN F-4 PHANTOM II UNITS IN COMBAT – PAGE 125**

7.4.4 AIM-54 EMPLOYMENT IN REAL LIFE: US NAVY AND IRIAF

The US Navy never managed to score a kill with the AIM-54 Phoenix. Initially reserved for specific targets, the AIM-7 was the dedicated weapon employed versus hostile fighters. This changed in mid/late 80s.
On the 5th of January 1999, during Operation Southern Watch, two F-14D launched against an Iraqi MiG-25. Both missed. The following video, The F-14 Tomcast Episode 22, discusses the event leading to the unsuccessful employment of the Phoenix.

Plate 10: The F-14 Tomcast Ep. 22 - Combat Phoenix Shot (Click to open the video).

The third AIM-54 launched in anger by the US Navy was fired a few months later, the 9th of September 1999, targeting a MiG-23 that turned cold after the launch.

When used by the Imperial Iranian Air Force, renamed Islamic Republic of Iran Air Force after the 1979 revolution, the Phoenix gained its fame of very successful missile during the Iran-Iraq war in the 80s. Although the numbers are still debated, the number of kills varies from 30 to 80.

> *It remains unclear exactly how many air-to-air kills were scored by the IRIAF F-14s between 7 September 1980 and 7 July 1988, as Air Force records were repeatedly tampered with during and after the war [..]*
> *Post-war, a conference that was held in Tehran [..] concluded that the IRIAF had fired a total of 71 AIM-54As and had lost ten more rounds when the F-14 carrying them [was lost]. This figure may be correct, although the conference also determined that the F-14 had scored just 30 kills during the war, [..] 16 were confirmed as having been achieved by the AIM-54As.*
> *[..] This conclusion was reached despite firm evidence existing for 130 confirmed and 23 probably kills by IRIAF F-14As. Of those, at least 40 were scored with AIM-54s, two or three with guns, around 15 with AIM-7s, and the rest with AIM-9s. In one instance, four Iraqi fighters were shot down by a single Phoenix, and there were two cases of two Iraqi fighters being destroyed by the same missile.*
>
> **TOM COOPER, FARZAD BISHOP - IRANIAN F-14 IN COMBAT. PAGE 82.**

The appendix of the book quoted above, Iranian F-14 in Combat, written by Tom Cooper and Farzad Bishop, includes a list of 159 confirmed kills

> *sourced from active or retired F-14, F-4 and F-5 pilots, retired Iraqi MiG-21, Su-20/22 and Mirage F-1EQ pilots, official Iranian records, US Navy documents [..] and third-hand sources as press releases or "war communiqués". The list also includes 34 probable/possible or unconfirmed kills [..].*
>
> **TOM COOPER, FARZAD BISHOP - IRANIAN F-14 IN COMBAT. PAGE 85.**

Without counting the possible / probable kills and the assigned kill without complete information, the total amount of kills scored by the AIM-54A Phoenix is 57.

7.4.5 THE AIM-54 PHOENIX IN DCS

The Phoenix has seen a lot of work done by Heatblur through the years to ensure a realistic representation of the missile. Understandably, not all the minute details of the AIM-54 are available to the devs opted for recreating a thorough simulation. The details are available in this whitepaper.

A BIT OF HISTORY

The AIM-54 in DCS went through an incredible number of changes and improvements. This paragraph briefly recaps the story of the missile, as a testament to the hard work of the devs, but also in case you run into old DCS docs and videos, and see something that it is not applicable nowadays.

2019: Initial Implementation

When the F-14 first entered the EA, the number of features and peculiarities the devs could implement were limited. This led to a number of workarounds. For instance, the guidance only marginally followed Heatblur's code until the activation, then it was left entirely to ED[67]. This created a series of issues in the terminal phase (e.g. abrupt manoeuvres leading to high-G spikes and a lot of wasted energy, degrading the performance of the missile), and the activation itself was automatic (similarly to an AIM-120), rather than commanded by the WCS.

It was soon announced that ED was granting access to a new missile API[68], potentially granting the devs more access to the missile behaviour, guidance and so on.

The first partial implementation of the new API was released one year later[69]. At the moment, the API is not completely integrated yet, forcing the developers to implement new workaround. Nevertheless, the API allowed Heatblur to create a much more realistic reproduction of the WCS and the AIM-54.

Examples of these workarounds are the employment of the AIM-54 in PSTT[70] and the guidance of the missile to the extrapolated track created when the radar loses a contact targeted by a Phoenix.

2019 AIM-54 Probability of Kill Study
This is a long study, completed in August 2019 and divided in four parts, aimed to better understand the characteristics of the AIM-54 in DCS.

1. Introduction;
2. Low altitude;
3. Altitude considerations;
4. Medium and Long range.

I empirically determined the parameters granting the highest Probability of Kill (PK) by employing taking into consideration a total of 3360 AIM-54C Mk47 and AIM-54A Mk60 (tests are not included in the total).

67 Source: gyrovague. /r/hoggit.
68 Source: Cobra. ED Forum. 06/10/2019.
69 Source: IronMike. ED Forum. 04/11/2020.
70 Source: Naquaii. ED Forum, following post and here. 05/05/2021.

This is vastly obsolete now. Back then, the absolute king was the AIM-54A Mk60, and the AIM-54C was de facto pointless, slower but with a bit better seeker than the AIM-54A Mk47.

2022: A Step Closer to a Proper Implementation

Coming September 2022, the AIM-54 Phoenix is now closer to its real behaviour. The AIM-54C Mk60 was introduced, but the most significant change touches the guidance.

The AIM-54A has always been a mediocre weapon when employed against aware and agile targets, such as fighters. Listening to the tales of former crews, it is really easy to be impresses by how poorly the A was considered. Albeit DCS is a simulation only marginally close to reality, due to how poor the representation of missiles, CM and ECM and SA is, the new updates to the Phoenix start to give a hint or two to why the AIM-54C was considered such a superior weapon.

A quick look at a TacView post update immediately show where the issue is: in Track-While-Scan, the most common employment mode, the missile is updated as the radar refreshes the track. This sort of almost-but-non-*bang-bang*[71] behaviour causes the missile to bleed more energy and react much slowly to changes in course and altitude when the target is not on the nose. The 70s TWS and the AIM-54A are now a combination only efficient versus less manoeuvrable or unaware targets, either due to poor SA or avionics, a situation the Iranians greatly exploited against the Iraqi in the 80s conflict.

The AIM-54C is now instead the go-to missile versus any type of target, due to its improved guidance, Inertial Navigation System and the ability to switching to active when the lock is lost.
Moreover, the AIM-54C now features the Mk60 engine, with shorter burst but greater impulse, thus negating the kinematic advantage of the AIM-54A Mk60.

Still a Long Way to Reality

The AIM-54 in DCS is unfortunately still plague by many issues, mostly due to how simplistic the radar and guidance simulation is in this game. For example, dual guidance is not available; hence the missile cannot rely on the F-14's radar for guidance if its seeker cannot find the target. Other issues, for example, prevent the proper usage PSTT, and so on.

Albeit DCS looks like a great simulation, there is still a lot of work required (and probably a proper series of API, starting from the missiles and ECMs) before reaching its goal. Quoting the homepage:

---

71 "Bang-bang" for the new AIM-54 can be misleading but, in my opinion, successfully conveys the message. LGB Paveway II's bang-bang guidance turns the surfaces all in to correct the trajectory, thus bleeding energy. The new AIM-54A guidance updates the missile at every TWS sweep (every ~2"). Therefore, it has to compensate for the missing adjustments, potentially commanding hard turns, rather than smooth, because it needs to catch up, potentially causing the loss of a considerable amount of energy.

> *Our dream is to offer the most authentic and realistic simulation of military aircraft, tanks, ground vehicles and ships possible.*
>
> DCS WEBSITE

AVAILABLE VERSIONS

Three versions of the AIM-54 are available to the players in DCS:

- **AIM-54A Mk47**: oldest version implemented in DCS, it has an analogue seeker and Mk47 rocket motor. It looks white in-game;
- **AIM-54A Mk60**: similar to the AIM-54A Mk47, but featuring the more powerful Mk60 rocket motor, albeit burning for a shorter period. As the A Mk47, it looks white in-game;
- **AIM-54C Mk47**: upgraded version of the Phoenix, featuring digital seeker with better countermeasure resistance and improved guidance. The Mk47 used by the AIM-54C produces less smoke.
- **AIM-54C Mk60**: upgraded version of the Phoenix, using the Mk60 rocket motor.

On top of the guidance, the new AIM-54C has better countermeasures resistance, quite comparable to the AIM-120B.

