THE FIGHTER COLLECTION

Eagle Dynamics

LOCK ON® Flaming Cliffs 3

DCS: Flaming Cliffs 3

Flight Manual

DCS: Flaming Cliffs 3 is the next evolution of the Flaming Cliffs series. Flaming Cliffs 3 updates both Lock On and Flaming Cliffs to include new features in modular structure DCS World.

Flaming Cliffs 3 was designed to continue the Flaming Cliffs series as what we term a "mid-fidelity" flight simulation.

General discussion forum: http://forums.eagle.ru

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AIRCRAFT INTRODUCTION

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The old adage, "use the right tool for the job" applies to air combat as much as carpentry. Aircraft missions, such as air superiority, close air support, deep strike, etc. generally have conflicting requirements. Heavy armor that protects a pilot while engaging an enemy AAA site is a serious disadvantage in a dogfight. Success in the air requires a thorough understanding of each aircraft's strengths and weaknesses. The following section identifies each of the player-flyable aircraft and summarizes its combat role.

Su-27 Flanker B

The Su-27 Flanker B and its variants are some of the most impressive and capable fighter aircraft in the world, designed to beat the vaunted F-15C. Born in the waning years of the Cold War, the Flanker did not have an easy life. The initial design suffered serious problems. Then, the breakup of the Soviet Union hindered its deployment, denying it the opportunity to prove itself as one of the world's greatest aircraft.

1-1: Su-27

The Su-27 is tailored for air-to-air combat, not air-to-ground. Armed with the R-27 (AA-10) Alamo series of missiles, the Flanker has an impressive beyond visual range (BVR) capability. Meanwhile, the helmet mounted sight and high off-boresight R-73 (AA-11) Archer heat-seeking missile, coupled with the Su-27's high thrust and sustained turn capability, gives the aircraft a powerful edge in a knife fight. High-AoA maneuvering helps the pilot point his weapons at the enemy. Finally, its very large internal fuel capacity keeps it in the fight well after other fighters are running on fumes. It carries as many as ten air-to-air missiles, giving it an impressive "punch".

Detractors criticize the Su-27's avionics and cockpit layout, citing limited ability to track/engage multiple targets, high reliance on Ground Control Intercept (GCI) control, and high pilot workload. However, its passive Electro-Optical System (EOS) lets it find and engage targets without any radar emissions (which can warn the target). Debate continues whether high-AOA maneuvers (such as tail slides and the famed "Cobra") are useful as combat tactics or merely impressive air show stunts.

Su-27 pilots should keep in mind that although the Flanker has a very large internal fuel capacity, hence the lack of external fuel tanks, a fully fueled Flanker can be a very poor performer in a dogfight.

Su-33 Flanker D

Originally named the Su-27K, this cousin of the Su-27 was specifically designed to operate from Soviet aircraft carriers. Equipped with canards for improved take off and landing performance, the first Su-27K made its maiden flight in 1985. The tail cone was shortened to reduce the risk of tail strike during high-AoA carrier landings, but this also reduced the space available for defensive countermeasures (including chaff and flare dispensers). The Su-33 uses the same radar as the Su-27 and, to a large extent, the same cockpit as well. Neither the Su-33 nor Su-27 has air-to-surface radar modes.

1-2: Su-33

MiG-29A Fulcrum A & MiG-29S Fulcrum C

Western observers often conclude, inaccurately, that the Su-27 and MiG-29 were born of a single design program, which copied the U.S. Navy's F/A-18, no less. Indeed, the Su-27 and MiG-29 look quite similar and some observers cannot readily tell the two aircraft apart, despite the MiG-29 being substantially smaller than the Su-27. Both the Su-27 and MiG-29 design teams reportedly worked with common research data and drew common design conclusions. The MiG-29 has been much more widely exported than the Su-27, serving in many former Warsaw Pact air forces, several of which have since joined NATO (bringing their Soviet-made MiG-29s with them).

The MiG-29 originally shared most of its avionics suite with the Su-27 (including the radar, the Electro-Optical System (EOS), and the helmet-mounted sight), but was designed as a short-ranged fighter, not as an interceptor. The EOS lets the Fulcrum search for, track, and engage targets without emitting telltale radar signals. Being smaller, it doesn't carry as many missiles as the Su-27, but its high-AoA maneuverability coupled with the R-73 (AA-11) Archer high off-boresight, heat-seeking missile and helmet mounted sight makes the MiG-29 a deadly dogfighter. The slow-speed turning fight is the MiG-29's preferred arena where it can use its high-AoA capability to point its weapons at a floundering target. The newer MiG-29S includes onboard electronic countermeasures, a greater fuel load, and the ability to carry the medium-ranged R-77 (AA-12) Adder missile.

1-3: MiG-29 (9-13)

As with the Su-27, critics cite weak avionics and poor cockpit design as weaknesses of the MiG-29. The later MiG-29S (Fulcrum C), though, incorporated numerous improvements including better defensive countermeasures and increased fuel capacity. The MiG-29 reportedly requires a significant amount of maintenance, especially the engines. German MiG-29s (inherited from the East when

Germany was re-unified) have had their engine performance "tuned down" to somewhat lengthen engine lifespan. Obtaining spare parts continues to be a concern for former Warsaw Pact nations.

Russian forces in DCS World employ the MiG-29A and MiG-29S, while German forces operate only the MiG-29A.

F-15C

The F-15C has often been labeled as the greatest fighter aircraft in the world. Designed to counter the exaggerated capabilities of the Soviet MiG-25 "Foxbat", the F-15C has been the backbone of U.S. air defense for three decades. The F-15C, equipped with improved avionics and weapons over the original F-15A, has scored over 100 air-to-air victories in the service of Israel, Saudi Arabia, and the U.S. without suffering any losses.

1-4: F-15C

The F-15C rules the Beyond Visual Range arena (BVR). No slouch in a dogfight, the F-15C excels at finding targets, positively identifying them as hostile, and engaging them with AIM-120C AMRAAM missiles before the enemy can respond.

The F-15's versatile pulse-Doppler radar system can look up at high-flying targets and down at low-flying targets without being confused by ground clutter. It can detect and track aircraft and small high-speed targets at distances beyond visual range down to close range, and at altitudes down to tree-top level. The radar feeds target information into the central computer for effective weapons delivery. For close-in dogfights, the radar automatically acquires enemy aircraft, and this information is projected on the head-up display.

The Eagle is somewhat restricted in the close-in dogfight. The AIM-9M Sidewinder, a reliable weapon that has soldiered on since the 1960’s, does not have the high off-boresight capability of recent

Russian heat-seeking missiles. F-15C drivers should generally favor the higher-speed "energy fight" in favor of the low-speed turning duel, especially against nimble adversaries.

Su-25 Frogfoot

The Su-25 Frogfoot bears little resemblance to the U.S. A-10A, but it was designed for a very similar Close Air Support (CAS) ground-attack mission. The Su-25 was built to operate near the forward edge of battle area (FEBA) from rough, "unimproved" airstrips, and can carry a loadout with tools, spare parts, auxiliary power supply, a pump for manual refueling and other "self deployment" supplies. It carries a wide variety of weapons for missions including anti-personnel, runway denial, and tank killing.

1-5: Su-25

The fortified cockpit and armored canopy help protect the pilot from anti-aircraft artillery (AAA) and small arms fire while engaging targets at low altitude. Ingressing at low level, the Su-25 hunts down targets, pops up, delivers its weapons, and dives back behind terrain. The Su-25 may arguably be the most power ground-attack aircraft in Eastern inventories.

The Su-25 is not intended for dogfighting though. Its primary defense against patrolling fighters is simple avoidance. When engaged, the Su-25 should operate at extremely low altitude, which hampers enemy fighters' ability to engage it. Using terrain as available, the pilot should turn to face oncoming threats or extend away from the fight if given the opportunity.

Su-25T Frogfoot

The Su-25 has limited capabilities to search for and attack moving, small-sized armored units. After its introduction, it was clear that there was a need for creating a specialized anti-tank aircraft. In 1976, the USSR Council of Ministers issued authorization for the commencement of the design and construction of an all-weather attack aircraft with anti-tank weapons.

The primary anti-tank guided missile (ATGM) system for the Su-25T is the "Vikhr". This was later followed by the "Vikhr-M" with laser guidance. The primary aiming system, "Shkval", provides acquisition and automatic target guidance. This works in conjunction with the "Prichal" system that provides laser illumination and range finder.

For low-light operations, the aircraft can be equipped with a fuselage-mounted pod with a low-level television camera. This system is termed "Mercury." "Mercury" provides an electro-optical aiming system to "Shkval" for night-time operations.

1-6: Su-25T

The television image from the aiming systems is transferred to the IT-23M television monitor (TVM), which is positioned in the upper right portion of the instrument panel. "Shkval" provides a 23-fold target magnification, "Mercury" – provides a five-fold level of magnification. This helps identify distant targets: a house – 15 km, a tank – 8-10 km, a helicopter like an "Apache" – 6 km.

The integrated Electronic Warfare (EW) system provides detection and direction finding of air, ground, and naval radar emitters, with an accuracy of +/- 30 degrees in azimuth. The EW system can detect and classify radars emitting in the 1.2-18 GHz bands. Adjustable, Electronic Attack (EA) jamming can be used to reduce the effectiveness of weapon control radars operating in continuous wave and pulse modes. EA pods can be fixed to under-wing suspension hard points. For protection against infrared-guided missiles, expendable flares are used. The Su-25T is equipped with 192 flare cartridges. Also for protection against infrared-guided missiles, the electro-optical jamming system "Sukhogruz" is installed in the tail section of the aircraft. This powerful cesium lamp, with an energy consumption of 6 kW, creates an amplitude-modulated jamming signal that prevents infrared-guided missiles from guiding.

To engage air defense radars, the Su-25T can be equipped with the "Viyuga" or "Phantasmagoria" target designation pods. This allows the Su-25T to designate targets for anti-radar missiles such as the Kh-58 and Kh-25MPU.

Although the Su-25T is much improved from the standard Su-25 in regards to its weapon delivery capabilities, its flight performance has taken a step back. The added weight in particular has given the Su-25T poor performance and handling. The Su-25T is a powerful weapon platform, but it takes a skilled pilot to fly it well.

When flying the Su-25T in game, it is suggested that you set your input controls to linear axis. This will provide the most realistic control of the aircraft.

A-10A

Designed as a Close Air Support (CAS) platform to counter the massive quantities of Soviet armor during the Cold War, the "Hog" is heavily armored and carries an impressive weapons load including the deadly GAU-8A 30mm anti-armor cannon. Efforts to retire the A-10 from active duty began gaining momentum in the late 1980s, but fell by the wayside after the aircraft's stellar performance during the 1991 Gulf War.

1-7: A-10A

The A-10 was intended to fly low, using the terrain to mask its presence from enemy SAMs. Low flying, however, places the aircraft in the heart of the AAA engagement zone. Therefore, the aircraft is heavily armored, including a "titanium bathtub" that surrounds the pilot. When the threat of SAMs has been reduced, the A-10 generally flies missions at medium altitudes, placing it safely out of the reach of AAA guns.

The sub-sonic A-10 can carry AIM-9 Sidewinders for self defense, but should avoid dogfighting. It carries an impressive air-to-ground weapons load, but lacks the power for a sustained fight against a dedicated air-to-air platform. When confronted by an enemy fighter, the Hog pilot should use the A-10's impressive turn rate capability to point the nose (and the dreaded 30mm cannon) at the attacker. When the attacker overshoots, unload and extend until the attacker makes another pass, then use another maximum-rate turn to point the nose back at the adversary.

2

GAME AVIONICS MODE

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.

2-1: Game Avionics Mode Radar Display

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]**

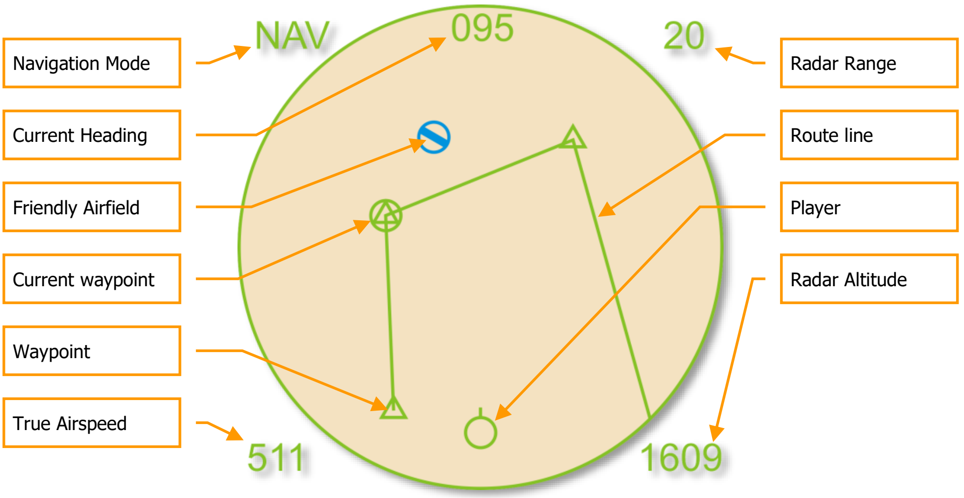
- **Radar Range**. Outside the top right of the display is the current range setting of the easy radar.

