THE FIGHTER COLLECTION

Eagle Dynamics

A-10A WARTHOG

A-10A: DCS Flaming Cliffs

Flight Manual

INTRODUCTION

Thank you for your purchase of A-10A: DCS Flaming Cliffs. This simulation is an outgrowth of our Flaming Cliffs series that provides great graphics and flight models, yet has a more shallow learning curve than some of our other DCS titles like the A-10C, Ka-50 and P-51D. While this A-10A retains the cockpits functionality of the A-10A from the Flaming Cliffs series, it adds a very advanced flight model.

Key features of the A-10A: DCS Flaming Cliffs include:

- Detailed and accurate 3D model and animations
- Six Degrees of Freedom (6DOF) capable cockpit
- Advanced Flight Model (AFM)
- Campaign and missions
- A-10A skins from a wide array of squadrons
- "Game" modes for more relaxed gameplay

Perhaps most important, as part of DCS World, the A-10A: DCS Flaming Cliffs operates in the regularly updated DCS World and is fully compatible with other DCS titles online.

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ABOUT THE A-10A

Identifying the Need

The need for the A-10 germinated from the experience of U.S. forces in the Vietnam War. While fast jets like the F-100, F-4 and F-5 could provide Close Air Support (CAS) to troops in emergency situations, their lack of loiter time, high speeds, and weapon delivery inaccuracy proved problematic and an expensive solution. On the other hand, slower aircraft like the U-10 and OV-10 lacked the firepower punch needed. This criticism resulted in charges that the U.S. Air Force did not take close air support seriously and a few high-level service members sought a specialized attack aircraft to remedy this.

The A-1 Skyraider was used to fill this CAS and Combat Search and Rescue (CSAR) role, and its ruggedness, large weapon loads and loiter capability proved to be a success in Southeast Asia. However, it was not deemed survivable enough in a European battlefield scenario.

Figure 1. The A-1 Skyraider

During the Vietnam War, the primary threat to CAS mission aircraft was small arms, surface-to-air missiles, and low-level anti-aircraft gunfire. This resulted in a desire for a much more survivable aircraft operating in the CAS environment. The primary environment was still considered Europe at the time, and such an aircraft would need to be survivable operating over Warsaw Pact forces with an extensive array of air defense weaponry.

In addition to the then current fast and slow Air Force attack aircraft, CAS supporting UH-1 and AH-1 gunships did not have the capability to effectively engage enemy armor forces in a feared mechanized Soviet thrust through Western Europe.

Given these items, the Air Force was looking for the following in a replacement for the A-1:

- Rugged and survivable
- Long-loiter capability
- Ability to carry large weapon loads including anti-armor
- Excellent slow speed agility
- Relatively short takeoff and landing rolls

Given the projected dense Warsaw Pact Integrated Air Defense System (IAS) threat, it was also determined that the flight profile of this aircraft would need to be very near and over the battlefield in order to maximize the use of terrain masking. This led to the requirement focusing on low- to mid-altitude operations at the exclusion of high-altitude flight profiles.

The A-X Competition

In June 1966 the Attack Experimental (A-X) program was launched and the requirement issued in September of the same year. The Request For Proposal (RFP) was issued by the Air Force to 21 defense contractors on March 6, 1967. By 1969, the characteristics of a target weight of 35,000 lbs, $1 million per aircraft, and using twin high-bypass fanjets was determined. The performance requirements were set as follows:

- Turbofans generating between 31.1 and 44.5 kN
- Combat mission radius of 250 nm
- Two hour mission loiter time at max mission radius with 9,500 lbs payload
- 4,000 ft takeoff distance
- Highly maneuverable below 1,000 ft
- Easy to maintain at Forward Operating Bases (FOB)
- Low cost
- Ability to use integrated 30 mm cannon to destroy main battle tanks
- Use of off-the-shelf hardware whenever possible to reduce costs

Moving away from the earlier fixed-price contract, it was decided to pursue a Fly-Before-Buy policy when choosing the A-X. As such, competitive RFP contracts were issued to 12 companies on May 7, 1970 with the intent to purchase 600 aircraft at a price of $1.4 million each (fly away cost). Of the 12 companies, Northrop and Fairchild Republic were selected as the winners of the prototype competition on December 18, 1970. Each company would build two prototypes. The Northrop entry would be designated the YA-9 and the Fairchild Republic would be designated the YA-10.

Figure 2. YA-10A

Figure 3. YA-9A

At the hands of test pilot Howard "Sam" Nelson, the YA-10 made its maiden flight from Edwards AFB on May 10, 1972. The YA-10A was initially fitted with an M61A1 20 mm cannon that would later be replaced in production aircraft with the GAU-8/A 30 mm cannon.

The competition between the two prototypes lasted between October 10, 1972 and December 9, 1972. At the conclusion of the faceoff, the YA-10 came out on top despite both aircraft exceeding requirement specifications. This was due to:

- Most of the test pilots generally preferred the flying qualities of the YA-10 over the YA-9
- Less roll inertia
- Ease of access to the under-wing hardpoints
- Shorter estimated transition from prototype to production model
- Use of the existing TF-34 engine that had already been in use with the U.S. Navy S-3 Viking
- Better system redundancy / survivability

The YA-10 was announced the winner on January 18, 1973. It is interesting to note that the losing YA-9A bears a striking resemblance to the Russian-developed Su-25 CAS aircraft that has seen service world-wide in large numbers. This is a testament to the excellent design of both contenders.

If you are interested in the Su-25, we suggest flying our simulation of the Su-25T in "Lock On: Platinum", available at your local retailer.

Production

After the pre-production $159.2 million contract was signed on March 1, 1973, 10 pre-production YA-10s went into construction by Fairchild Republic. In parallel, General Electric was funded to provide slightly modified TF34 engines. The modified engine is hardier and became designated the TF34-GE-100A. While there has been discussion updating the engines of the A-10, the TF-34-100A has proved a reliable and durable engine for the past 40 years.

Responding to a congressional recommendation, the Air Force was asked to evaluate the new YA-10 against the existing A-7D Corsair II. Between April 16 and May 10, 1973, the two aircraft squared off at

McConnell AFB by experienced Air Force pilots to evaluate which aircraft was better suited to the initial A-X requirements. At the end of the second evaluation fly-off, the YA-10 was again deemed to be the better aircraft for the mission due to:

- More survivable
- More lethal with the to-be-fitted 30 mm cannon
- Less expensive to operate
- Significantly longer loiter times. Two hours versus only 11 minutes of the A-7D!

Figure 4. A-10A in earlier camouflage

The first pre-production YA-10 entered testing in February of 1975 and included several changes from the two prototype aircraft that took part in the fly-off competitions (YA-9 and A-7D). During this time, the number of pre-production aircraft was reduced by four due to budget constraints. These changes included:

- Added leading edge slats for improved airflow to engines at higher angles of attack
- Added trailing edge fairings
- Wing span slightly increased
- Maximum flap deflection was reduced
- Vertical stabilizers were reshaped
- Aerial refueling receptacle was added to the nose
- Added an integrated boarding ladder
- Gun boresight was reduced 2-degrees for better over-the-nose aiming
- A pylon on the right side of the forward fuselage was added to carry the Pave Penny pod laser spot tracker

The six pre-production aircraft created were each tasked to specific areas of the aircraft flight test program:

- Aircraft No. 1, 73-1664. Performance and handling
- Aircraft No. 2, 73-1665. Weapon certification
- Aircraft No. 3, 73-1666. Sub-systems and weapon delivery
- Aircraft No. 4, 73-1667. Operational test and evaluation
- Aircraft No. 5, 73-1668. Independent Initial Operational and Evaluation (IOT&E) and stores certification
- Aircraft No. 6, 73-1669. Climate test certification

Note: Aircraft No. 6 was lost due to gun gas ingestion that flamed out both engines. This was later rectified in production aircraft.

The first production A-10A flew on October 10, 1975, and along with the next three production aircraft, took part in the flight testing effort. Due to the reduction in test aircraft from 10 to 6, the first operational A-10A was delivered five months behind schedule to the 355th Tactical Fight Wing (TFW) in March 1976. By today's standards, not much of a delay! The 355th conducted final operational tests and brought the A-10A to Europe for the first time for air shows and NATO exercises. 355th A-10As went on to put the new aircraft through its paces during Operation Jack Frost arctic exercise, Red Flag, and the Joint Attack Weapon System (JAWS) trials.

Figure 5. A-10A at JAWS Trials

At the delivery of the 100th A-10A, the Pentagon christened the aircraft the Thunderbolt II. However, in the tradition of the F-84 nickname "Groundhog", the F-84F "Superhog" and the F-105 "Ultra-Hog", the A-10A community nicknamed the A-10A the "Warthog" or just "Hog" for short. This nickname tradition coupled with the not-so-graceful lines of the A-10A was quite apt.

In an effort to create a night-attack all-weather version of the A-10, Department of Defense (DoD) and Fairchild Republic converted pre-production aircraft No. 1 to create the YA-10B Night/Adverse Weather (N/AW) prototype. It included a second seat for a weapons system officer responsible for ECM, navigation and target acquisition. The vertical stabilizers were also extended. A Forward Looking Infrared (FLIR) pod was to be mounted on the right side of the fuselage and a ground mapping radar on the left side. In the event the Air Force lost interest, it was also proposed as a combat-trainer for the A-10. The variant was ultimately canceled and the only two-seat A-10 built now sits at Edwards Air Force Base.

In total, 715 A-10s were produced, the last delivered in 1984.

Figure 6. A-10 in current operational colors

A-10 Evolution

The A-10 has received many upgrades over the years.

Initial aircraft were upgraded with the Heading Attitude Reference Systems (HARS) that provided basic inertial navigation and the Pave Penny laser sensor (marked target seeker) pod that allowed the pilot to detect laser energy for PID (Positive Identification) of an illuminated target. The Pave Penny is a passive seeker and cannot self-designate a target for a Laser Guided Bomb (LGB). Pave Penny control is done through the Target Identification Set, Laser (TISL) panel in the cockpit. Although Pave Penny functions have largely been replaced in modern A-10s by the targeting pod, the system and capability remain.

The first major upgrade to the A-10A fleet was the Low-Altitude Safety and Targeting Enhancement (LASTE). LASTE provided computerized weapon-aiming equipment, a Low Altitude Autopilot (LAAP), and ground-collision warning system (GCAS). LASTE updated aircraft evolved over several forms including LASTE v4.0 and LASTE v6.0 with and without embedded INS GPS (EGI) navigation.

Figure 7. A-10A Cockpit

A-10 Missions

In the 30+ years of operational service, the A-10 mission has continued to evolve to meet ever-changing mission requirement and battlefield complexities. Meeting the initial A-X requirements, the A-10 was initially focused on Close Air Support (CAS) of friendly troops in contact with Warsaw Pact forces in the event of the Cold War going hot. However, with actual A-10 combat operations in the Persian Gulf, the Balkans, and Afghanistan, the initial low-altitude CAS mission changed dramatically.

Given the much greater air defense threat at low-altitude compared to medium altitude, A-10 operations generally moved to medium altitude (12,000 to 20,000 ft) to minimize the threat from Anti-Aircraft Artillery (AAA) and Man Portable Surface to Air Missiles (MANPAD). This was made possible due either to a lack of credible medium to high altitude air defense threats and/or sufficient friendly support assets to neutralize the threat. As such, most of the A-10s combat use has been above 12,000 ft with excursions to lower altitude to employ weapons (strafing and CCIP rocket/bomb delivery). Today's A-10C in particular and use a combination of the Litening II AT targeting pod with precision-guided bombs and missiles to attack from medium altitudes and stand-off ranges to avoid low-altitude threats.

Working from these altitudes in such a manner, the A-10C has four general types of missions in can conduct:

Close Air Support (CAS)

As the initial mission of the A-10, this is what it was designed to do… provide direct support to friendly ground forces in contact with the enemy. Although this was originally envisioned as NATO forces holding off a Warsaw Pact advance, today CAS is a common mission for A-10C crews supporting allied forces in Iraq and Afghanistan. Often A-10C crews will be tasked to eliminate hostile forces within "danger close" range of friendly units. The updates to the A-10C of the better integrated targeting pod and the SADL datalink system provide an improved level of coordination and weapon employment accuracy to avoid tragic blue-on-blue, friendly fire incidents.

Paramount of effect CAS support is the Joint Terminal Attack Controller (JTAC) on the ground with friendly troops. It is the JTAC mission to coordinate with the A-10C pilot to effectively and accurately deliver weapons exactly on the directed target to best support the friendly ground forces in contact with the enemy. With the integration of the datalink, a JTAC can now send digital tasking onto the moving map display and a text message. However, this does not preclude the traditional verbal directions over a radio to talk the pilot's eyes onto the intended target.

Battlefield Air Interdiction (BAI)

The goal of BAI is to use airpower to attack enemy forces behind the front line that are not in contact with friendly forces. This can include rear echelon reinforcements, artillery/rocket system, logistics, and lines of communication. Depending on how far the target is behind the front line, there are generally two levels of BAI: Deep Interdiction against targets far behind the front line that generally consisted of logistical, command and control, line of communication, and Petroleum, Oil, Lubricants (POL) targets; and Battlefield Interdiction target targets second-echelon forces behind the front line that are currently not in contact with friendly ground forces.

For many years the A-10 was relegated to Battlefield Interdiction while other aircraft such as the F-15E, F-16, F-117, and F-111 took the Deep Interdiction missions. However, this has gradually changed and now BAI mission assignments are based on weather, target type, expected threats, and terrain. As such, more and more A-10s are assigned both types of BAI missions.

Because targets are well behind the front line, contact with a JTAC is rare except when tasked by a Special Forces team behind enemy lines.

Or combat operations like Desert Storm and Allied Force, this was the most common type of mission. In ODS, A-0 crews were often assigned "Kill Boxes" to hunt for and destroy enemy units. In OAF, there was a similar target area assignment, but also target handoff from an Airborne Forward Air Controller (AFAC).

Airborne Forward Air Controller (AFAC)

Much like a JTAC tasks a CAS-assigned aircraft to a specific target, the AFAC performs the same role but from the cockpit of an aircraft. Unlike a JTAC that this is most often assigning CAS strikes, the AFAC often performs the dual function of assigning both CAS and BAI attacks. Clear examples of this can be seen in the AFAC role the A-10 often played in coordinating BAI strikes in the Balkans, where as the A-10 AFAC role in Iraq and Afghanistan was for often are tasking CAS strikes supporting friendly troops in contact.

When an A-10 is performing the AFAC role, it is termed an OA-10. There is no real difference between an A-10 and an OA-10 other than the mission and the OA-10 will generally have an AFAC payload consisting of Willy Pete marker rockets and several weapons. An A-10 that is dual tasked for CAS/BAI and AFAC is sometimes referred to as an A/OA-10 or a "Killer Scout".

With the addition of the Litening II AT targeting pod, the A-10 is a much more capable AFAC that can operate day or night. Previously, nighttime AFAC could be problematic and relied solely on the use if night vision goggles (NVG). For day time AFAC, the older OA-10 models had to use binoculars.

Along with the targeting pod, the SADL datalink allows the OA-10 to digitally transmit target locations to other aircraft on the network as well as sending clarifying text messages. Of course, the verbal "talk on" is also available over the radio.

Combat Search and Rescue (CSAR)

When an aircrew goes down behind enemy lines, an A-10 flight is a crucial part of the package that will go in to retrieve him or her. In the CSAR role, the A-10 will often be the on-site coordinating party responsible for the extraction operation. Additionally, the A-10 will have responsibility for attacking enemy forces threatening the rescue helicopters and enemy ground forces closing in on the position of the downed pilot.

During operations of Serbia and Kosovo, both CSAR operations where run from the cockpit of an A-10.

Operational Use

The first operational unit to receive the A-10 was the 355th Tactical Training Wing, based at Davis-Monthan Air Force Base in Arizona in March of 1976. The first unit to achieve full combat-readiness was the 354th Tactical Fighter Wing at Myrtle Beach AFB, South Carolina in 1978. Deployments of A-10s followed at bases both at home and abroad. A-10s are deployed with active duty, Reserve, and Air National Guard (ANG) squadrons. Current operators of the A-10 as of mid-2009 include:

Figure 8. 25th Fighter Squadron 'Assam Draggins', 51st Fighter Wing (PACAF), Osan AB, Republic of Korea, Tailcode OS

Figure 9. 47th Fighter Squadron (Training), 917th Wing (ACC), Barksdale AFB, Louisiana, Tailcode BD

Figure 10. 74th Fighter Squadron 'Flying Tigers', 23rd Fighter Group, 23rd Wing (ACC), Moody AFB, Georgia, Tailcode FT

Figure 11. 75th Fighter Squadron 'Tiger Sharks', 23rd Fighter Group, 23rd Wing (ACC), Moody AFB, Georgia, Tailcode FT

Figure 12. 81st Fighter Squadron 'Panthers', 52nd Fighter Wing (USAFE), Spangdahlem AB, Germany, Tailcode SP

Figure 13. 103rd Fighter Squadron, 111th Fighter Wing (Pennsylvania ANG), Willow Grove ARS, Pennsylvania, Tailcode PA

Figure 14. 104th Fighter Squadron, 175th Wing (Maryland ANG), Martin State AP Air Guard Station, Baltimore, Maryland, Tailcode MD

Figure 15. 107th Fighter Squadron, 127th Wing (Michigan ANG), Selfridge ANGB, Michigan, Tailcode MI

Figure 16. 172nd Fighter Squadron, 110th Fighter Wing (Michigan ANG)
Battle Creek ANGB, Michigan, Tailcode BC

Figure 17. 184th Fighter Squadron, 188th Fighter Wing Flying Razorbacks (Arkansas ANG), Fort Smith Regional Airport, Fort Smith, Arkansas, Tailcode FS

Figure 18. 190th Fighter Squadron, 124th Wing (Idaho ANG), Boise ANGB, Idaho, Tailcode ID

Figure 19. 303rd Fighter Squadron, 442nd Fighter Wing (AFRC), Whiteman AFB, Missouri, Tailcode KC

Figure 20. 354th Fighter Squadron 'Bulldogs', 355th Fighter Wing (ACC), Davis Monthan AFB, Arizona, Tailcode DM

Figure 21. 357th Fighter Squadron 'Dragons' (Training), 355th Fighter Wing (ACC), Davis-Monthan AFB, Arizona, Tailcode DM

Figure 22. 358th Fighter Squadron 'Lobos' (Training), 355th Fighter Wing (ACC), Davis Monthan AFB, Arizona, Tailcode DM

Figure 23. 66th Weapons Squadron, Nellis AFB, Nevada, Tailcode WA

Figure 24. 422nd Test & Evaluation Squadron, Nellis AFB, Nevada, Tailcode OT

Operation Desert Storm

In 1991 the 23rd , 354th and 917th Tactical Fighter Wings (TFW) deployed to King Fahd International Airport and Al Jouf airfields in Saudi Arabia to support Operation Desert Storm (ODS). Consisting of 144 A-10s, the A-10 deployment contributed 16.5% of total coalition sorties during ODS.

The primary focus of A-10 operations was the seven Iraqi Republican Guard divisions along the Iraq-Kuwait border. The goad of this effort was to dramatically reduce the combat effectiveness of these divisions before the coalition ground assault.

Figure 25. A-10A in Operation Desert Storm

Some of the more remarkable statistics the A-10 achieved are:

- 987 Iraqi tanks destroyed
- 501 armored personnel carriers destroyed
- 249 command and control vehicles destroyed
- 1,106 trucks destroyed
- 926 artillery pieces destroyed
- 96 radars destroyed
- 72 bunkers destroyed
- 50 AAA sites destroyed
- 28 command posts destroyed
- 11 MRL destroyed
- 10 parked aircraft destroyed
- 9 SAM sites destroyed
- 2 helicopters destroyed with the GAU-8/A gun
- 19,545.6 hours / 8,755 sorties
- 7,445 weapons delivered
- 98.87% mission reliability rate

Most mission days consisted of three missions over an 8-hour period. However, mission days were expanded to 10-hour flying day when A-10s where tasked for "Scud Hunting" duties in the western desert.

Figure 26. A-10's kills

In addition to BAI and "Killer Scout" missions, A-10s also maintained CSAR strip alert.

Both wings had one squadron assigned to night sorties and this often comprised the use of night vision goggles and using the seeker from an Infrared Imaging (IIR) AGM-65D Maverick to hunt for targets at night.

The strong contribution of the A-10 in ODS contributed in a large way to the Air Force reversing its decision to phase out the A-10 and replace them with a CAS version of the short-legged, drop-two-bombs, and run F-16.

Operation Allied Force

The A-10 saw its next combat in 1999 when the 81st FS deployed to Aviano AB in Italy in support of Operation Joint Forge. With a deployment of 15 aircraft by 23 March, combat operation over Kosovo commence with the goal of removing all Serbian forces from Kosovo. This marked the start of Operation Allied Force.

Figure 27. A-10 Thunderbolt II at Gioia del Colle, Italy, for a NATO Operation Allied Force mission on April 12, 1999

On March 27, A-10s from the 81st FS led the CSAR effort to retrieve the downed F-117 pilot.

In early April of 1999, A-10s conduct their first successful attacks. A-10s were tasked with a combination of both CAS and AFAC duties. Whereas F-16 units provided nighttime AFAC, A-10 units provided daytime AFAC support to coalition aircraft operating over Kosovo. Also in April, the 81st FS did a remarkable and rapid re-deployment from Aviano AB to Gioia del Colle AB in southern Italy and elements of the 74th FS from Pope AFB were co-deployed with the 81st FS. This relocation placed A-10 units much nearer to Kosovo and increased their mission effectiveness.

Near the end of the operation, the 103rd, 172nd, and 190th FS deployed to the region in support of the operation.

During the course of the operation, A-10 units accounted for the destruction of more Serbian deployed weapons than any other aircraft. Additionally, the A-10 in its CSAR role was a large part of why now downed allied pilot was ever captured. Although two A-10s received battle damage, not a single one was lost to enemy fire.

As with ODS, OAF showed that the A-10 could be an effective platform in today's battlefield.

Current Operations in Iraq and Afghanistan

Following the events of 9/11, US forces conducted combat operation in Iraq (Operation Iraqi Freedom) and in Afghanistan (Operation Anaconda).

In support of Operation Iraqi Freedom, 60 National Guard and Reserve A-10s from various squadrons were deployed to the region in support of the initial ground offensive. Despite losing one aircraft to hostile fire late in the operation, A-10s provided valuable CAS to rapidly advancing forces and contributed to the rate of advance. In addition to traditional CAS operations, A-10 units also conducted BAI along the line of advance. A-10 units concluded the operation with a 85% mission capable rate and fired 311,597 rounds of 30 mm gun ammunition. In late 2007, the Maryland ANG 104th FS took the A-10C into combat for the first time.

Figure 28. A-10 Thunderbolt II maintenance members inspect aircraft after it was hit by an Iraqi missile

A-10 operations in Afghanistan have been operating from Bagram airfield and a continual rotation of A-10 squadrons has conducted operations from Bagram to locations all around Afghanistan. More so than ODS and OAF, A-10 operations in Afghanistan have focused heavily on CAS and AFAC missions. As with the Iraqi theater, the A-10C has been also been deployed operationally to Afghanistan.

GENERAL DESIGN

The A-10A/C is a fixed-wing, single-pilot aircraft with two high bypass turbofan engines that is optimized for the Close Air Support (CAS) combat mission. Originally designed to counter a mass-Soviet armor thrust across Europe, the A-10 was designed from the ground up to be the most survivable and potent CAS aircraft over a very deadly battlefield.