Forced Drawbacks and Fake Advantages: Real life and DCS

DCS is unfortunately incapable of providing all the tools the devs need to implement all the features of the AIM-54 have in real life. The status quo prevents them to achieve a greater degree of realism. For example, dual guidance is not supported, thus the AIM-54 cannot take full advantage of the support of the AWG-9 if its seeker cannot find the target. This is just one of the many limitations DCS imposes on the devs and the weapon systems. Other examples are the AIM-7 guidance, and the status of the AIM-54 launched in PSTT.

On the other hand, the AIM-54A was such a poor missile, compared to modern standards, that really required the AWG-9 to continuously illuminate the target over time to increase the odds of success. Not doing so, would probably cause the missiles to be trashed. In DCS instead, the A can be used to execute "launch and leave" tactics without drawbacks (discussed later in this book).

Moreover, the new AIM-54C introduced recently are perfectly capable of being activated and left to their own devices, both in real life and DCS, whereas activating the A and leave, would have thrashed them in reality.

DCS giveth, DCS taketh.

7.4.6 GUIDANCE: AIM-54A VS AIM-54C

Note: The following is a brief look at the new implementation of the AIM-54, merely a week after the release. I want to wait until a more finalised version before commit a hefty amount of time to create a proper, detailed study.
These are “hot takes”, written shortly after the tests. I will add more details and observations as we get to know the new missile better.

MODUS OPERANDI

The two criteria I used are the speed and the range at the impact. The total number of samples for Part I is about one hundred, plus two or three times that number in side tests. I would have preferred a much higher number of samples before drawing the preliminary conclusions, along the apex of the parabolic trajectory, but those numbers require TacView, whereas the speed at impact and the range at impact come straight from DCS. Hence, they are quicker to collect.

There are at least two sets of datapoints per scenario to minimise measuring errors. Still not enough, but there are no blatant discrepancies.

Targets are non-manoeuvering, and not dispensing CMs.

Now, preamissa’s off, let’s get to the observations:

AIM-54A TWS VS AIM-54A STT

In general, TWS provides slightly greater speed at impact, especially at long range. The advantage is minuscule, though. On the other hand, STT hits further. An interesting observation is the fact that TWS A, post activation, when TA is not irrelevant, arrives within the last few miles with an offset, then it “slides” onto the target almost sideways. Possible explanation: since the target is drifting, TA is increasing exponentially over time and the frequency of the TWS guidance is not high enough to provide accurate final steering before the handover to the seeker’s missile. Curiously, the terminal speed for the TWS is still higher than STT. I guess that STT corrects more whilst the missile is in the air, thus bleeding slightly more speed. This cost is offset by the more precise positioning at the handover, which should improve the odds if the target, now aware, tries to defend turning cold.

AIM-54C TWS VS AIM-54C STT

Not really much to say here, the numbers are quite similar overall. The advantage, hopefully at some point, would be having the target less aware of the missile incoming. It’d be great if ED could make the activation parametric: Small TGT SIZE would be quite cool with the new C logic (as we know already, at the moment is hardcoded to 10nm, at least for the AI).

AIM-54A MK47 VS AIM-54C MK47

This is an interesting one. In general, the A arrives faster in TWS, the C arrives earlier. Another case of tighter control equal a bit more energy lost, but more efficient endgame, perhaps. The only peculiar case in SET VIII, where the target was flying an S-shape patterns. This feels like a case where fewer corrections were actually useful, since the A noticeably bled much less speed, thus hitting earlier. This seems to be confirmed by the A TWS vs STT case, where A STT is much closer to C STT.

This is almost meme material and reminds me of the Tomcast episode where they said that the AWG-9 may not even notice that a target notched for a few seconds, due to how it worked, lol

Finally, the A tends to arrive “more vertical” and at a much higher number of Gs, sometimes almost perpendicular to the target, especially in TWS. It may be due to the guidance being less accurate?

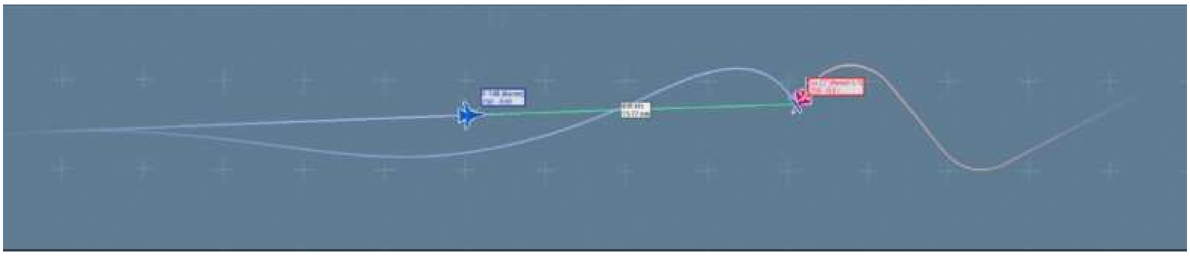


Figure 238: Set VIII - Scenario.

Figure 239: AIM-54A Mk47 – Trajectory.

Figure 240: AIM-54C Mk47 – Trajectory.

AIM-54C MK47 VS AIM-54C MK60

Notes: The "real" Mk60 is a procurement to diversify the supplier. From my understanding, it wasn't necessarily as powerful as depicted in the older simulation of the missile, at most of the stock was used rather quickly for different reasons.

The old Mk60 was a beast. In my 2019 model it blew away every other version: who cares of a X% greater chaff resistance, when the missile is coming 1 mach faster? Nowadays, it's very different, but there are some interesting results.

In primis, it consistently hit farther. An in-depth analysis of the trajectory is necessary to explain this. Perhaps it doesn't loft as high, thus going "straight" earlier. This may be confirmed by the fact that the speed at the impact is lower consistently, besides in some cases: at higher altitude and longer range, the Mk60 has greater speed at impact. When it happens, however, the difference in terms of range is not as pronounced as in the other cases. Intriguing.

ADDITIONAL NOTES

I had a problem of ghost tracks in a scenario where multiple targets were in the air (SET V, IIRC). It didn't happen when I used TWS Manual to highlight only the target I wanted, or told the WCS to disregard the others.

The issue of the STT track disappearing from the DDD and appearing as lost on the TID at high ATA is still present.

I didn't consider the A Mk60 initially, but the results are quite interesting, and I may re-do the tests for that version as well, but definitely include them for the following parts of the study.

CONCLUSION

It's too early to take solid and numbers-backed conclusions, but the feeling is that the missile is much slower, but bleeds incredibly less speed than before. Thus, if the Phoenix can be launched faster, the difference in terms of terminal speed won't be as pronounced. It will just take longer to get there. Before, a target turning would defeat an AIM-54 coming much faster just by slightly turning. This is not the case any more.

7.4.7 ENERGY: MK47 VS MK60

Note: The same considerations about this brief look into the missile are applicable here. More observation may come in the future.

The scenario I used is simple, but different from the previous. In fact, even the lowest TA / ATA scenario used Part I was not a parallel head-on. Since the idea was assessing the guidance, an offset was always induced, albeit minimal in some cases. In this case, instead, both TA and ATA equal zero.

The first set used sees both aircraft at 25,000ft at similar speed (0.9 vs 0.8). A common situation in a long mission, where fuel is a fundamental asset. Before the recent patch, the Mk60 had no issues in this scenario although, of course, it benefitted by higher speed and altitude.

The second set sees the F-14 flying higher, at FL350, and faster, M1.2. The results are fascinating.

For simplicity's sake, I used only TWS, and compared A vs C for both motors.

A TWO-SPEEDS BEAST

The results of the first test are almost as expected. The geometry allows the A to perform very well, in conjunction with its lighter weight. A peculiar behaviour is appreciable between 40 and 60 nautical miles SR: the impact speed of the missile actually increased, before winding down after 65nm.

The Charlie version is heavier but with a much improved seeker, and it had no real reasons to shine in this test, as the target is a straight-flying drone.

Compared to the AIM-54A, it does not share the same increase in speed between 40 and 60 nm, and it seems to suffer noticeably both at low and high ranges. In particular, between 15nm and 30nm, with a quite absurd drop at 20nm.

The second set included the AIM-54A Mk47 TWS, the C47 TWS and the A 60 TWS. The results are unexpected. Rather than a simple positive offset, they are drastically different. In fact, the Phoenix is an entirely different beast when launched fast and high, although I deliberately decided not be too extreme (35,000ft M1.2 is reachable even with a fairly heavy Tomcat by unloading to gain speed and trading it for altitude).

The difference at short range is staggering: at 15nm, the “slow” A Mk47 reaches M2.3, the fast and higher reaches 3.1. Most importantly, the huge performance gap at 20nm is missing. It is probably due to the fact that at 15nm and 20nm, the Phoenix does not loft, but it does loft at 25nm+. Thus, at 20nm the missile has exhausted its motor, but has no altitude to trade for speed.