  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

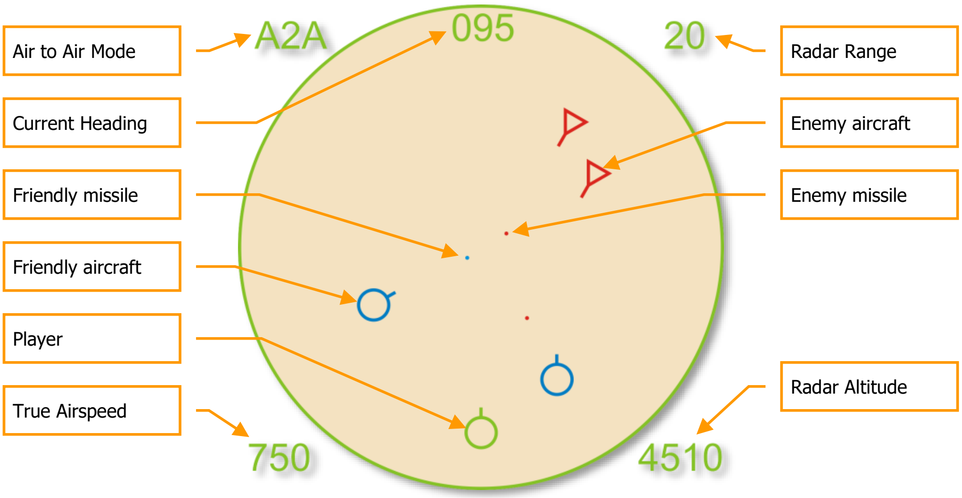


2-2: Navigation Mode

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



2-3: Air to Air Mode

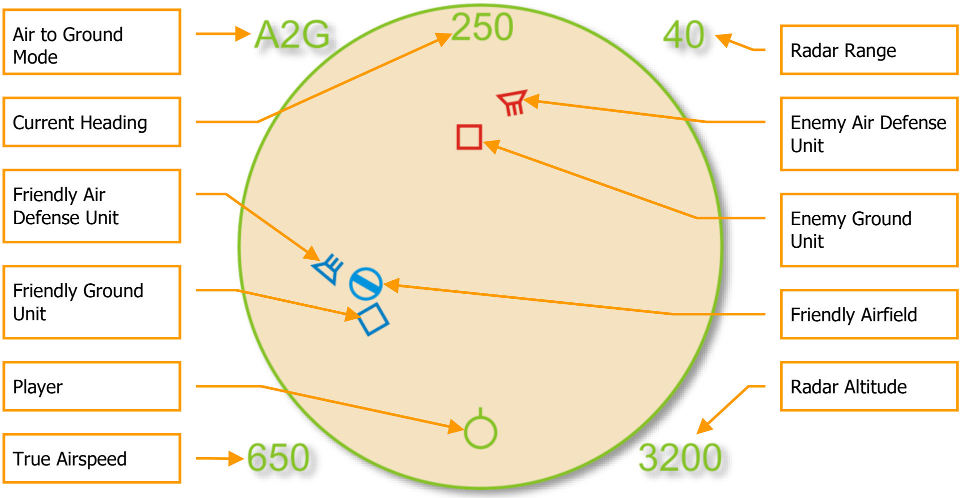
Unique symbols of the Air to Air mode include:

- **(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



2-4: Air to Ground Mode

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]**

3

COCKPIT INSTRUMENTS OF RUSSIAN AIRCRAFT

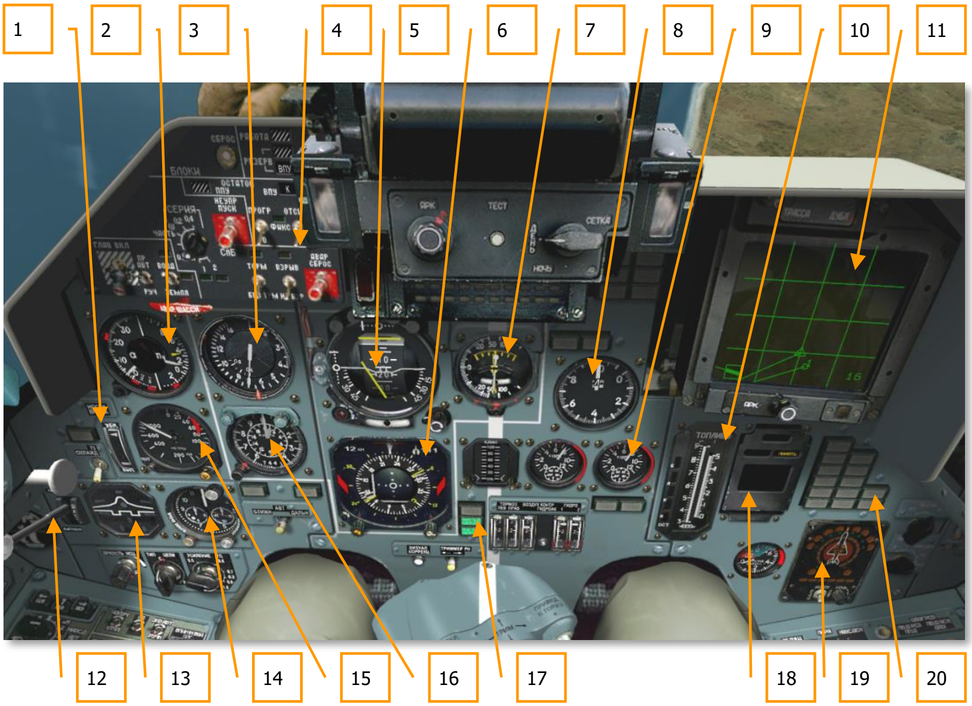
COCKPIT INSTRUMENTS OF RUSSIAN AIRCRAFT

Equipment within an aircraft's cockpit is customized to perform specified tasks of each aircraft. Nevertheless, all cockpits have much in common. For example, such instruments as airspeed indicator, ADI, vertical velocity indicator are a must in every cockpit.

This chapter will instruct you about the cockpit instrumentation of each aircraft. For successful piloting, you must understand the function and position of all cockpit instruments.

Su-27 and Su-33 Cockpit Instruments

The Su-27 and Su-33 cockpit instruments are almost identical. Most instruments are also very similar to those of the MiG-29 and Su-25.



3-1: Su-27 instrument panel

1. Wing leading edge flap position indicator
2. AOA indicator and Accelerometer
3. Airspeed and Mach indicator
4. Weapons control panel
5. Attitude Direction Indicator (ADI)
6. Horizontal Situation Indicator (HSI)
7. Vertical Velocity Indicator (VVI)
8. Tachometer

9. Interstage turbine temperature indicators
10. Fuel quantity indicator
11. Head Down Display (HDD)
12. Landing gear control valve
13. Mechanical devices indicator
14. Clock
15. Radio altimeter
16. Pressure altimeter
17. Trimming lights neutral position indicator in pitch, roll and yaw channels
18. "Ecran" control panel
19. SPO-15 "Beryoza" radar warning system
20. Warning lights

Airspeed and Mach Indicator

The airspeed and Mach indicator shows the indicated airspeed (IAS). The scale is graduated from 100 to 1,600 km/h. The Mach number is indicated in the interior of the gauge. The scale is graduated from 0.6M to 3M.

3-2: Airspeed and Mach indicator

Pressure Altimeter

The barometric air pressure altimeter indicates the aircraft’s altitude above sea level. The Inner altimeter ring scale is graduated from zero to 20,000 meters in 1,000 meter increments. The outer altimeter ring scale is graduated from zero to 1,000 meters in increments of 10 meters. The aircraft’s altitude is the sum of the readings of both scales.

3-3: Pressure altimeter

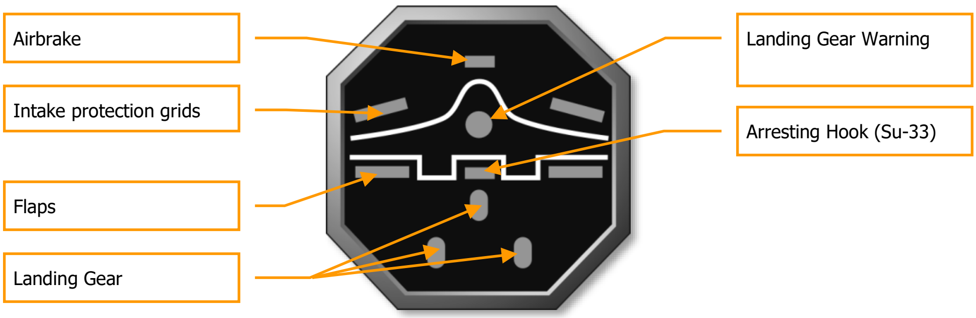
Radar Altimeter

The radar altimeter shows the aircraft's altitude above ground, and therefore fluctuates according to terrain height when flying straight and level. It measures heights from zero to 1,000 meters only. Accurate readings cease with excessive bank.

3-4: Radio altimeter

Mechanical Devices Indicator

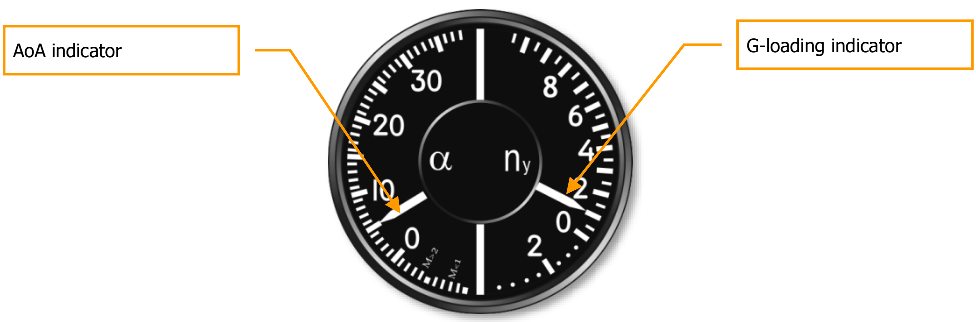
The mechanical devices indicator shows the position of the landing gear, flaps, leading edge flaps and airbrake. If the landing gear is not extended or retracted, a red lamp lights in the center of the indicator.



3-5: Mechanical Devices Indicator

AoA Indicator and Accelerometer

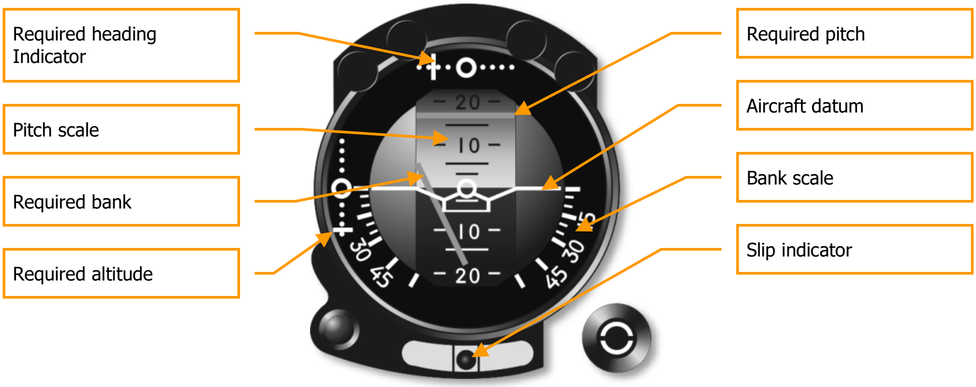
The Angle of Attack (AoA) indicator and accelerometer displays the current angle of attack and G-load. The left portion of the indicator shows the AoA in degrees and the right portion shows G-loading.



3-6: AoA indicator and Accelerometer

Attitude Direction Indicator (ADI)

The Attitude Direction Indicator (ADI) shows the current angles of pitch and aircraft roll. In the lower part of the indicator is a yaw slip indicator. Changing the rudder position eliminates slipping, so try to have the indicator in the central position. On the front portion of the indicator are the required bank and pitch indicators to reach the next waypoint. When both yellow bars are in the central position, the aircraft is following the correct route. During landings, the W-shaped glidescope deviation indicator provides Instrument Landing System (ILS) direction.



3-7: ADI

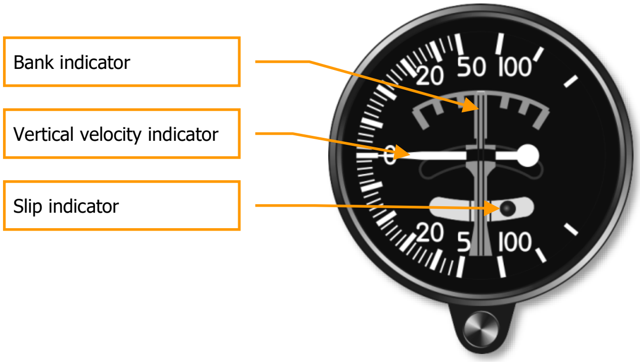
Horizontal Situation Indicator (HSI)

The Horizontal Situation Indicator (HSI) provides a top/down view of the aircraft in relation to the intended course. The compass rotates so that the current heading is always shown at the top. The Course Arrow shows the required heading and the Bearing Pointer points to the next waypoint. Distance to the next waypoint and required heading are shown numerically at the top. The ILS localizer and glide slope bars are in the center.

3-8: HSI

Vertical Velocity Indicator (VVI)

The Vertical Velocity Indicator measures the aircraft's vertical speed, i.e. rate of climb or sink. The Slip Indicator backs up the Slip Indicator on the ADI. The Bank Indicator shows the rate of bank, though the rate of bank shown is only approximate.



3-9: Vertical velocity indicator

Aircraft Clock

The aircraft clock shows the current time as set in the Mission Editor.

3-10: Aircraft clock

Tachometer

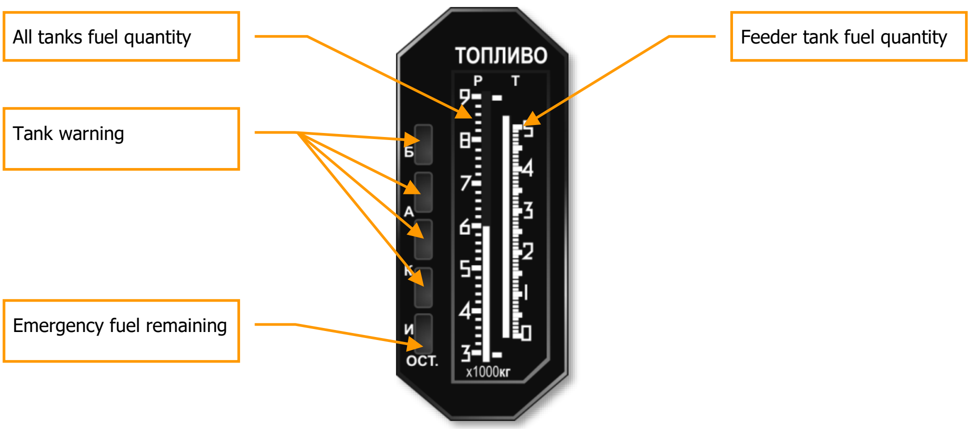
The Tachometer measures the RPM of both engines and is shown as a percent of maximum RPM. Full afterburner power (reheat) is shown above 100%. When full afterburner is on, green lights show above the Tachometer.

3-11: Tachometer

Fuel Quantity Indicator

Fuel quantity (P for Резервное топливо for "reserve fuel") shows the fuel remaining in all tanks. Fuel quantity (T for Топливо "fuel") shows the fuel remaining in the feeder tank.

If external fuel tanks are carried, a warning light indicates that they are about to be empty. Note that the Su-27 and Su-33 cannot be loaded with external fuel tanks.



3-12: Fuel quantity indicator

Interstage Turbine Temperature Indicators

The two Interstage turbine temperature indicators show the temperature of the exhaust gas from the left and right engine turbines.