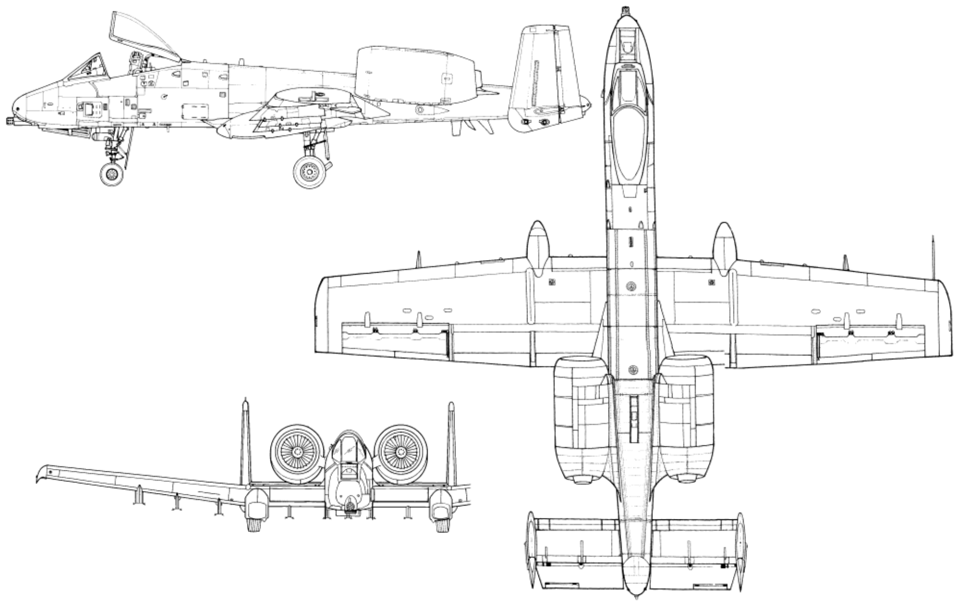


Figure 29. A-10A

In this chapter, we will discuss the various design components of the A-10 and how they contribute to its combat mission.

Fuselage and Wings

The A-10 uses stressed, machined skin panels to cover the fuselage and wings. A system of ribs, spars and bulk heads in turn strengthen the internal assembly to provide a rigid and robust structure.

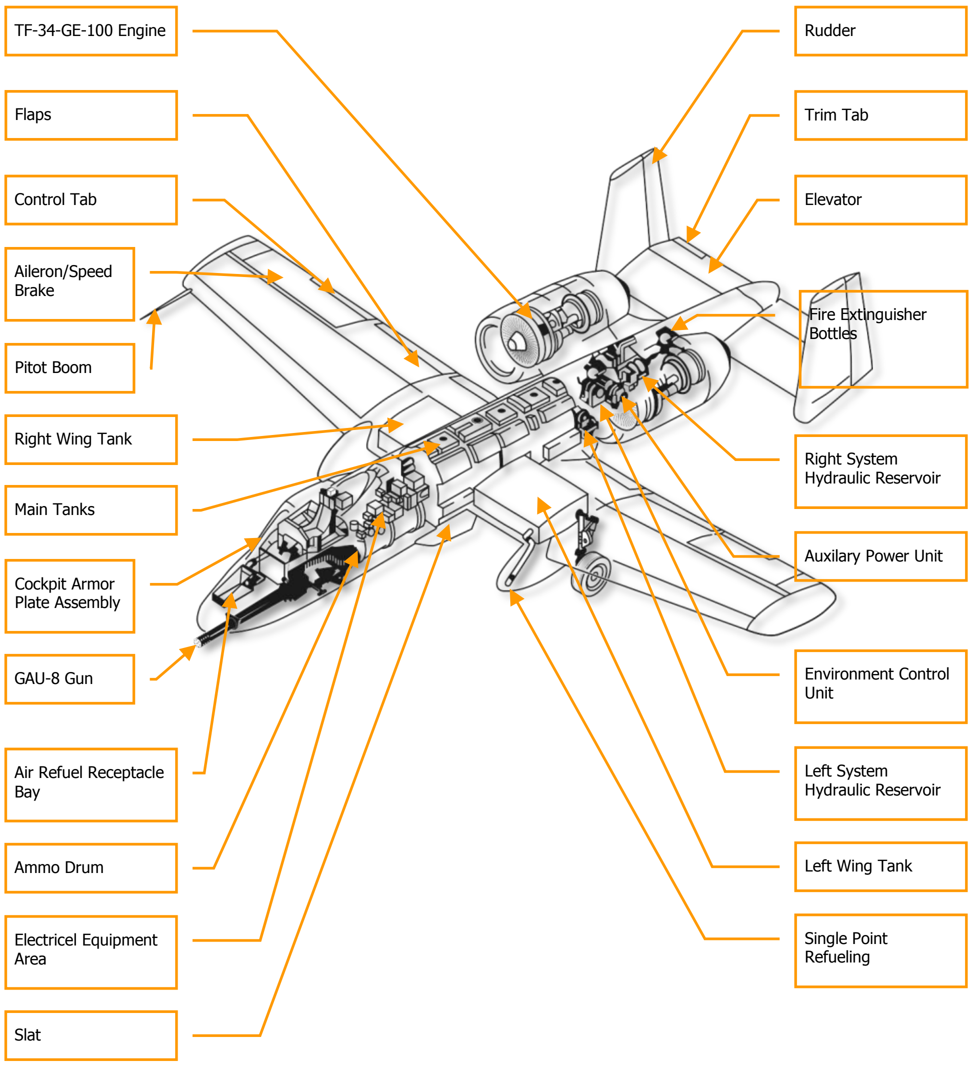


Figure 30. General A-10 Design Features

Fuselage

The most forward section of the fuselage houses the GAU-8/A 30 mm gun barrels and firing mechanism that extend back behind the cockpit. Alongside of the gun barrels is the nose gear that is installed right of centerline. This allows the gun to be mounted centrally along the fuselage for increased accuracy. The nose gear retracts fully into the fuselage. The cockpit sits high over the gun and nose gear bay and consists of a retractable Plexiglas canopy, a zero-zero ejection seat, and the various cockpit controls and instrumentation. The high, forward position of the cockpit provides excellent visibility over the nose. Additionally, the forward fuselage houses multiple avionics bays, the aerial fueling receptacle, and other equipment.

The center section of the fuselage contains the forward and aft fuselage fuel tanks. Along the lower surface of the center fuselage are the hard points for store stations 5, 6 and 7. Loading on stations 5 and 7 is exclusive to loading on station 6. Generally, station 6 is only loaded with the TK600 external fuel tank.

The aft portion of the fuselage has the two primary functions of mounting the two engine nacelles and the attachment point to the elevator and rudder control surface assemblies. Mounted on either side of the aft fuselage spine are the two nacelles for the TF-34-GE-100 engines. Between the nacelles and inside the fuselage are Auxiliary Power Unit (APU), the left and right hydraulic system reservoirs, and the Environmental Control Unit (ECU).

Wings

The wings of the A-10 are of the low-mounted straight design and provide low wing loading. This provides excellent maneuverability and a low stall speed. However, it does limit the A-10 to pedestrian speeds compared to other fighter aircraft. This does provide the A-10 the ability to better loiter over the battlefield in both regards to endurance and more easily stay over a CAS assigned target area. The wings have Hoerner wingtips that reduce induced drag and wingtip vortices. They also improve aileron effectiveness at low speeds.

Figure 31. A-10 maintenance

At the base of the left and right wing are the left and right wing fuel tanks. Additionally, TK600 fuel tanks can also be mounted on wing stations 4 and 8. Fuel is first depleted from any external tanks and then the wing tanks. As with the fuselage tanks, the tanks are self-sealing and filled with a flexible foam to prevent a fuel tank explosion. Note that the external tanks do not have such precautions and are never flown with in combat.

On the inside leading edge of the wings are the slats that automatically deploy according to Angle of Attack (AoA). They only have two positions and are deployed down to improve air flow to the engines at high AoA. This is governed by the Emergency Stall Prevention System (ESPS).

On the side trailing edge of the wings are the flaps. The flaps are generally manually controlled from the flap lever on the throttle quadrant and can be set to UP (0-degrees), MVR (7-degrees), and DN (20-

degrees). Flaps will not extend or auto-retract if the airspeed exceeds 185 to 219 KIAS depending on altitude. Flap position is indicated in the cockpit on the flap position indicator. The flaps themselves are divided into two outer and inner "wings". They all raise and lower simultaneously. Flaps are set to MVR for takeoff.

Underneath each wing and extending forward left and right of the slats are the wheel wells. The two main gears are partially covered by the wells and the gears retract forward into them. The forward end of the right wheel well housing contains the single point refueling receptacle. The corresponding left wheel well end is colored black and houses the IFF receiver.

On the outer left and right trailer edges are the ailerons that can also split to act as speed brakes.

Beneath the wing are the remaining eight hard points that a wide variety of stores can be mounted on. These include single pylons, Triple Ejector Racks (TER), Maverick and AIM-9 launchers, etc. Stations 3, 4, 5, 7, 8 and 9 are 1760 smart stations and allow the A-10C to talk to stores such as IAMs, targeting pods, and Maverick.

Control Surfaces

The three controlling forces on the aircraft are pitch, roll and yaw, and these in turn are provided by the elevator, aileron and rudder control surfaces on the aircraft. These control surfaces have the following functionality and characteristics that are often unique to the A-10.

Figure 32. Control Surfaces

Elevators

Pitch control is provided by two elevators attached to the trailing end of the horizontal stabilizer. The two elevators are attached using a sharable crossover shaft that can be sheared if one of the elevators becomes jammed. This will allow the other to still operate but with less pitch authority.

Figure 33. Elevator

Each elevator is in turn powered by a separate hydraulic actuator. The each actuator has inputs sent to it via a cable and linkage path that connect to it to a disconnect unit. A series of push rods then provide input from the control stick to the disconnect unit. If the elevators are still connected with the sharable crossover shaft, a single elevator actuator / control path can power both elevators if one of the actuators or control paths fail.

Elevator trim is provided by trim tabs on the outboard trailing edge of the elevators and can be set both from the control stick and from the Emergency Flight Control System panel using two, independent electrical circuits. These circuits lead to a trim motor that sets the trim tabs and provides artificial feel.

The Stability Augmentation System (SAS) channels provide pitch rate dampening for better tracking and dampening pitch when the speed brakes are deployed.

If an elevator jams in place, the Elevator Emergency Disconnect switch can be used to free it.

Ailerons

Roll control is provided by the two ailerons at the trailing outside end of each wing. Each aileron is powered by either hydraulic system. Roll inputs from the control stick are sent to a disconnect unit through push rods. From the disconnect units, inputs are sent to the hydraulic aileron actuators using cables and linkage paths.

Because of the tandem hydraulic control mechanism, the loss of one system will not impact aileron control.

If however the linkage is lost to one of the actuators, roll control will only be supplied by the operating aileron. As such, roll control authority will be reduced by half and great stick forces will be required.

Figure 34. Wing Tip and Aileron

If an aileron jams in place, the Aileron Emergency Disconnect switch can be used to free it.

Aileron trim is provided by trim tabs on each aileron trailing edge that are powered by trim motors. In addition to manual roll trimming of the aircraft, the aileron trim tabs also provide artificial stick feel. Even if the aileron of the trim tab is disengaged, the trim will still function.

Note that roll trim is not available when in Manual Reversion Flight Control System (MRFCS) mode. Instead, stick movements drive the roll trim tabs.

In addition to the primary function of imparting roll control to the aircraft, each aileron can also split vertically to form a speed brake.

Rudders

Yaw control is provided by the two rudders running vertically down the trailing edge of the vertical stabilizers. Each rudder is powered by separate hydraulic actuators that are in turn connected to the rudder pedals via a cable and linkage path. Unlike the elevators and ailerons, there is no disconnect option.

If hydraulic power is lost to a rudder, control of both rudders is still possible, but an increase in pedal input will be required. If however power is lost to both, direct control using the cables is automatically provided.

"GAME" AVIONICS MODE

The Game Avionics Mode provides "arcade-style" avionics that make the game more accessible and familiar to the casual gamer.

This mode can be selected from the Gameplay Options tab or by setting the Game Presets to "Game".

Figure 35. Game Mode Easy Radar

The display, located in the top right corner of the screen is a top down view with your aircraft (green circle) located at the bottom center of the display. Symbols located above your symbol are located in front of you, symbols to the right and left are located to the side of you.

The images below illustrate the various features of the Game Avionics Mode. Note that you will see different symbols depending what mode the aircraft is in: Navigation, Air to Air or Air to Ground.

However, each mode will have the following data in common:

- **Mode**. Indicated outside of the top left corner of the display. This can show NAV (navigation), A2A (air to air) or A2G (air to ground).

  Mode keys:

  - Navigation: **[1]**
  - Air to Air: **[2]**, **[4]** or **[6]**
  - Air to Ground: **[7]**

- **Radar Range**. Outside the top right of the display is the current range setting of the easy radar.

  Radar range keys:

- Zoom in: **[=]**
- Zoom out: **[-]**

- **True Airspeed (TAS)**. Outside the lower left of the display is the true airspeed of your aircraft.
- **Radar Altitude**. Outside the lower right of the display is the radar altimeter that indicates your altitude above the ground or water.
- **Current Heading**. Inside the display at the center top is your current aircraft magnetic heading.

Navigation Mode

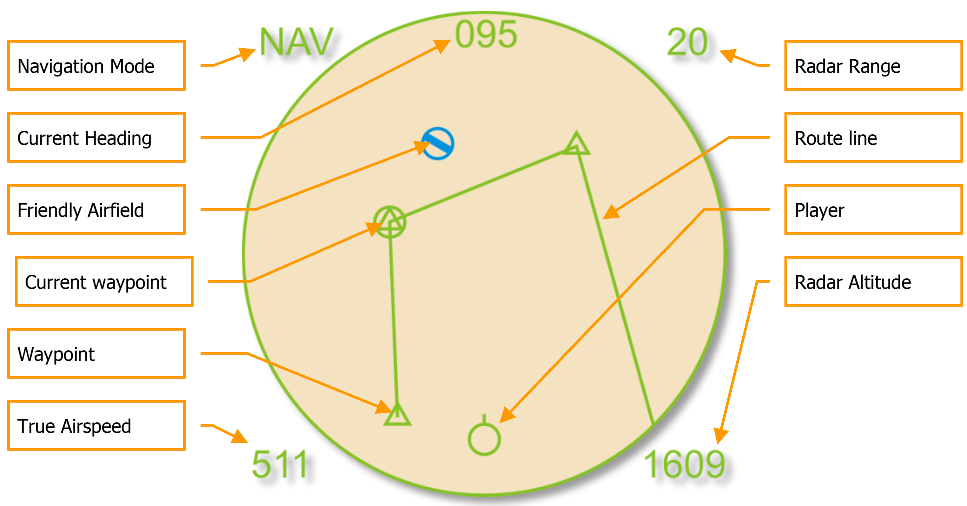


Figure 36. Game Mode NAV Display

Unique symbols of the Navigation mode include:

- **(Player symbol)**. Your aircraft is indicated as a green circle at the bottom of the display.
- **(Friendly Airfield symbol)**. This blue symbol indicates friendly airfields.
- **(Current waypoint symbol)**. This green circle indicates your current waypoint. You can cycle your waypoint with the **[LCtrl - ~]** (tilde) key.
- **(Waypoint symbol)**. This green triangle indicates other waypoints in your flight plan.
- **(Route line)**. Green route lines connect the waypoints in your flight plan.

Air to Air Mode

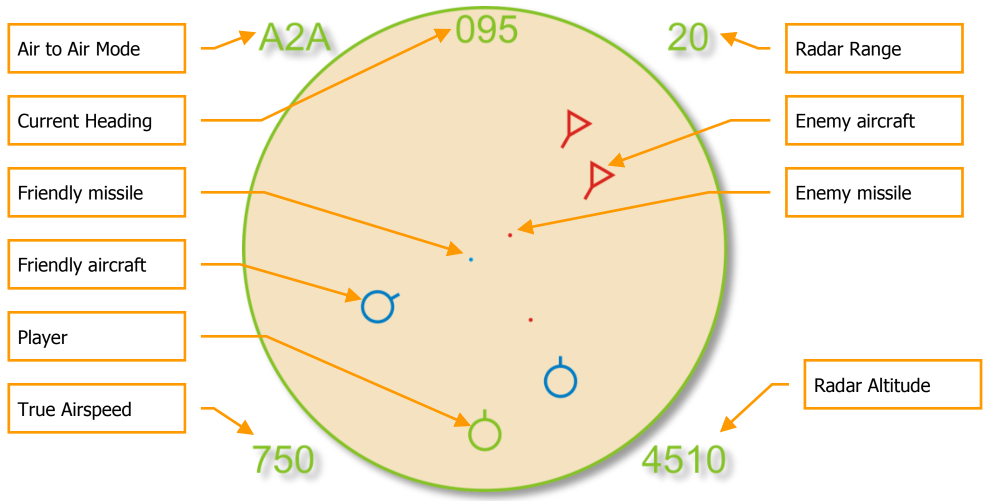


Figure 37. Game Mode Air Display

Unique symbols of the Air to Air mode include:

- **(Player symbol)**. Your aircraft is indicated as a green circle at the bottom of the display.
- **(Friendly aircraft)**. All friendly aircraft are indicated as blue circles with lines coming from them that indicate flight direction.
- **(Enemy aircraft)**. All enemy aircraft are indicated as red circles with lines coming from them that indicate flight direction.
- **(Friendly missile)**. A friendly missile is indicated as a blue dot.
- **(Enemy missile)**. An enemy missile is indicated as a red dot.

Useful key commands when in Air to Air mode include:

- Auto Lock Center Aircraft: **[RAlt - F6]**
- Auto Lock Nearest Aircraft: **[RAlt - F5]**
- Auto Lock On Next Aircraft: **[RAlt - F7]**
- Auto Lock Previous Aircraft: **[RAlt - F8]**

Air to Ground Mode

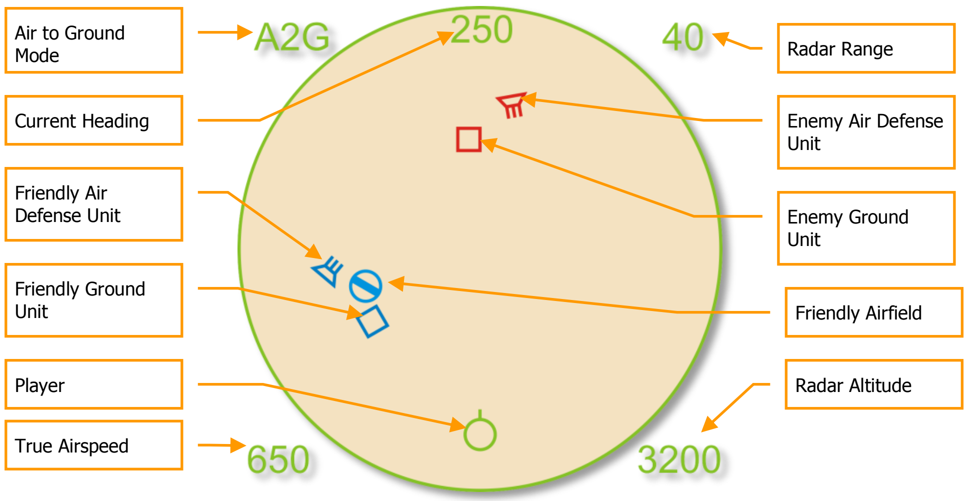


Figure 38. Game Mode Ground Display

Unique symbols of the Air to Ground mode include:

- **(Player symbol)**. Your aircraft is indicated as a green circle at the bottom of the display.
- **(Friendly ground unit)**. All friendly ground units are indicated as blue squares.
- **(Enemy ground unit)**. All enemy ground units are indicated as red squares.
- **(Friendly Air Defense Unit)**. A friendly air defense unit is indicated as a blue trapezoid with three lines coming from it.
- **(Enemy Air Defense Unit)**. An enemy air defense unit is indicated as a red trapezoid with three lines coming from it.

Useful key commands when in Air to Ground mode include:

- Auto Lock Center Ground Target: **[RAlt - F10]**
- Auto Lock Nearest Ground Target: **[RAlt - F9]**
- Auto Lock On Next Ground Target: **[RAlt - F11]**
- Auto Lock Previous Ground Target: **[RAlt - F12]**

TARGETING SYSTEMS

The targeting systems of the A-10A allow enable the detection of ground targets from a great distances. Close Air Support (CAS) aircraft, do not commonly have radars. This is because it is not sensible to install expensive radars on a rather simple aircraft that operate over the battle field at low altitudes. Such aircraft primarily rely on visual acquisition of targets.

Figure 39. Pave Penny Pod

The A-10A's inertial navigation system and LASTE system is used for most unguided munition targeting calculations. Missiles, like the Maverick, are aimed with the help of their own seekers. The image from the seeker is shown on a TV-Monitor (TVM) in the cockpit. Using the TVM image, the pilot can detect and track targets outside of visual range. For interaction with forward air controllers (FAC) and getting precise target location, the aircraft is equipped with the "Pave Penny" pod, which is a reflected laser energy detector. The Pave Penny pod can detect the reflected laser energy from a target being designated by a third party source. Pave Penny is not an active designator and thus cannot designate its own targets.

A-10A COCKPIT INSTRUMENTS

The A-10A was designed for close air support of troops on the battlefield. It is equipped with the essential instruments to achieve this task; however, that does include a radar.

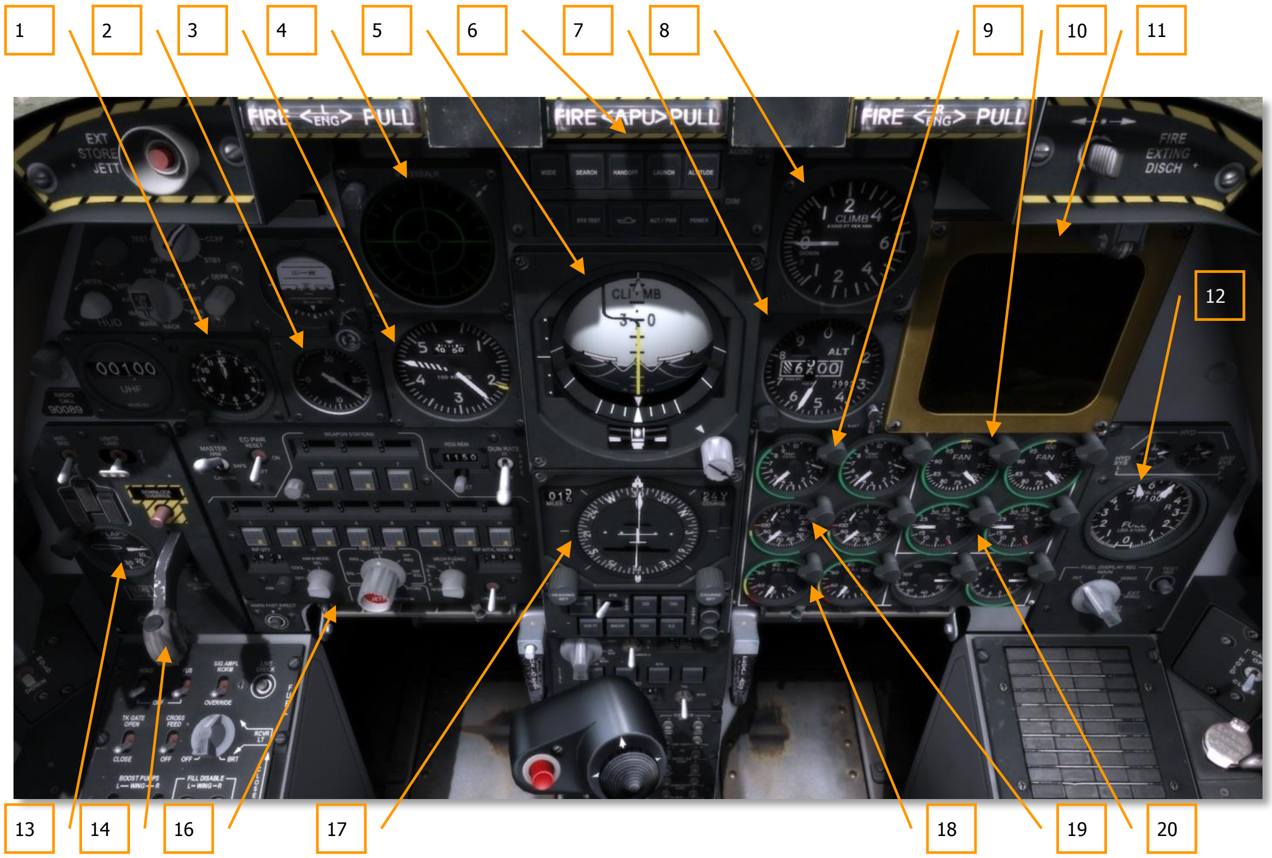


Figure 40. A-10A Cockpit

A majority of instruments in the A-10A cockpit are for flight performance monitoring, power systems, and control systems. The television monitor (TVM), positioned in the upper right corner of the cockpit, displays video directly from the seeker of the currently selected AGM-65 Maverick tactical air to surface missile (TASM). The TVM is not a multi function display (MFD).