An interesting characteristic of the Mk60 motor is that it provides the AIM-54 a greater speed in the endgame, right before “falling”. At short range, it is slightly less performing than the Mk47 in terms of top speed, but as the next paragraph will show, those missiles impact the target earlier than the Mk47s.

Other interesting observations touch the ability of the new AIM-54 to retain energy, at least against low TA targets. Especially when employed fast and high, the performance is very similar no matter the range. In this profile, even against distant targets, the motor is still pushing almost until the end of the first, steeper, part of the climb, thus allowing the Phoenix to trade a considerable amount of energy for altitude.

Again at long range, when the AIM-54 start its dive it accelerates further if its altitude is above ~50,000ft.

These considerations highlight a fundamental aspect of the new missile: **investing in speed and altitude is worth it**. The old Mk60 was so powerful that it benefitted proportionally less of the energy investment, whereas the new missile is a whole different beast if pushed fast enough. Getting high is important now and, as mentioned, a subsequent series of climbs and unloads help to get high and fast relatively quickly.

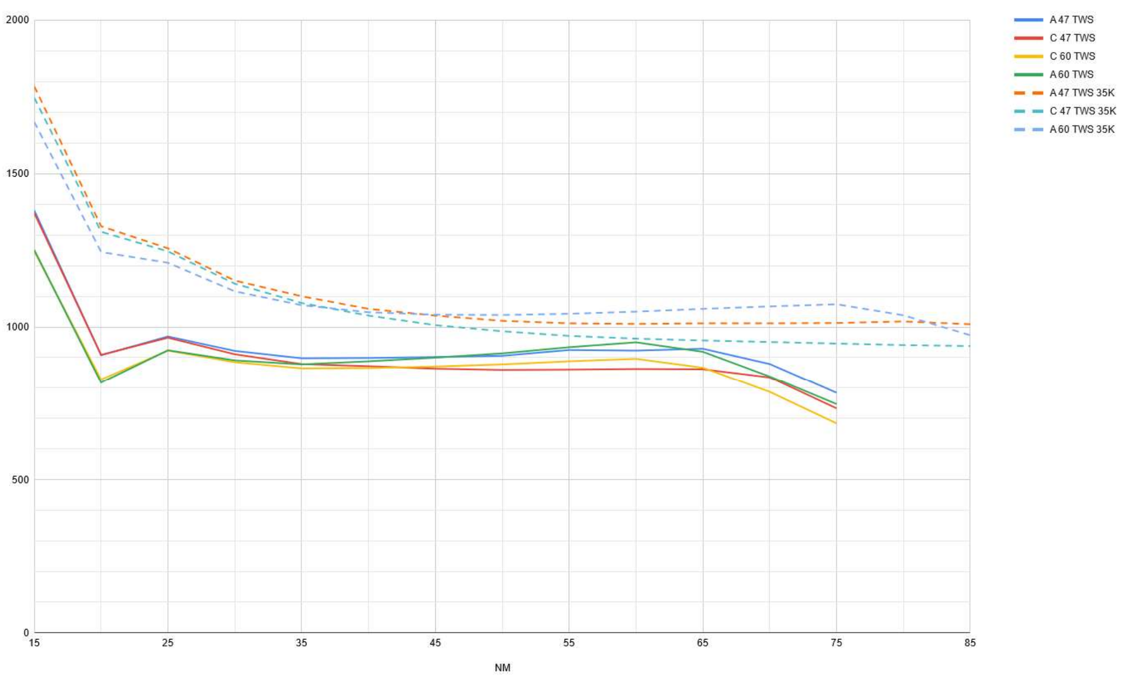


Figure 241: New AIM-54: TAS (impact) vs Launch Range. High-res here.

IMPACT DISTANCE

The chart in Figure shows the impact distance relative to the distance travelled against the range. The dashed series are the “high and fast” ones.

This chart is less intuitive than the previous, so here is a short explanation: if the percentage is high, it means that the F-14 has got quite close to the target at the impact. Obviously, the F-14 can crank or manoeuvre post A-Pole, but in this case, it is not. The point is conveying how investing more energy into the missile pays dividends. Looking at the dashed lines, in fact, the percentage is lower; thus the impact happened relatively far away, no matter the fact that the Tomcat flew at Mach 1.2 the whole time. Translated into a more understandable scenario, it means that the investment in energy allows the missile to arrive faster and farther. This benefits the missile’s endgame, plus creates greater separation between the target and the fighter, allowing room for a recommit for example, and, in general, more flexibility.

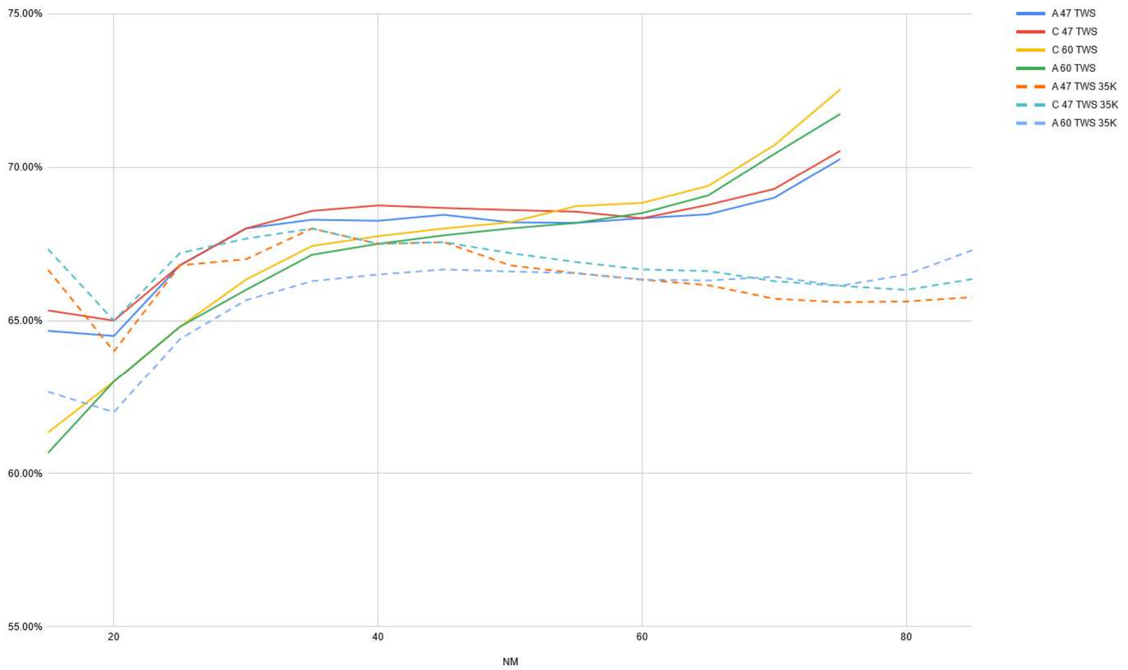


Figure 242: New AIM-54: Impact range / Travel Distance (%) vs Launch Range. Lower is better. High-res here.

FOOD FOR THOUGHTS & CONCLUSIONS

Before wrapping up this brief look, two more points:

- Cooperation with MRM carriers: although the 20-25nm gap can be filled by the AIM-7 Sparrow properly assisted, playing along MRM carriers will bring more benefits. As we have seen, the new AIM-54 is still a beast at long range if shot following new parameters (most of them still have to be discovered and refined), but the medium range sees it falling behind. I have not studied the missile acceleration yet, but the older implementation was already lagging behind missiles such as the AIM-120.

Therefore, if you play in a modern setting, this is where F-16 or F/A-18 can come in and cooperate. In previous time settings, capable SARH missile carriers such as the Mirage 2000 can fit nicely too.

- Imagining the new LAR: The lack of datapoints prevent the determination of a proper LAR, but crossing the observations of Part I with the new data, we can imagine two different LAR diagrams, one for each mission (potentially, two more, one for each motor). The LAR of the AIM-54A will probably be more elongated and narrow, since the guidance is not as accurate and, probably, getting closer to the beam may affect it more than the new, “fancy”, Charlie. On the other hand, the C is heavier, it does not provide the same results against low TA targets, but guidance and features help it more in unfavourable conditions.

At the end of the day, the missile is now generally closer to its real counterpart when real data and DCS are compared. There is always room for improvements, of course: this is not the final version, and there are still some limitations plaguing the Phoenix and the AWG-9 even outside the mere missile performance (e.g. lack of dual guidance, the activation of the seeker hardcoded at 10nm, et cetera).