3-13: Interstage turbine temperature indicators

Head Down Display (HDD)

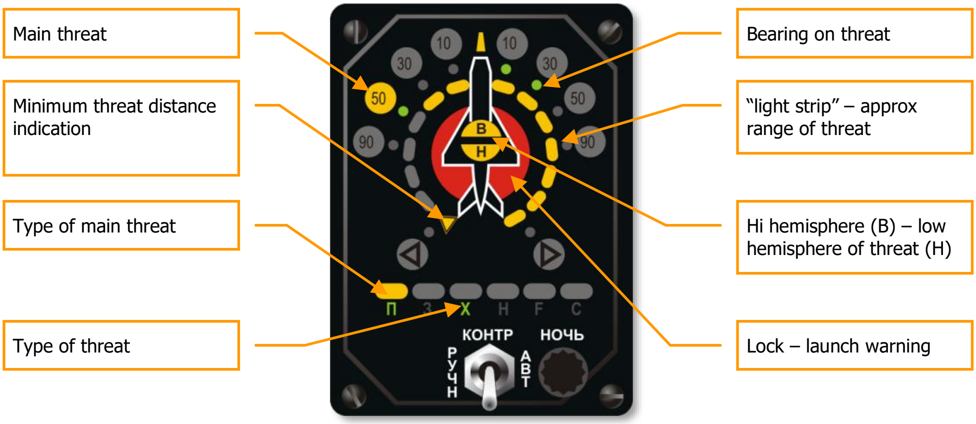
The Head Down Display (HDD) is positioned in the right upper corner of the instrument panel. It shows information about the preplanned route, waypoint and runway locations. In combat modes, the radar and electro-optical system information is shown.

The scale of the HDD can be changed by the pilot.

3-14: HDD

Radar Warning System (RWS)

The RWS indicates radars illuminating the aircraft. Information is presented as symbols of the types and directions of the radars. Six indicator lights in the lower portion inform the pilot of the types of radars illuminating the aircraft. The system warns of every radar; both adversarial and friendly. Detailed information on RWS operation is described in the corresponding chapter.



3-15: RWS indicator

The circular arrangement of RWR lights indicates your distance from the threat. As a radar emitter (e.g., active radar missile) approaches, more light segments illuminate along the indicator in a counterclockwise direction. When all the segments have illuminated, the radar emitter should be near your aircraft.

PPD-SP Panel

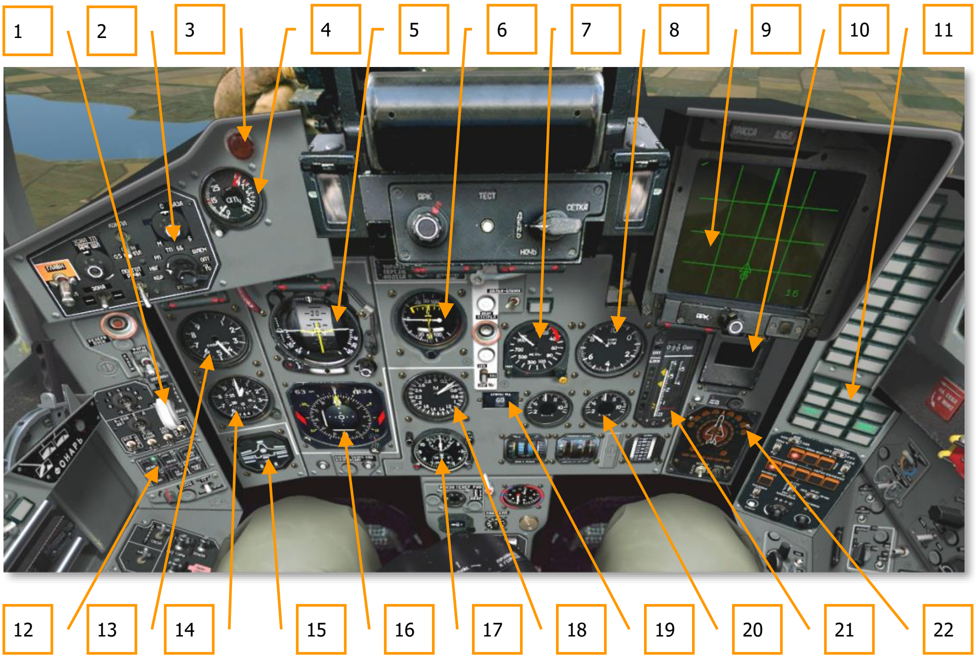
On the right side of the cockpit is the PPD-SP control panel. In the central part of the panel is the PI-SP indicator. This displays the remaining infrared flares and radar reflecting chaff bundles. The left column indicates remaining chaff. One indicator light corresponds to 16 chaff bundles. The right column indicates the number of remaining flares. One indicator light corresponds to eight flare cartridges. Flares are released in pairs.

3-16: PPD-SP panel

1. PI-SP indicator

MiG-29 Cockpit Instruments

The MiG-29 cockpit is shown below. The MiG-29A and MiG-29S cockpits are identical. Most instruments are similar or analogous to those of the Su-27.



3-17: MiG-29 instrument panel

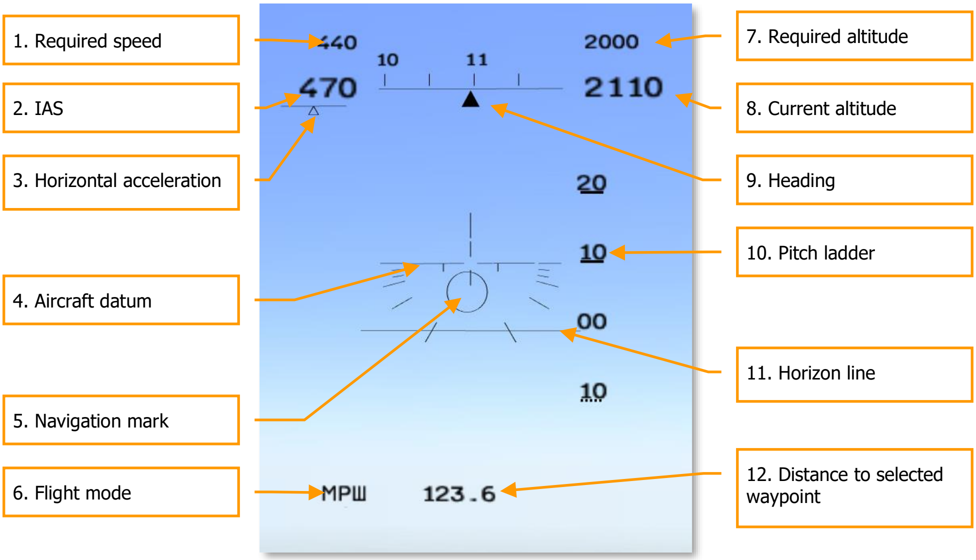
1. Landing gear control valve
2. Weapon control panel
3. Master warning light
4. AoA indicator and Accelerometer
5. Attitude Direction Indicator (ADI)
6. Vertical Velocity Indicator (VVI)
7. Radio altimeter
8. Tachometer
9. Head Down Display (HDD)

10. "Ekran" panel
11. Warning lights
12. Autopilot panel
13. IAS indicator
14. Barometric Pressure altimeter
15. Mechanical devices indicator
16. Horizontal Situation Indicator (HSI)
17. Aircraft clock
18. Machmeter
19. Chaffs and flares counter
20. Interstage turbine temperature indicators
21. Fuel quantity indicator
22. SPO-15 "Beryoza" radar warning system panel

Su-27, Su-33, MiG-29
HUD and HDD Operational Modes

Basic HUD symbols

Regardless of the aircraft type, some HUD symbology is unchanged between aircraft. As an example, we will take a look at the HUD indicators from the MiG-29 МРШ (ROUTE) mode.

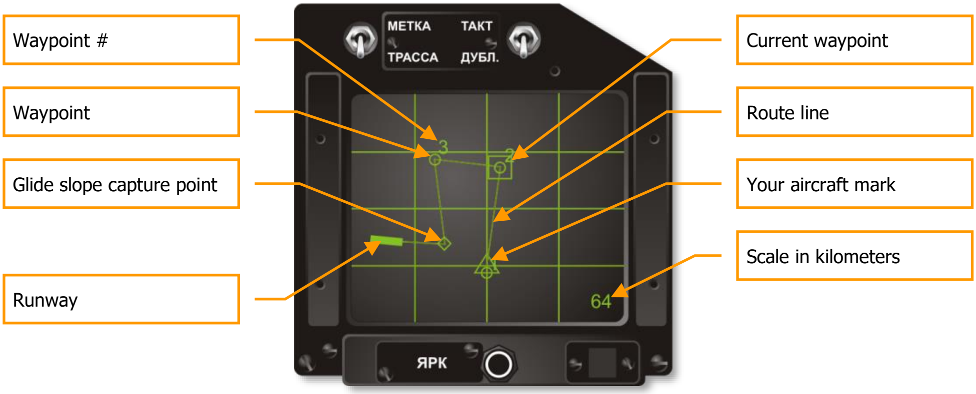


3-18: MiG-29 basic symbols

1. The Required Speed indicator displays the assigned airspeed for the current flight mode. When in ROUTE mode, the Required Speed will be the assigned airspeed for the currently selected route leg.
2. Indicated airspeed (IAS) is shown to the left of the scale. Above the current IAS, the required airspeed is indicated. It depends on the flight mode, and in the case of route flight mode, it shows the required aircraft speed.
3. Under the numerical speed indicators is a triangular index that shows horizontal acceleration. To the right – acceleration, to the left – deceleration.
4. In the center of the HUD there is an aircraft datum, indicating aircraft pitch and roll.
5. The navigation mark (large ring) shows the flight direction to follow the preplanned route and altitude to the next waypoint. When it is in the center of the datum, you are on-route.

6. In the lower left corner, the current flight mode is shown.
7. The Required Altitude value will vary depending on the selected flight mode. In ROUTE mode, it will indicate the assigned altitude for the currently selected route leg.
8. To the right of the heading scale, the current altitude is indicated. For altitude less than 1,500 meters above ground level, the radio altitude is indicated to within 1 m. At an altitude over 1,500 meters barometric, the height is shown to within 10 meters. Above the scale the required altitude is shown. This will depend on the flight mode and in the case of route flight mode, it shows the preplanned route altitude.
9. The aircraft's current heading is displayed in the upper portion of the HUD. It is indicated in tens of degrees (example: "11" corresponds to 110 degrees).
10. The pitch ladder, situated in the right portion of the HUD, displays the current pitch angle.
11. The artificial horizon line indicates a virtual horizon that corresponds to 0 degrees of pitch and is intended to assist the pilot when flying in poor visibility conditions.
12. In the lower center part of the HUD, the distance to the selected waypoint is indicated in Km.

When in navigation modes, information on the route (route direction, waypoints, and airfields) is indicated on the HDD.



3-19: HDD types in navigation modes

- Waypoints are indicated by circular marks
- Waypoint number is indicated next to the waypoint
- Initial point for glide slope interception is indicated by a diamond
- Runways are indicated by a solid rectangle
- Current waypoint is framed by a square
- All waypoints are connected by a route line

In navigation mode, navigation information is displayed on the HUD and HDD. There are three navigation sub-modes: **МРШ (ROUTE)**, **ВЗВ (RETURN)**, **ПОС (LANDING)** and mode without task. Switching between sub-modes is performed by successive presses of the **[1]** key.

The next route and waypoint will be displayed on HDD.

In ROUTE mode, the route line passes through all planned waypoints. To switch between waypoints you can use the **[LCtrl-~]** key. The route line will connect your current position with the selected waypoint.

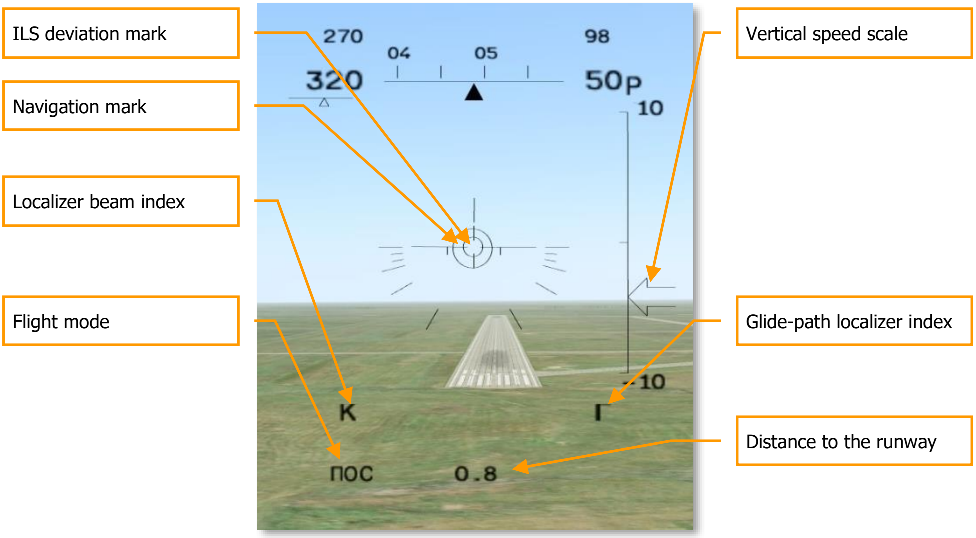
In RETURN mode, the route line will lead to the glide slope intercept point.

In LANDING mode, the route line will lead to the desired air base. Airfield selection can be chosen by cycling the **[LCtrl-~]** key.

Navigation Mode

When in the ROUTE sub-mode, a circular sighting mark is displayed on HUD; this shows the direction to reach the current waypoint point. Above the airspeed and altitude indications are indicators for the preplanned speed and altitude on a given route leg. When the current route point is reached, the sighting mark will automatically switch to the next waypoint. Planned route and waypoints are displayed on HDD.

In the RETURN sub-mode, the sighting mark shows the glide slope intercept point. The shortest line to the glide slope point will be indicated on HDD. Manual switching between airfields is performed by pressing the **[LCtrl-~]** key. After reaching the glide slope intercept point, the RETURN sub-mode will automatically switch to the LANDING sub-mode and the Tower will provide landing instructions.



3-20: ILS landing

In the LANDING sub-mode, the HUD director circle points to the landing airfield. The direction to the landing airfield is also displayed on the HDD. Different airfields can be cycled with the **[LCtrl-~]** key. Upon approach, the airport control Tower will provide final directions. A vertical velocity scale appears at the right side of the HUD to indicate the aircraft rate of descent.