1. Clock.
2. Angle-of-Attack (AoA) Indicator
3. Airspeed Indicator
4. Radar Warning Receiver (RWR) display
5. Attitude Director Indicator (ADI)
6. RWR Control panel
7. Altimeter
8. Vertical Velocity Indicator (VVI)
9. Interstage Turbine Temperature Indicator (L & R)

10. Fan Speed Indicator (L & R)
11. TV Monitor
12. Fuel Quantity Indicator
13. Flap Position Indicator
14. Landing Gear Handle
15. Landing Gear Position Display
16. Armament Control Panel
17. Horizontal Situation Indicator (HSI)
18. Engine Oil Pressure Indicator (L & R)
19. Engine Core Speed Indicator (L & R)
20. Fuel Flow Indicators

Figure 41. A-10A HUD Area

1. Accelerometer
2. AoA indexer
3. HUD
4. Magnetic compass

TV Monitor (TVM)

The television monitor (TVM) displays direct video from the seeker of the AGM-65 Maverick. Details regarding the operating modes of the AGM-65 are provided in the corresponding section.

Figure 42. TVM

Radar Warning Receiver (RWR)

The A-10A's radar warning system consists of two components. The radar warning receiver (RWR) display in the upper left corner of the instrument panel displays data about radars that are radiating, or "painting" the aircraft.

Figure 43. RWR Scope

Threat information is displayed in the form of symbols that indicate the threat type and bearing. The second element is the radar warning receiver control panel that is positioned under the HUD. It enables the filtering of threats according to their operational mode. Detailed information on how to work with the radar warning equipment can be found in the corresponding chapter.

Airspeed Indicator

The Airspeed indicator is positioned under the RWR display. It shows the current calibrated airspeed (CAS) of the aircraft. The indicator scale is graduated from 50 to 500 knots. The readings may slightly vary from those on the HUD. There is a dashed-arrow showing speed limitation for reasons of flight safety.

Figure 44. Airspeed Indicator

Angle-of-Attack (AoA) Indicator

The AoA indicator is positioned on the instrument panel to the left of the airspeed indicator. It indicates the current instrumented AoA of the aircraft within the limits of zero to 30 units. AoA values on the indicator do not correspond to degree values of AoA. For landing, the range of AoA is marked between 15 and 21 units.

Figure 45. AoA Indicator

Angle-of-attack (AoA) Indexer

The AoA indexer is positioned to the left of the HUD on the frame. It consists of three symbols that present AoA information while performing a landing. If the upper indicator is lit, it means that the current AoA is too larger and the airspeed is too low. If the lower indicator is lit, it means that the current AoA is too small and the airspeed is too fast. The central indicator is lit when the aircraft AoA equals the correct landing AoA. If the central indicator is lit simultaneously with any of the two remaining indicators, it means that the current AoA is only slightly off from the desired landing AoA.

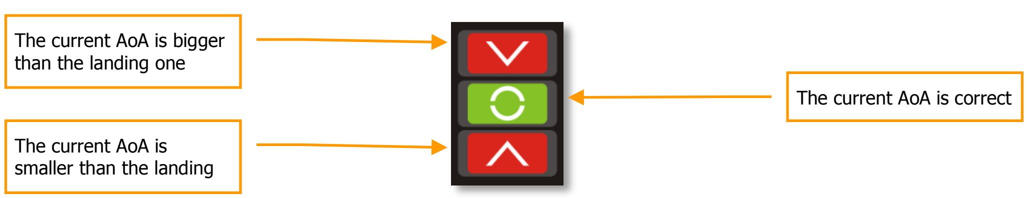


Figure 46. AoA Indexer

Attitude Director Indicator (ADI)

The ADI is positioned in the central part of the instrument panel. The attitude ball shows the current pitch and bank angles relative to the miniature "W" aircraft in the center. The pitch scale is graduated for 5 degrees; the bank scale is graduated for 10 degrees. On the ball are vertical and horizontal bars that show the aircraft's course and height deviation from the planned route. During instrument landings, you should have minimal deviation from these bars; and they should form a "+" sign.

In the lower part of the instrument is a sideslip indicator. Deflecting the rudders with the help of the pedals can eliminate slip. Try to keep the slip needle in the central position.

Figure 47. ADI

Horizontal Situation Indicator (HSI)

The HSI is intended to assist you in providing proper heading and alignment of your flight path on the planned route. This is done by using radio beacons and inertial navigation (INS) when enroute and approach. The rotating compass shows the current aircraft heading relative to the upper lubber line. The course arrow shows the course to the next waypoint, or to the selected air base. In the center of the compass is the moving Course Deviation Indicator (CDI) that moves relative to the Course Deviation Scale. This shows deviation from the selected course. When on a landing glideslope, the CDI indicates the current deviation from the landing course (localizer). In this situation, it is identical to the vertical bar at ADI.

In the upper right corner of the instrument panel, the set course value is shown. In the upper left corner, the distance to the current waypoint is indicated. The distance is measured in nautical miles.

Figure 48. HSI

Altimeter

The altimeter is intended for barometrical altitude measurement. The scale factor is 20 feet. A digital altitude indicator is also displayed on the indicator.

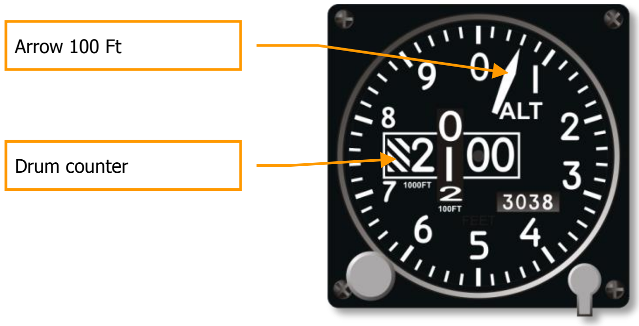


Figure 49. Altimeter

Vertical Velocity Indicator (VVI)

The VVI is intended to measure vertical velocity (i.e. rate of climb, or descent, in feet per minute) rates. The arrow moves in a clockwise direction if increasing altitude or moves counter-clockwise if losing altitude.

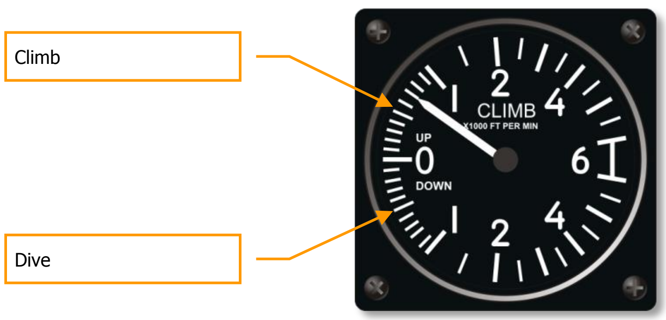


Figure 50. VVI

Accelerometer

The Accelerometer shows the current positive and negative G loads. G markers show the maximum allowable positive and negative loads. These instrument readings are independent and are not as accurate as the readings indicated on the HUD.

Figure 51. Accelerometer

Interstage Turbine Temperature Indicator (ITTI)

Two interstage turbine temperature indicators show the temperature of the exhaust gas from the high and low pressure turbines. The temperature is measured in degrees Celsius.

Figure 52. ITTI

Engine Core Speed Indicator

Two engine core speed indicators are intended for monitoring the turbine speed connected with the engines compressors. The measuring is indicated in percent of maximum speed.

Figure 53. Engine Core Speed Indicator

Oil Pressure Indicator

Two engine oil pressure gauges are intended for monitoring the current the oil pressure of both engines. If the oil pressure drops lower than 27.5 units, the warning lamp on the caution panel will light.

Figure 54. Oil Pressure Indicator

Fan Speed Indicator

Two fan speed indicators are used to monitor turbine speed connected with the engine fans. The measuring is indicated in percent of maximum speed.

Figure 55. Fan Speed Indicator

Fan speed indicator is an indicator of TF-34 engine thrust.

Fuel Flow Indicator

Two fuel flow indicators show fuel flow for each engine. Fuel flow is measured in pounds per hour.

Figure 56. Fuel Flow Indicator

Flap Position Indicator

The flap position indicator shows angle of flap deflection in degrees.

Figure 57. Flap Position Indicator

Fuel Quantity Indicator

The fuel quantity indicator displays the remaining fuel quantity in the aircraft's fuel tanks. The mechanical gauge shows a total fuel quantity. The arrows on the indicator scale shows fuel quantity in the left and right fuel tanks, starting from the remaining 6,000 lbs. Fuel quantity is measured in pounds.

Figure 58. Fuel Quantity Indicator

Armament Control Panel (ACP)

The Armament control panel is located in the lower left corner of the instrument panel.

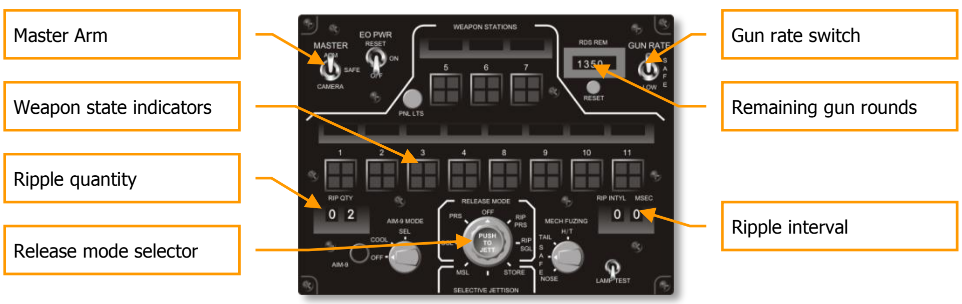
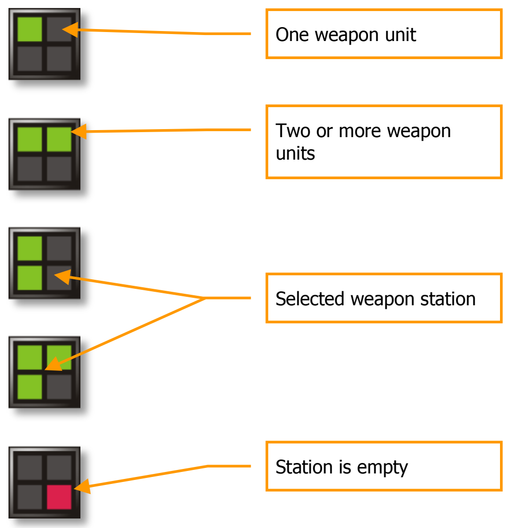


Figure 59. ACP

The ACP is intended for ordnance selection, setting weapon release options, and an indication of a weapon's current state.

Using the Release Mode knob, you can choose the release mode for unguided bombs **[LShift-Space]**, including: SGL – single release bomb mode at the release pulse, PRS – pairs release mode that drops two bombs per release pulse, RIP PRS – ripple pairs release mode that drops pairs of bombs drop a release pulse, RIP SGL – ripple single release mode drops multiple bombs one at a time during the release pulse. In a ripple release mode you can choose the number of bombs per pickle with the **[LCtrl-Space]** key. The number that will be released is indicated on the numeric indicator in the left part of the ACP. You may also set the interval (time) between each weapon drop. This allows you determine the distance between bomb impacts. To increase release interval, press the **[V]** key, and press the **[LShift-V]** key to shorten it. The select interval setting can be seen on the numeric display on the lower right portion of the ACP. Release interval is indicated as milliseconds between release pulses with a maximum setting of five milliseconds.

In the upper right corner of the ACP is the gun fire rate switch and counter of the remaining rounds.



The weapon state indicators show weapons availability on each weapon station and weapon readiness state.

Two upper green indicators indicate the number of weapons on that station. Both indicators are lit when there are two or more weapons loaded on that station. If only one weapon is loaded on the station, then one indicator will be lit. If the station is empty, one lower, red indicator is lit.

The active weapon and loaded weapons are indicated as selected when the left indicator on the lower row is lit. Switching between weapon types will correspondingly select other weapon stations.

A-10A HUD and TV Monitor operating modes

Basic HUD and TVM Symbology

There are a group of symbols that remain on the HUD regardless of operating mode.

Figure 60. Basic HUD

- The heading tape is located in the lower, center portion of the HUD. It displays the aircraft heading in five degree increments. At the center of the tape is a caret that represents the current heading. (For example, 14 on the tape corresponds to a value of 140 degrees).
- The digital airspeed indicator, which is positioned along the left side of the HUD, indicates calibrated air speed (CAS) of the airspeed in knots.
- The altitude indicator, on the right side of the HUD, displays the barometrical altitude in feet. BARO will be displayed in the lower left portion of the HUD.
- The numerical pitch value indicator is positioned below the altitude indicator and displays the current pitch angle (in degrees) of the aircraft.
- The total velocity vector indicator is displayed within the bounds of the HUD and shows the current flight trajectory of the aircraft. If the velocity vector is off the HUD and not showing true flight trajectory, the symbol with flash.
- The tadpole is the small circle with a stem extending from it. To reach the selected waypoint, fly the velocity vector onto the Tadpole. When the Tadple overlays the velocity vector and the stem is pointing towards the top of the HUD, you are on-route.

Navigation (NAV) Mode

When in navigation mode (NAV), the HUD displays various navigational information that allows the pilot to fly from one waypoint to the next.

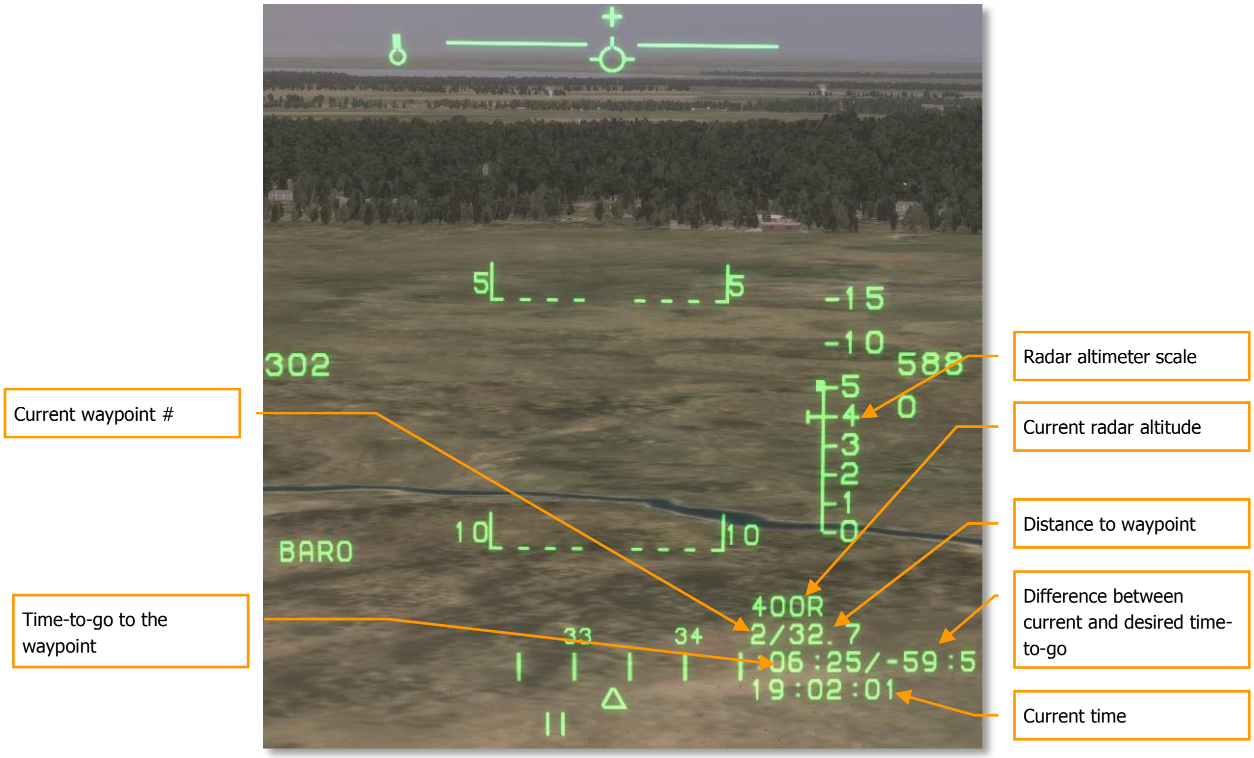


Figure 61. Navigation HUD

In NAV **[1]** key mode, a data block of information is displayed in the lower right portion of the HUD. Functions include:

- At the top of the data block is the digital radar altimeter. This indicates the aircraft's altitude above ground level.
- Below the radar altimeter, the currently selected waypoint number is displayed. The waypoint number can be cycled with the **[LCtrl-`]** key. To change waypoints and have valid navigation data though, the aircraft must be in navigation mode. The numbers following the sign "/" show distance to the selected waypoint in nautical miles.
- The next data line indicates the time remaining to reach the selected waypoint. The number following the "/" informs the pilot if he is ahead or behind the pre-planned time on station.
- A diamond symbol on the HUD indicates a target this is being laser designated for you.
- At the bottom of the data block is the current mission time.
- A small vertical double-line is displayed below the heading scale that indicates the flight heading to reach the selected waypoint. When you line up this mark with the heading caret, you are flying to the selected waypoint.
- The autopilot mode is indicator is shown of the left side of the HUD and has three possible modes":

Message	Autopilot operating modes
PATH HLD	Following the set course
ALT HLD	Following the set flight altitude
BARO	Autopilot is off

Landing Mode HUD and ILS

In the instrumental landing system (ILS) mode, information to assist an instrument approach and landing is displayed.

To enter landing mode, press the NAV **[1]** key. Along the right portion of the HUD, an analog vertical velocity indication is displayed.

The course and glideslope deviation bars are displayed in the HSI when in landing mode and you have reached the ILS intercept point. The horizontal bar (glide slope) shows the aircraft vertical deviation from the landing glideslope. The vertical bar shows the aircraft deviation from the landing course (localizer). When the two bars form a cross, the aircraft is flying a landing approach on the proper course and at the landing glideslope.

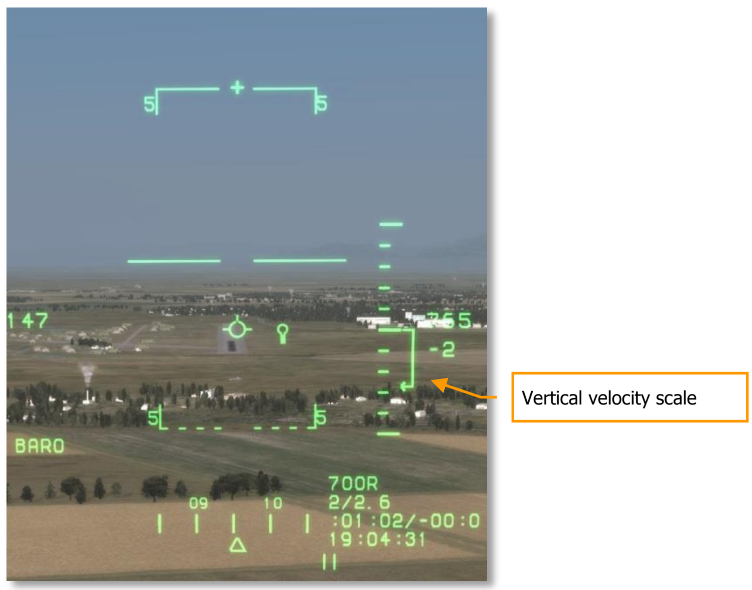


Figure 62. Landing HUD

To maintain proper landing approach, you must monitor the vertical velocity indicator (VVI) and the AoA lights on the right HUD frame.

Internal Gun and Unguided Rocket (RKT) Delivery Modes

When in the air-to-ground mode by selecting the **[7]** key, you may select the internal GAU-8A 30mm cannon by toggling the **[C]** key. When in HUD Gun mode, a reticule with a center pipper will be displayed on the HUD. Inscribed in the circle is a range clock that unwinds counter clockwise as slant range to the ground under the pipper decreases. A digital slant range is also shown below the reticule in nautical miles.

The pipper in the center of the reticle is a continuously computed impact point (CCIP). This means that the shells will land in the area under your pipper when you fire the weapon, assuming range requirements are met.

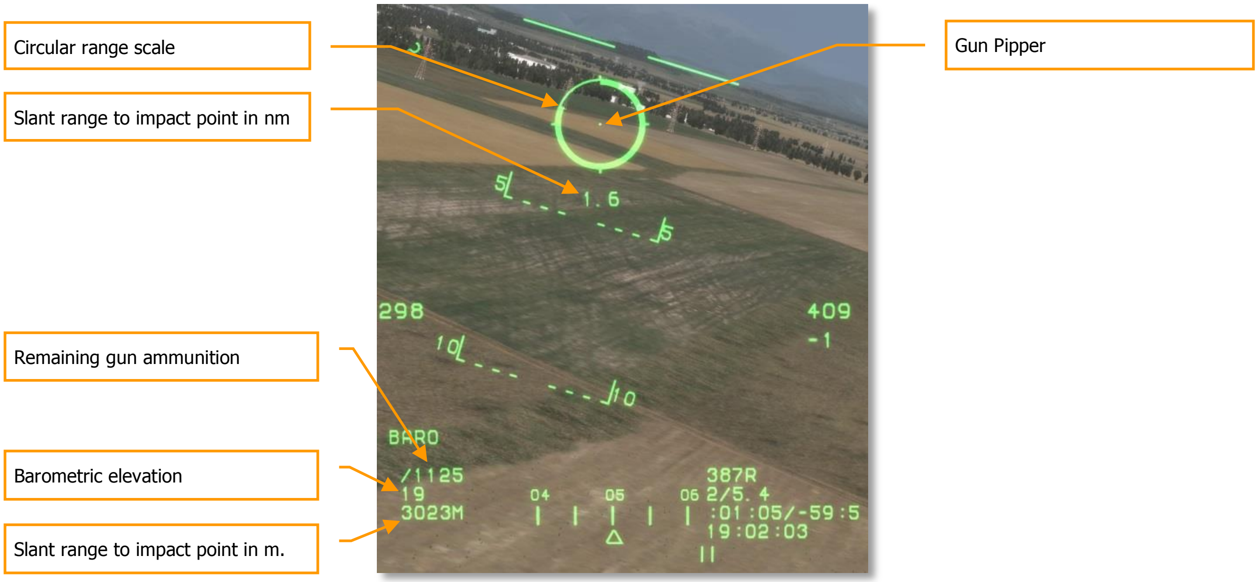


Figure 63. Gun HUD

If rockets are selected by pressing [D] to cycle weapons, the "RKT" indicator will be shown under the reticule and displays the rocket impact point. The pipper is considered a continuously computed impact point (CCIP). This means that the rockets will hit the area under your pipper when you fire the weapon, assuming range requirements are met.

Also on the HUD is a CCIP run cross. Below the CCIP gun cross is the slant range to the location under the center piper on the cross. When the range is goo far, the cross will have an X through it.

Figure 64. Rocket HUD

When in a weapon mode, a data block in the lower left corner of the HUD is displayed. This consists of three lines. The top line indicates the selected weapon and the quantity of the weapon remaining. The second line indicates the barometric elevation, in meters, of the terrain below the weapon pipper. The third line indicates the range in meters to the terrain point underneath the weapon pipper.

Unguided Bomb Delivery Modes

There are two delivery modes for unguided bombs in game: Continuously Computed Impact Point (CCIP) and the Continuously Computed Release Point (CCRP).

In CCIP mode, the aiming is done visually with the pipper of the CCIP. The bomb's flight time depends on its ballistic characteristics, initial speed and altitude when it was dropped. Bombs with a high drag coefficient or braking devices have very curved trajectories. This is why the aiming pipper often appears from below the HUD when at low altitude. When using such bombs, it is recommended to use high delivery speeds.