7.4.8 AIM-54 EMPLOYMENT

The AIM-54 Phoenix is an Active Radar Homing missile. Since the implementation of the new missile API, it can be launched in different ways:

> *[..]Here is a brief summary of what these changes include:*
>
> - *TWS with range >10NM: LTE 3s, loft, SARH/DL, missile goes active at 16 seconds time-to-impact*
> - *PDSTT with range >10NM: LTE 3s, loft, SARH/DL, missile does not go active (SARH/DL all the way to target)*
> - *TWS or PDSTT with range <10NM, or PH ACT selected: LTE 3s, no loft, active directly after launch*
> - *PSTT or BRSIT or (ACM cover up with no track or PSTT or PDSTT): LTE 1s (unless STT and angle >15deg then 3s), no loft, active immediately*
>
> **COBRA847 – ED FORUM**

The September 2022 patch provided much greater depth and further marked the differences between the A and the C.

Generally speaking, the behaviour of the missile is still close to what posted in 2019. However, there are still some issues, mostly due to the immaturity of the missile API. For example, the AIM-54C guided in PDSTT is active at 10nm[72]. This warns the target (and "M" should appear on most modern RWR).

72 You may have noticed that this value recourses often when discussing the activation of a missile. In fact, this is hard-coded in DCS.

“ACTIVE” AIM-54

The Phoenix can be launched with its seeker already active as it leaves the weapon rail. The WCS criteria dictating whether the missile is active off the rail or not are listed above, but the Radar Intercept Officer can force such status by actioning the Mission Options switch located in the Weapon Panel (Figure 236).

The AIM-54 can still take advantage of the radar in this scenario:

> *If launched in active mode the range drops to about 10 NM for a fighter sized target, varying slightly with target size. Notable though that the missile will revert to SARH mode if no target is detected if selected for active launch in a SARH mode.*
>
> DCS F-14 MANUAL

VIDEO RESOURCES

The following videos show a few scenarios and the behaviour of the AIM-54:

- Single Target Track (Pulse and Pulse Doppler);
- Track-While-Scan and Situational Awareness. Plus the related article on FlyAndWire.

7.5 M61 “VULCAN”

The M-61 Vulcan can be used in both air-to-air and air-to-ground. It is a 6-barrelled, 20mm automatic cannon, capable of firing 4000 or 6000 rounds per minute, with the possibility of setting different burst lengths (50, 100, 200 rounds).

It is a veteran of the western armies, an it is used by the US, some NATO members and others.

The F-14 carries a maximum of 676 rounds, weighting 520 lbs[73].

Similarly to the AIM-9 Sparrow, the gun is complete competence of the Pilot.

73 Value from the DCS Mission Editor.

8. AVIONICS IV: RADAR MANAGEMENT

This chapter introduces some common practical uses and issues often encountered during a mission and expands the concepts mentioned in Chapter 6.

Most of the observations are personal and are suggestions about how to deal with such issues. The Radar Intercept Officer will then find his own way of dealing with those and will create his own workflow.

8.1 ANTENNA ELEVATION ANGLE

One of the very first issues a new RIO has to learn to deal with is where the antenna should be set in order to illuminate a contact of interest.

Considering the airspace from the perspective of the RIO, three parameters must be met to find the contact mentioned above:

1. Distance;
2. Azimuth;
3. Altitude.

The Distance is not applicable to Pulse Doppler radar modes, only to the Pulse radar. The RIO can set the maximum range if the range is unknown. This is usually a non-issue.

The Azimuth is usually simple, especially when the target is Datalinked or a bearing or clock-reference is provided.

The Altitude, instead, can be a tough problem for a new RIO. The problem lies in the fact that the radar scan volume is much wider than taller and, especially at short range, the ratio between the covered airspace and the number of bars is not convenient. In other words, it can take a relative long time to scan a fraction of the airspace.

The solution is changing the antenna elevation to an angle so that the contact is contained within the boundaries of the airspace scanned by the radar.

8.1.1 THE MEANING OF "BARS"

Chapter 2.6 introduced the radar by describing the path followed by the antenna as an '*S*'. The more Bars are selected by the RIO, the more horizontal sweeps are made (each at a decreasing angle), before starting again from the top.

Each Bar increments the scanned volume on the vertical axis by a few degrees:

- 1 Bar = 2.3°;
- 2 Bars = 3.6°;
- 4 Bars = 6.3°;
- 8 Bars = 11.5°.

The Bars overlap slightly (otherwise, 2 Bars would be equal to 4.6°, for instance). This means that a contact can be swept by two Bars one after the other.

When multiple Bars are scanned, the "**EL indicator**" (discussed more in-depth later, in Chapter 8.4.2), placed just on the left of the DDD, moves downwards depending on the Bar being scanned. When it reaches the end, it starts again from the angle equivalent to the top Bar.

8.1.2 DETERMINING THE ELEVATION ANGLE

There are multiple ways to determine the Elevation to set depending on the altitude of the F-14 and the target. The following are three examples:

1. Trigonometry: and deriving Antenna Elevation Table;
2. Mnemonic Formula: simple and immediate, one of the most commonly used techniques;
3. Experience: eventually, most of the settings are driven by your "guts", and the precedent means will be used only for the rare occasions where finer adjustments are helpful (see the INS Fix Update using the radar – Chapter 6.14.4).

TRIGONOMETRY

One of the very first articles on FlyAndWire covered this topic, following different approaches. Eventually, the Simplest turned out to be the approximation of the angles through simple trigonometry.

Determining the height of the scanned volume is immediate.

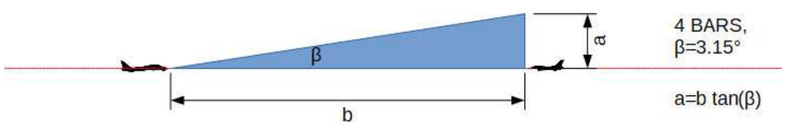


Figure 243: Determining the airspace covered by the bars.

Figure 243 shows how that value is calculated.
β represents half of the angle covered by a defined amount of Bars. In this example, 4 Bars. The height is immediately calculate using:

$$a = b * \tan(\beta)$$

with the range (b) in feet.

Using a similar method, the elevation angle knowing the difference in altitude between the F-14 and the contact of interested can be immediately calculated:

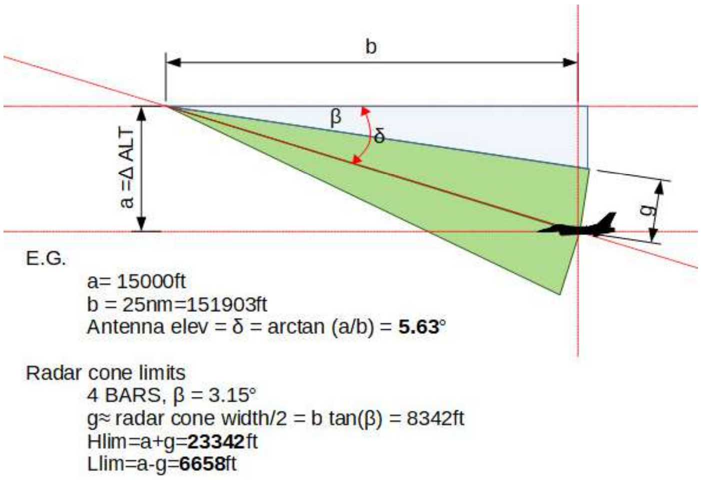


Figure 244: Determining the antenna elevation angle.

Given δ as the angle to be determined, all is required is the range and the altitude difference:

$$Elevation\ Angle = \delta = \arctan \frac{a}{b}$$

The results can then be group in a table and added to a Kneeboard page[74] or other quick-reference document.

> Note: since it is based on Maths, this model is applicable to any aircraft.

MNEMONIC FORMULA

The formula discussed in Chapter 8.1.2 can hardly be calculated during a mission. Another formula, instead, provides a good approximation of the elevation angle, using a similar principle:

$$Elevation\ Angle = \frac{\Delta_{ALT}}{SR * 100}$$

Similarly to the precedent formula, it relies on the Altitude difference and the range to determine the Angle, but removes the arctangent, making it much simple to use.

74 The Antenna Elevation Angle model is part of the FlyAndWire Kneeboard Pack.

A further simplification consists in removing the “100” and simply drop the last two figures of ΔALT.

Example I

$ALT_{F-14} = 25{,}000\,ft$
$ALT_{TGT} = 15{,}000\,ft$
$\Delta_{ALT} = 10{,}000\,ft$
$SR = 25\,nm$

$$ElevationAngle = \frac{\Delta_{ALT}}{SR * 100} = \frac{10{,}000}{25 * 100} = \frac{100}{25} = 4\,°$$

Example II

$ALT_{F-14} = 30{,}000\,ft$
$ALT_{TGT} = 15{,}000\,ft$
$\Delta_{ALT} = 15{,}000\,ft$
$SR = 15\,nm$

$$ElevationAngle = \frac{\Delta_{ALT}}{SR * 100} = \frac{15{,}000}{15 * 100} = \frac{150}{15} = 10\,°$$

ALTF14 = Altitude F-14
ALTTGT = Altitude Target

SR = Slant Range
ΔALT = Altitude difference between F-14 and Target

EXPERIENCE

Eventually, as the Radar Intercept Officer becomes more confident in his role, he will be able to use his “guts” to determine the angle, by simply eyeballing the altitude difference and knowing the approximate range.