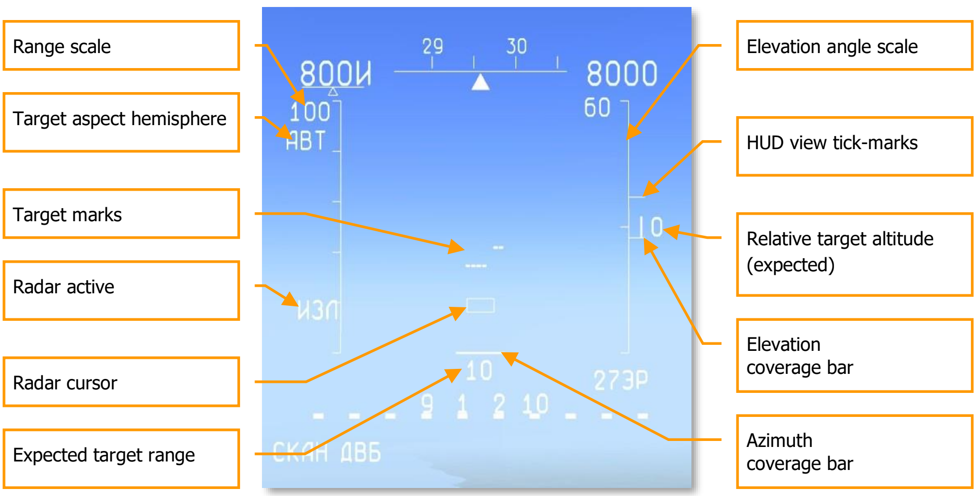
Beyond Visual Range Combat Modes (BVR)

There are several beyond visual combat (BVR) combat modes: СКАН (SCAN) – scan, СНП (TWS) – track-while-scan, and РНП – АТАКА (STT) – single target track.

СКАН (SCAN) MODE

СКАН (SCAN) mode is first activated by pressing the **[2]** key. This is the primary BVR search mode. Up to 24 targets can be detected. It's also necessary to turn on one of the fire control sensors (radar or IRST) before targets can be detected and engaged. In BVR mode, the fighter's radar is normally used. The radar enables target detection at longer ranges, and also the use of semi-active radar homing (SARH) missiles.

Information necessary for target search and lock on is displayed on HUD. The range scale can be controlled with the **[+]** and **[-]** keys. The scan pattern can be slewed discretely through three azimuth positions, center – right – left. The scan pattern can be slewed in elevation using one of two methods - smoothly by direct elevation slewing, or discretely by the range-angle method. To use the range-angle method, first you should set the expected range to target in kilometers using the **[RCtrl-+]** and **[RCtrl--]** keys, then set the expected target elevation difference with respect to your aircraft using the **[RShift-;]** and **[RShift-.]** jeys, also in kilometers. The expected range you set is indicated under the azimuth coverage mark at the bottom of the HUD, and the expected elevation difference is indicated to the right of the elevation coverage mark on the right side of the HUD.



3-21: SCAN mode - BVR

When the fire control sensor detects a target, it is represented by a small, horizontal row of dots on the HUD. "Friendly" targets responding to the radar's identification system (IFF) are represented by a double row.

- Range scale is changed by the **[+]** and **[-]** keys.
- The expected target aspect hemisphere is controlled with the **[RShift-I]** key. ABT (ILV) mode can be used if the target aspect is unknown. The expected target aspect determines the pulse repetition frequency (PRF) to be used by the fighter radar in search mode. High PRF (HPRF), which provides the longest detection range against approaching forward-hemisphere targets, is indicated by ППС (HI), whereas medium PRF (MPRF) for receding rear-hemisphere targets is indicated by ЗПС (MED). In ABT (ILV) mode, high and medium PRFs are interleaved on alternate bars of the radar scan pattern. This provides all-aspect target detection at the expense of a 25% reduction in maximum range.
- An air target is indicated on the HUD as a horizontal row of dots. The number of dots corresponds to the approximate size of the target as measured by its radar cross-section (RCS). One dot indicates a target RCS of 2 sq. m or less, two dots – from 2 up to 30 sq. m, 3 dots – from 30 up to 60 sq. m, and four dots - 60 sq. m or more. Tactical fighters typically have RCS values between 3 and 30 sq. m, dependent upon the type, external payload, and aspect angle. Most fighters are thus usually displayed on the HUD as a row of 2 dots. Friendly aircraft have an identification marking in the form of a second row of dots positioned above the main one.
- The "**И**" symbol on the left side of the HUD indicates that the radar is turned on and actively transmitting.
- The radar cursor for target designation is moved by using the **[;], [,], [.], [/]** keys.
- The expected range to target (often derived from AWACS and GCI data), as set by **[RCtrl-+]** and **[RCtrl--]** keys and is indicated at the bottom of the HUD under the azimuth coverage bar. The elevation coverage of the radar scan pattern is calculated from this parameter.
- The expected relative altitude of the target with respect to your aircraft, as set by the **[RShift-;]** and **[RShift-.]** keys is indicated on the right side of the HUD, next the elevation coverage bar. This parameter is also used to calculate the scan pattern elevation coverage.

IF YOUR FIGHTER IS AT AN ALTITUDE OF 5 KM AND AWACS REPORTS A TARGET AT RANGE 80 KM AND ALTITUDE 10 KM, YOU SHOULD TURN YOUR AIRCRAFT TOWARDS THE TARGET, THEN ENTER THE RANGE OF 80 KM AND RELATIVE ALTITUDE 5 KM INTO THE RADAR. THE RADAR SCAN ZONE WOULD THEN BE CORRECTLY AIMED AT THE EXPECTED TARGET ELEVATION.

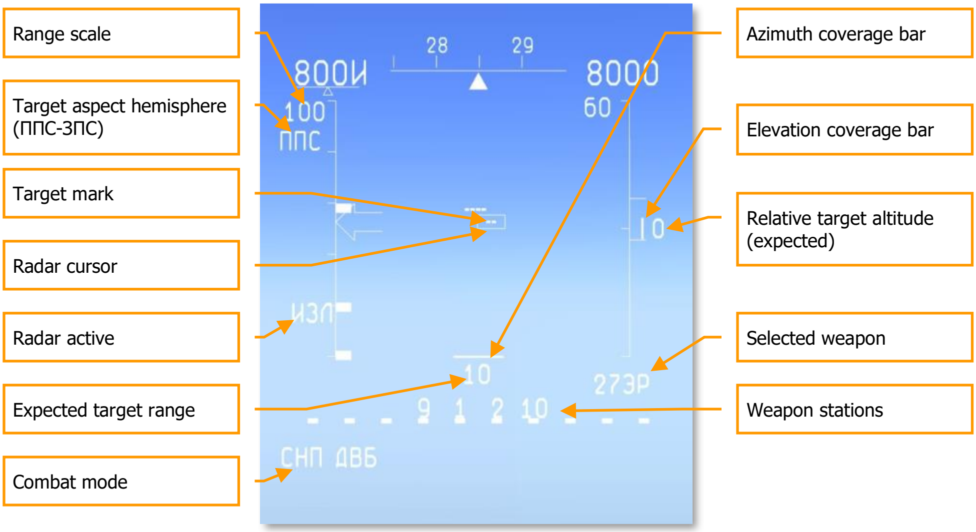
- The elevation angle scale is also at the right side of the HUD. The scale limits are ±60 degrees, indicated by inwards facing tick marks at the top and bottom of the scale. A third inward tick mark represents the horizon. Outward facing tick marks represent the viewing angle of the HUD. Next to the fixed elevation scale is a moving elevation coverage bar, which indicates the limits of the scan pattern in elevation. It cues the pilot to look in the same direction as the radar scan pattern, using the HUD as a reference. If the elevation coverage bar is between the HUD tick marks on the elevation scale, then the radar is searching for targets in the elevation zone visible through the HUD.

- The azimuth coverage bar is displayed at the bottom of the HUD. It has three fixed positions corresponding to the selected scan pattern azimuth: left – center – right.

СНП (TWS) MODE

Another BVR combat mode is СНП (Track-While-Scan or TWS). It is activated from the СКАН (SCAN) mode by pressing **[RAlt-I]**. The radar can correlate tracks for up to 10 targets simultaneously in СНП (TWS). The main distinction from SCAN mode is that the radar retains target parameters, like elevation and velocity vector, while continuing to search for additional targets. The HDD provides a top-down view of the tactical situation including all tracked targets, together with their direction of travel and position.

TWS mode provides automatic target lock on (transition to STT). This is enabled by moving the radar cursor over a target. The cursor will "snap" to the target and follow it thereafter. Automatic lock on occurs at a range equal to 85% of the calculated maximum weapon launch range. The pilot can force an earlier lock on by pressing the **[Enter]** key.



3-22: СНП (TWS) MODE

The HUD symbology in СНП (TWS) mode is similar to that of СКАН (SCAN) mode.

- СНП - ДВБ (TWS – BVR) in the lower left corner of the HUD indicates the current mode.
- Weapon stations carrying the chosen weapon are indicated along the bottom of the HUD.
- The chosen weapon is indicated in the lower right corner of the HUD, beneath the elevation angle scale. The **27ЭР** above indicates R-27ER missiles.
- The range scale at the left side of the HUD features three thick inwards facing tick marks. Going from the top downwards, these are: Rmax - maximum permitted launch range vs.

non-maneuvering target, Rtr - maximum permitted launch range vs. maneuvering target ("no-escape zone"), and Rmin - minimum permitted launch range.

СНП (TWS) mode is only available together with ППС or ЗПС selected. The interleaved - PRF ABT mode is not compatible. This mode therefore requires head-on or pursuit target aspect to be known in advance.

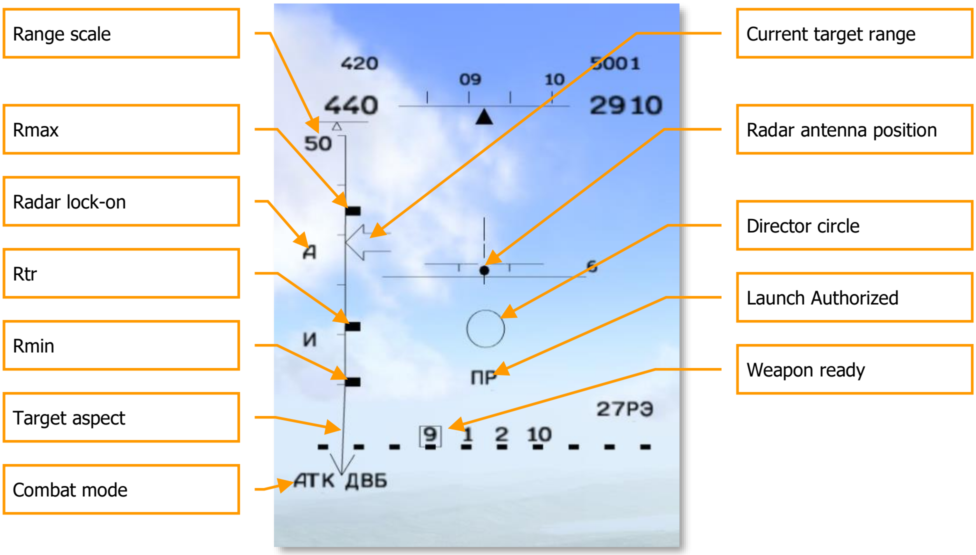
The following information is displayed on the HDD in СНП (TWS) mode:

3-23: HDD for СНП – ДВБ (TWS - BVR)

- Scanned azimuth is shown in dark green
- Selected elevation angle of the scan pattern is displayed on the left
- Selected azimuth position of the scan pattern is displayed at the top
- Triangles denote hostile targets. A short line indicates the direction of motion
- Circles denote friendly aircraft. A short line indicates the direction of motion
- The own fighter symbol is fixed near the bottom of the HDD
- Display scale is indicated in the lower right corner

Атака – РНП (ATTACK – STT) MODE

After locking up the target in either mode, SCAN or TWS, the radar automatically switches to Single Target Track (STT) mode. It stops tracking all other targets and additional information is indicated at the HUD in the following form:

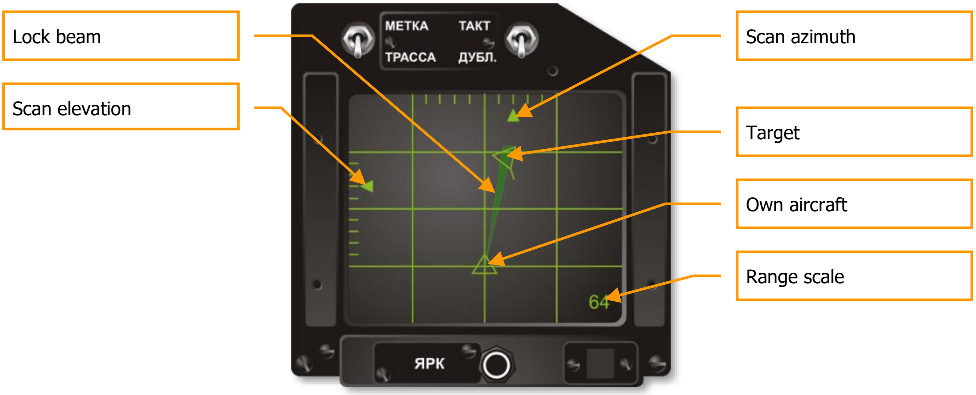


3-24: АТК – ДВБ (ATTACK – BVR) MODE

- Rmax – maximum permitted launch range vs. non-maneuvering target.
- Rtr - maximum permitted launch range vs. maneuvering target.
- Rmin – minimum permitted launch range.
- The attack symbol indicates an active radar lock. After missile launch, the attack symbol flashes at a frequency of 2 Hz.
- Aspect angle shows target velocity vector in the plane turned in the HUD vertical plane.
- АТК – ДВБ mode is displayed in the HUD left lower corner.
- The arrow indicating current range to target moves along the range scale.
- A round dot indicates the radar antenna position relative to the fighter heading.
- The director circle is superposed over the target in the HUD.
- The ПР (LA) Launch Authorized symbol appears when the target enters the permitted range limits and any other launch conditions are satisfied.

In STT mode, all radar energy is concentrated on the target to provide greater accuracy and reduce the probability of tracking failure, which may be caused by target countermeasures.

Note that this radiation-intensive mode is interpreted by enemy RWR as a "lock" and preparation for missile launch. As a result, using it may prompt the target to take evasive action or to start a counterattack.



3-25: HDD АТАКА – РНП (ATTACK – STT)

In the STT mode, the scanned zone becomes a narrow direction-indicating radar beam.

During missile launch the radar changes to continuous wave illumination. This is unambiguously interpreted by the enemy warning system as a missile launch and usually prompts some form of defensive measures.