Unique CCIP and CCRP HUD symbology is as follows:

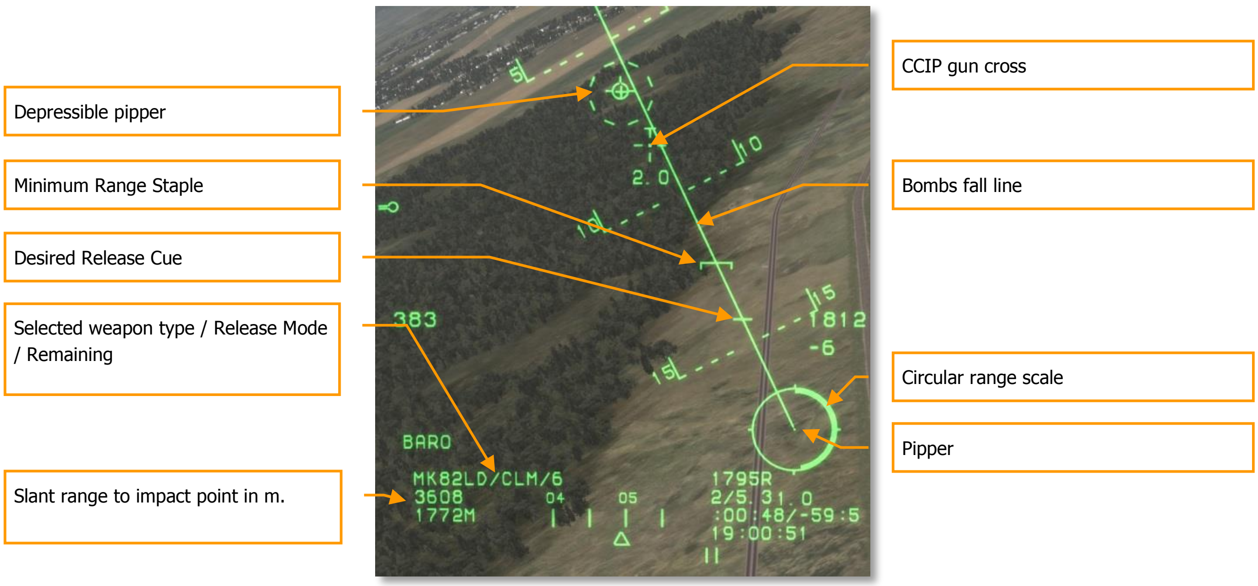


Figure 65. CCIP Bombing HUD

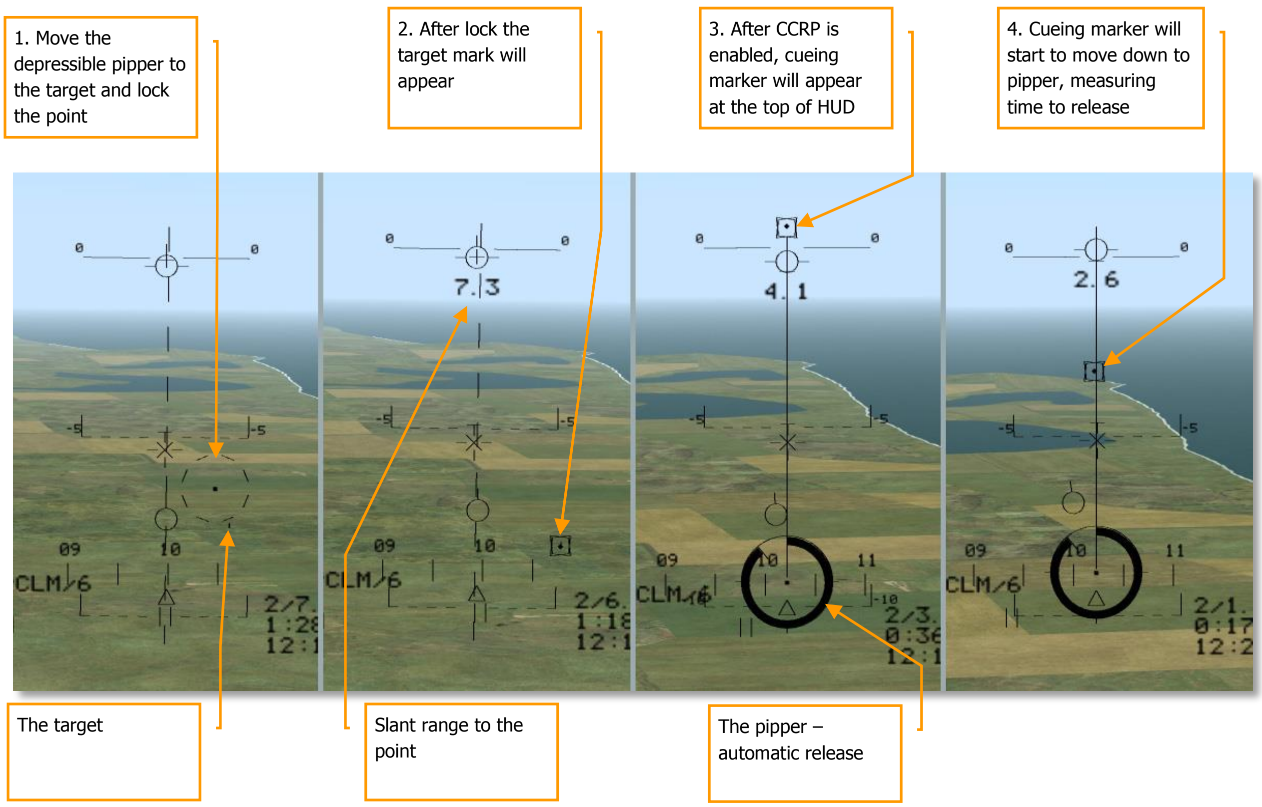
- The constantly displayed CCIP gun cross shows the current shells impact point. The slant range to the impact point in miles is displayed under the pipper. When an "X" is drawn through the pipper, the impact point is not accurate.
- The bomb fall line shows the line on which bombs will fall in a ripple release.
- The pipper shows the bomb impact point.
- The circular range scale around the pipper displays the slant range to impact point from two miles.
- The slant range to the impact point, in miles, is digitally displayed under the bombing reticule.
- There are two bars on the bomb fall line. The bar closer to the pipper is the Desired Release Cue (DRC) – optimal bomb drop altitude. The bar further away is the Minimum Range Staple (MRS) - minimal safe drop altitude. The minimal safe altitude is determined on the basis blast fragmentation patterns.
- The selected weapon type and remaining number are displayed in the lower left corner of the HUD. Terrain elevation and distance under the pipper are also displayed in meters.

The CCRP mode is generally used to bomb from level flight when the target is out-of-sight – "under the nose". It is first necessary to first designate the aim point by using the depressible pipper and the fire control computer (FCC). The depressible pipper is the dashed reticule in the HUD with the pipper in the center. By designating a point on the ground, the FCC can calculate when to release the bombs automatically. The pilot must simply fly the aircraft in the direction of the designated area, marked by the box on the HUD.

The depressible pipper can be moved with the **[,], [.], [/], [;]** keys. Once the depressible pipper is over the desired target, press the **[Enter]** to lock the position in the FCC. A small, square target marker is now placed on the target area.

To activate the CCRP steering mode, press the **[O]** key. The target marker will move to the top of the HUD and represent the required steering azimuth the pilot must fly to reach the release point. To ensure an accurate pass, the pilot must place the target marker on the bomb all line. As the pilot nears the release point, the target marker will begin to drop down the bomb fall line. When it reaches the pipper, the bomb(s) will be dropped automatically.

The CCRP process is illustrated below.



As soon as the target is marked by the target designator, the slant range to the target is displayed under the velocity vector indicator in miles.

Air-to-Air Weapons Delivery Mode

The A-10A can use the GAU-8A and short range air-to-air missiles simultaneously. In the air-to-air weapons delivery mode, that can be activated with the **[2]** or **[3]** key, the targeting information needed to employ the AIM-9M infrared missile and GAU-8A gun is displayed on the HUD. HUD symbology in this mode is nearly identical to other HUD modes with the following exceptions:

- The HUD displays a reticule that represents the azimuth limits of the missile's seeker. To lock the seeker on a target, you must fly the aircraft such that the reticule overlays the target. If the seeker can lock on to the target, you will hear a high pitched lock tone and the seeker reticule will follow the target until seeker lock is broken.

- The gun funnel is located near the top of the HUD, above the AIM-9 seeker reticule. It displays the predicted flight trajectory of shells. To use against airborne targets, you must line the wing tips of the target aircraft with the sides of the funnel. Given that the funnel is calibrated to a fighter-sized target, you will need to adjust accordingly for a larger aircraft.

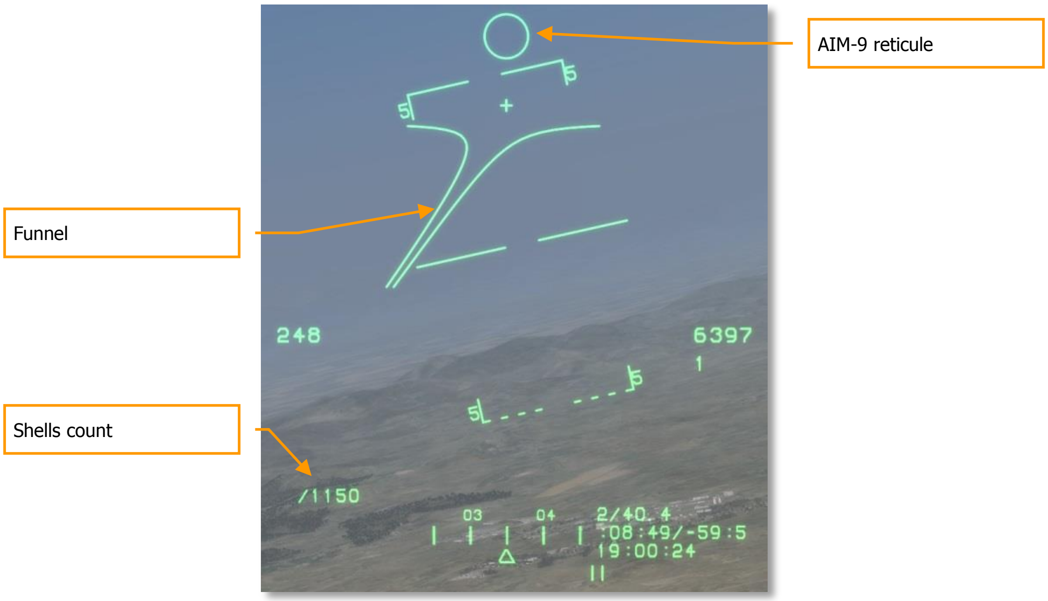


Figure 66. Air to Air HUD

The AGM-65 Guided Missiles Delivery Mode

Because the A-10A does not have a radar, target acquisition is done with help of the pilot's eyes and the AGM-65 Maverick seeker. The A-10A can carry two versions of the Maverick, each with a different seeker. These include the AGM-65K with daylight TV-guidance and the AGM-65D with imaging infrared guidance.

The AGM-65 delivery modes provide the pilot with an aiming reticule that shows seeker position on the HUD and TVM, seeker gimbal limits, and the slant range to target. The AGM-65K can lock on to a target from three nautical miles away and the AGM-65D can lock a target from eight nautical miles.

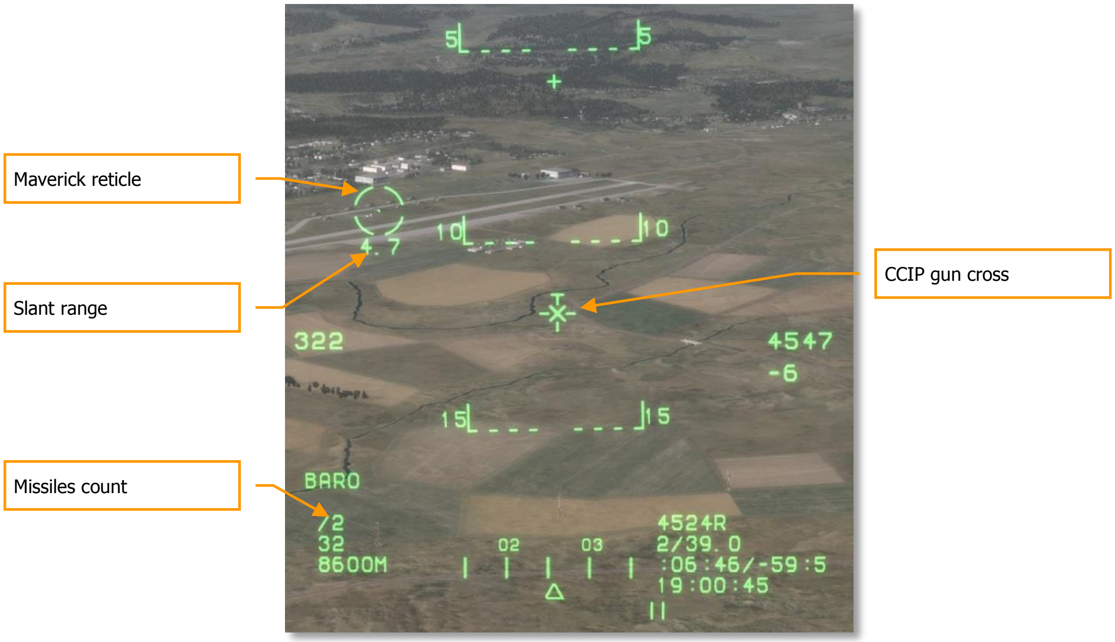


Figure 67. Maverick HUD

The direct video from selected missile seeker is displayed on the TV Monitor (TVM). The TVM is located in the upper right portion of the dash. The selected missile type can be determined from the image on the TVM.

Both the AGM-65K and AGM-65D have a 3x magnification level; however, the AGM-65D also has a 6x magnification level. Using the **[-]** and **[=]** keys, you may toggle between AGM-65D magnification levels. You can determine when you are in the AGM-65D 6x magnification level by the lack of field of regard brackets on the TVM.

The first step of using the Maverick is to acquire the target. This can be done by using the **[,], [.], [/], [;]** keys to slew the seeker around its gimbal limits. As you slew the seeker view, the Maverick reticule on the HUD will move as well to reflect where the seeker is looking. The reticule is a dashed "wagon wheel" circle with a pipper in the center. Below the reticule is the range from aircraft to the aim point that the piper is over. At the same time, the video image on the TVM will reflect the image that the Maverick seeker is seeing. You can use the combination of HUD and TVM to locate and identify targets.

Once you have the pipper near a target, press the **[Enter]** key to stabilize the seeker on that terrain point. This will ground stabilize the seeker. You can then use the slew keys to place the HUD reticule / TVM targeting cross on the target. If in range, the seeker will "snap to" to the target and lock it. It will then track and maintain lock as long as it can. When the pointing cross on the TVM flashes, it indicates that you have a valid lock and can fire the missile.

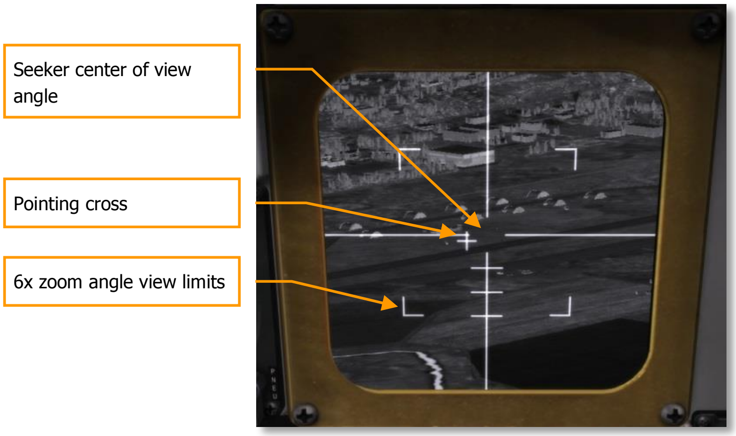


Figure 68. Maverick TVM 3x

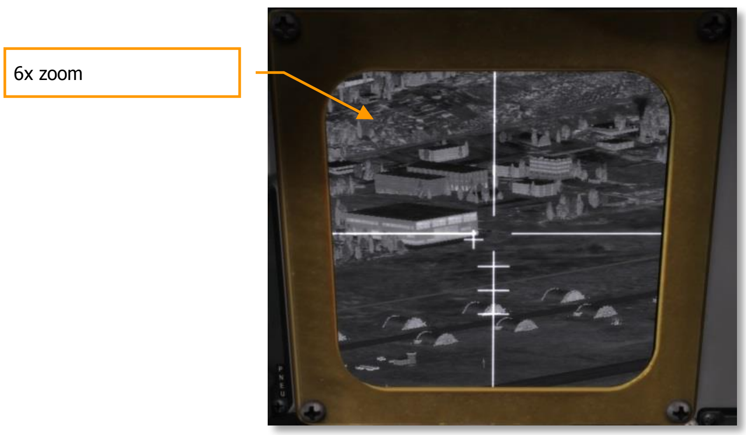


Figure 69. Maverick TVM 6x

On the TVM, the seeker's position is in regards to the longitudinal axis of the aircraft, and is displayed as a pointing cross. When the pointing cross flashes, it indicates a valid lock. If the cross is lower and to the left of TVM center, then the missile seeker is directed down and to the left. The seeker's gimbal limits are in width ±60 degrees. For launch however, it is necessary that the target be within ±30 degrees.

AIR-TO-AIR MISSILES

AIM-9 Sidewinder

The Sidewinder's design began in 1948 and flight tests of development models were carried out in 1952-54. In 1956 the first model, AIM-9A Sidewinder, entered operational service with the United States Air Force.

The Sidewinder is designed according to canard aerodynamic plan. It has a cylindrical body with a diameter of 127 mm and a cross trapezoidal wing. Rollerons are installed on the tail wing back edges. They provide limitations of the missile turn angle velocity along the longitudinal axis. All models of the Sidewinder have the same number of primary components, they are: guidance and control system (including target seeker, pneumatic aerofoil drive, electric power source and impact fuse), proximity fuse, warhead, motor. All Sidewinders, except the AIM-9C and AIM-9R, are equipped with infra-red target seekers that are best used in good weather conditions. The AIM-9C is equipped with radar seeker; therefore, it can attack targets in both good and bad weather conditions.

As power source, except for AIM-9D which has an electric battery installed, a gas generator is used. It powered by hot gases that are generated by the burning of a combustible cartridge.

Figure 70. AIM-9P

The warhead is of the expanding-rod type. The warhead detonation is commanded by the proximity fuse when the missile flies within 5-6 m of the target. In the case of a direct hit, the impact fuse detonates the warhead. The motor is solid-propellant two stages (boost and sustainer-flight).

Sidewinders have been widely used in local conflicts from the 1960s to the 1990s. During the Falklands War, according to English sources, Harriers launched 27 Sidewinder missiles that hit 16 Argentinean aircraft and helicopters. The excellent performance of the Sidewinder was primarily due to its advanced, all-aspect seeker. However, even this seeker could have difficulties with low-infrared targets that disperse the signature. A good example is propeller-driven transports. It is known that Harrier launched 2 Sidewinders at an Argentinean C-130 transport, one of them missed and the other damaged a wing. After which, the English pilot flew up to C-130 and put 240 shells into the fuselage. Against Argentine righter jets though, the Sidewinder proved deadly.

AIM-9L – The Vietnam War illustrated the poor effectiveness of early Sidewinder models. These early models limited the maneuverability of the launch aircraft and it proved difficult to hit any targets maneuvering at high G loads. Due to this, development on the AIM-9L began in 1971. The maximum range of the AIM-9L at high altitude was 18 km.

To improve the original AIM-9L seeker of photoresistance of sulphureous lead (PbS), it was replaced by photoresistance of antimonous indium (InSb). This significantly increased its sensitivity and possibility to lock targets not only from both rear and forward aspect hemispheres. Another enhancement was to increase the gimbal limits and increase target tracking rate.

In AIM-9L missile seeker has a cryogenic cooling system of photoresistance. Argon used in this system and is stored in a container positioned in the missile body. This allowed crews to load the missile on aircraft without need of additional launcher equipment (earlier Sidewinder models had containers in the launchers).

Figure 71. AIM-9M

For the AIM-9L, electronic circuit chips are used and a thermal battery used as the power source.

The AIM-9L missile was the first "air-to-air" missile in the world that was equipped with a laser proximity fuse. Its main section contains both emitting and receiving elements. As the laser emitter diode (gallium arsenide) is used, reflected energy from a passing target is detected by the receiving elements (silicon photodiode). This triggers the warhead detonation.

AIM-9L warhead is also a new development. It has two layers of steel rods with cuts to form pieces at a defined weight. The explosion is performed by initiating pulses from the fuse to the two ends of the explosive at the same time.

The AIM-9L Sidewinder has been in operation since 1976 and is in service with many aircraft types including: F-4, F-5, F-14, F-15, F-16, Tornado, Sea Harrier and Hawk

AIM-9M. In the spring of 1979, flight tests of the new AIM-9M began. This missile is an enhanced version of the AIM-9L. The AIM-9M is equipped with a new engine with a reduced smoke motor (less aluminum oxidizer).

The primary difference from the AIM-9L is the infrared seeker with a closed-loop cooling system that does not need coolant refilling. The missile seeker is better at rejecting IR countermeasures (flares), and it can better distinguish targets from terrain background. The AIM-9M entered operational service in 1983.

AIR-TO-SURFACE WEAPON

AGM-65K and AGM-65D Maverick Guided Missiles

The AGM-65 Maverick is a highly successful mass-produced precision guided missile. Since its initial service entry in 1972, it has been developed into a family of modifications that have seen action in numerous armed conflicts. It is carried primarily by the A-10A, F-4E, F-16, F/A-18 and F-15E attack aircraft.

The AGM-65 is usually fitted with an imaging electro-optical (EO) seeker that provides autonomous guidance "launch-and-leave" ("fire-and-forget") capability, which affords the shooting aircraft total freedom of maneuver after launch. Imaging seekers also allow these weapons to be used against moving targets such as vehicles and ships, and the missile's penetration warhead is effective against armored tanks.

The Maverick was originally designed as an anti-armor weapon, to help NATO close support aircraft overcome the great numerical superiority of Soviet tank armies in Europe. For this purpose the original AGM-65A, B and D variants were fitted with a 57 kg armor-piercing shaped-charge warhead.

Figure 72. AGM-65K

The seeker head of the original AGM-65A missile included a miniature television (TV) camera, which could lock onto an object by detecting visual edge discontinuities of optical contrast between the target and the surrounding terrain. As long the missile was suspended on a weapon station pylon before launch, the image being viewed by the seeker was shown on a monochrome TV display in the shooting aircraft cockpit, together with a pipper in the HUD for indicating the direction the seeker was looking. The pilot could "cage" (bore sight) the missile's TV seeker to the aircraft longitudinal axis, then aim by steering the entire aircraft to put the pipper over the target, or the seeker could be "un-caged" (i.e. gyro-stabilized, or "locked onto the ground") and then manually slewed over the intended target.

The missile's powerful rocket motor gave it a theoretical range of up to 20 nm, but the limitations of the TV seeker meant that in practice; targets could only be engaged once they were visible, and sufficiently large in the TV display to trigger the edge-detection lock. Target camouflage and/or atmospheric conditions such as smoke, haze, dust, and humidity could also degrade seeker performance, and most launches actually occurred at ranges of only 1-2 nm. Even with these limitations, Israeli use of the AGM-65A in clear Middle Eastern skies over the Suez Canal yielded a staggering 87 percent hit rate in 1973, such that it was finally employed not only against Egyptian tanks but also against radars, parked aircraft and other high-contrast targets. The short range of the AGM-65A however gave the pilot very little time to spot, identify and attack targets, and so it was used primarily by the two-seat F-4E - the back-seater would lock up the target with the TV display while the pilot maneuvered the aircraft to shoot.