There are also a few radar settings the RIO can use to find a target, especially at short range an in look-down situations.

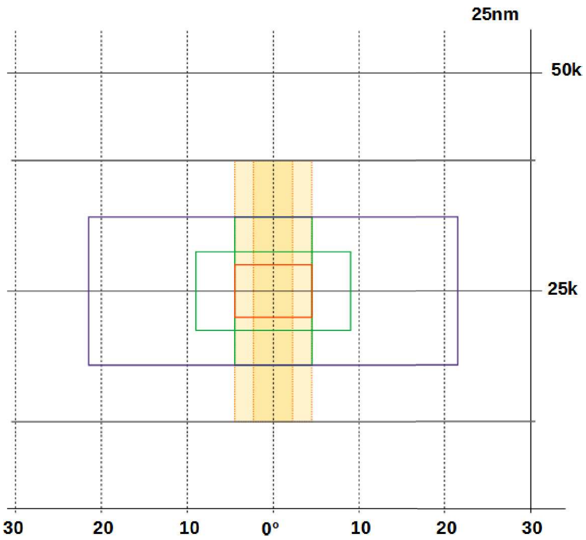


Figure 245: Radar coverage using "tall & narrow" settings.

One of those "tricks" consists of setting the radar in a "tall and narrow" mode, by reducing the Azimuth and increasing the Bars. To counter possible defensive manoeuvres, the RIO can switch to PSRCH, whilst reducing the radar Gain to the minimum to attenuate the ground returns.

Figure 245 shows the scanned volume for ±10° 8 Bars and ±20° 8 Bars at 25 nm. If the target is Datalinked, then finding the target becomes very simple for the RIO.

This is an example of how the RIO should not stick to some radar setting all the time, but should be able to adapt to the situation, using every possible tool to his advantage.

8.2 PULSE RADAR MODES

Introduced in Chapter 2.5.2 Pulse radar is a Low PRF radar mode used primarily in ACM mode and to spot contacts hiding in the Pulse Doppler blind zones. It can also be used to conduct intercepts as it allows to visually determine the drift very easily from the DDD.

Compared to HPRF radar modes, it has a reduced detection range but a PSTT lock is considered, in DCS, an almost unbreakable "Iron Grip".

8.2.1 PULSE RADAR: MODES, RANGE, GUIDANCE

Two Pulse radar modes are available to the RIO[75]:

MODE	FUNCTION	WEAPONS CAPABILITY	RANGE
Pulse Search	Medium range search and	Boresight missiles.	60nm

75 Source: DCS-F14 Manual.

	detection, secondary air-to-ground.		
Pulse STT	Short to medium range single target track and missile launch.	Gun and missiles, AIM-7 in CW and AIM-54 in active launch.	50nm

As a Radar Intercept Officer, Pulse Single Target Track (PSTT) is the most common method of weapons employment (via a Continuous Wave antenna in case of the AIM-7).
Pulse Search (PSRCH) instead, can be used in several phases of the flight: it makes understanding the drift very intuitive.

A few tips and the basic usage of the Pulse radar have been discussed in Chapter 6.2.1: DDD in Pulse Doppler mode.

8.2.2 BASIC GROUND MAPPING

The AWG-9 in Pulse mode can be employed is an elemental ground mapping radar by means of Pulse mode. It can be successfully used to highlight the coastline and ground features that stand out from the horizon.

Figure 246: Ship lock - HUD.

Figure 247: Ship lock - TCS.

Ships can be detected from about 80nm and also be locked as a locked and targeted as shown in Figure 247. As any other target, the locked ship is visible both on the TCS and on the HUD of the pilot.

This can be used for different purposes such as recce of recover in case of TCN failure or other technical issues.

The Ground mapping features of the AWG-9 are a consequence of the Pulse radar mode not filtering ground returns. It is a very basic form of ground radar and works best over the sea surface to highlight the coastline.

Figure 248: Basic ground mapping example.

Figure 246 shows a ship located a dozen miles from the F-14 and the outline of the coast. The map in the top-right corner is the F10 view of the situation whereas the bottom-left is the same view but distorted to resemble what is displayed on the DDD.

Despite not being a real ground mapping radar and suffering from excessive clutter when feet-dry, the Ground mapping can be useful to increment the spatial awareness in a degraded or zero-visibility conditions flight.

In a mountainous area, focusing on the peaks can spotted easily by adjusting the antenna elevation. Such peaks also offer an easily identifiable visual reference for the Pilot.

HAVING SOME FUN: BLIND VALLEY RUN

Flying as RIO may sometimes not sounding as exciting as the front seat. Sometimes instead, it's a helluva lot of fun.
This video shows a for-fun flight down in a valley in zero-visibility conditions, along the related article.

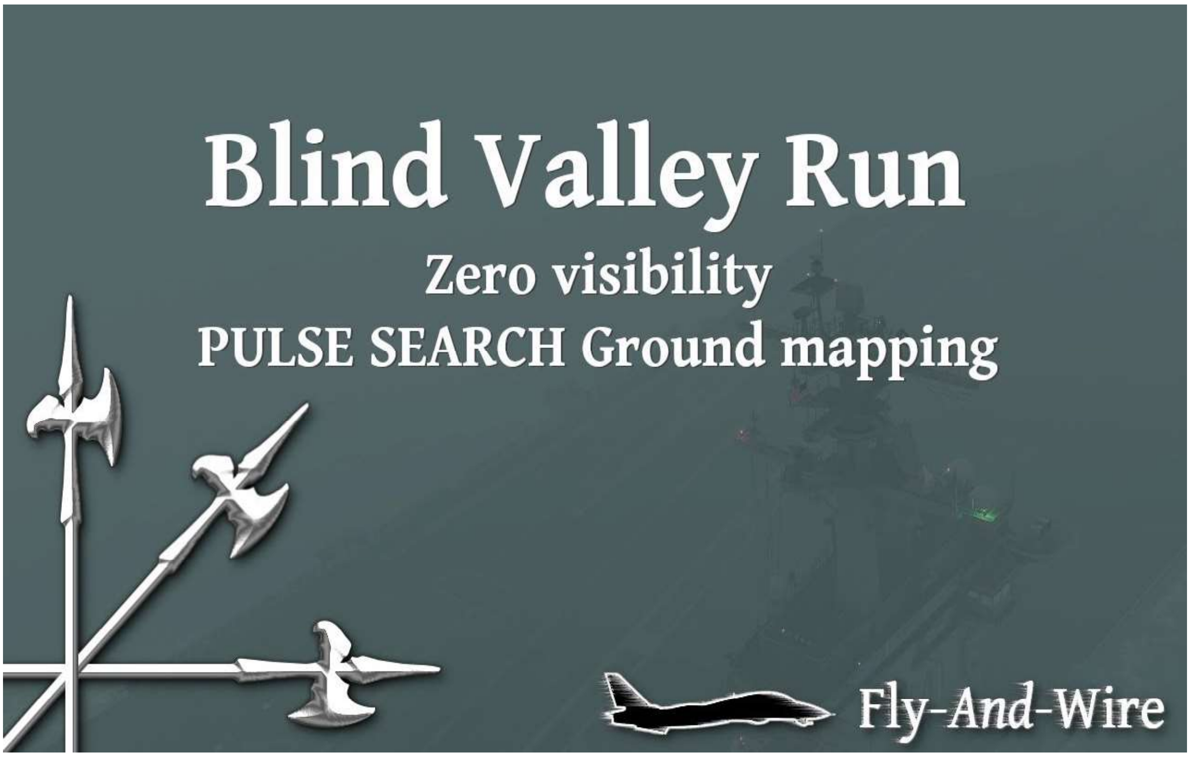


Figure 249: 4Fun Video - Blind Valley Run.

8.3 PULSE DOPPLER RADAR MODES

The manual reports the following details for the Pulse Doppler radar mode (Detection-range approximation for a 5m²-target):

MODE	FUNCTION	WEAPONS CAPABILITY	RNG
Pulse Doppler Search	Long range search and detection.	Boresight missiles.	110 nm
Range While Search	Long range search, detection and ranging.		90 nm
Track-While-Scan	Long range search, detection, multiple target track and missile guidance.	AIM-54, multiple target capability.	90 nm
Pulse Doppler STT	Long range single target track and missile guidance.	Gun and all missiles. AIM-7 in PD and CW and AIM-54 in PD and active.	90 nm

Pulse Doppler radar is the primary radar mode used by the RIO. It allows the F-14 to spot contacts further than any other aircraft in DCS, at the moment.