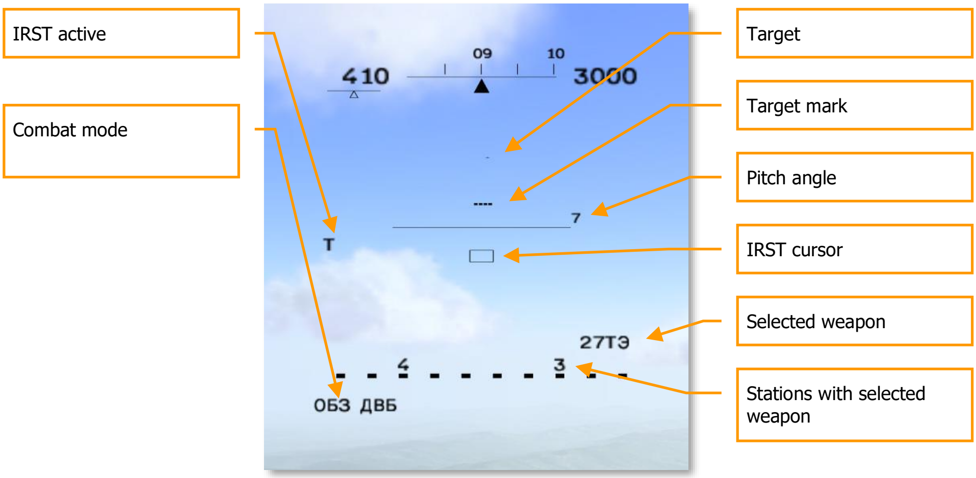
When semiactive radar homing (SARH) missiles are used, it's necessary to illuminate the target until the missile hits. When active radar homing (ARH) missiles are used, it's necessary to illuminate the target until the missile seeker switches to active homing, beginning from a distance of 15 km from the target.

SCAN – IRST MODE

Use of the Infra-Red Search and Track (IRST) system as the chosen sensor changes the HUD symbology accordingly.

When searching with IRST, target information is displayed in the HUD azimuth-elevation coordinates (as opposed to the azimuth-range coordinates when searching with radar). Azimuth is along horizontal, elevation angle along the vertical axes respectively.

After the locking the target with the help of the IRST cursor, the display switches to the ATTACK mode described earlier.



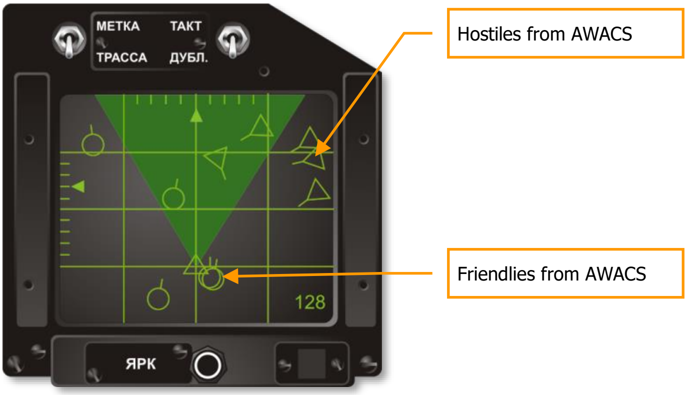
3-26: СКАН – ДВБ (SCAN – BVR) Mode with IRST as chosen sensor

- The "T" symbol at the left side of the HUD indicates IRST operation.
- The name of the chosen mode is displayed in the left lower corner.
- Target mark is displayed in the azimuth-elevation angle format.
- The pitch elevation of the scan pattern is displayed at the HUD center-right.

Since the target's RWR cannot detect the laser rangefinder employed by the IRST, this sensor makes it possible to conduct a "stealth" attack. For this type of attack, only "heat-seeking" missiles with seekers that employ infra-red homing (IRH) can be used.

Digital Datalink

The Su-27 and Su-33 carry the necessary radio equipment to receive digital target information directly from off-board sensors (A-50 AWACS aircraft and ground-based EW radars) without using voice communications. The command post transmits the air combat tactical situation to the fighter, and this data is then displayed in a top-down view on the HDD to improve the pilot's situational awareness. This tactical display shows the positions of all aircraft detected by off-board sensors, using the fighter's own position as a reference. The digital datalink is automatically active when the fighter radar is first turned on (**[I]** key), so long as a friendly AWACS aircraft or early warning (EW) ground radar station is available in the mission. The datalink will remain active, and targets will continue to be displayed on the HDD, even if the radar is thereafter switched off.



3-27: HDD with active AWACS datalink

It should be noted that some AWACS-detected targets appearing in the dark green triangular zone may not be visible to the fighter's own radar, if they are outside the radar elevation scan limits in altitude. The fighter's own radar should be controlled with the help of the HUD display.

Work in Complicated Countermeasures Conditions

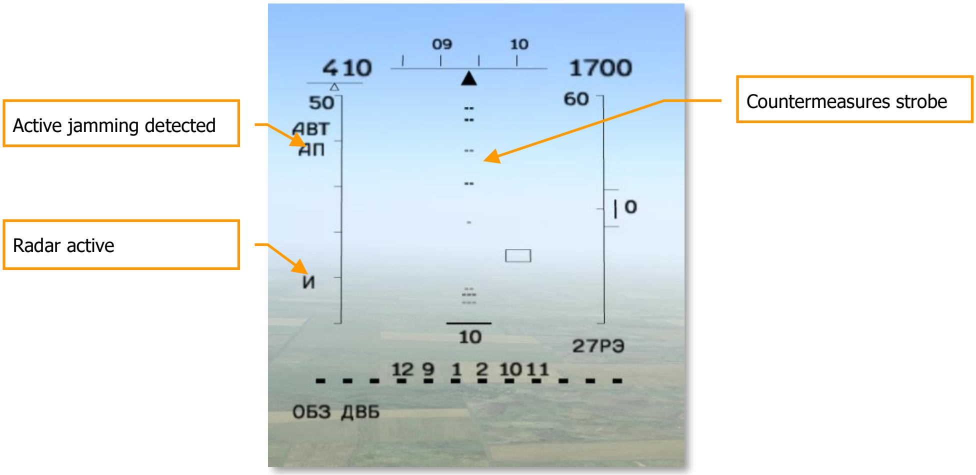
In complicated countermeasures conditions, when the enemy uses passive and/or active radar jamming, the TWS mode cannot be used. SCAN mode should be used instead. In the conditions of strong radio-electronic countermeasures the radar cannot determine the range to the target – instead, a vertical jamming strobe of randomly flashing target marks appears in the HUD along the jammer's bearing. Detection of ECM in the radar scan pattern also causes the "АП" (active noise) symbol to appear at the right side of the HUD. Nevertheless, it is possible to obtain a bearing-only "angle-of-jam" (AOJ) lock on the countermeasures strobe and to launch semi-active radar homing (SARH) missiles, which in this case will guide in the passive "home-on-jam" (HOJ) mode.

The AOJ lock is effected by using the **[;], [,], [.], [/]** keys to move the radar cursor over the countermeasures strobe, and pressing the lock-on **[Enter]** key. The fighter radar will then point its antenna in the direction of the noise source and track it. The target range displayed in the HUD with an active AOJ lock is not measured by the radar but rather provided by the fighter pilot (e.g. according to instructions received by radio), with the default value 10 km. If the entered target range is longer than the range of the chosen missiles for this altitude, then missile launch requires either that the entered range is manually reduced with **[RCtrl--]** until the "ПР" symbol appears, or that launch authorization override is enabled with **[LAlt-W]**.

It should be noted that when using missiles against a jamming target, the lack of range information can make it difficult to gauge when to shoot - the target may be outside the permitted launch zone. In addition, missiles flying in the passive mode have a lower probability to hit the target.

At the range of less than 25 km to the jammer, the radar power is sufficient to "burn through" the jamming and provide accurate target location, including range. The display on the HUD then becomes the standard SCAN mode showing the distance to the target.

THE MOMENT WHEN THE FIGHTER RADAR CAN RECOGNISE THE REFLECTION OF ITS OWN SIGNAL ABOVE THE JAMMING NOISE AND RECEIVE THE INFORMATION ON THE TARGET MOVEMENT IS CALLED "BURN-THROUGH". WHEN THE RADAR STARTS TO PROVIDE FULL DATA ON THE TARGET DESPITE THE PRESENCE OF ECM NOISE, THE RADAR HAS "BURNED-THROUGH" THE INTERFERENCE.

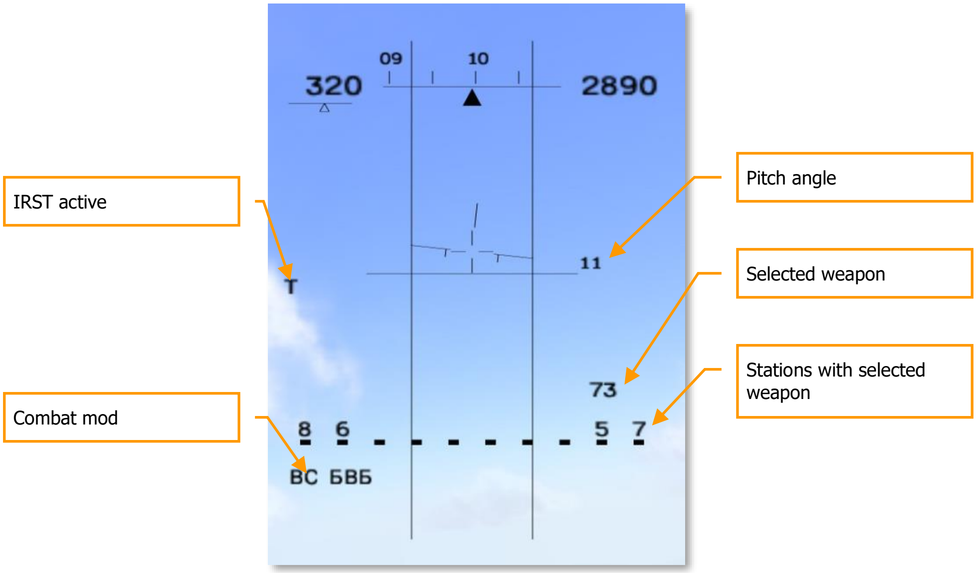


3-28: SCAN Mode with jammer strobe

- Blinking vertical countermeasures strobe is located at the jammer azimuth. Upon locking it, the information on the HUD is similar to the STT mode with fixed mark of the current range to the target.
- The **АП** active jamming indicator is displayed when electronic countermeasures are detected in the fighter radar scan zone.

Vertical Scanning (VS) - Close Combat Mode

This sub-mode [3] is the most frequently used mode in close maneuvering air combat. In this sub-mode the radar or IRST scan pattern is a vertical bar with width of 3 degrees and vertical elevation angle limits of –10+50 degrees. The HUD displays two vertical lines denoting the boundaries of the scanned zone. Lock-on is automatic when a target moves into the scan zone, which starts at the lower edge of the HUD and extends above it by about two more HUD lengths. Aiming is accomplished by maneuvering the fighter so that the target is placed into this scan zone.



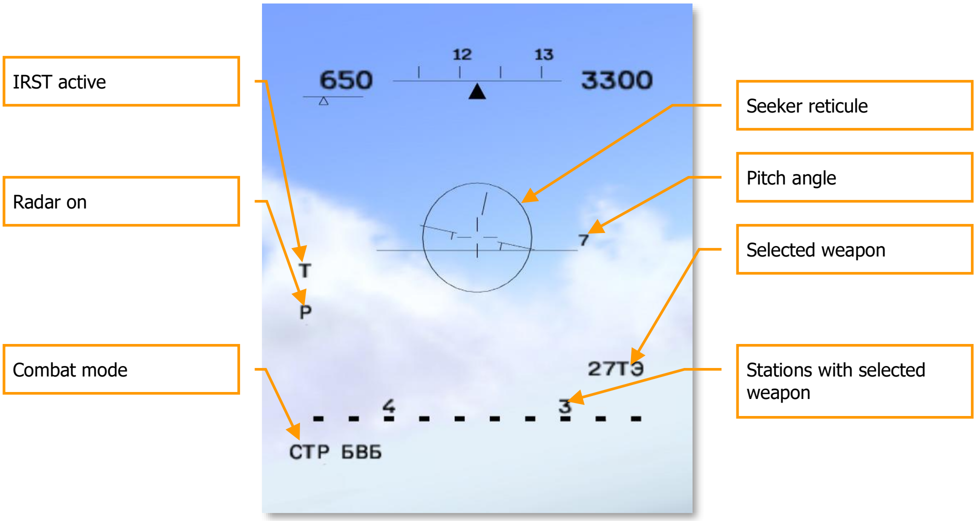
3-29: VS MODE

Automatic lock-on occurs within 1 – 3 seconds of the target entering the scan zone. After the target is locked, the display on the HUD changes to the Attack (STT) mode.

Vertical Scan mode selects the IRST sensor by default. The default weapon is the R-73 close combat missile. In order to launch missiles with radar instead, the radar is first activated with the **[I]** key, and then the desired missile is selected with the **[D]** key.

ОПТ – СТРОБ (BORE) Close Combat Mode

This sub-mode **[4]** is similar to VS mode, with the distinction that the sighting system does not scan, but is rather bore sighted in one direction along the aircraft axis in a narrow (about 2.5 degrees) cone. This zone is displayed on the HUD in the form of circle with the angular size of 2.5 degrees. Target lock-on is accomplished by moving the circle over the target, either by maneuvering the fighter or with the help of target designator control keys **[;], [,], [.], [/]**, and pressing the lock-on **[Enter]** key. After locking the target, the display on the HUD will change to Attack (STT) mode. This mode provides good aiming precision and a slightly longer lock range than the VS mode.

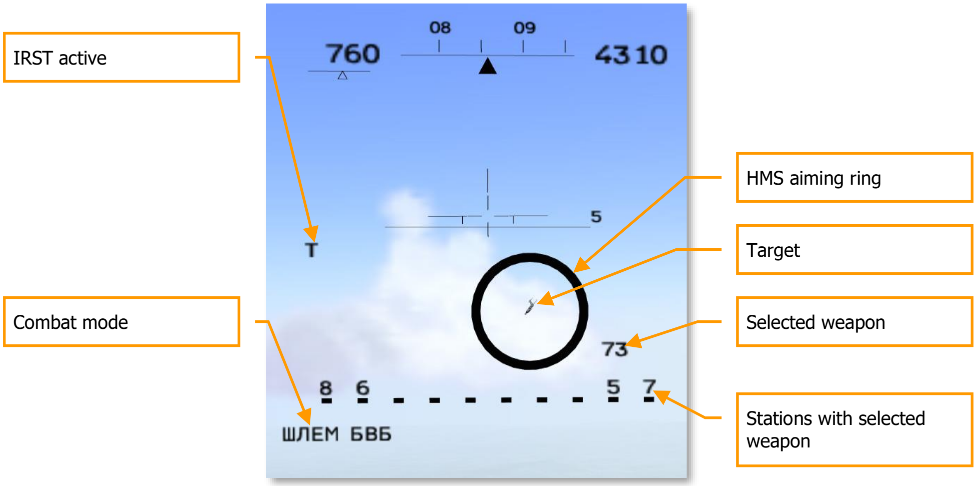


3-30: BORE MODE

Vertical Scan mode selects the IRST sensor by default. The default weapon is the R-73 close combat missile. In order to launch missiles with radar instead, the radar is first activated with the **[I]** key, then the desired missile is selected with the **[D]** key.