The AGM-65B variant introduced "scene magnification" optics for the TV seeker, to help single-seat aircraft pilots successfully lock targets from somewhat longer range, whereas the AGM-65D uses an imaging infrared (IIR) seeker to detect thermal contrast from even greater distances. The AGM-65D can thus be used day or night, in a wide variety of atmospheric conditions, with a launch range against vehicle targets approaching 6 nm. This is not a sufficient range to perform standoff attacks against modern radar-guided SAM sites, but the Maverick is nevertheless a highly valued weapon in the close support role. A total of 5255 AGM-65B and D missiles were employed during the 1991 US war against Iraq, with about 4000 of these launched by single-seat A-10A close support aircraft. The A-10A can carry up to six (6) Mavericks on triple-rail LAU-88 launchers just outboard of each wing's undercarriage nacelles, but the two innermost rails are usually left empty. This avoids damaging the A-10A landing gear with the Maverick's powerful rocket exhaust, and reduces the maximum practical load to four (4) AGM-65 missiles. A commonly practiced A-10A tactic is to destroy first and last vehicles in a column with Mavericks, then to strafe the vehicles trapped in between with 30 mm cannon, thus rendering them combat-ineffective.

Figure 73. AGM-65D

Mk-82, Mk-82AIR and Mk-84 Unguided Bombs

The Mk-80 series of free-fall bombs are the main US Air Force air to ground (A-G) weapons. They have been widely used in all the large-scale military conflicts of the last few decades. Almost any type of aircraft can employ these bombs. They are used in large numbers against a wide spectrum of targets – enemy wheeled vehicles and trucks, ground structures, and personnel. During the Persian Gulf War in 1991, Allied aviation dropped 77,653 Mk-82 500 lb and 12,189 Mk-84 2000 lb bombs on Iraqi positions.

Free-fall bombs are unguided weapons that are aimed visually by the pilot before release. Practice has shown that a well-trained pilot can achieve about a 50 percent hit rate with a carefully aimed attack. Guided weapons are more accurate, but also more expensive. For this reason, the simple and inexpensive Mk-82 and Mk-84 gravity bombs should remain in use with tactical aviation for many decades.

Figure 74. Mk-82

The range at which these bombs can be employed depends on the speed and altitude of the launching aircraft at the moment of release. The range increases with release altitude and speed.

This Mk082AIR version of the Mk-82 adds the BSU-49/B high drag tail assembly, also called the "ballute". This allows the bomb to rapidly slow down after release. By slowing down, you can release such a retarded weapon at low altitude and not be caught in the blast effect of the weapon.

Figure 75. Mk-82AIR

The instructions for use of these unguided bombs are given in the sections of this manual dealing with the weapons control system.
These bombs are in service with the air forces of all NATO member nations.

Mk-20 Rockeye Cluster Bomb

The Mk-20 Rockeye cluster bomb contains 247 bomblet sub-munitions. The bomblets are scattered over a wide area and are effective against armor, vehicles and troop concentrations. They are not effective against fortified structures like pillboxes or bridges. During the Persian Gulf War in 1991, NATO aircraft dropped about 28,000 such bombs.

Figure 76. Mk-20

The Mk-20 is aimed much like any other free-fall bomb. The pilot aims the bomb visually with the use of a HUD pipper, and its range and hit accuracy depend on the aircraft speed and altitude at the moment of release.

This bomb is in service with the air forces of all NATO member nations.

CBU-87 Cluster Bomb

The CBU-87 Combined Effects Munition (CEM) weighs 950 lbs and is an all-purpose cluster bomb. The SW-65 Tactical Munition Dispenser contains 202 BLU-97/B Combined Effects Bomblets (CEB) and they are effective against armored and unarmored targets.

Each BLU-97/B CEB contains a shaped-charged, scored steel casing and a zirconium ring for anti-armor, anti-personnel fragmentation, and incendiary effects device. Each CEB is designed to fragment into 300 fragments. Given the top attack angle of the weapon, the CEB can be effective against the generally light armor covering the top of an armored vehicle such a tank.

LAU-61 Rocket Launchers

Western armed forces are oriented to fight an armored opponent. For this reason, unguided rockets, with their relatively small warheads and dispersal of firepower, are not in widespread use. Unguided rockets don't have any capability to home on a moving or distant target, and their hit accuracy is greatly affected by conditions at the moment of launch. Even a small perturbation in the aircraft flight trajectory during launch can lead to significant aiming error. Wind can also degrade the hit accuracy.

Figure 77. LAU-61

Unguided rockets are used against enemy infantry and unarmored vehicles. The rockets are launched in salvos to increase the targeted area and the probability of a hit.

The LAU-61 rocket launcher contains 4 rockets of 5 inch diameter. The LAU-61 rocket launcher contains 19 rockets of 2.75 inch diameter.

Figure 78. 2.75" rocket

The instructions for use of unguided rockets are given in the sections of this manual dealing with the weapons control system.
These rockets are in service with the air forces of many NATO member nations.

Electronic Countermeasures (ECM) Stations of NATO

AN/ALQ-131 ECM station

The Westinghouse AN/ALQ-131 active jamming pod began development at the beginning of the 1970s as a modernization of the earlier AN/ALQ-119. The AN/ALQ-131 provided an extended frequency range over its predecessor, and a special power control module to adjust output signal level when acting as a deception jammer. Most importantly, the station introduced a re-programmable processor, which allowed the pod to be kept up to date with the latest threats, allowing it to continue to be used in service to the present day. The station significantly reduces the tracking and lock range of hostile radars.

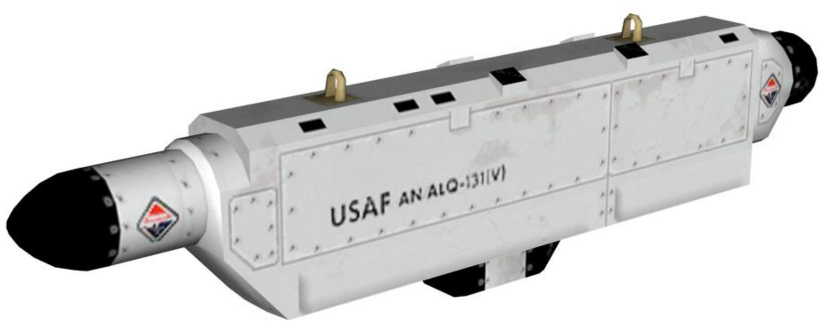


Figure 79. AN/ALQ-131

The AN/ALQ-131 pod may be carried by the NATO F-4E, F-16C, A-10 and other aircraft.

Radar Warning Receiver

On the A-10A Warning Receivers (RWR) scope, the center position indicates the location of your aircraft from a top-down perspective. Around the center position (your aircraft), radars that are illuminating your aircraft are displayed. An emitter above your aircraft on the scope indicates a radar in front of you, an emitter to the right of your aircraft is off your right wing, etc

The AN/ALR-69 RWR is installed on the A-10A/OA-10A. It is a modified and improved version of the AN/ALR-46 RWR.

The RWR system provides a constant detection of radar signals between an azimuth - +/- 180, and an elevation range of - +/- 45.

The maximum number of threats on the RWR scope: 16.

The threat history duration display time: 7 seconds.

RWR function modes: All (acquisition) or Lock (the "Search" button and RWR control indicator in the A-10A).

The radar emitter distance from the center of the RWR scope corresponds to the emitter's signal strength. Radars emitting with greater power are shown closer to the center of the scope.

The AN/ALR-69 (A-10A) has azimuth marks on the scope (at 15 grad intervals) and two zones (or "rings") divided by a circle. A threat in the inner ring is an immediate threat to your aircraft.

Early warning radars and AWACS symbols will never be displayed in the inner ring area.

When a new threat is detected, a high pitched audio tone is heard once, and the threat symbol displays a hemisphere mark above the symbol.

When the RWR detects a radar in acquisition mode, a chirp audio tone will be heard.

When a threat locks on to your aircraft, the RWR tone will change from a periodic chirp to a constant chirping sound.

Figure 80. RWR Scope

If an active radar homing (ARH) missile is detected, an "M" symbol will be displayed in the inner ring and become a high-priority threat. The initial position of a detected ARH, the symbol will be located close to the attacking aircraft's symbol and about half the distance from the inner ring.

In the A-10A, acquisition and lock signals from the enemy radars are also shown on a RWR control indicator.

Figure 81. RWR Panel

There are two light indicators on the panel.

The first indicator is the green "SEARCH" light. This light will light when an acquisition radar is illuminating you.

The second indicator is the red "LAUNCH" light. This will light when the RWR detects a radar-guided missile launch directed against your aircraft.

Note that all RWS and RWR systems will only detect radar systems. They will not alert you of infrared-guided systems.

The following symbols and markers are present on RWR display.

Airborne radar. All radars of this type are indicated by the ^ mark, which appears over the aircraft type symbols. Ground-based and ship-based radar symbols designations are described in the table below

Upper semi-circle– denotes a new threat. Such a mark appears over the newest by time of detection.

«Diamond» – the primary threat mark. This of mark denotes the most dangerous threat. It is positioned very close to your aircraft or the launching enemy.

Flashing circle indicates that a missile launch has been detected.

Flashing circle with a «diamond» around an «M» symbol – ARH missile activity (R-77, AIM-120C, AIM-54C, MICA-AR). Active missile are always the primary threat.

It should be noted that symbols and marks can be combined. For example: the mark of a new threat (the upper semi-circle) can be combined with the mark of a detected missile launch (the blinking circle). As a result, a circle with a blinking lower part will be shown.

The symbol of radar type and class can provide detailed information about the type of attacking subsystem. In the table below, you can find the TEWS and RWR symbols and their corresponding radar types.

Airborne Radars

Platform	RWS symbol
MiG-23	23
MiG-29, Su-27/33	29
MiG-31	31
Su-30	30
F-4E	F4
F-14A	14
F-15C	15
F-16C	16
F/A-18C	18
A-50	50
E-2C	E2
E-3C	E3

Ship-based Radars

Platform	SAM system	RWS symbol
Albatros, Grisha V class frigate	SAM "Osa-M" (SA-N-4 Gecko)	HP
Kuznetsov, aircraft carrier	SAM "Kinzhal" (SA-N-9 Gauntlet) AAA "Kortik" (SA-N-11 Grison)	SW
Rezky, Krivak II class frigate	SAM "Osa-M" (SA-N-4 Gecko)	TP
Moskva, Slava class cruiser	SAM S-300F "Fort" (SA-N-6 Grumble) SAM "Osa-M" (SA-N-4 Gecko)	T2
Neustrashimy, Jastreb class frigate	SAM "Kingal" (SA-N-9 Gauntlet) AAA "Kortik" (SA-N-11 Grison)	TP
Carl Vinson, CVN-70	RIM-7 Sea Sparrow	SS
Oliver H. Perry, FFG-7	SM-2 Standard Missile	SM
CG-47 Ticonderoga	SM-2 Standard Missile	SM

Ground-based Radars

SAM system	NATO classification	RWS symbol
S-300PS 40V6M	SA-10	10
S-300PS 40V6MD	SA-10 Clam Shell	CS
S-300PS 5N63S	SA-10	10
S-300PS 64N6E	SA-10 Big Bird	BB
Buk 9S18M1	SA-11 Snow Drift	SD
Buk 9A310M1	SA-11	11
Kub 1S91	SA-6	6
Osa 9A22	SA-8	8
Strela-10 9A33	SA-13	13
PU-13 Ranzhir	Dog Ear	DE
Tor 9A331	SA-15	15
2S6 Tuguska	2S6	S6
ZSU-23-4 Shilka	ZSU-23-4	23
Roland ADS	Roland	RO
Roland Radar	Giraffe	GR
Patriot search and track radar	Patriot	P
Gepard	Gepard	GP
Hawk search radar	I-HAWK PAR	HA
Hawk track radar	I-HAWK HPI	H
Vulcan	M-163	VU
S-125 P-19 radar	SA-3 Flat Face B	FF
S-125 SNR	SA-3 Low Blow	LB

RADIO COMMUNICATIONS AND MESSAGES

In the early days of air combat, communication between pilots was difficult, and often impossible. Lacking radios, early pilots were basically limited to hand signals. Coordination between pilots, especially during a dogfight, was generally impractical.

Although modern electronics have greatly improved communications capability, communications still faces some frustrating limitations. There may be dozens, if not hundreds, of combatants using any given radio frequency. When those people all try to talk at once in the heat of battle, the resulting conversations generally become jumbled, cut-off, and unintelligible. Pilots, therefore, strive to adhere to a strict radio discipline with each message, conforming to a standard Callsign, Directive, Descriptive. The "callsign" indicates who the message is intended for and who it is from, the "directive" contains brief instructions for the recipient, and the "descriptive" specifies additional information. For example:

Chevy 22, Chevy 21, hard right, bandits low 4 o'clock

This message was sent by #1 of Chevy flight to #2 of "Chevy" flight. Chevy 21 has instructed Chevy 22 to execute a hard right turn. The descriptive portion of the message explains why… there are bandits at Chevy 22's four o'clock low position.

RADIO MESSAGES SHOULD BE BRIEF AND TO THE POINT

There are three types of radio communications in game:

- Radio commands that the player issues to other aircraft.
- Radio messages sent to the player from other aircraft, ground controllers, etc.
- Voice messages and warnings from the player's own aircraft.

Radio Commands

The following table describes the kinds of messages that the player may send and lists the key strokes needed to send each message. Depending on the type of command, it will take either two or three keystrokes to issue the desired message. There are also hot keys that allow the sending of a complex message as a single keystroke.

- Message target – This column indicates who the message is intended for, and may be the entire flight, a specific wingman, an AWACS/GCI controller, or an air traffic controller.
- Command – The command indicates the type of message you intend to send (such as an "Engage" command, or a "Formation" command, etc.)

Sub Command – In some cases, the sub-command specifies the exact type of command (such as "engage my target" or "Formation, line abreast.")

As illustrated in the table below, depending on the type of command, it takes either two or three keystrokes to generate the desired message. For example, to order the #3 wingman to engage the player's target, press F3, F1, F1.

Player-Generated Radio Commands

Message Target	Command	Sub Command	Definition of Command	Response(s) to Command
Flight or Wingmen	Engage...	My Target	Player requests wingmen to attack the target that is the focus of a sensor (radar or EOS) or padlock. When the target is destroyed, wingmen will return to formation.	If wingman is capable of carrying out this command, he will respond **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
		My Enemy	Player requests wingmen to attack enemy aircraft that is attacking him.	If wingman is capable of carrying out this command, he will respond **"(x) Copy," "(x) Roger," or "(x) Affirm,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative," or "(x) Unable,"** where (x) is the flight member.
		Bandits	Player requests wingmen to leave formation and engage bandits (enemy aircraft) within sensor range. When the target is destroyed, wingmen will return to formation.	If wingman is capable of carrying out this command, he will respond **"(x) Engaging bandit,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
		Air Defenses	Player requests wingmen to leave formation and attack any air defense units they detect. When the target is destroyed, wingmen will return to formation.	If wingman is capable of carrying out this command, he will respond **"(x) Attacking air defenses,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
		Ground Targets	Player requests wingmen to leave formation and attack enemy ground targets. Valid ground targets include any structure or vehicle assigned as enemy in the mission editor. When the target is destroyed, wingmen will return to formation.	If wingman is capable of carrying out this command, he will respond, **"(x) Attacking target,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.

		Naval Targets	Player requests wingmen to leave formation and attack any enemy naval target within sensor range. When the target is destroyed, wingmen will return to formation.	If wingman is capable of carrying out this command, he will respond, **"(x) Attacking ship,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
		Mission and Rejoin	Player requests that wingmen leave formation and attack the mission objective as identified in the mission editor. Once complete, the wingman will rejoin formation with player.	If wingman is capable of carrying out this command, he will respond, **"(x) Attacking primary,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
		Mission and RTB	Player requests that wingmen leave formation and attack the mission objective as identified in the mission editor. Once complete, the wingman will return to base.	If wingman is capable of carrying out this command, he will respond, **"(x) Attacking primary,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
Flight or Wingmen	Go to…	Return To Base	Wingmen will leave formation and land at their designated airfield. If no airfield is designated, they will land at the nearest friendly airfield.	If wingman is capable of carrying out this command, he will respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
		Route	Wingmen will leave formation and proceed to route by mission editor plan.	If wingman is capable of carrying out this command, he will respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.

		Hold Position	Wingmen will leave formation and fly around current point.	If wingman is capable of carrying out this command, he will respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
Flight or Wingmen	Radar…	On	Player requests that wingman to activate radar to search.	Wingman will respond, **"(x) Radar On,"** where (x) is the flight member.
		Off	Player requests wingman to deactivate radar.	Wingman will respond, **"(x) Radar Off,"** where (x) is the flight member.
Flight or Wingmen	ECM…	On	Player requests wingmen to activate ECM.	The wingman will respond, **"(x) Music On,"** where (x) is the flight member.
		Off	Player requests wingmen to deactivate ECM.	Wingman will respond, **"(x) Music Off,"** where (x) is the flight member.
Flight or Wingmen	Smoke	On	Player requests wingmen to activate smoke containers.	Wingman will activate smoke generators and respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member.
		Off	Player requests wingmen to deactivate smoke containers.	Wingman will activate smoke generators and respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member.
Flight or Wingmen	Cover Me		Player requests wingmen to attack the airplane which is nearest to the player's aircraft.	Wingman will respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member.
Flight or Wingmen	Jettison Weapons		Player requests wingmen to jettison weapons.	If wingman is capable of carrying out this command, he will respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.

Flight	Go Formation	Rejoin Formation	Wingmen will cease their current task and rejoin formation with the player.	If wingman is capable of carrying out this command, he will respond, **"(x) Copy rejoin,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
		Line Abreast	Orders wingmen into Line Abreast formation.	If wingman is capable of carrying out this command, he well respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, "**(x) Negative**," or "**(x) Unable**," where (x) is the flight member.
		Trail	The player is the lead aircraft and aircraft two .5 miles behind the player. Aircraft three is .5 miles behind aircraft two and aircraft four is .5 miles behind aircraft three.	
		Echelon	Standard formation	
		Close Formation	Player requests that the formation or wingmen decrease aircraft separation.	
		Open Formation	Player requests that the formation or wingmen increase aircraft separation.	
AWACSes	AWACS callsign	Request BOGEY DOPE	Player requests the bearing, range, altitude and aspect of the nearest enemy aircraft.	If AWACS/GCI has contact with an enemy aircraft then: **"(a), (b), bandits bearing (x)(x) for (y)(y)(y). (c) (d),"** where (a) is the callsign of the player, (b) is AWACS callsign, (x)(x) is the bearing to the threat in degrees, (y)(y)(y) is the range to the threat in miles if AWACS is western or kilometers if AWACS is Russian, (c) is the altitude of the contact, and (d) is the aspect of the contact. If AWACS/GCI does not have contact with any enemy aircraft then: **"(a), (b), clean,"** where (a) is the callsign of the player and (b) is AWACS callsign. If enemy aircraft are within five miles of player then: **"(a), (b), merged"** where (a) is the callsign of the player and (b) is AWACS callsign.

		Vector to Home Plate	Player requests the bearing and range to the nearest friendly airfield.	**"(a), (b), Home bearing (x)(x) for (y)(y)(y),"** where (a) is the player's callsign, (b) is AWACS callsign, (x)(x) is the bearing to the airfield in degrees, and (y)(y)(y) is the range in miles or kilometers depending on American or Russian AWACS.
		Vector to Tanker	Player requests the bearing and range to the nearest friendly tanker aircraft.	**"(a), (b), Tanker bearing (x)(x) for (y)(y)(y),"** where (a) is the player's callsign, (b) is AWACS callsign, (x)(x) is the bearing to the airfield in degrees, and (y)(y)(y) is the range in miles or kilometers depending on American or Russian AWACS. If no friendly tanker is present in the mission, then: **"(a), (b), No tanker available"**
		Request PICTURE	Player requests the bearing, range, altitude and aspect of the all enemy aircraft in zone.	If AWACS/GCI has contact with a enemy aircraft: **"(a), (b), bandits bearing (x)(x) for (y)(y)(y). (c) (d),"** where (a) is the callsign of the player, (b) is AWACS callsign, (x)(x) is the bearing to the threat in degrees, (y)(y)(y) is the range to the threat in miles if AWACS is western or kilometers if AWACS is Russian, (c) is the altitude of the contact, and (d) is the aspect of the contact. If AWACS/GCI does not have contact with any enemy aircraft: **"(a), (b), clean"**
ATC - Tower	Airfield callsign	Request Taxi to Runway	Player asks tower permission to taxi to runway.	ATC will always respond **"(a), Tower, Cleared to taxi to runway (x)(x),"** where (a) is the callsign of the player and (x)(x) is the heading number of the runway.
		Request Takeoff	Players asks permission from tower to takeoff.	If no aircraft are taking off from the runway and/or no aircraft are on final on that runway, then ATC will respond **"(a), Tower, You are cleared for takeoff,"** where (a) is the callsign of the player.

		Inbound	Player requests permission to land at the nearest friendly airbase	**"(a), (b), fly heading (x)(x), QFE, runway (y) to pattern altitude"** where (a) is the player's callsign, (b) is the airbase call sign, (x)(x) is the heading, and range, QFE is a Q-code Field Elevation, (y) the heading number of the runway.
Ground Crew		Rearm…	Player requests ground crew to rearm aircraft according to package selection.	Ground crew answers: "Copy ". After rearming informs: "Rearming complete ".
		Refuel…	Player requests ground crew to refuel	
		Request Repair	Player requests ground crew for repair	Complete repair is made within 3 minutes.
Other	Other messages specified by mission creator via trigger events.			

Radio Messages

Communications is a two-way process; the reports from another aircraft are as important as the reports sent by the player. Such reports describe the task accomplished, or to be accomplished, by a wingman. They can also warn the player, give target designation, and provide bearings to the different objects and airbases. The following table contains a complete list of possible reports.

- Report initiator – the unit sending the report – wingmen, AWACS, tower, etc.
- Event – Corresponding action of the report.
- Radio report – The message that is heard by the player.