Even in real-life, the F-14 was used as a sort of an AWACS by the Iranians during the Iran – Iraq war:

> *Iran has been flying American-built F-14 Tomcat fighters as radar surveillance and control planes to guide F-4 Phantom fighter-bombers attacking ships in the Persian Gulf, according to Middle Eastern diplomats and American officials.*
>
> *[..] The diplomats and officials said Iran was using the F-14's, which have advanced radar systems, as ''mini- Awacs,'' or reconnaissance planes to spot ships in the gulf and to guide the F-4's, which carry far less effective radar, toward those ships.*
>
> *[..] The radar of the F-14, according to naval officers, can pick up aircraft at distances of more than 100 nautical miles and can spot a ship. The ship appears only as a ''blip'' on the radar screen and cannot be identified as to size or type, they said.*
>
> *[..] The pilot and radar operator aboard the two-seat F-14 can transmit by radio headings and other information directly to pilots in the F-4's [..].*
>
> **NEW YORK TIMES – 07/07/1984**

8.3.1 WHICH MODE WHEN

Pulse Doppler Search stands out compared to the other PD modes for two main reasons:

1. it displays targets only on the DDD, rather than the DDD and the TID;
2. it has the greatest range, due to the lack of ranging information.

This mode is helpful to have a general idea of the situation at incredible ranges where often not even an AWACS is able to see. The drawback is that all the RIO's got, is the DDD. This topic has been discussed already in Chapter 6.2.1.

The other three radar modes have similar detection range, but vastly different usage:

- Single Target Tracking is, as the name suggests, a radar mode fully dedicated to the tracking and possible employment of a missile vs a contact. Its main drawback is degraded Situational Awareness caused by the fact that the radar is fully focused on a single contact;
- Track-While-Scan made the AWG-9 famous for its ability of engaging up to six targets at the same time, also enabling the Tomcat to perform launch-and-leave tactics. Other aircraft, such as the F-15, acquired this capability with the AIM-120 a couple of decades later.

TWS can track up to 24 contacts, but only 18 can be displayed at the same time.
Its main drawback is the reduced airspace volume scanned, due to the necessity of refreshing contacts every 2”. TWS is in fact limited to two combinations of Azimuth and Bars: ±20 4B or ±40 2B.
TWS is used when the AIM-54 Phoenix is employed (see Chapter 7.4), allowing the F-14 to engage multiple targets without warning them until the missile activates its internal active radar. This radar mode can also be used to employ the AIM-7 sparrow in Pulse Doppler mode rather than Continuous Wave (see Chapter 7.3), giving it a longer range and more resistance to ECM and Jamming. The drawback is the susceptibility to the two big blind spots that affect a HPRF Pulse Doppler radar: ZDF and MLC (see Chapter 2.5.2).

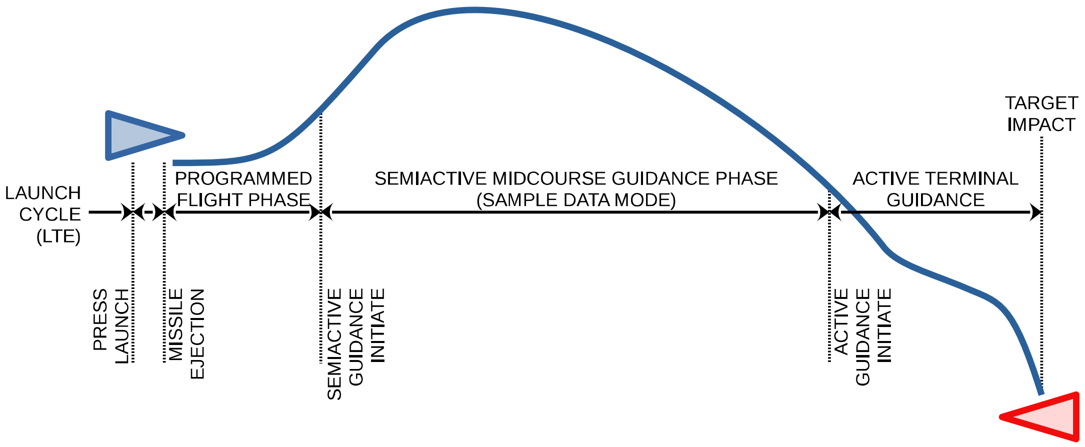


Figure 250: Track-While-Scan - Missile guidance sequence.

- Range While Search is the go-to radar mode for creating and maintaining Situation Awareness. It cannot create tracks, but it is not limited to any combination of Azimuth and Bars, and can display up to 48 contacts on the TID. Therefore, it can be maintained “fully opened” to monitor an impressive amount of airspace, at the cost of a minor reduction in range.
  RWS is usually used until the aircraft is committed and starts the intercept. In this phase the leader usually switches to TWS to get more information about the target, but the wingman maintains his radar to RWS to cover a wide area of space until “Meld” is called (see Chapter 9.7.7) - this modus operandi is a contract that can be changed and depends on the situation.

8.4 ESTIMATE CONTACT’S ALTITUDE

Chapter 8.1 discussed how the antenna can be adjusted to spot a target given its altitude. However, what if the radar mode in use does not provide the altitude? Is such cases, how can the Radar Intercept Officer know the altitude to correlate or communicate the target’s position, or switch from a search radar mode to TWS? What if the TID is not functioning due

to failures or damage?
The same question can be expanded to include those aircraft that let the crew know the antenna angle in use, but do not provide the target's altitude reading.

The AWG-9 WCS features a number of search radar modes: Range While Search provides the target's altitude in a set of intervals displayed on the TID, but Pulse Search and Pulse Doppler Search rely solely on the DDD.
This chapter is a quick look at how the RIO can estimate the altitude of a contact returned by the radar.

8.4.1 LOOK-DOWN, FLY-SAFE

Scenario: our F-14 is flying at 35,000ft, radar fully opened, nothing in RWS nor PSRCH. In PD SRCH, however, the DDD shows a return (Figure 251).

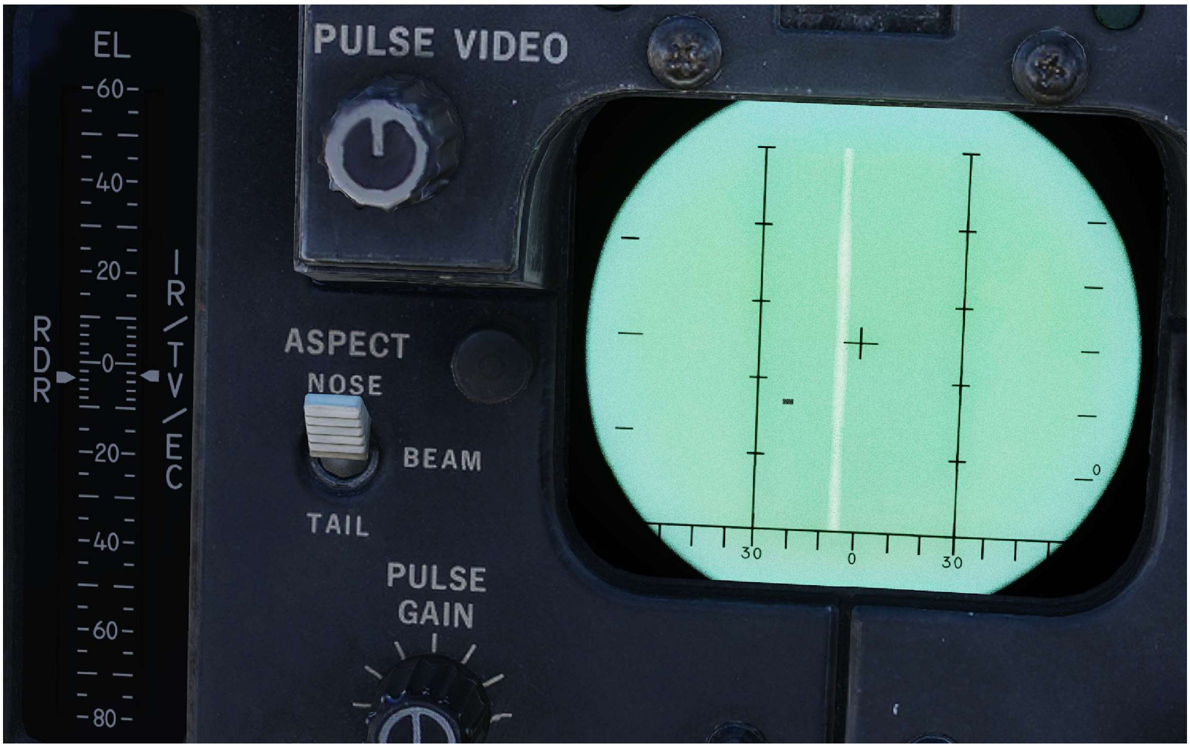


Figure 251: Estimate altitude - Scenario.