ШЛЕМ (HELMET) - Close Combat Mode

This unique mode is useful for maneuvering combat, and selected with the **[5]** key. The pilot can aim weapons at the target simply by turning his head to look at it, with the help of the Schel-3UM helmet-mounted sight (HMS). The sighting ring on the screen emulates the HMS sighting system viewfinder located in front of the pilot right eye. The pilot can superpose the viewfinder over the target by panning the view. The viewfinder is not a HUD symbol remains in the center of the screen even when the view is panned off the HUD. This mode is used in close combat to get an advantage in guided missile launch as HMS permits lock-on and missile launch from high off-bore sight angles, without turning the whole fighter to point at the target. After locking the target by superposing the sighting ring and pushing the **[Enter]** key, if all the launch criteria are satisfied, the ring starts flashing at a frequency of 2 Hz, signaling LA "launch authorized." If the target moves out of the missile seeker’s angular gimbal limits, an X symbol will appear above the ring.



3-31: Helmet mode

The HUD display switches to Attack (STT) mode after locking the target.

It's efficient to use the HMS mode together with the "padlock" view. First padlock the target with the **[NUM DEL]** key, then select the HMS mode with the **[5]** key. The HMS ring will then be placed over the target and it and be locked by pressing **[Enter]**.

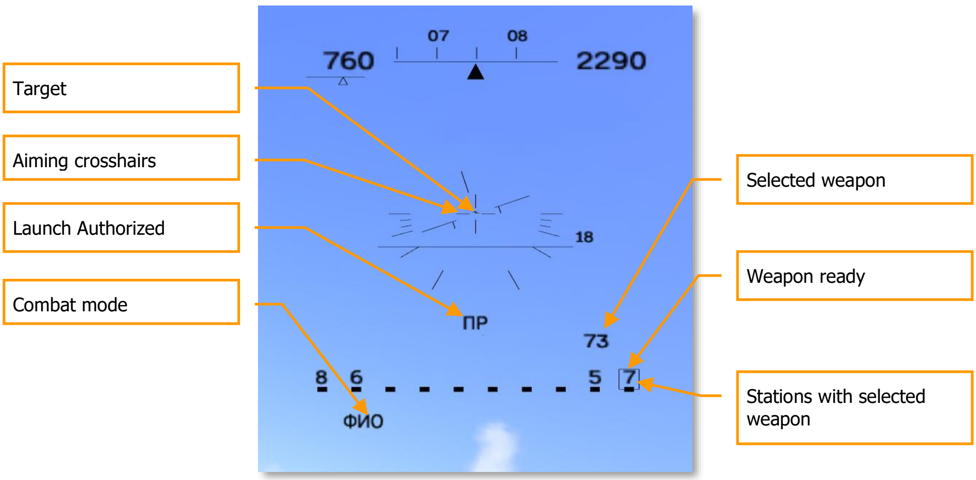
ФиО (FiO) – Longitudinal Aiming

Close Combat Mode

Fi0 (Fi-Zero) is a backup mode in case of failure of the fighter weapons control system (WCS) radar and IRST sensors. This mode is selected with the **[6]** key, but can be used only with active radar (ARH) or "heat-seeking" infra-red homing (IRH) missiles which have seekers capable of acquiring the target independently of the fighter's sensors. In this mode the missile's own seeker, which has a 2-degree conical field of view looking forward along the missile axis, is used to lock the target. It's necessary to maneuver the fighter to place the aiming cross-hair over the target. The LA symbol appears immediately when the missile seeker has locked the target, regardless of target range. The pilot should judge the target range visually to ensure the missile will have enough energy to complete the intercept, especially in the case of receding pursuit targets.

The use of infra-red homing (IRH) missiles in the Fi0 mode will not trigger the target's RWR, and as such can be used to affect a passive "stealth" attack. The target can detect the missile launch only visually.

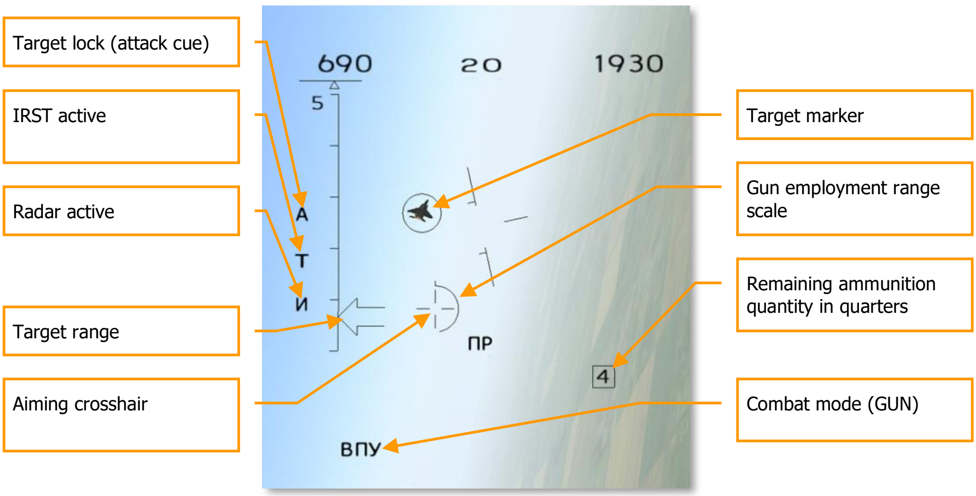
Active radar homing (ARH) missiles like the R-77 cannot be used for a stealth attack, since the missile's own radar emissions can be detected by the target RWR.



3-32: Fi0 (Longitudinal) MODE

Gun Employment

The aircraft cannon can be employed from any air-to-air combat mode. To do so, first select the cannon by pressing the [C] key. If a sensor lock is present, the WCS will automatically enter the Lead Computed Optical Sight (LCOS) mode.



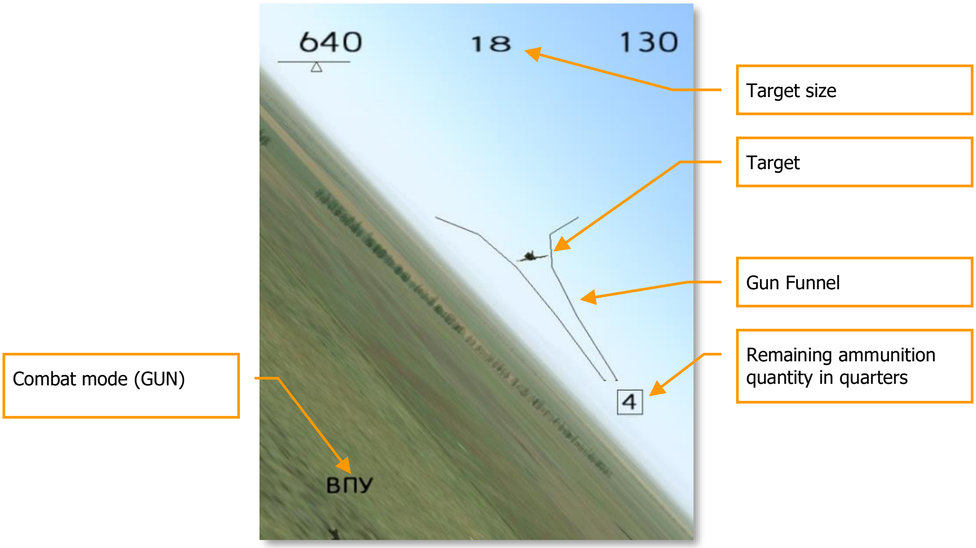
3-33: Lead Computed Opitcal Sight (LCOS) mode

- The aiming crosshair appears when the target range is less than 1200 meters.

- The gun employment range scale indicates target range from 0 to 1200 meters.
- Target range is also displayed on the vertical range scale on the left side of the HUD. The scale is set for 5 km.
- The remaining ammunition quantity displays the remaining ammunition in quarters, from 4 to 1.

For effective fire, place the aiming crosshair over the target marker and open fire by pressing the **[Space]** key.

If the targeting sensors are malfunctioning or disabled, the Gun Funnel mode can be used for aimed cannon fire.



3-34: Gun Funnel cannon mode

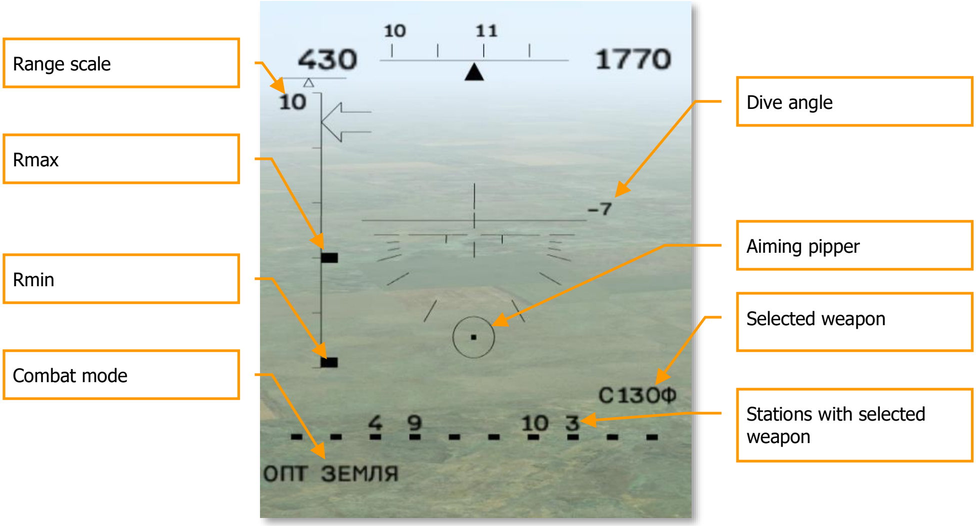
In Gun Funnel mode, a graphic funnel is displayed on the HUD to indicate the calculated flight path of cannon rounds. The distance between the sides of the funnel is based on the Target Size setting. Target Size is an approximated value of the target's wingspan. The Target Size value can be adjusted in increments of 10 by using the **[RCtrl--]**, **[RCtrl-+]** keys or in single digits by using the **[RAlt--]**, **[RAlt-+]** keys. The default Target Size value is 20 meters.

For effective fire using the funnel, maneuver the aircraft to place the funnel over the target so that the target's wingtips contact the sides of the funnel. If the Target Size is set accurately to correspond to the target's wingspan, you will have a good firing solution. Fire accuracy is greatest if the target's plain of motion is matched, e.g. if the target is turning with 30-degrees of bank, you should match the turn with equal bank from behind the target. The gun funnel can only be employed from the rear hemisphere.

Air-to-Ground Mode

The MiG-29, Su-27 and Su-33 fighter jets can carry a limited variety of air-to-ground weapons. This includes unguided "iron" bombs and rockets (RKT).

The GROUND mode [7] is used with these weapons. Air-to-ground aiming symbols are displayed in the HUD. The mode name ОПТ ЗЕМЛЯ (VISUAL GROUND) appears in the lower left corner of the HUD, and below it, the chosen weapon. The aiming principles are generally similar for all weapons – it's necessary to superpose the aiming pipper over the target, and drop or launch weapons when the LA symbol indicates that the firing criteria have been met.



3-35: ОПТ – ЗЕМЛЯ (VISUAL – GROUND) MODE

- The display scale is provided in the upper left.
- Rmax and Rmin tick-marks are displayed on the range scale.
- Chosen "ОПТ ЗЕМЛЯ" mode is displayed in the lower left corner of the HUD.
- Dive (pitch) angle is displayed at the center-right of the HUD.
- Moving aiming pipper indicates the computed point of weapon impact.

Hi-drag weapons such as retarded bombs and cluster sub-munitions dispensed from containers have a low drop trajectory which may cause the aiming pipper to remain below the lower limit of the HUD even in a diving attack. In this case it's better to use the continuously computed release point (CCRP) bombing mode. This mode is described in detail in the "Weapon usage" section.

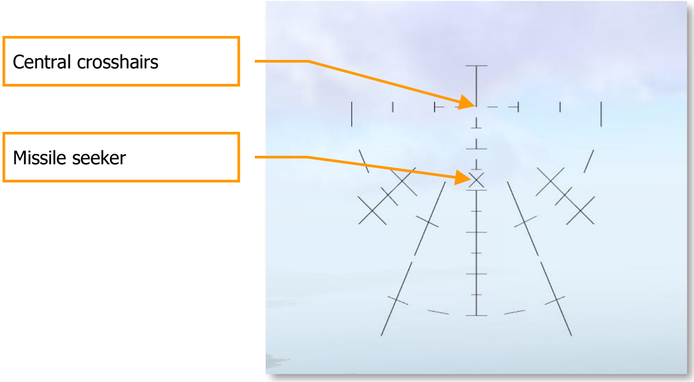
Reticle

The fixed reticle is not a combat mode, but rather a calibrated image that can be displayed on the HUD by pressing the [8] key. The fighter WCS remains in the same mode as before [8] was pressed, but the HUD indications are replaced by the fixed reticle.

The reticle is also a backup instrument for aiming in case of WCS failure or damage.

The reticle displayed on the HUD is an analog to a simple collimator sight. Lead aiming and computing is accomplished with the help of the reticle markings or "by eye".

The reticle central crosshair is aligned with the gun axis. Missile seekers aimed in Fi0 mode are aligned somewhat lower below the central crosshair, at the position of the "X" aiming mark.



3-36: Reticle

Su-25 Cockpit Instruments

Most of the Su-25's cockpit instruments are the same as those of Su-27 and MiG-29.