Radio Messages

Report initiator	Event	Radio report
Wingman	Begins takeoff roll	**"(x), rolling,"** where (x) is the wingman's flight position
	Wheels up after takeoff	**"(x), wheels up,"** where (x) is the wingman's flight position.
	Hit by enemy fire and damaged	"**(x) I'm hit,**" or " **(x) I've taken damage,**" where (x) is the flight member. Example: "Two, I've taken damage."
	Is ready to eject from aircraft	**"(x) Ejecting,"** or **"(x) I'm punching out,"** where (x) is a US flight member. Example: "Three, I'm punching out." **"(x) Bailing out,"** or **"(x) I'm bailing out,"** where (x) is a RU flight member. Example: "Three, I'm bailing out."
	Returning to base due to excessive damage	**"(x) R T B,"** or **"(x) Returning to base,"** where (x) is the flight member. Example: "Four, R T B."
	Launched an air-to-	**"Fox from (x),"** if an American aircraft or **"Missile away from**

	air missile.	**(x),"** if a Russian aircraft, where (x) is the flight member. Example: "Fox from two"
	Internal gun fired	**"Guns, Guns from (x),"** where (x) is the flight member. Example: "Guns, Guns from three."
	Illuminated by enemy airborne radar	**"(x), Spike, (y) o'clock,"** where (x) is the flight member and (y) is a number one through twelve. Example: "Two, spike three o'clock."
	Illuminated by enemy ground-based radar	**"(x) Mud Spike, (y) o'clock,"** where (x) is the flight member and (y) is a number one through twelve. Example: "Two, mud spike three o'clock."
	Surface-to-Air Missile fired at wingman	**"(x) Sam launch, (y) o'clock,"** where (x) is the flight member and (y) is a number one through twelve. Example: "Two, Sam launch three o'clock."
	Air-to-Air Missile fired at wingman	**"(x) Missile launch, (y) o'clock,"** where (x) is the flight member and (y) is a number one through twelve. Example: "Two, Missile launch three o'clock."
	Visual contact on enemy aircraft	**"(x) Tally bandit, (y) o'clock,"** where (x) is the flight member and (y) is a number one through eleven or nose. Example: "Two, Tally bandit three o'clock."
	Performing defensive maneuver against threat	**"(x) Engaged defensive,"** where (x) is the flight member. Example: "Two, Engaged defensive."
	Shot down enemy aircraft	**"(x) Splash one,"** **"(x) Bandit destroyed,"** or **"(x) Good kill, good kill,"** where (x) is the flight member. Example: "Two, Splash my bandit."
	Destroyed enemy ground structure, ground vehicle, or ship	**"(x) Target destroyed,"** or **"(x) Good hits,"** where (x) is the flight member. Example: "Two, Target destroyed."
	Wingman has spotted enemy aircraft and wishes to attack	**"(x) Request permission to attack,"** where (x) is the flight member. Example: "Two, Request permission to attack."
	Iron bomb or cluster bomb released	**"(x) Bombs gone,"** where (x) is the flight member. Example: "Two, Bombs gone."
	Air-to-ground missile fired	**"(x) Missile away,"** where (x) is the flight member. Example: "Two, Missile away."
	Air-to-ground, unguided rockets fired	**"(x) Rockets gone,"** where (x) is the flight member. Example: "Two, Rockets gone."
	Flying to attack target after passing IP	**"(x) Running in"** or **"(x) In hot,"** where (x) is the flight member. Example: "Two, Running in."
	Enemy aircraft	**"(a) Contact bearing (x)(x) for (y)(y)(y)"** where (a) is the flight member, (x) is the bearing in degrees and (y) in the range

	detected on radar	in miles for US aircraft and kilometers for Russian aircraft. Example: "Three, Contact bearing one eight for zero five zero."
	Has reached fuel state in which aircraft must return to base or risk running out of fuel	**"(x) Bingo fuel,"** where (x) is a US flight member. Example: "Two, Bingo fuel." "**(x) Low fuel,**" where (x) is a RU flight member. Example: "Two, Low fuel."
	No remaining weapons on wingman's aircraft.	**"(x) Winchester,"** when US wingman and (x) is flight member. **"(x) Out of weapons,"** when Russian wingman and (x) is flight member.
	Enemy aircraft is behind player's aircraft.	**"Lead, check six"**
	Player's aircraft is about to explode or crash.	**"Lead, bail out"**
Tower	Player has come to a halt after landing on runway.	**"(x), Tower, taxi to parking area,**" where (x) is the callsign of the aircraft. Example: "Hawk one one, Tower, taxi to parking area."
	Player has reached approach point and has been passed over to tower control. The runway is clear for landing.	**"(x), Tower, cleared to land runway (y)(y),"** where (x) is the callsign of the aircraft and (y) is the two-digit runway heading of the runway the aircraft is to land on. Example: "Hawk one one, Tower. cleared to land runway nine zero."
	Player has reached approach point and has been handed over to Tower control. However, an aircraft is already in the pattern.	**"(x), Tower, orbit for spacing,"** where (x) is the callsign of the aircraft. Example: "Falcon one one, Tower, orbit for spacing."
	Player is above glide path while landing	**"(x), Tower, you are above glide path,"** where (x) is the callsign of the aircraft. Example "Eagle one one, Tower, you are above glide path."
	Player is below glide path while landing	**"(x), Tower, you are below glide path,"** where (x) is the callsign of the aircraft. Example "Eagle one one, Tower, you are below glide path."
	Player is on glide path while landing	**"(x), Tower, you are on glide path,"** where (x) is the callsign of the aircraft. Example "Eagle one one, Tower, you are on glide path."

Voice Messages and Warnings

Computer technology has revolutionized combat aircraft; modern jets continually diagnose themselves and provide announcements, warnings, and even instructions to the pilot. In the days before women could become combat pilots, designers decided a woman's voice would be immediately noticeable over the clamor of male voices flooding the airwaves.

- Message Trigger – The event that prompts Betty to announce the message
- Message – The exact phrase that Betty announces.

Voice Message System Messages

Message Trigger	Message
The right engine is on fire.	"Engine fire right"
The left engine is on fire.	"Engine fire left"
Flight control systems have been damaged or destroyed.	"Flight controls"
Landing gear is deployed over 250 knots.	"Gear down"
Landing gear is not deployed and player is on ILS final approach.	"Gear up"
The aircraft has just enough fuel to reach the closest friendly airbase.	"Bingo fuel"
Fuel is at 1500 pounds/liters	"Fuel 1500"
Fuel is at 800 pounds/liters	"Fuel 800"
Fuel is at 500 pounds/liters	"Fuel 500"
The automated control system is not functional	"ACS failure"
Navigation systems failure	"NCS failure"
ECM is not functional	"ECM failure"
Flight control system hydraulics are not functional	"Hydraulics failure"
The missile launch warning system (MLWS) is not functional	"MLWS failure"
Avionics systems failure	"Systems failure"
The EOS is not functional	"EOS failure"
The radar is not functional	"Radar failure"
ADI in the cockpit does not function.	"Attitude indicaton failure"
Damage to aircraft systems that does not include fire or flight control systems.	"Warning, warning"
Aircraft has reached or exceeded its maximum angle of attack.	"Maximum angle of attack"
Aircraft has reached or exceeded its maximum G level.	"Maximum G"
Aircraft has reached or exceeded its maximum speed or its stall speed.	"Critical speed"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is in front of the player, and is at a lower altitude than the player.	"Missile, 12 o'clock low"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is in front of the player, and is at a higher altitude than the player.	"Missile, 12 o'clock high"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is behind of the player, and is at a lower altitude than the player.	"Missile, 6 o'clock low"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is behind of the player, and is at a higher altitude than the player.	"Missile, 6 o'clock high"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is to the right of the player, and is at a lower altitude than the player.	"Missile, 3 o'clock low"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is to the right of the player, and is at a higher altitude than the player.	"Missile, 3 o'clock high"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is to the left of the player, and is at a lower altitude than the player.	"Missile, 9 o'clock low"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is to the left of the player, and is at a higher altitude than the player.	"Missile, 9 o'clock high"

THEORETICAL TRAINING

To be successful in air combat is not an easy task. Fighter pilots of all countries practice for many years to achieve the skills necessary to get the maximum performance out of their aircraft. Though it is impossible to model every aspect of flight training, it is nevertheless important to understand some principles of combat aviation.

Indicated Air Speed and True Airspeed

As a rule, when flight altitude decreases, the air density increases. The denser atmosphere contributes to a greater lift force, but the drag component increases as well. The thinner air at high altitudes reduces aircraft lift, but drag will decrease. This contributes to higher airspeeds at high altitude. An aircraft traveling at 700 km per hour possesses different flight characteristics when flying at 1,000 km per hour. The actual speed at which aircraft flies through the air mass is called the true air speed (TAS). TAS automatically compensates for air pressure and density. Related to TAS, Ground Speed (GS) is the aircraft's actual speed across the earth. It equals the TAS plus or minus the wind factor.

Most modern aircraft have airspeed indicators that take into account air density and humidity changes at different altitudes. When these changes are not taken into account, the aircraft velocity is called Indicated Air Speed (IAS). For the pilot, the IAS is the basis for defining maneuvering capabilities of an aircraft; it is usually displayed on the HUD and dash.

THE AIRSPEED INDICATOR SHOW THE AIRCRAFT’S INDICATED AIR SPEED

Velocity Vector

The total velocity vector indicator is a common feature on western HUDs; it is also called the Flight Path Marker (FPM). The velocity vector indicates the actual flight direction of the aircraft, which may not correspond with where the nose of the jet is actually pointed. If you place the velocity vector on a point on the ground, eventually, the aircraft will fly directly into that point. This indicator is important tool for pilots and can be used from combat maneuvering to landing approaches.

Angle-of-Attack (AoA) Indicator

As described above, the velocity vector may not coincide with the longitudinal axis of the aircraft. The angle between the velocity vector projection and the aircraft’s longitudinal axis is termed angle-of-attack. When the pilot pulls the control stick back, he generally increases the aircraft angle-of-attack. If during a straight and level flight the pilot reduces the engine thrust, the aircraft will start to lose altitude. To continue the level flight, one needs to pull back on the stick and thereby increasing AoA.

AoA and IAS are connected with an aircraft’s lift characteristics. When aircraft AoA is increased up to critical value, aerodynamic lifting force also increases. Increasing indicated airspeed at a constant AoA can also contribute to lifting forces. However, induced airframe drag also increases when AoA and airspeed increase. One has to keep this in mind or the aircraft could depart controlled flight. For example, the aircraft may depart if the pilot exceeds AoA limits. Limitations are always indicated on the aircraft’s AoA indicator gauge.

ABRUPT, HIGH-G MANEUVERING AT HIGH ANGLES-OF-ATTACK MAY CAUSE THE AIRCRAFT DEPARTURE

When aircraft AoA is increased up to a critical value, the airflow becomes disrupted over the wing and the wing ceases to generate lift. Asymmetrical air-mass separation from the left and right wings can induce side movement (yaw) and stall the aircraft. The stall may happen when the pilot exceeds the allowed AoA. It is especially dangerous to get into stalls when in air combat; in a spin and out of control, you’re an easy target for the enemy.

When in a spin, the aircraft rotates about its vertical axis and constantly losing altitude. Some types of aircraft may also oscillate in pitch and roll. When in a spin, the pilot has to concentrate all his attention on recovering the aircraft. There are many methods to recover various aircraft types from a spin. As a general rule, one should reduce thrust, deflect rudder pedals in the opposite direction of the spin, and keep the flight stick pushed forward. The control devices should be kept in this position until the aircraft stops spinning and enters a controllable, nose-down pitch angle. After recovering, place the aircraft back into level flight, but be careful not to re-enter a spin. Altitude loss during a spin can reach several hundred meters.

TO RECOVERY THE AIRCRAFT FROM A SPIN: REDUCE THRUST, DEFLECT RUDDER PEDALS IN THE OPPOSITE DIRECTION OF THE SPIN, AND PUSH THE CONTROL STICK FORWARD. LEAVE THE CONTROLS IN THIS POSITION UNTIL THE SPIN CEASES

Turn Rate and Radius of Turn

The aerodynamic lift force vector is oblique to the aircraft's velocity vector. As long as the force of gravity is balanced by the lifting force, the aircraft maintains level flight. When the aircraft's bank angle changes, the lift force projection on the vertical plane decreases.

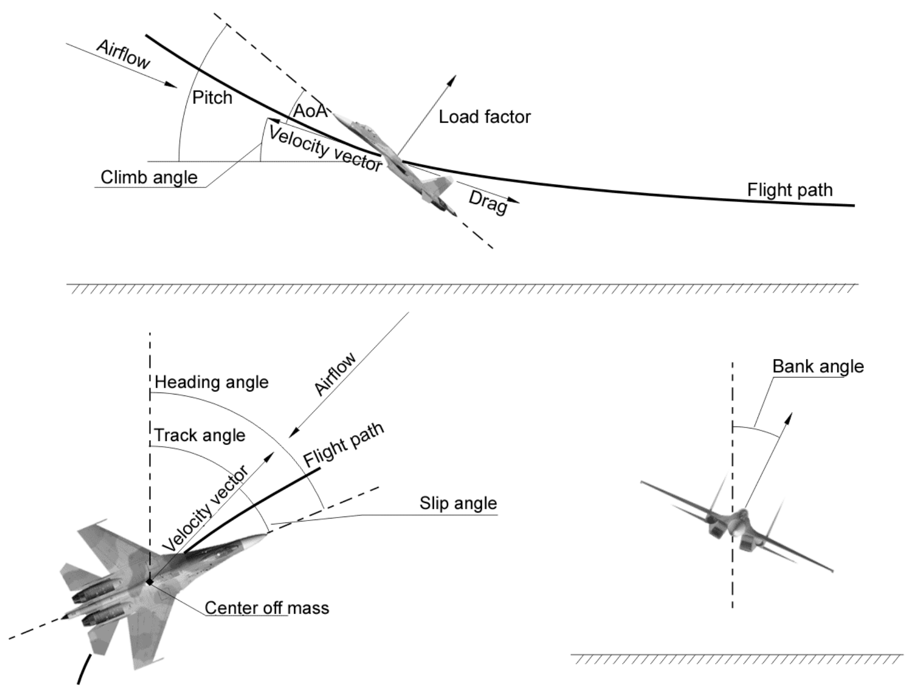


Figure 82. Aircraft aerodynamic forces

The amount of available lift influences the aircraft's maneuvering characteristics. Important indicators of maneuvering capability are maximum turn rate in the horizontal plane and radius of turn. These values depend on the aircraft's indicated air speed, altitude, and its lifting characteristics. Turn rate is measured in degrees per second. The higher the turn rate, the quicker the aircraft can change its flight direction. To max-perform your aircraft, you must distinguish between sustained corner velocity (no speed loss) and instantaneous corner velocity (with speed loss) turn rates. According to these values, the best aircraft should be characterized by a small turn radius and a high turn-rate over a broad range of altitudes and speeds.

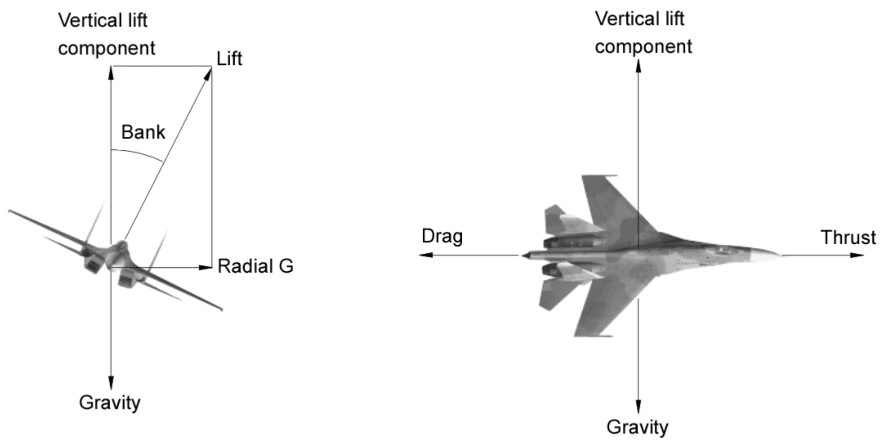


Figure 83. The forces acting at the aircraft maneuver

Turn Rate

When G-load increases: turn rate increases and radius of turn decreases. There is an optimal balance at which maximum possible turn rate is achieved with the smallest possible turn radius.

> THERE IS AN OPTIMAL BALANCE AT WHICH MAXIMUM POSSIBLE TURN RATE IS ACHIEVED WITH THE SMALLEST POSSIBLE TURN RADIUS.
>
> IN A DOGFIGHT, YOU MUST TO STAY CLOSE TO THIS AIRSPEED

The diagram below illustrates turn rate vs KIAS (knots indicated airspeed) performance chart of a modern fighter at afterburner thrust. Airspeed is displayed along the X axis and degrees per second is displayed along the Y axis. The "dog house" looking plot is the aircraft's turn performance along this scale. The other lines represent G-loads and radius of turn. Such a diagram is often called a "dog house" plot or an Energy and Maneuvering (EM) diagram. Though the turn rate at 950 km/h has a maximum turn rate (18.2 degrees per second), the speed to achieve a smaller turn radius is around 850-900 km/h. For other aircraft, this speed will vary. For typical fighters, corner speeds are in 600-1000 km/h range.

> YOUR AIRSPEED AND ALTITUDE ARE CRITICAL IN DETERMINING THE TURN PERFORMANCE OF YOUR AIRCRAFT. LEARN YOUR CORNER SPEEDS AND THOSE OF YOUR ENEMY

For example: performing a sustained turn at 900 km/h, the pilot, if necessary, can pull maximum G to increase turn rate to 20-degrees per second for a short time period. This simultaneously decreases turn radius. Doing this, the aircraft will slow down due the high-G excursion. By then entering a sustained G-loading turn, the turn rate will increase up to 22 degrees per second with noticeably decreasing of turn radius. By keeping the aircraft at AoA close to maximum you can hold this turn radius and maintain a sustained turn with a constant airspeed 600 km/h. Using such a maneuver will help either achieve a positional advantage or to break a bandit off your six.

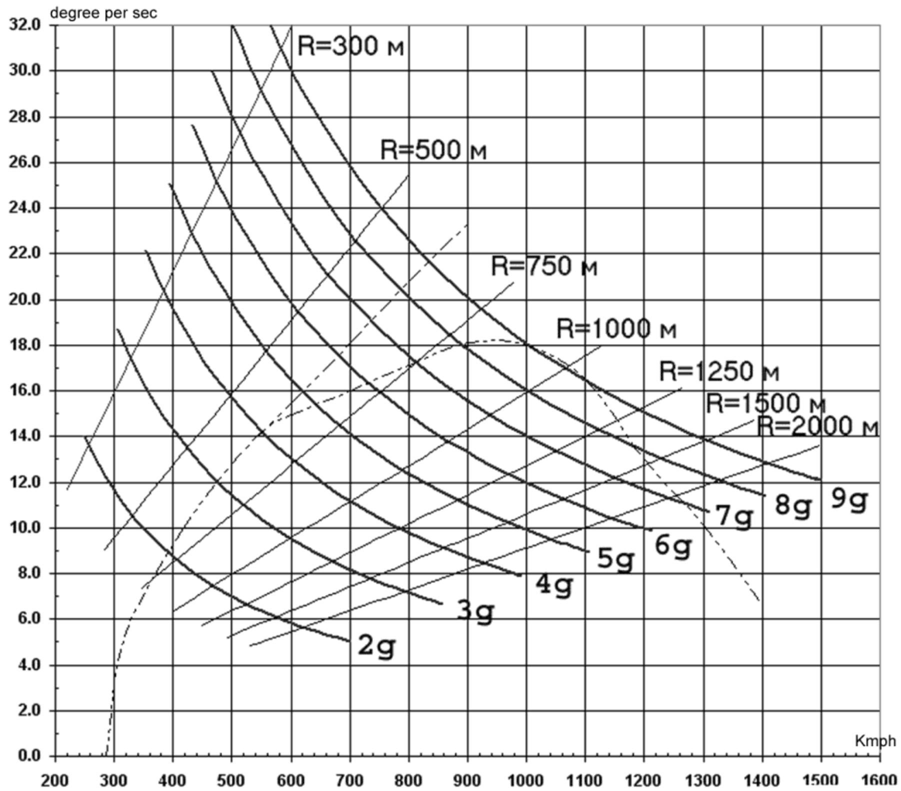


Figure 84. Typical turn rate vs KIAS "dog house" plot of a modern fighter

Sustained and Instantaneous Turns

An instantaneous turn is characterized by high turn rates and airspeed loss during maneuvering. The airspeed loss is due to the significant drag generated by the high G and AoA levels. AoA and G loading factors can often reach their maximum, allowable values in a "max-performance", instantaneous turn. Although it will slow your aircraft down, it is the fastest way to get your nose on a target. You may be in an energy-hole after doing so though.

REGULAR, INSTANTANEOUS TURNS RESULT IN SIGNIFICANT AIRSPEED LOSS

When performing a sustained turn, drag and gravity are balanced by engine thrust. The sustained turn rate of turn is lower than the instantaneous turn rate, but is achieved without airspeed loss. In theory, the aircraft can perform a steady turn until it runs out of fuel.

Energy Control

In air combat, the pilot must control the aircraft's energy state. The total energy of an aircraft can be represented as a sum of potential energy and kinetic energy. Potential energy is determined by the aircraft's altitude; kinetic energy is determined by airspeed. Because thrust developed by the engines is limited, flying at a high AoA will cancel out the thrust. The aircraft will lose energy. To prevent this during combat, the pilot should keep his flight envelope such that he is maneuvering at the aircraft's maximum sustained turn rate and minimizing turn radius simultaneously.

TOO MANY HARD TURNS WITH ALTITUDE LOSS LEAD TO AN AIRCRAFT WITH LITTLE ENERGY

Suppose that energy is equivalent to "money" used to "buy" maneuvers. Suppose there is a constant replenishment (while the aircraft's engines are running). Optimal control requires rational "money" consumption for necessary maneuver purchases. Performing high-G turns causes the aircraft to lose speed and consequently the energy supply (bank) lowers. In this case you can say that the price for cheap turn rate was too high. You now have little money left in the bank and are an easy target for an enemy with a fist full of cash.

Therefore, without a critical need, you should avoid high-G maneuvers that result in speed loss. You should also try to maintain high altitude and not lose it without good reason (this is money in your energy bank). In close combat, try to fly the aircraft at speeds that maximize your sustained turn rate while minimizing your turn radius. If your airspeed reduces significantly, you have to reduce AoA by pushing the stick forward and "unloading" the aircraft. This will allow you to gain speed quickly. However, you need time this unloading carefully or you will give an enemy an easy kill.

IF YOU LOSE CONTROL OVER AIRCRAFT ENERGY MANAGEMENT, YOU WILL SOON FIND YOURSELF WITH LITTLE AIRSPEED AND ALTITUDE

COMBAT OPERATION BASICS

Modern air combat tactics have changed in revolutionary ways in less than a century. The small, propeller-driven fighters of decades ago have evolved into the modern jet fighters of today.

The primary reason why virtual pilots crash or are often killed is due to the inconsistency between a combat situation and the weapons they use. Today's aircraft are much more powerful than their WWII era brethren. However, enemy firepower is much more accurate and lethal now, and it can engage targets at much longer ranges. In short, the battlefield has become more dangerous than it was before.

Air Combat Tactics

Maneuvers

When within visual range (WVR), the classic dogfight will often ensue.

> THE CLOSE AIR COMBAT IS NOT A CHESS GAME. A PILOT DOES NOT THINK: "HE IS DOING A LOOP AND I MUST DO A TURN". THIS IS A FLEXIBLE, DYNAMIC AND CONSTANTLY CHANGING ENVIROMENT. A PILOT ESTIMATES WHERE HE SHOULD BE IN ORDER TO USE HIS WEAPONS AND BRING HIS WEAPONS TO BEAR BEFORE THE ENEMY

Combat Turnaround

The combat turnaround is one of the most basic maneuvers. The pilot performs a 180–degree turn while simultaneously performing a climb. This accumulates energy for the following maneuver. This maneuver should be done at MIL power, or even full AB thrust, in order to accomplish it quickly and without significant loss of airspeed.

If you are in the offensive position with a speed advantage and the enemy performs a defensive maneuver (such as a break), then you can perform a "Hi Yo-Yo" maneuver that will retain your offensive position and energy.

"Hi Yo-Yo" Maneuver

The "Hi Yo-Yo" maneuver is similar to a combat turnaround. First execute a steep climb perpendicular to the target's flight path. During this maneuver, it is important that you do not lose sight of the enemy; always know his location. This maneuver should be accomplished a bit behind and higher than the target. As you climb past the target, roll back into the same maneuver plane as the target. This sets you up with an attack with both a positional and energy advantage. Generally speaking, the execution of a series of small "Hi Yo-Yo" maneuvers is better than performing a single, large maneuver. Be careful of the enemy pilot that recognizes this maneuver and reverses back into you; this can then form into a "scissors" dog fight.

Scissors Defensive Maneuver

If the enemy approaches you from behind and is about to fire, you must take immediate action. One of the most effective maneuvers that can quickly turn the attacker into the defender is called the "scissors". The essence of the maneuver is simple; use the speed advantage of the enemy to turn inside him and force him into a series of single-circle merges. The one with the higher roll rate and slow speed maneuvering capability will get behind the other.

Gun Employment in Air Combat

Using the gun of a moving aircraft against another maneuvering aircraft is a not trivial task. First, the number of cannon shells onboard and effective gun range are quite limited. During a fight, an enemy is constantly maneuvering and it is very difficult to estimate the point at which the pilot should fire. World War II pilots had to calculate this point "by sight" and estimate when the fired shells and the enemy aircraft would intersect. As a result, it was very difficult for a pilot to maneuver in two planes and quickly calculate the lead angle.

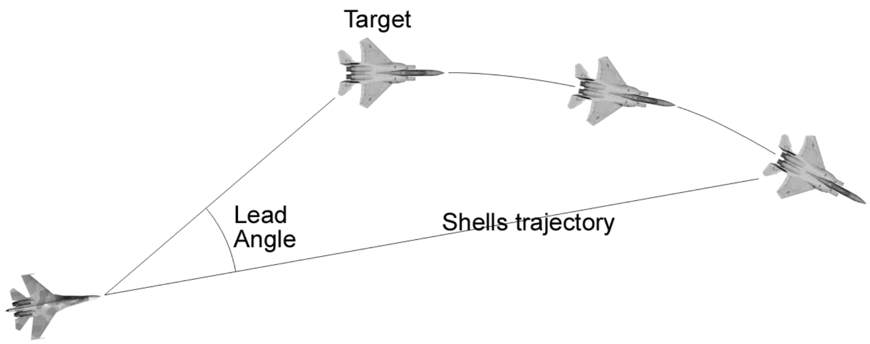


Figure 85. Gun use during air combat

Meanwhile, the attacking aircraft is also constantly moving and flies along a curvilinear trajectory. From inside the aircraft, shell trajectory appears to be "bent", when in fact they are flying straight. If everything goes according to plan, the pilot is aiming with proper lead, opens fire and watches the "bent" line and corrects fire.