In primis, a consideration: at 35,000ft the odds of having other contacts drastically higher and still unnoticed is quite low. Therefore, lowering the antenna angle or apply proper sanitization techniques (Chapter 8.6) is highly recommended. In fact, dealing with lower-altitude targets is a common occurrence, and it is especially important to spot the "leakers" before they can attack our aircraft unseen from below.
This technique works in DCS (especially in simulative scenarios, where the means of "cheating awareness" are limited) and it worked in real life too:

> *On 15 November 1981 the IrAF Mirages managed to shoot down two F-14As by approaching at low altitude before climbing and attacking from below – well outside the envelope of the Tomcat's radars and weapons. This prompted the*

IRIAF to task F-5Es with flying additional low-altitude CAPs in order to cover possible Iraqi ingress routes toward F-14s.

TAGHVAEE, BABAK. IRANIAN TIGERS AT WAR (MIDDLE EAST@WAR).

Back to the scenario, the question therefore is: how high is the contact?

Although Range While Search shows the altitude bracket of the target, if more precision or the antenna angle is require, or Pulse / Pulse Doppler Search is used, no direct indication of the target's altitude is displayed. The avionics, however, has an often overlooked tool that can help the Radar Intercept Officer to answer the question.

8.4.2 THE "EL INDICATOR"

This very handy tool shows two values:

1. the elevation of the antenna as it goes through the scan pattern;
2. the elevation of the sensor in use (normally the radar, but if IR/TV is selected, the TCS).

The first point is what the RIO needs to determine the altitude of the target. The Elevation Indicator is mentioned in the documentation (P-825/02 – see Chapter 10.10.2), it is also the intuitive way of determining the altitude of a contact when the radar operates in Search mode (either Pulse or Pulse Doppler).
I looked for confirmation of this means of employment to Scott "Weird" Altorfer:

Yes, the elevation indicator and some RIO rounding math to figure out the delta altitude.

SCOTT "WEIRD" ALTORFER – F-14A RIO

Note that the RIO may not need the altitude per sé, rather the corresponding antenna elevation to better point the antenna in TWS, and circumvent its limitations.

If the latter is the case, then the Radar Intercept Officer just has to apply the same angle displayed in the left meter when switching to TWS, with a caveat: *the angle displayed on the left does not match the manual setting*, not even when the RIO set 0°, 1 Bar:

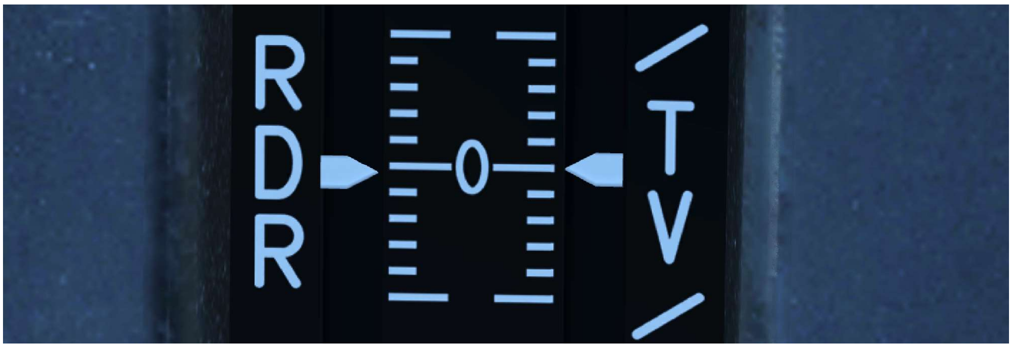


Figure 252: EL Indicator - RDR and Sensor settings.

Note: the reason behind this discrepancy in unknown to me at the moment. The read value is -0.49° (via DCS-BIOS) when the manual setting is 0°, 1 Bar.
It can be due to the fact that the RDR reading represent the bottom of the bar, rather than the bisector of the volume. However, 1 Bar is 2.3° ("half bar" = 1.15°), and 0.5° does not sound related.
In fact, I create a test scenario, with my F-14 flying at 15,000ft, two other 20nm in front flying at ±2,000ft. According to my chart, ±0.9° is necessary to see both aircraft; however, I was able to see only the lower one, flying at 13,000ft. This means that the EL Indicator is actually correct, and the volume is slightly pointing downwards.
Moreover, the angle is not constant, and changes depending on the manual setting.
I am investigating this further.

Figure (253) shows the detail of the "*EL Indicator*": t he right-hand meter shows that the elevation setting is now circa -2°, whereas the left-hand meter tells where the antenna is at the moment. The reading is a bit more than -3.5°, let's say circa -3.7°. Due to the previous considerations, let's grind 0.5° from it, obtaining -3.2°.

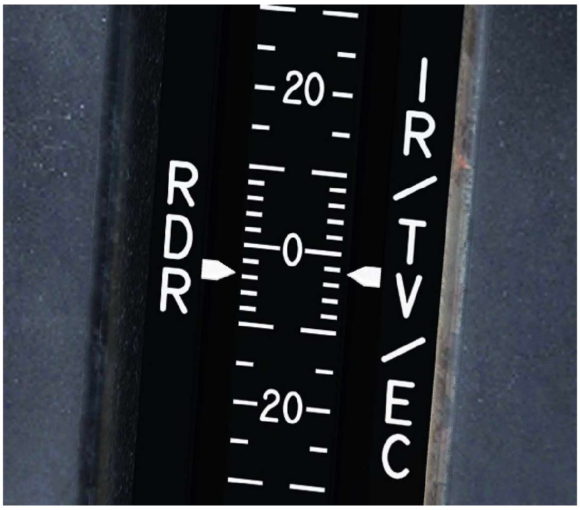


Figure 253: Estimate altitude - "EL Indicator".

Once the correct elevation is known, the rest is the opposite of that was discussed in Chapter 8.1: the altitude of the F-14 is known, the elevation angle is known; finding the target's altitude is straightforward.

8.4.3 ALTITUDE ESTIMATION USING MATHS

Using the same nomenclature used in Figure 243, we have:

$$a = b * \tan(\beta)$$

where *a* is the altitude difference, *b* the range and *β* the elevation angle.

The range in PD SRCH is unknown, but we can approximate it: we know the target is probably a fighter, otherwise it would be displayed in RWS. Fighters, even the smallest, are usually displayed when closer than ~80nm. Saying that the range is about 90nm is usually a good bet. Moreover, a further target may not be displayed at all, and the further we are, the less the imprecisions impact the outcome. On top of that, the mission briefing can help to assess the type of aircraft: if the mission is set in the early 80s, chances are that most of REDFOR is using MiG-23 or MiG-21, and not big Sukhoi Su-27, for example.

Therefore, in this scenario:

$$a = b * \tan(\beta) = 90 \tan(3.7) = 5.03\, nm$$

5.03 nm, which in feet is equal to 30600 ft. Since the F-14 is flying at 35,000ft, it means that the contact is flying quite low to the ground, probably between 30,000ft ±5,000ft.

Let’s verify in-game.
Figure 254 shows the details of the contact. The range was 105 nm. The altitude is within the bracket, so it’s not too bad.

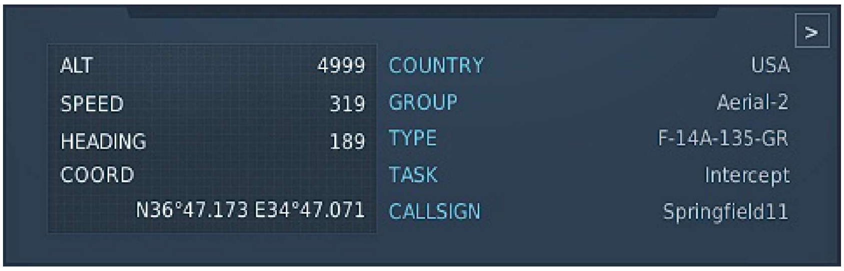


Figure 254: Estimate altitude - Contact's details.

OBSERVATIONS

To recap, it is worth noting that the EL Indicator tells which bar is spotting the contact, not the contact’s altitude, and the wider the range, the “taller” each bar is, so the imprecision is greater.
Therefore, using maths to solve the dilemma sounds rather pointless, as the magnitude of the estimation is not irrelevant at all.