3-37: The Su-25 Instrument Panel

1. Landing gear control lever
2. Angle of Attack (AOA) indicator and Accelerometer ("G meter")
3. Airspeed indicator (IAS)
4. Attitude director indicator (ADI)
5. Aircraft clock

6. Vertical velocity indicator (VVI)
7. Machmeter.
8. Fuel quantity ind icator.
9. SPO-15 "Beryoza" radar warning receiver (RWR)
10. Warning lights
11. Weapons status panel
12. WCS panel
13. Configuration indicator
14. Distance to waypoint counter
15. Radar altimeter
16. Barometric pressure altimeter
17. Horizontal situation indicator (HSI)
18. Tachometer (revolutions per minute or RPM)
19. Inter-stage turbine temperature indicators
20. RSBN panel (short-range navigation)

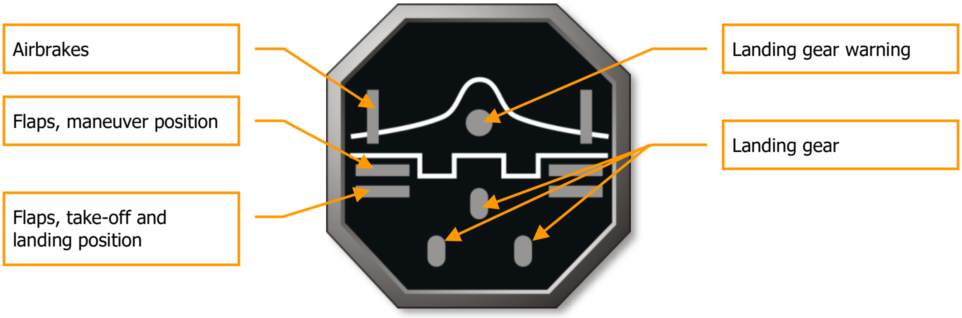
IAS – TAS Indicator

The IAS - TAS gauge indicates the aircraft's True Airspeed (TAS) in the interior of the gauge and Indicated Airspeed (IAS) in the outer portion of the gauge. The speed scale ranges from 0 to 1,100 km/h.

3-38: Su-25 IAS- TAS Indicator

Configuration Indicator

The configuration indicator for mechanical devices shows the position of the landing gear, flaps, and airbrakes. If the landing gear is not successfully extended or retracted, a red lamp lights in the center of the indicator.



3-39: Configuration Indicator

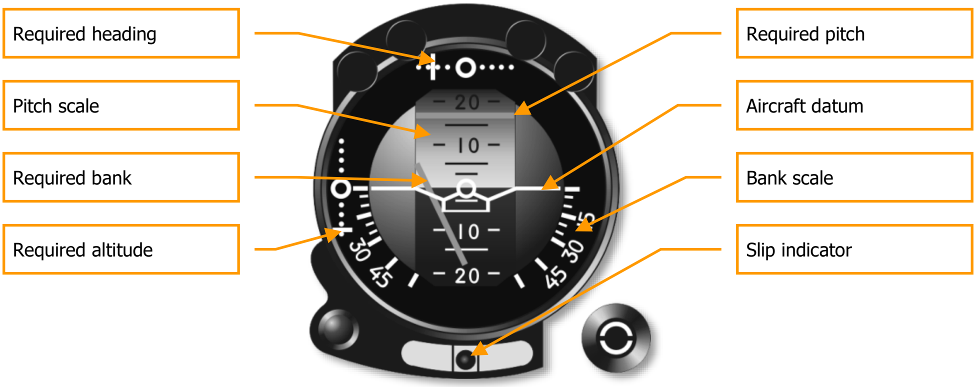
AOA Indicator and Accelerometer

The Angle of Attack (AoA) indicator and accelerometer displays the current angle of attack and G-load. The left part of the indicator shows the AoA in degrees, whilst the G-load is shown in the right part.

3-40: AOA Indicator and Accelerometer

Attitude Director Indicator (ADI)

The Attitude Direction Indicator (ADI) shows the current angles of pitch and aircraft roll. In the lower part of the indicator is a slip indicator. Changing the rudder position eliminates slipping, so try to have the indicator in the central position. On the front portion of the indicator are the required bank and pitch indicators to reach the next waypoint. When both bars are in the central position, the aircraft is following the correct course. During landings, the W-shaped glide slope deviation indicator provides Instrument Landing System (ILS) direction.



3-41: Attitude Director Indicator (ADI)

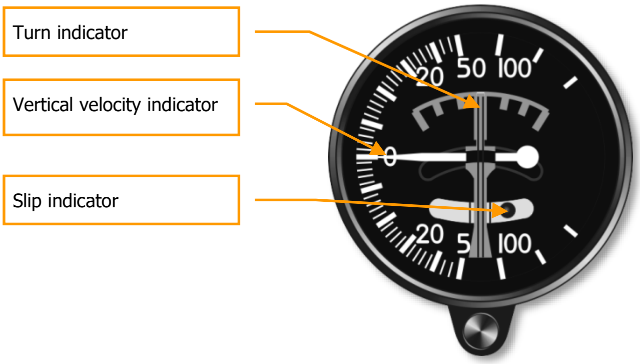
Horizontal Situation Indicator (HSI)

The Horizontal Situation Indicator (HSI) provides a top/down view of the aircraft in relation to the intended course. The compass rotates so that the current heading is always shown at the top. The Programmed Course Arrow shows the required heading to reach your route leg and the Next Waypoint pointer indicates the direction to your selected waypoint. The ILS localizer and glide slope bars are in the center.

3-42: Horizontal Situation Indicator (HSI)

Vertical Velocity Indicator (VVI)

The Vertical Velocity Indicator measures the aircraft's vertical speed, i.e. rate of climb or sink. The Slip Indicator backs up the Slip Indicator on the ADI. The Turn Indicator shows the turn direction, though the rate of turn shown is only approximate.



3-43: Vertical Velocity Indicator (VVI)

Radar Altimeter

The radar altimeter indicates altitude above the ground from 0 to 1500 meters.

3-44: Radar altimeter

Tachometer

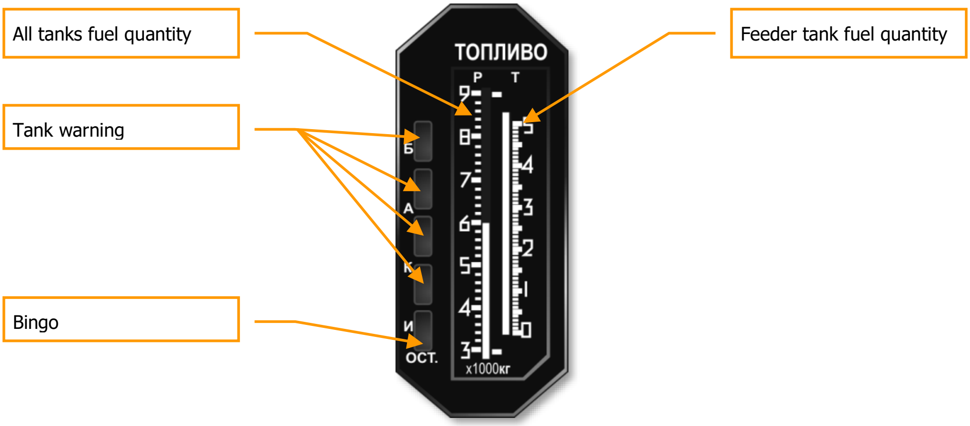
The tachometer is intended for measuring rotor RPM of both engines. Measuring is indexed in percent from maximum rotor RPM.

3-45: Tachometer

Fuel Quantity Indicator

Fuel quantity (P) shows the fuel remaining in all tanks. Fuel quantity (T) shows the fuel remaining in the feeder tank.

If external fuel tanks are carried, a warning light indicates that they are nearing empty.



3-46: Fuel Quantity Indicator

Jet Engine Turbine Temperature Indicators

The two inter-stage turbine temperature indicators show the temperature of the exhaust gas from the left and right engine turbines.

3-47: Engine Temperature Indicator

SPO-15 "Beryoza" Radar Warning Receiver

The RWR display indicates any threat radars illuminating ("painting") the aircraft. Information is presented as symbols representing the type and direction to the threat. Six illuminated symbols at the bottom of the display notify the pilot of the threat radar type. The system indicates both enemy and friendly radars. Detailed information on the SPO-15 RWR is provided in a separate chapter.

Weapon Status Panel

The weapon status panel is located beneath the throttle handle in the left side cockpit instrument panel. The type, quantity and readiness of the currently selected weapon and the remaining gun ammunition are indicated.

3-48: Weapons status panel

- The yellow lamps in the upper row indicate weapon availability and presence on hardpoint stations. When ordnance is launched or released, the corresponding yellow lamp goes dark.
- The green lamps in the lower row indicate currently selected weapons that are ready for launch or release.
- The currently selected weapon type is indicated in the upper right of the panel:
  Б for bombs,
  УР for missiles,
  НРС for rockets,
  ВПУ for the built-in 30 mm cannon.

- The remaining cannon rounds are indicated in the lower right of the panel:
  K for full,
  1/2 for one-half,
  1/4 for one-quarter.

Short-Range Navigation Panel

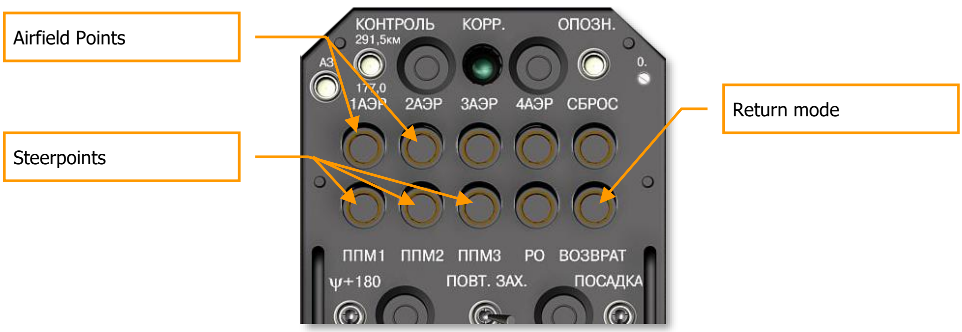
The RSBN Short-Range Navigation Panel is used to select navigation modes. In reality, the aircraft can store up to 4 Airfield Points and 3 Steerpoints.

The system's functionality in the simulation is slightly simplified. Selection between ROUTE – RETURN – LANDING – NO TASK modes is made by cycling the **[1]** key.

In ROUTE mode, one of the three Steerpoint buttons will be lit, depending on the currently selected steerpoint. If the steerpoint selected is greater than 3, all steerpoint buttons will be turned off.

In RETURN mode, one of the three Airfield Point buttons will be lit in addition to the Return mode button.
1АЭР – Take-off airfield
2АЭР – Landing airfield

In LANDING mode, one of the three Airfield Point buttons will be lit.



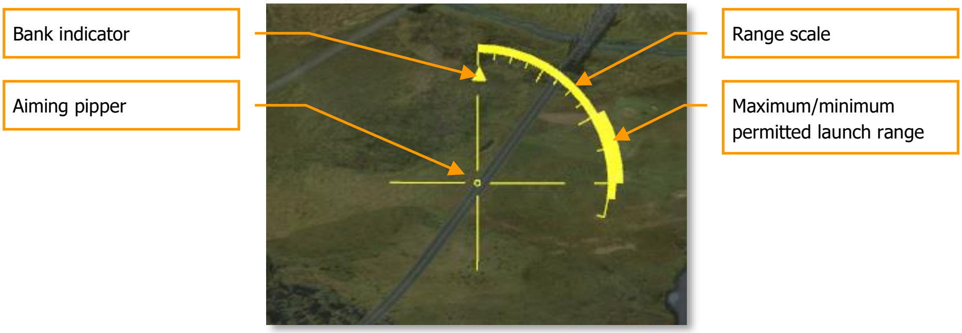
3-49: Short-Range Navigation Panel

In NO TASK mode, all buttons are turned off.

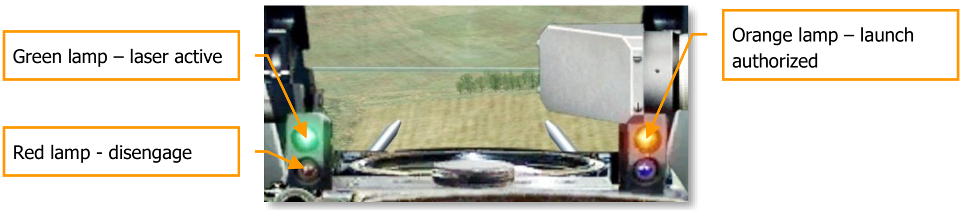
When cold-starting the aircraft, the navigation system will be in NO TASK mode.

ASP-17 Gunsight

In contrast to other 4th generation aircraft, the Su-25 lacks a HUD, and the pilot flies using the cockpit instruments. The Su-25 is, however, fitted with an ASP-17 gunsight for aiming weapons.



3-50: ASP-17 gunsight indication



3-51: ASP-17 gunsight lamps

The gunsight symbology is quite simple. A crosshairs aiming pipper appears in the center. An arc drawn clockwise from the top of the crosshairs indicates the range to the point in the crosshairs as measured by the "Klyon-PS" laser rangefinder/target designator carried in the nose of the Su-25.

A thickened part of this arc indicates the allowable launch range for the currently selected weapon. As the aircraft approaches the target, the ranging arc begins to vanish, becoming ever shorter. When the aircraft reaches the permitted firing range and the widened part of the arc also begins to disappear, an orange lamp in the lower right of the gunsight illuminates to indicate that launch is authorized. A small triangle at the top of the crosshairs also indicates the aircraft's current bank angle. Accurate aiming of many Su-25 weapons is improved by reducing this bank angle to zero (i.e. the bank indicator should be aligned with the vertical part of the crosshairs).

Three lamps at the bottom of the gunsight mounting provide additional indications.

The green lamp located in the lower left indicates that the "Klyon-PS" laser target designator is active.

The orange lamp located in the lower right indicates that weapon launch, release or fire is authorized.

The red lamp located in the lower left, below the green lamp, indicates that the aircraft has approached within the minimum allowable employment range for the currently selected weapon, and the attack run should be broken off for another pass.

When laser-guided missiles are selected, the aiming pipper can be slewed with the **[;]**, **[,]**, **[.]**, **[/]** keys.