Based on the above, we can conclude that range to target is one of the most important factors in hitting another aircraft with the gun. The farther the target is, the longer the shell flies, and the more it is affected by the drag and gravity. Therefore, the pilot should consider greater lead angle for larger cannon shells. Due to this challenge, many pilots of World War I and II would not open fire until they were in range to see the face of the enemy pilot. This ensured a minimal effect of drag and gravity on their shells. The lower the range to the target is, the greater the hit possibility. The correct lead-angle becomes more and more difficult as range to target grows.

In the modern aircraft, pilots are now capable of determining correct lead points due to weapon control systems that continuously calculate the lead aiming point; however, they do have their limits. In order to calculate a lead point it is necessary to know the range to target; this information is supplied to the WCS by a radar or laser range-finder. Based on the aircraft and target movement parameters, the lead point is calculated and the gun pipper is drawn on the aircraft HUD. The pilot then flies the aircraft to place the pipper on the target and fire the gun. The gun pippers of Russian and American aircraft looks different, but their function is essentially the same.

In situations where it is impossible to get range data on the target due to radar malfunction or ECM, other gun aiming systems are available. Such a system is the "funnel" that indicates the ballistic flight path of cannon rounds. The center-area of the funnel is the shell flight path; the two outside lines denote target wingspan (also called "target base").

To aim with the funnel, you must place the target within the funnel and have the target’s wingtips touch the sides of the funnel. If done properly against a fighter-sized target, the cannon shells will impact the target. The funnel is not as accurate against high aspects targets because of the angular rotation values. Similarly, it is difficult to aim at targets that are maneuvering with variable angular velocity and/or rapidly changing their direction of flight.

A gun attack assumes a relatively smooth approach to the target, a sustained firing position and opening fire. On the other hand, a shot opportunity is available with a snap-shot when the enemy aircraft, possibly unexpectedly, appears in front of you and in guns range. It is necessary to seize this moment and hit the target while it is "caught" in the gun pipper.

When maneuvering at high-G loads, the gun pipper is usually along the lower portion of the HUD and it is very difficult to aim in such a situation. In such a case, maneuver with lead pursuit inside the target's maneuver plane, and for a brief moment, decrease your G-loading. Squeeze a gun burst shortly before the target flies through the gun pipper and allow the gun burst to walk through the target.

Accuracy with the gun takes a great deal of skill, and above all, lots of practice. Try to stay in the same maneuver plane as your target as this will allow a steady tracking shot. There are two maneuver vectors. There is the longitudinal vector and the lift vector. Though a good marksman can consistently hit targets in both planes and combination of them, a target not maneuvering or maneuvering in only a single plane can be an easy target. Avoid doing so or you may soon be under someone else's gun pipper.

To best match your target's maneuver plane, try to match the target's angle of bank and pitch. You can achieve a high hit percentage by maneuvering behind the enemy and adapting yourself to his maneuver. If you blend this with the predicted target trajectory, then the target will soon be in your sights.

Air-to-Air Missile Tactics

When within visual range of enemies, the pilot should strive for situational awareness and never lose track of what is going on around him. Never lose sight of the enemy, especially when you are on the defensive. Remember that threat warning systems do not alert you to the launch of an infrared-guided missile. That is why you can suddenly get a missile up your tail pipe without warning. As such, it is often best to use pre-emptive flares when entering a fight with aircraft loaded with infrared weapons. The only way you will detect the launch of an infrared system is with your own eyes or a wingman's warning. In the WVR arena, keep your eyes out of the cockpit and look for the tell-tail sign of a missile trail heading your way. Also remember that your jet engines are a magnet for infrared seekers. To reduce your vulnerability to infrared seekers, keep out of afterburner if you can. During combat, try to only use AB when the enemy cannot take a shot at you. If an infrared-guided missile is launched on you, reduce engines to mil power, pump out flares, and perform a high-G break when the missile nears. For best results, dispense 2-3 flares every second until the missile has missed.

Air Defense

Air defense includes surface-to-air missile (SAM) systems and antiaircraft artillery (AAA), and is an integral part of the modern battlefield. When tied to an early warning radar (EWR) network, these weapon systems provide defense of high-value installations and ground forces. A properly prepared pilot should have exhaustive knowledge of these weapons and understand their strengths and weaknesses.

Antiaircraft Artillery (AAA)

AAA is an effective weapon when used against low-flying targets. Many armed forces have adopted multi-barrel, self propelled anti aircraft guns (SPAAG) that are directed by a fire control radar. The addition of the fire control radar provides all-weather engagement capability and is generally more accurate than manual control. In contrast to ground force AAA systems, navalized AAA has more uses than just shooting down enemy aircraft.

AAA cannon shell consists of a warhead, an impact fuse, and often time-delay fuse that triggers at a predetermined time after the round is fired. Some systems even have miniaturized proximity fuses that detonate a small warhead when the round passes near a target. Most targets downed by AAA are damaged or destroyed by the warhead fragments.

Ground systems such as ZSU-23-4 "Shilka" are multi-barreled, have a high rate of fire, and provide mobility. Equipped with its own radar, SPAAG systems often use multiple detection bands to locate and track their target, e.g. IR, radar and optical systems. As such, defeating the radar lock of a radar-directed SPAAG system may not ensure safety.

To destroy a low-flying target, many ships use multi-purpose guns that can be used against enemy ships, aircraft, and anti-ship cruise missiles. Naval artillery is divided into three categories: large (100 – 130 mm), medium (57 – 76 mm) and small (20 – 40 mm) calibers. All these guns use a highly automated fire direction, reloading, and firing. Small-caliber guns (20 – 40 mm) are most effective against low-flying aircraft and cruise missiles. Small-caliber AAA is usually a ships last defense. Such weapons can fire up to 6,000 rounds per minute, and this creates a "curtain" of fire between the targeted ship and the enemy out to 5,000 meters.

Surface-to-Air Missile (SAM) systems

SAM systems form the foundation of an integrated air defense system (IADS), and each SAM unit provides its acquisition and targeting data into the network. Short-range and man-portable air defense (MANPADS) systems generally operate independently and are usually attached to mechanized units.

Air defense missiles consist of the following elements: seeker head, fuse, warhead, and rocket motor. Over the air frame of the missile, the wings and control surfaces are attached.

During flight, the missile is controlled by the guidance system. The seeker either uses data received from its own antenna or from a fire control radar on the ground. Missile guidance can be: command, semi-active, active, passive or combined.

Command Guidance

Command guidance can be compared with older remote guidance methods. During the missile's flight, the target and the missile are both tracked from the ground by the fire control radar or by equipment onboard the missile.

When a missile is launched in command guidance mode, all the information to calculate the flight trajectory is processed by the ground station and steering commands are sent to the missile to provide an intercept course. When the missile reaches the intercept point, the radar transmits encoded information to the missile by a radio channel that is protected from jamming. Upon the decoding of the signal, the missile's onboard equipment sends commands to the actuators.

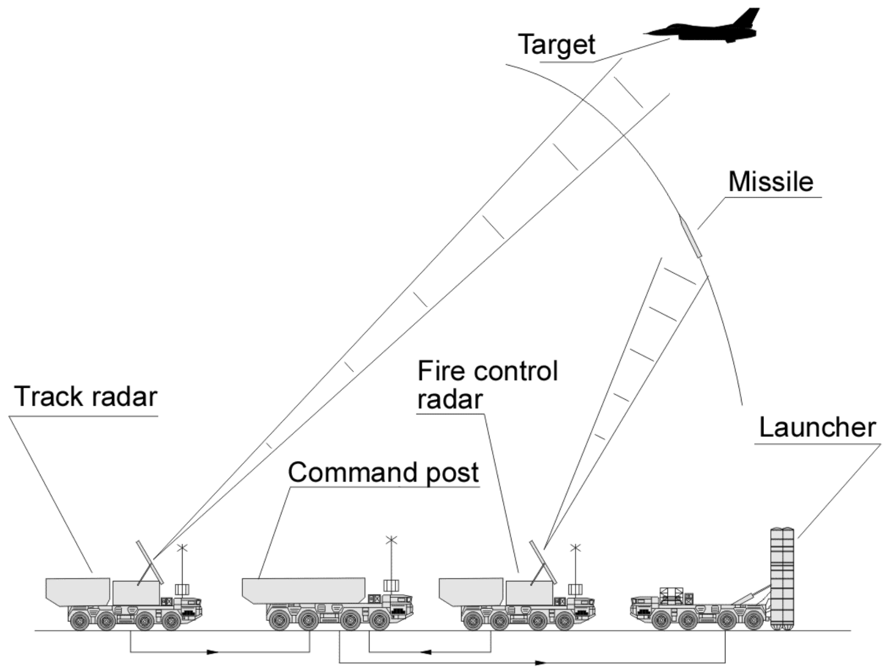


Figure 86. Command guidance

The missile and target coordinates are tracked by the fire control radar. After the missile and the target coordinates are the same, the control station transmits a warhead detonation command to the missile. Such a guidance system is used in both older systems like the C-75 (SA-2) and in newer systems like the SA-19 "Tunguska" and SA-15 "Tor".

Semi-Active Guidance

The semi-active guidance method is based on the missile guiding itself to the target based on the reflected radar energy off the target into the missile's antenna. The source of this radar energy is a SAM system's fire control radar. All control commands are calculated onboard the missile. This guidance method is similar to air-to-air missiles that use the same system. For successful guidance to the target, the illumination radar must track the target during the duration of the missile's flight. If the radar loses lock, the missile will self-destruct. One drawback of this method is that effectiveness drops in a heavy ECM environment.

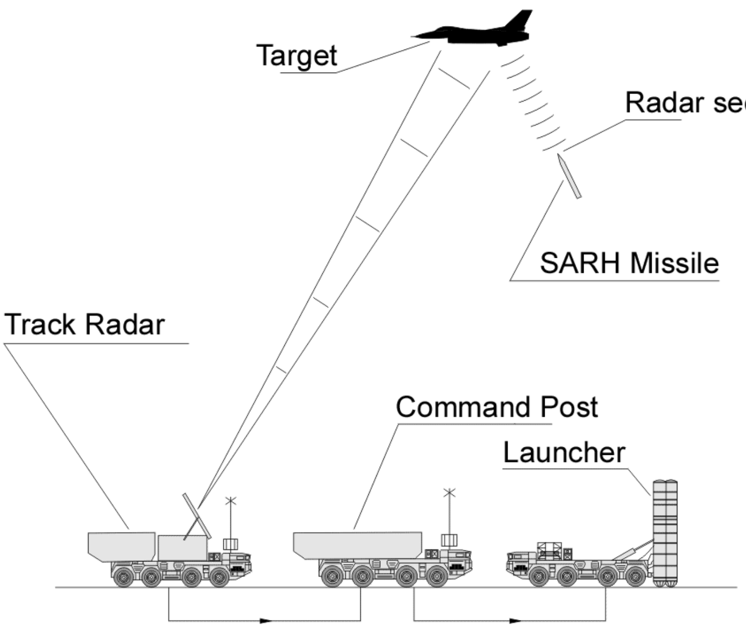


Figure 87. Semi-active guidance

Active Guidance

This differs from semi-active guidance in that the seeker not only has a receive function, but also a transmitter that can illuminate targets i.e. it can illuminate the target itself and guide to the target autonomously.

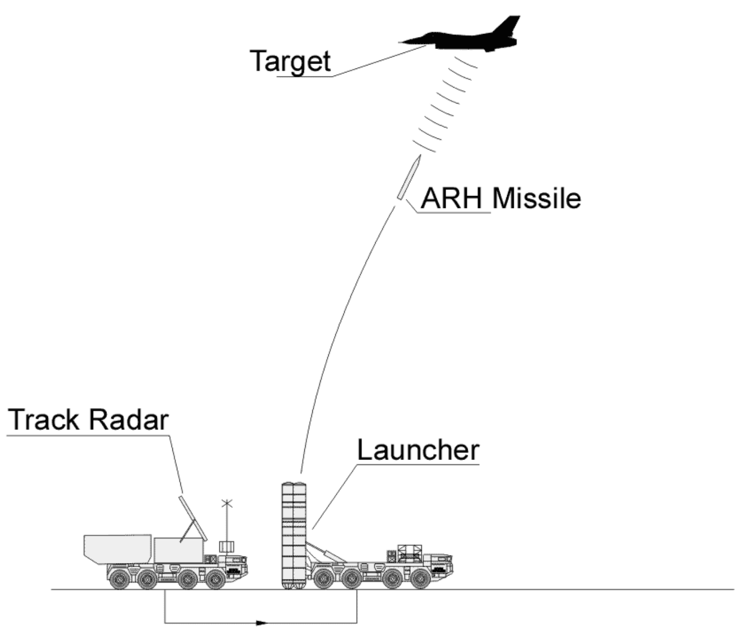


Figure 88. Active guidance

This method has great advantages in that it permits the SAM system to not illuminate the target with its radar, but instead using the missile. Like semi active guidance, active systems are also susceptible to heavy jamming.

Passive Guidance

This method is most often used with infrared-guided systems. The missile locks on to the target's thermal signature before the missile is launched and then guides itself to the target based on the infrared lock. Such a system permits a passive emission attack that will generally not alert an enemy, a radar track is not required. Shortcomings include reduced performance in bad weather conditions like fog, clouds and precipitations, the lock can often be defeated with flares, and target lock range is often much less than radar-guided systems. Infrared systems are often short-ranged systems assigned to ground units or MANPADS.

Combined Guidance

As one may assume from the name, some missiles combine guidance methods to increase effectiveness. The S-300 is an example of a system with combined guidance. It maintains guidance by command guidance during initial guidance and then semi-active guidance when the missile reaches the terminal portion of the flight. This allows high accuracy at long ranges.

During missile guidance to the target, target data is also passed from the missile back to the fire control radar, the missile's flight path is then adjusted according to this track via missile (TVM) method. Combined with its own inertial guidance system, radio-correction commands from the ground control are also used to guide the missile. Such guidance scheme provides high effectiveness in heavy jamming environment and significantly reduces missile detection.

SAM Engagement Zone

Like air-to-air missiles, SAM missiles have a limited engagement zone.

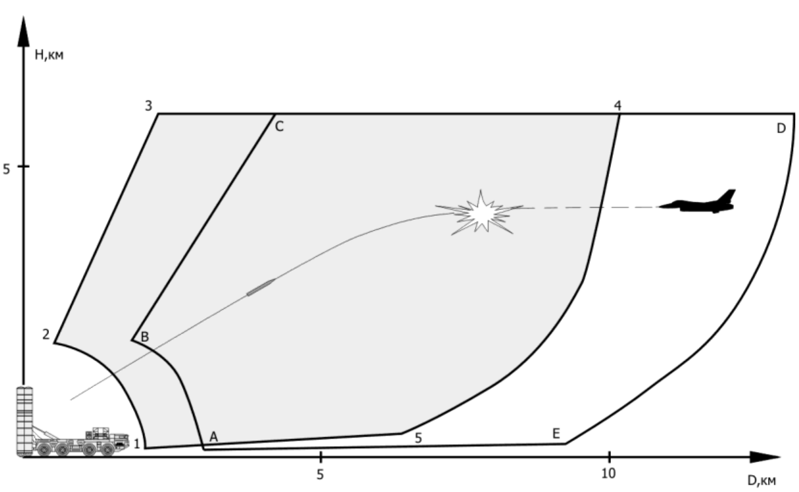


Figure 89. SAM typical engagement zone

The optimal target engagement zone is generally located in the center of the weapons employment zone (WEZ). Like air-to-air missiles, the WEZ depends upon target range, altitude and aspect angle. In this WEZ diagram, the areas designated "1-2-3-4-5" reflect possible engagement zones. The areas designated "a-b-c-d-e" reflect the WEZ of a target flying towards the SAM; as you can see, this significantly increases the range of the SAM. Each SAM system has a "dead zone" that is represented by the 1-2-3 or a-b-c curve on the diagram. The size of this zone depends on the SAM type; modern SAMs have smaller "dead zones." The altitude of the WEZ is designated by 3-4 (a-b) and distance by 4-5 (d-e). These mainly depend on the missile's energetic characteristics and the guidance system type. This border illustrates the maximum interception point in altitude and range. A SAM's WEZ will also depend on the target speed and altitude and course.

The maximum acquisition and lock range is determined by the target's radar cross section (RCS), its range and altitude.

SAMs are usually classified by range:

- Long-range (>100 km)
- Medium-range (20-100 km)
- Medium and short-range (10-20 km)
- Short-range (<10 km)

The lower boarder of the WEZ depends on the SAM radar's ability to detect and track low-flying targets and the missile's ability to intercept low-flying targets; at low altitudes, the proximity fuse may detonate the warhead prematurely.

Many factors such as terrain masking, radar wave feedback into the antenna and ground noise limit the ability of radars to detect low flying aircraft. If the radar antenna is located at ground level, the radio horizon is 20 m at a range of 20 km and 150 m at 50 km. To better detect low-flying aircraft, some SAM systems mount the radars on masts.

Even with elevated radars, it is quite difficult for radars to detect targets over the natural noises from the earth and objects placed on it such as buildings, moving vehicles etc. These noises can lead to mistakes in target angular data and range. These mistakes can adversely influence target tracking and eventually lead to a dropped track.

In order to guide a SAM missile to a target intercept point, most antiaircraft missile systems are equipped with a horizontal (by azimuth) and vertical (elevation angle) guidance mechanisms. Such systems are the targeting bearing and height finder radars. By contrast, modern systems use a phased array antenna that electronically scans instead of a mechanical scan (rotating and nodding antennas). They are able to detect targets over a wide sector and are often used with vertical launch systems (VLS) that permit a 360-degree engagement capability.

Ground Control Intercept

Modern IADS systems connect early warning radars and fire-control radars with a Ground Control Intercept (GCI) network. This permits one search, or track, radar to use data from other radars of the same network. This allows a launcher to not only use local radars, but also receive data from radars located elsewhere. This can lead to a situation where you have detected a radar outside its associated WEZ, but then you have a launcher below you and well within its WEZ. This can present a very dangerous situation with little time to respond to the threat. In order to accomplish your mission and return to the base, it is vital that you familiarize yourself thoroughly with the preplanned threat locations before taking off.

Enemy Air Defense Penetration

Penetrating an IADS is a very difficult task. The following recommendations will help you reach your initial attack point, detect and destroy your target, and return home.

Don't Get Shot At…

It seems obvious, but the best way to avoid being shot down is to prevent enemy missiles from ever being launched at you. Fighter pilots are often depicted as modern-day knights of the sky, seeking to find a duel. However, in reality, they are more similar to assassins that prefer to keep silent, take any advantage and kill unsuspecting victims. You should try to avoid concentrated, enemy defense areas whenever possible, and plan routes outside of known IADS coverage. When conducting strike-package missions, it is wise to plan a dedicated flight to neutralize enemy air defenses and allow strike aircraft to reach their targets unhindered. However, such measures may be powerless to destroy all small, mobile SAM systems.

Suppression of Enemy Air Defenses (SEAD)

Modern tactical aircraft, except those designed with "stealth" technology, are easily detected by air defense radars. This is why pilots must employ special tactics to defeat this threat. One of the most effective ways to neutralize this threat is to destroy it with the appropriate weapon system, an anti-radiation missile. To this, you first must acquire the target, launch your weapon and then quickly exit the threat area. However, if the enemy radar detects the anti-radar missile (ARM) you launched at it, it can take measures to defeat your attack by turning off its radar or even shooting your missile down with its own.

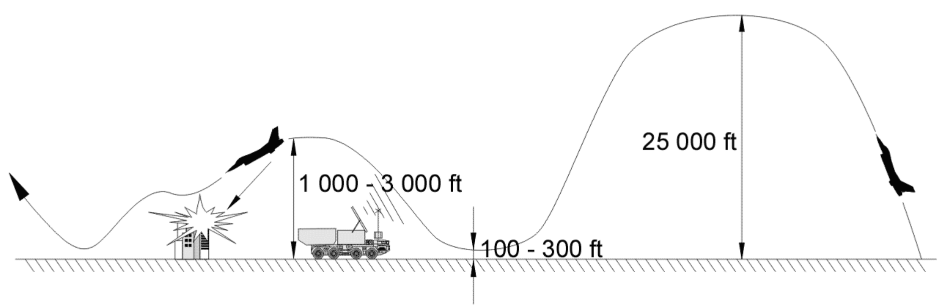


Figure 90. SEAD flight profile

The best way to avoid being acquired and attacked by air defense systems is fly at very low altitude; this is particularly true for early warning radars (EWR). Such flying should be as low as 30 m above ground level. When terrain relief such as hills and mountains are present, you should use this terrain by placing it between you and the threat systems. This is termed terrain masking and can be very useful against even the most deadly SAM systems. All tactical detection systems rely on line-of-sight between the sensor and the target; laser, radar, optical and IR cannot penetrate mountains and other obstacles. Flying at ultra-low altitude can be very effective in defeating air defense threats, but it can also be a very effective way to run your aircraft into the ground; at high speed and low altitude, a minor mistake can lead to tragedy. You should always keep your eyes open for small-caliber antiaircraft artillery that can create big problems for you at low altitude. While low altitude flight can protect you against SAMs due to terrain masking and radar horizon, it will not protect you against an over-flown AAA site or an AWACS operating at high altitude.

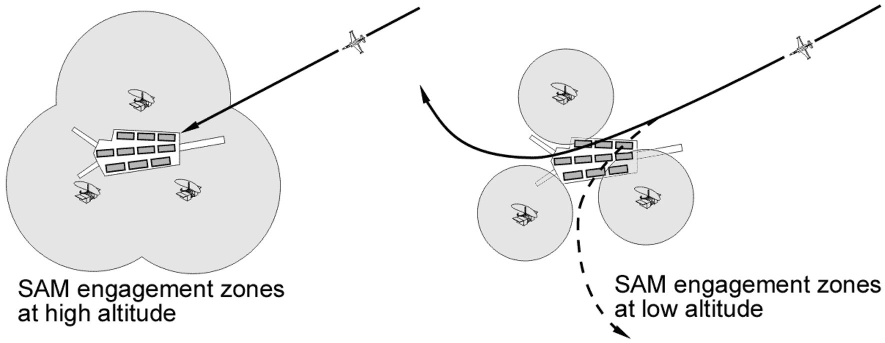


Figure 91. SAM engagement zones at high and low altitudes

Antiaircraft artillery (AAA) defense

AAA is generally ineffective at altitudes above 1,500 m; however, that does not mean that AAA is ineffective at 1,501 m. Enemy forces will often deploy AAA at higher terrain elevations, thereby increasing the altitude component of their WEZ. If you suddenly find AAA fire arcing towards you, remember these rules:

- Maneuver! The maneuver should be done in two planes, as this creates a more complex target for the antiaircraft system's ballistic computer to hit. Projecting the correct lead intercept point for its fire will be very difficult.
- Don't waste a lot of energy and do not slow down. A slow aircraft is a dead aircraft and you want to exit the WEZ of the AAA as fast as possible. One lucky hit may be all that it takes.

If you are flying near 1,500 m, you may climb rapidly and get out of the AAA WEZ. This, however, can place you in the heart of a SAM system's WEZ.

Missile Breakaway

Missiles are a deadly and difficult threat to defeat. They are much faster than aircraft, they can sustain three to four times greater G-loads, and are quite difficult to visually acquire. Successful defense against a missile depends on many factors such as timely detection, distance to missile, missile type, air speed, and altitude. Depending on circumstances, you can use countermeasures and perform anti-missile maneuvers.

Fortunately (for the target aircraft), missiles are affected by the same physics laws as aircraft. When missile motor burn is complete, it flies only on the energy it built up during its acceleration. When the target aircraft maneuvers, the missile also has to maneuver and this energy expenditure significantly reduces the missile's speed. As speed decreases, missile control surfaces become less effective and will eventually be unable to generate the required G to intercept the target.