8.4.4 ALTITUDE ESTIMATION VIA KNEEBOARD CHART

As the previous and “rigorous” attempt as demonstrated, estimating the altitude via the Bars set is not a precise operation.
Therefore, since a very accurate altitude value is not obtainable, why not minimize the time spent by using a different tool? The first option would be by reversing the mnemonic formula equation discussed in Chapter 8.1.2. However, a much quicker one is looking at the *Antenna Elevation chart* contained in the Kneeboard Pack (note that the version below is extended, for the sake of this example).

ANTENNA ELEVATION

	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	90	100
1000	1.9	0.9	0.6	0.5	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
2000	3.8	1.9	1.3	0.9	0.8	0.6	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2
3000	5.6	2.8	1.9	1.4	1.1	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3
4000	7.5	3.8	2.5	1.9	1.5	1.3	1.1	0.9	0.8	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4
5000	9.3	4.7	3.1	2.4	1.9	1.6	1.3	1.2	1.0	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5
6000	11.2	5.6	3.8	2.8	2.3	1.9	1.6	1.4	1.3	1.1	1.0	0.9	0.9	0.8	0.8	0.7	0.6	0.6
7500	13.9	7.0	4.7	3.5	2.8	2.4	2.0	1.8	1.6	1.4	1.3	1.2	1.1	1.0	0.9	0.9	0.8	0.7
9000	16.5	8.4	5.6	4.2	3.4	2.8	2.4	2.1	1.9	1.7	1.5	1.4	1.3	1.2	1.1	1.1	0.9	0.8
10000	18.2	9.3	6.3	4.7	3.8	3.1	2.7	2.4	2.1	1.9	1.7	1.6	1.5	1.3	1.3	1.2	1.0	0.9
12500	22.4	11.6	7.8	5.9	4.7	3.9	3.4	2.9	2.6	2.4	2.1	2.0	1.8	1.7	1.6	1.5	1.3	1.2
15000	26.3	13.9	9.3	7.0	5.6	4.7	4.0	3.5	3.1	2.8	2.6	2.4	2.2	2.0	1.9	1.8	1.6	1.4
17500	29.9	16.1	10.9	8.2	6.6	5.5	4.7	4.1	3.7	3.3	3.0	2.7	2.5	2.4	2.2	2.1	1.8	1.6
20000	33.4	18.2	12.4	9.3	7.5	6.3	5.4	4.7	4.2	3.8	3.4	3.1	2.9	2.7	2.5	2.4	2.1	1.9
25000	39.5	22.4	15.3	11.6	9.3	7.8	6.7	5.9	5.2	4.7	4.3	3.9	3.6	3.4	3.1	2.9	2.6	2.4
30000	44.6	26.3	18.2	13.9	11.2	9.3	8.0	7.0	6.3	5.6	5.1	4.7	4.3	4.0	3.8	3.5	3.1	2.8
35000	49.0	29.9	21.0	16.1	13.0	10.9	9.3	8.2	7.3	6.6	6.0	5.5	5.1	4.7	4.4	4.1	3.7	3.3

Figure 255: Antenna Elevation extended chart.

Using figure 255 and the parameters discussed above (range 90 nm, elevation angle 3.7° → 3.2°), we find that altitude difference should be about 30,000ft ± 5,000ft. The problem, again, is the fact that 8 bars, at 80nm, cover 55,000ft in vertical volume. Considering that the bars overlap and that the range is higher than 80 nm, it is easy to understand why ±5000 ft is the bare minimum altitude interval to consider.

8.4.5 A MORE REALISTIC SCENARIO

If the example just described is very theoretical, there is a more concrete, yet niche, application.

Pulse Search radar can be used as a follow-up means to monitor a target that successfully defended from an AIM-54, or it is simply beaming, when feet-dry.
Depending on the intentions of the crew and other factors, a PSTT lock is often a viable option. However, in case the crew wants to avoid alerting the target and "pretend" that the defensive manoeuvre is successful, then the STT lock should be avoided.
Pulse Search provides ATA and Range, but the altitude cannot be established without a solid lock. This is where the EL Indicator can be used to estimate the altitude and communicate with the controller and/or wingman, in order to increase the awareness of the flight.

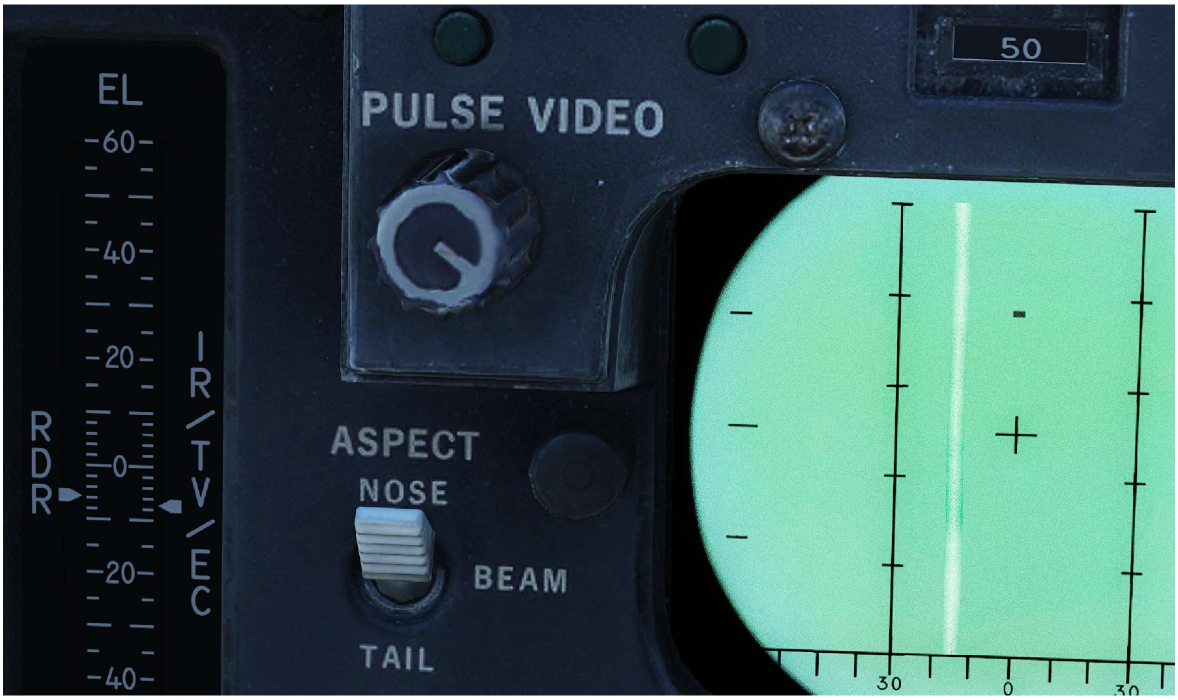


Figure 256: Estimate Altitude - PSRCH example.

Rather than the clunky mathematical procedure, the RIO can eyeball the angle as the antenna sweeps through, take a peek at the elevation chart, and assess the altitude. Since the range is provided by the DDD, the estimation is quick and fairly precise.

The angle looks to be slightly more than 5°. Considering what was said about the default antenna elevation, let's consider it to be ~4.5°. The range is slightly short of 40 nm. The F-14 is flying at 25,000ft.
Let's check the chart.

ANTENNA ELEVATION

	5	10	15	20	25	30	35	40
1000	1.9	0.9	0.6	0.5	0.4	0.3	0.3	0.2
2000	3.8	1.9	1.3	0.9	0.8	0.6	0.5	0.5
3000	5.6	2.8	1.9	1.4	1.1	0.9	0.8	0.7
4000	7.5	3.8	2.5	1.9	1.5	1.3	1.1	0.9
5000	9.3	4.7	3.1	2.4	1.9	1.6	1.3	1.2
6000	11.2	5.6	3.8	2.8	2.3	1.9	1.6	1.4
7500	13.9	7.0	4.7	3.5	2.8	2.4	2.0	1.8
10000	18.2	9.3	6.3	4.7	3.8	3.1	2.7	2.4
12500	22.4	11.6	7.8	5.9	4.7	3.9	3.4	2.9
15000	26.3	13.9	9.3	7.0	5.6	4.7	4.0	3.5
17500	29.9	16.1	10.9	8.2	6.6	5.5	4.7	4.1
20000	33.4	18.2	12.4	9.3	7.5	6.3	5.4	4.7
25000	39.5	22.4	15.3	11.6	9.3	7.8	6.7	5.9
30000	44.6	26.3	18.2	13.9	11.2	9.3	8.0	7.0
35000	49.0	29.9	21.0	16.1	13.0	10.9	9.3	8.2

Figure 257: Estimate Altitude - Chart: Example #2.

A close approximation is 18000ft ± a certain buffer (at this range, probably about 2,500ft).