Launch Warning

The launch warning of a radar-guided missile comes from the RWS. In some circumstances, a wingman may observe a missile launch and make a warning call over the flight radio. This information is especially valuable if an infrared-guided missile is launched at you because your RWS will not detect such a launch. In this case, a wingman message may be the only warning given. In any case, you should try to visually detect the tell-tail smoke trail from a missile to time your defensive maneuver properly. When you are over enemy territory, you should be constantly scanning the airspace around you to detect missile motor smoke. Note that some missiles, like the AIM-120, use a smokeless motor.

Remember that there will be no smoke trail once the motor has burned out. As such, early detection is crucial. Long and medium range air-to-air missiles use a "loft" flight trajectory when launched at long range. This gives them an arcing flight path that extends their range. Be especially attentive to arcing trails on the horizon.

Knowledge is Power

Your primary weapon is the knowledge of enemy weapon systems and how to use their characteristics to better your situation. For example: a particular air-to-air medium- range missile has a nominal range of 30 km at an altitude of 5,000 m. On your radar and RWS you detect an enemy aircraft 30 km and you hear the launch warning. You understand that a missile has been launched from maximum range for this altitude, and because of this, you may be able to escape it. You turn 180 degrees, select afterburner and fly away from the oncoming missile. Your success depends on how fast you can turn at maximum G (the aircraft can accelerate to 9 g, a fully loaded one – 5 g) and how fast you accelerate after the turn. If you received a launch warning early enough, you have a good chance of escaping the missile. If you detected the missile too late, or the enemy waited to launch until you were within Rpi range, this tactic may not work.

Electronic Warfare Means

Electronic countermeasures (ECM) systems were primarily designed to interfere with radar systems. ECM systems are divided into two general types: noise jammers that are generally mounted on dedicated electronic warfare aircraft and self-protection deception jammers that are mounted as external pods or installed internally on tactical aircraft. Self-protection jamming is accomplished by sampling the threat radar's signal and sending a mimic back but changed to give incorrect data to the enemy radar operator. Deception jammers are generally active only when the target aircraft is being illuminated by radar. There are several types of deception jamming that include range gate stealing, terrain bounce, velocity gate stealing, and many others.

Noise jammers on the other hand bombard an area with either broad noise jamming that covers a large range of frequencies or spot noise jamming that focuses of a smaller range. Such jamming is often used to mask a larger group of aircraft and is done preemptively. The result is that the enemy radar is unable to lock on the aircraft; it only sees the strobe of the jammer along the azimuth that the jammer is transmitting. The radar cannot deduce the range or altitude of the jammer. Sending false signal back into the antenna of the radar can create the outward appearance that the aircraft is at varying distances than it actually is.

However, as the range between the radar and the noise jammer lessens, the ratio of good to bad signal ratio allows the radar operator to overcome the noise jamming. This is commonly referred to as "burn through."

ECM systems have one, large shortcoming: by emitting, it shows its presence to enemy aircraft in the area. Imagine a person screaming at the top of his lungs during a meeting. The noise volume forces the others to keep silent, but it also attracts attention to the screaming person. The same happens to be true with noise jammers. The noises can eliminate the current threat, but it also can attract enemy attention. Modern air-to-air missiles like the R-77, AIM-7, and AIM-120 have the ability to lock on to the jamming signal and intercept its origination point. However, such guidance is not very accurate and the missile flies a less efficient flight trajectory.

Of the flyable aircraft in game, only two aircraft have on-board ECM systems – MiG-29S and F-15C. The MiG-29A does not have the ability to carry ECM; the rest of the aircraft can be equipped with ECM as externally mounted pods. To activate ECM, press the **[E]** key.

Missile Evasion Maneuver

Missile evasion maneuvers are divided into two types: break radar lock and out-maneuver the missile.

If you have been launched on by a radar-guided missile, the first thing you should try is to break the radar lock. Without a radar lock, the missile will go ballistic. The simplest way to do it is to activate your ECM system if present on your aircraft. ECM will attempt to jam the enemy radar and may cause the radar to break lock. Remember though that modern missiles can home in on jamming sources. In reality, the probability of kill is significantly lower than a radar-supported shot because it does not have data on target range and thus cannot develop an efficient flight trajectory. Unfortunately, ECM is not a panacea when approaching within 25 km of a radar. Below this range, the enemy may receive enough reflected energy from the target over the false jamming noise to get a valid lock on you. In this case, or if you do not have ECM, you can try to break the lock by another method.

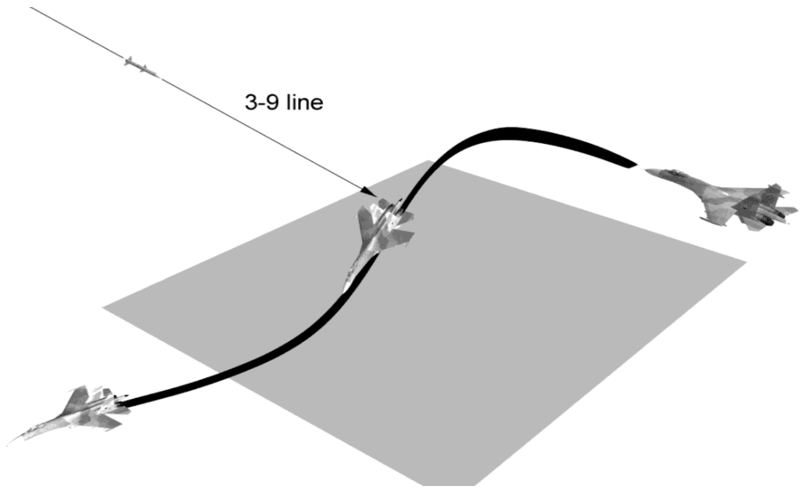


Figure 92. Missile evasion maneuver

Modern pulse-Doppler radars, with all their advantages, have a serious shortcoming – they have difficulties tracking targets that are flying perpendicular to their flight path. If the target is also at a lower altitude and forcing the radar into a look-down situation, radar tracking can be very problematic. This zone is termed the look down clutter notch. Accordingly, to break a radar lock one should place the enemy radar at 3 or 9 o'clock and get below the enemy radar's altitude.

> THE OPTIMAL MISSILE EVASION MANEUVER IS TO BREAK THE ENEMY RADAR LOCK BY DESCENDING IN A STEEP SPIRAL UNTIL THE ENEMY IS LOCATED ON YOUR 3–9 LINE WHILE ACTIVATING ECM AND DISPENSING CHAFF

If the radar lock warning on your RWS ceases, it means that the radar has lost lock and is unable to support the missile. At this point you can either switch to the offensive or use terrain masking and other means to prevent the radar from re-acquiring you.

If the missile has a radar seeker though, the missile may continue the intercept.

It should be noted that this method only applies to airborne radars; SAM radars work differently and have the ability to track targets "in the beam" (perpendicular to the radars line of sight), but with some limitations.

Another set of maneuvers is designed to out-maneuver the missile. Modern missiles calculate the intercept impact point in relation to the target. This means that every time the target changes direction the missile also has to change its direction. The missile will attempt to fly a leading flight path in order to hit its target. This navigation method is termed proportional navigation (Pro Nav). If you see a missile on a constant bearing relatively to you, i.e. its visible position on your canopy does not change, this is a sure sign that the missile is tracking you towards its calculated intercept point. In such a situation, you need to take defensive action like activating ECM or dispensing chaff and flares. If the missile then starts to lag behind you, it means that the missile has probably lost lock or has been decoyed by a countermeasure.

Missiles, like aircraft, require energy to perform maneuvers and each maneuver depletes energy. Both you and a missile will lose greater speed and energy as you increase the G-loading of a maneuver. The more aggressive you are maneuvering, the more G-loading will be required of the missile to correct its intercept flight trajectory.

There are some additional items to keep in mind. The lower the altitude is; the greater the air density will be. Accordingly, the missile will lose speed and range much quicker when flying at lower altitudes. When a missile is inbound, fly a perpendicular course in relation to the missile's flight path and dispense the chaff and flares. During this maneuver, try to stay near your aircraft's instantaneous corner velocity. If the missile continues to track, you will need to perform a "last ditch" maneuver. When the missile is approximately 1 – 2 km from you (depending on missile speed), perform a nose-low maximum-G break turn into the flight path of the missile. For this to work, a couple factors have to be in your favor. First – the missile should be low on energy and unable to generate a high-G maneuver. Second – the missile seeker, as any mechanical device, has a limited speed at which is can gimbal and finite a angle at which it can track targets. If you provide a radical enough change in course, the seeker may be unable to track your aircraft.

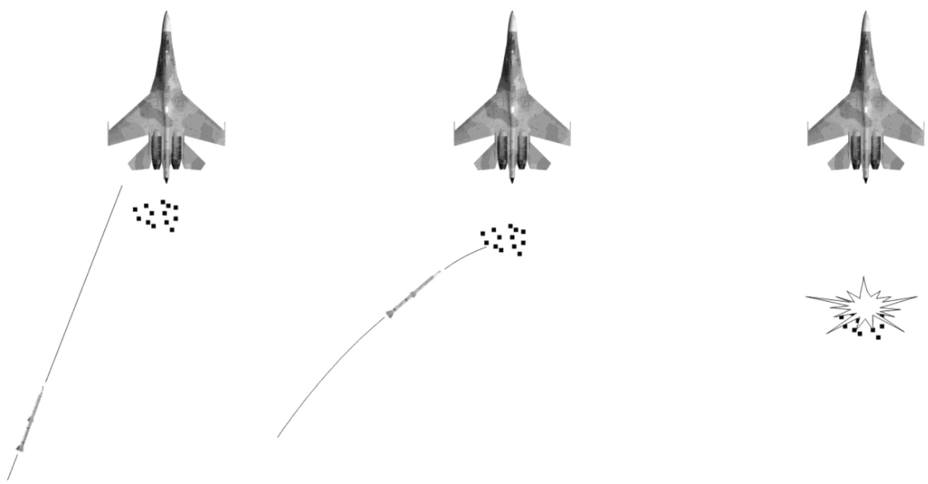


Figure 93. Decoying missiles with chaff and flares

You should use all means at your disposal to "trash" the missile fired at you, including active and passive jamming in combination with missile evasion maneuvering. The key to survival though is the early launch detection. However, no matter how early the threat is detected and what countermeasures you employ, there is no guarantee that the missile will miss, especially when several missiles are launched at you from different directions.

A-10A EMPLOYMENT CHECK LISTS

Air-to-Air Weapons

The A-10A has limited capabilities to engage in air-to-air combat. If forces to do so, the AIM-9 short range missile and GAU-8A internal gun are available.

AIM-9 Sidewinder

A radar is not installed in the A-10A, as such, it must acquire its air targets visually. Target lock is done with the weapon bore sight mode that only uses the infrared seeker of the AIM-9.

Step 1

Identify the target visually.

Step 2

Select air-to-air mode by pressing **[6]** key. Maneuver the aircraft to place the target inside the AIM-9 seeker reticule on the HUD.

Step 3

Wait until the missile seeker achieves lock, represented by the high-pitched tone. Lock range depends on target IR-signature and can vary from .1 to 10 miles. When the target is framed by the reticule and the lock tone sounds, you have a valid seeker lock. Launch the weapon by pressing the weapons release button on your joystick or by pressing the **[RAlt-Space]** key on your keyboard.

MAINTAIN A STEADY AIM-9 MISSILE SEEKER LOCK BEFORE FIRING.

Internal Gun Application in Air-to-Air Mode

Step 1

Identify the target visually.

Step 2

Select air-to-air mode by pressing **[6]** key. The gun funnel and AIM-9 seeker reticule will be visible on the HUD.

Step 3

Maneuver your aircraft to place the target inside the funnel such that the target's wingtips touch the funnel edges. Press the fire button on your joystick or **[Space]** key on your keyboard to fire.

Effective fire is generally below 800 meters. For better accuracy, try to maneuver in the same plane as your target. The gun funnel is most accurate when used from behind the target.

Air-to-Ground Weapons

The A-10A is built to strike ground targets with accuracy, including mobile armor. Its arsenal includes general purpose bombs, AGM-65 Maverick guided missiles, unguided rockets, and the GAU-8A Avenger 30-mm cannon.

Bombing in CCIP Mode

The A-10A can carry several types of freefall bombs, including Mk-82 and Mk-84 general purpose bombs and the MK20 "Rockeye" cluster bomb.

Step 1

Identify the target visually.

Step 2

Select air-to-ground mode by pressing the **[7]** key. Select bomb type by cycling the **[D]** key. Confirm the selected bomb type on the HUD and on the WCP. Enter a wings-level dive towards the a point just beyond the target.

Step 3

When the CCIP pipper is over the target, release the bomb(s) by pressing the weapon release key on your joystick or by pressing the **[RAlt-Space]** key on your keyboard.

> BEFORE BOMB RELEASE, ENTER A WINGS-LEVEL DIVE TO A POINT JUST BEYOND YOUR TARGET. ANY DEVIATIONS IN BANK, PITCH OR YAW AND SIGNIFICANT AIRSPEED CHANGES WILL LEAD TO INACCURATE BOMB IMPACTS

Bombing in CCRP Mode

Step 1

Identify the target visually.

Step 2

Select air-to-ground mode by pressing the **[7]** key. Select bomb type by cycling the **[D]** key. Confirm the selected bomb type on the HUD and on the WCP.

Step 3

Place the dashed circle over the target with the **[;], [,], [.], [/]** keys. Press the **[Enter]** key to lock that point on the ground. The TDC will appear over the designated target area.

Step 4

Select CCRP mode by pressing the **[O]** key and the TDC will be placed at the top of the HUD. Align the TDC with the bomb fall line and allow the TDC to fall down the bomb fall line. When the TDC reaches the bomb pipper, the bomb(s) will be released automatically.

The closer you keep the TDC on the bomb fall line, the more accurate your bombing pass will be.

Step 5

Switch off the CCRP mode pressing the **[O]** key.

Unguided Rockets and GAU-8A Cannon

Step 1

Identify the target visually.

Step 2

Select air-to-ground mode by pressing the **[7]** key. Select unguided rockets by cycling the **[D]** key or select the cannon by toggling the **[C]** key. Confirm weapon selection on the HUD and WCP. Enter a wings-level dive towards the target.

Step 3

When the target is under the rocket or gun pipper, fire the weapon by pressing the weapon release key on your joystick or the **[Space]** key on your keyboard.

The A-10A can use the cannon in any air-to-ground sub-mode. A small gun cross is located at the top of the HUD. At a distance of more than 2.5 miles this cross-hair is crossed out by an "X" symbol. At a distance less than 2.5 miles, the range to ground is displayed under the cross-hair.

AGM-65 Guided Missiles

Step 1

Identify target location area visually. Select air-to-ground mode by pressing the **[7]** key. Select the AGM-65K or AGM-65D by cycling the **[D]** key. A seeker image will appear on the TV monitor.

Step 2

Place the HUD aiming reticule over the target area and press the **[Enter]** key. The missile seeker will then ground-stabilize to that point. Using the TVM, you can then refine your targeting and place the centering point of the missile seeker over the target. For the AGM-65D, the seeker has two levels of magnification, 3x and 6x. You can switch between these two levels by pressing the **[+]** key. Once the seeker can detect enough contrast between the target and its back ground, the seeker will "snap" to the target and lock it. If the wrong target was locked, you can move the aiming point by pressing the **[;], [,], [.], [/]** keys.

Step 3

Keep the locked target within the gimbal limits of the seeker, ±30 degrees in relation to the aircraft's longitudinal axis. Launch the missile when the target enters the allowable launch range and the targeting cross starts to flash.

> THE AGM-65 SEEKER MUST LOCK ON TO A TARGET BEFORE LAUNCH TO HIT THE TARGET.

SUPPLEMENTS

Acronym List

AAA	Anti-Aircraft Artillery
AC	Alternating Current
ADF	Automatic Direction Finder
ADI	Attitude Direction Indicator
AF	Airfield
AGL	Above Ground Level
AH	Attack Helicopter
ALT	Altitude
AMMS	Advanced Moving Map System
AOA	Angle Of Attack
AP	Autopilot
AP	Armor Piercing
APU	Auxiliary Power Unit
ASL	Above Sea Level
ATC	Air Traffic Control
ATGM	Anti-Tank Guided Missile
BIT	Built In Test
BP	Battle Position
CAM	Course Aerial
CAS	Calibrated Air Speed
CDU	Central Distribution Unit
CDM	Course Doppler
CG	Center of Gravity
DC	Direct Current
DCS	Digital Combat Simulator
DH	Desired Heading
DR	Drift Angle
DST	Distance

DT	Desired Track
DTA	Desired Track Angle
EDP	Engine Dust Protectors
EEG	Electronic Engine Governor
EGT	Exhaust Gas Temperature
EO	Electro Optical
ETA	Estimated Time of Arrival
ETP	Estimated Touchdown Point
FAC	Forward Air Controller
FARP	Forward Arming and Refueling Point
FEBA	Forward Edge of Battle
FOV	Field Of View
FPL	Flight Plan
FSK	Function Select Key
GG	Gas Generator
GNSS	Global Navigation Satellite System
GS	Ground Speed
HDG	Heading
HE	High Explosive
HMS	Helmet Mounted Sight
HSI	Horizontal Situation Indicator
HUD	Head Up Display
IAF	Initial Approach Fix
IAS	Indicated Air Speed
IDM	Inertial Doppler
IDS	Information Display System
IFF	Identify Friend or Foe
IFR	Instrument Flight Rules
IFV	Infantry Fighting Vehicle
INU	Inertial Navigation Unit
IWP	Initial Waypoint

LAT	Latitude
LLT	Linear Lead Turn
LONG	Longitude
LWR	Laser Warning Receiver
LWS	Laser Warning System
MANPADS	Man-Portable Air Defense System
ME	Mission Editor
MILS	Abbreviation for milliradian; Bomb/Gun sight settings were expressed in mils, an angular measurement; one degree was equal to 17.45 mils.
MRB	Magnetic NDB Bearing
MWL	Master Warning Light
NATO	North Atlantic Treaty Organization
NDB	Non Directional Beacon
NVG	Night Vision Goggles
OEI	One Engine Inoperative
PT	Free Turbine
PNK	Russian "ПНК". Aircraft Flight and Navigation system
PrPNK	Russian "ПрПНК". Aircraft Targeting, Flight and Navigation System
RAIM	Receiver Autonomous Integrity Monitoring
RALT	Radar Altitude
RB	Radio Bearing
RMI	Radio Magnetic Indicator
RPM	Revolutions Per Minute
ROF	Rate Of Fire
RTB	Return To Base
SAI	Stand-by Attitude Indicator
SAM	Surface-to-Air Missile
STP	Steerpoint

TAS	True Air Speed
TCA	True Track Angle
TH	True Heading
TOW	Takeoff Weight
TP	Target Point
TV	Television
TVM	Television Monitor
UHF	Ultra High Frequency
UTC	Coordinated Universal Time
VHF	Very High Frequency
VFR	Visual Flight Rules
VMU	Voice Message Unit
VNAV	Vertical Navigation
VOR	VHF Omnidirectional Range
VVI	Vertical Velocity Indicator
WCS	Weapon Control System
WPT	Waypoint
XTE	Cross Track Error

DEVELOPERS

Eagle Dynamics Team

Management

Nick Grey	Project Director, Director of The Fighter Collection
Igor Tishin	Project Development Manager, Director of Eagle Dynamics, Russia
Andrey Chizh	Producer, Assistant Development & QA Manager, technical documentation
Alexander Babichev	Projects manager
Matt "Wags" Wagner	Producer, technical documentation, game design
Eugene "EvilBivol-1" Bivol	Associate Producer
Matthias "Groove" Techmanski	German language co-ordinator

Programmers

Dmitry Baikov	Lead programmer
Ilya Belov	GUI, map, input
Maxim Zelensky	AC, AI AC, flight dynamics, damage model
Andrey Kovalenko	AI AC, weapons
Alexander Oikin	Avionics, aircraft systems
Evgeny Pod'yachev	Graphics, EDM models, build system
Timur Ivanov	Effects, graphics
Konstantin Stepanovich	AI AC, radio, mission editor
Oleg "Olgerd" Tischenko	Avionics
Vladimir Feofanov	AI AC flight dynamics
Sergey "Klen" Chernov	Weapons
Konstantin Tarakanov	GUI, mission editor
Alexander "SFINX" Kurbatov	AI vehicles, ships
Eugene Gribovich	Avionics
Dmitri Robustov	Terrain
Eugeny Panov	AI vehicles
Alexey Militov	Graphics, effects, 3d models
Pavel Pestov	AI

Michael Ershov	AI

Artists and Sound

Pavel "DGambo" Sidorov	Lead artist
Yury "SuperVasya" Bratukhin	AC, vehicles, weapons models
Alexander "Skylark" Drannikov	GUI graphic, AC models
Timur Tsigankov	AC, vehicles, ships, weapons models
Stanislav "Acgaen" Kolesnikov	Cockpit, AC models
Eugene "GK" Khizhnyak	AC, vehicles models
Konstantin "btd" Kuznetsov	Sound Developer, Music Composer
Sergey "tama" Ashuiko	Buildings, Terrain
Andrey "LISA" Reshetko	Characters
Maxim Lysov	AC models
Igor Piskunov	2D artist
Yury Starov	AC models
Alexandra Alexeeva	2D artist

Quality Assurance

Valery "USSR_Rik" Khomenok	Lead-tester
Sergey "Foreman" Gusakov	Testing
Ivan "Frogfoot" Makarov	Testing
Roman "Dr.lex" Podvoyskiy	Testing
Michael "Yurcha" Urevich	Testing

Localisation

Andrey "Andrey Andreevich" Kryuchenko	Lead localization
Elena Pryanichnikova	Localization

Science Support

Dmitry "Yo-Yo" Moskalenko	Mathematical models of dynamics, systems, ballistics

IT and Customer Support

Konstantin "Const" Borovik	System and network administrator, WEB, forum
Ekaterina Perederko	WEB
Andrey Filin	System and network administrator

Andrey Ustinovich	Customer support
Alena Yurykovskaya	Customer support

Testers Staff

Alexander "asd1234" Amelin

Alexander "BillyCrusher" Bilievsky

Alexander "vatel" Tyshkevich

Andrea "FCS_Heater" Papaleo

Anthony "Blaze" Echavarria

Carlos "Design" Pastor Mendez

Chris "Ells228" Ellis

Christopher "Mustang" Wood

Daniel "EtherealN" Agorander

Danny "Stuka" Vanvelthoven

Darrell "AlphaOneSix" Swoap

David "USAFMTL" Slavens

Dmitry "Laivynas" Koshelev

Dmity "Simfreak" Stupnikov

Ed "Manawar" Green

Edin "kuky" Kulelija

Erich "ViperVJG73" Schwarz

Evan "Headspace" Hanau

Gareth "Maverick" Moore

Gavin "159th_Viper" Torr

George "GGTharos" Lianeris

Grayson "graywo1fg" Frohberg

Guillaume "Dimebug" Leleve

James "Dusty_Rhodes" Rhodes

James "Eddie" Knight

Jeff "Grimes" Szorc

Jens "=STP=Dragon" Giesser

John "Speed" Tatarchuk

Jon Espen "Panzertard" Carlsen

Kiko "Mistral" Becerra

Matthew "44th_Rooster" Sartin

Matthias "Groove" Techmanski

Nick "BlueRidgeDX" Landolfi

Nikolay "Agm" Borisov

Norm "SiThSpAwN" Loewen

Paul "paulrkii" Kempton

Paul "PoleCat" Johnston

Pavel "Shadowowweosa" Kuzin

Peter "Weta43" McAllister

Phil "Druid_" Phillips

Raul "Furia" Ortiz de Urbina

Roberto "Vibora" Seoane Penas

Scott "HuggyBear" Matthew

Stephen "Nate--IRL--" Barrett

Steve "joyride" Tuttle

Steve Davies

Timothy "WarriorX" Westmore

Tyler "krebs20" Krebs

Vadim "zetetic" Vyveritsa

Valery "=FV=BlackDragon" Manasyan

Vladimir "lester" Ivanov

Werner "derelor" Siedenburg

Zachary "Luckybob9" Sesar