Su-25T Cockpit Instruments

Most of the Su-25T cockpit instruments are the same as those in the Su-25:

3-52: The Su-25T Instrument Panel

1. Landing gear control lever
2. Autopilot control panel (ACS)
3. Angle of Attack (AOA) indicator and Accelerometer ("G meter")
4. Airspeed indicator (IAS)
5. Attitude director indicator (ADI)
6. Vertical velocity indicator (VVI)
7. Tachometer (revolutions per minute or RPM)
8. Fuel quantity indicator
9. "EKRAN" built-in test system display
10. SPO-15 "Beryoza" radar warning receiver (RWR) panel

11. IT-23M cathode ray tube (CRT) television (TV) display
12. Aircraft clock
13. "Sukhogruz" infrared (IR) jammer indicator lamp
14. Weapon system control panel (WCS)
15. Flaps, slats, airbrake and landing gear configuration indicator
16. Radar altimeter
17. Barometric pressure altimeter
18. Horizontal situation indicator (HSI)
19. Neutral (takeoff) trim in pitch, roll and yaw indicator lamp
20. Weapon status panel
21. Engine temperature
22. Hydraulic pressure meters
23. Warning lamps

Weapon System Control Panel

The weapon system control panel can be seen near the bottom of the left instrument panel. Among other functions, this panel is used to control weapon salvo quantity **[LCtrl-Space]** and release interval **[V]**.

3-53: Su-25T Weapon System Control Panel

The weapon system control panel includes:

- the release mode switch with positions **ЗАЛП – 0.1 - 0.2 – 0.3 – 0.4 – СЕРИЯ КМГУ-МБД** for free-fall ordnance, and **0 – ФИКС – ПРОГР** for use with gunpods.
- the salvo size switch with positions **ПО 1 - ПО 2 – ПО 4 – ВСЕ**.

The release mode switch controls the manner in which air to ground weapons are employed:

ЗАЛП (SALVO) – all weapons in the salvo are released simultaneously.

0.1– 0.4 – individual weapons in the salvo are released with the selected interval (in seconds) between them.

СЕРИЯ КМГУ-МБД (SSC-MJM SERIES) – a special release mode for the KMGU submunition dispenser and multiple ejection rack (MER). KMGU submunitions are dispensed at 2-second intervals, MER munitions are released 0.3 seconds apart, according to the total quantity specified by the salvo size switch.

0 – gunpods boresighted (aligned with aircraft longitudinal axis) for firing in a dive.

ФИКС (FIX) – gunpods barrel depression set to a fixed value for strafing runs in level flight. The barrel depression angle is controlled with **[RCtrl - [ ]** and **[RCtrl -]]**.

ПРОГР (PROGR) – gunpod barrel depression angle under automatic control for strafing a target designated with the onboard laser rangefinder from level flight.

The salvo size switch is cycled with **[LCtrl - Space]** and selects the quantity of ordnance to be released with each pull of the trigger:

ПО 1 – ПО 2 – ПО 4 – ВСЕ (Singly – In pairs – Four at a time – All) – The quantity of ordnance to be released.

Note that even the **ПО 1** setting will still release ordnance hung from the outermost weapon stations in symmetric pairs, to avoid excessively unbalancing the aircraft. Only the four innermost wing stations provide individual weapon release with this setting.

MERs always release all attached weapons together. It is not possible to command individual bomb release from the Su-25T's MERs.

When using onboard or podded guns, the salvo size switch positions assume a different meaning:

ПО 1 (FOR 1) – Internal cannon only.

ПО 2 (FOR 2) – Firing with a single pair of gunpods.

ПО 4 (FOR 4) – Firing with all gunpods.

With gunpods selected, strafing in a line can be accomplished from level flight in the **ФИКС** mode, controlling barrel deflection with **[RCtrl-=]** and **[RCtrl--]**.

The **ПРОГР** mode is used to concentrate gunpod fire on a point target from horizontal flight. For this it is necessary to depress the barrels to the desired angle with **[RCtrl-=]** and **[RCtrl--]**, switch on the laser range-finder - **[RShift-O]**, maneuver the aircraft to put the pipper over the target and pull and hold the trigger. The gun barrels will automatically start firing at the right time, then deflect automatically in vertical plane to stay on target.

Autopilot (ACS) Panel

The ACS-8 automatic control system (ACS or "autopilot") panel is located in the left instrument panel. It indicates the ACS operational mode and includes six illuminated pushbuttons.

The available ACS operating modes include:

- Route-following and Landing;

- Combat steering;
- Attitude hold mode (retains current pitch and bank);
- Barometric altitude hold;
- Barometric altitude and bank angle hold;
- Emergency leveling mode;
- Radar altitude hold with automatic terrain avoidance;
- Momentary override (programming) mode.

3-54: ACS Panel

The attitude and/or altitude hold modes attempt to retain the aircraft and/or altitude as it was the moment the mode was engaged.

In all modes except for "Emergency leveling", "Route-following" and "Landing," the ACS is limited to ±60 degrees in bank and ±35 degrees in pitch. When any of these limits is reached, the ACS disengages and the aircraft reverts to manual control. ACS modes cannot be engaged beyond these limits.

The ACS is further limited to 15 degrees angle of attack (AOA) and 0-3 G, as measured by the aircraft instruments. It is not recommended to engage the autopilot at AOAs exceeding 12 degrees. If AOA exceeds 12 degrees while the autopilot is active, the pilot should immediately advance the engine throttles to increase airspeed and thrust.

The "momentary override" mode is engaged by pressing and holding **[LAlt-~]** in any autopilot mode (corresponding to the "SAU" trigger on the control stick of the real Su-25T). This mode allows temporary manual control of the aircraft, usually to adjust the desired attitude and/or altitude. This override mode has two peculiarities in the "Combat steering" ACS mode (see the description of the "Combat steering" mode further below).

Pressing **[LAlt-9]** will disable any engaged ACS modes (corresponding to the "OTKL. SAU" trigger on the control stick of the real Su-25T).

- Route-following mode - **АУ-МАРШР**. This mode is selected by pressing the **[A]** or **[LAlt-6]** key with the aircraft avionics in the "ENROUTE" or "RETURN" navigation operational mode. The autopilot follows the assigned flight path.
- Landing mode - **АУ-ПОСАД.** This mode is selected by pressing the **[A]** or **[LAlt-6]** key with the aircraft avionics in the "LANDING" navigation operational mode, which is switched to automatically from the "ENROUTE" and "RETURN" navigation operational modes when approaching a runway. The "Landing" ACS mode keeps the aircraft on the landing aerodrome’s glide slope beacon. The ACS switches off automatically after descending to 50 meters altitude above ground level (AGL). If the aircraft departs the glide slope beacon for any reason, the ACS mode switches automatically from "Landing" to "Attitude to horizon"

mode. The "Landing" ACS mode is normally disengaged by the pilot for a manual landing from an altitude of 100-200 m AGL. Autopilot descent to the 50 m AGL minimum is recommended only in conditions of poor visibility, when the runway is obscured by fog.

- Combat steering mode - **АУ-МАРШР-КВ**. This mode is selected by pressing the **[A]** or **[LAlt-6]** key when a target or terrain point is locked by the onboard "Shkval" targeting system. The autopilot uses bank to steer the aircraft onto the locked target bearing. The pitch axis is used to maintain altitude. Engaging the "Momentary override" mode **АУ-МАРШР** by pressing and holding **[LAlt-~]** allows the pilot to control the aircraft only in the pitch axis - the ACS retains control of bank angle. After releasing the "override" mode, the autopilot returns the aircraft to the initial altitude.
- Attitude hold mode - **АУ**. This mode is selected by pressing **[LAlt-1]**. It stabilizes the current angles of pitch and bank.
- Barometric altitude and bank angle hold mode - **АУ-КВ**. This mode is selected by pressing **[LAlt-2]**. It stabilizes the current pressure altitude above sea level (ASL) and angle of bank. It is convenient for making continuous level turns.
- Emergency leveling mode - **АУ-ПГ**. This mode is selected by pressing **[LAlt-3]**. It brings the aircraft to straight and level flight from any initial attitude. While the initial bank angle exceeds ±80 degrees, ACS control is applied first in roll, then in pitch. When bank angle is within ±7 degrees and pitch angle within ±5 degrees, the "barometric altitude hold" ACS mode is activated and bank is further reduced to zero.
- Barometric altitude hold mode **АУ-КВ**. This mode is selected by pressing **[H]** или **[LAlt-4]**. It stabilizes the current pressure altitude ASL.
- Radar altitude hold mode - АУ-РВ. This mode is selected by pressing **[LAlt-5]**. It stabilizes the current radar altitude AGL. In this ACS mode the "terrain avoidance" submode is also active.

The "terrain avoidance" submode is engaged whenever:

- The current altitude AGL as measured by the radio altimeter is half or less than its initial value in the "barometric altitude hold" ACS mode, or
- The rate of descent measured by the radio altimeter exceeds –50 m/s.

In the absence of an assigned waypoint, glideslope beam or locked target (e.g. in non-navigation avionics operational modes), pressing **[A]** to engage the autopilot will default to the "emergency leveling" mode, illuminating the corresponding pushbutton on the ACS-8 panel.

When landing crosswind exceeds 10 m/s, it is recommended to disengage the ACS autopilot at a radar altitude of not less than 100 m AGL to revert to manual control.

In the "ENROUTE" and "LANDING" navigation operational modes of the aircraft avionics, the "attitude hold" АУ **[LAlt-1]** and "altitude hold" ("barometric" АУ-КВ **[LAlt-4]** or "radar" АУ-РВ **[LAlt-5]**) ACS modes are available. When one of these modes is engaged, the "route-following" or "landing" ACS modes cannot be selected until the prior mode is switched off by a repeat press of **[LAlt-1]**, **[LAlt-4]** or **[LAlt-5]**.

"Terrain avoidance" is engaged automatically from the "radar altitude hold", "barometric altitude hold", or "attitude hold" ACS modes, and also in "ENROUTE" and "LANDING" navigation avionics operational modes with any attitude or altitude hold ACS mode (e.g. "radar altitude hold," "barometrical altitude hold") engaged.

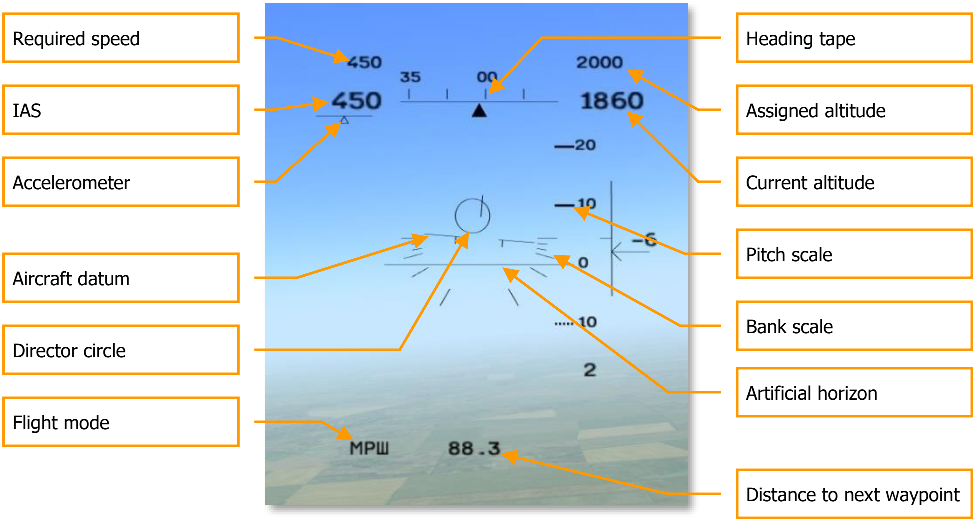
"Emergency leveling" ACS mode can be deactivated by pressing either **[LAlt-9]** or **[A]**. So in the navigation operational mode, switching from the "emergency leveling" to "route-following" ACS modes requires two presses of the **[A]** key.

In the "combat steering" ACS mode, loss of target or terrain point lock for any reason causes the ACS to automatically switch to the "emergency leveling" mode.

Operational Modes of the Su-25T HUD and TV Indicators

Basic HUD Symbology

The Su-25T has several operational modes. Some basic symbols displayed on the Head Up Display (HUD) are common across most modes.



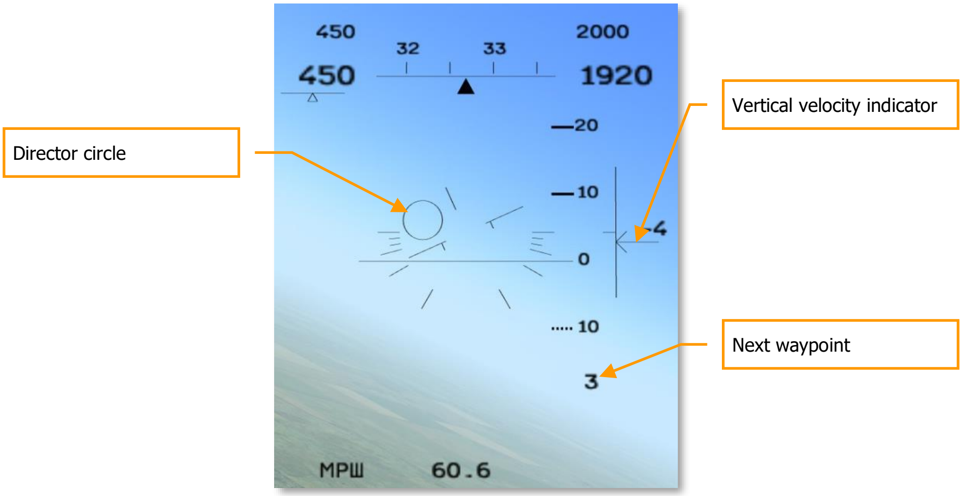
3-55: Su-25T Basic HUD Symbols

- The aircraft datum in the center of the HUD rotates to indicate aircraft bank and roll.
- A heading tape appears at the top of the HUD. Tick marks are labeled in tens of degrees (e.g. the number "35" indicates a heading of 350 degrees).
- To the left of the heading tape is the indicated airspeed (IAS). The assigned airspeed for the next waypoint (depending on the operational sub-mode) is shown directly above the IAS.
- An accelerometer is displayed under the IAS in the form of a bar scale and triangular marker. A marker to the right of center indicates acceleration; to the left of center - deceleration.
- To the right of the heading tape is the current flight altitude in meters. At altitudes less than 1500 m above ground level (AGL), radar altitude is indicated with 1 m accuracy. Above 1500 m AGL, pressure altitude above sea level (ASL) is indicated with 10 m accuracy. The assigned altitude for the next waypoint (depending on the operational sub-mode) is shown directly above the current flight altitude.

- When the aircraft is on the assigned flight path, the director circle is aligned with the aircraft datum in the center of the HUD. When the aircraft flies away from the assigned flight path, the director circle indicates the direction to return to it.
- A pitch tape is located to the right of the aircraft datum. Aircraft pitch can be read from this tape with reference to the aircraft datum in the HUD.
- To the right of the pitch tape is a vertical velocity indicator (VVI). Aircraft rate of ascent or descent between ±30 m/s is indicated by an arrow and a numeric value. The arrow stops at the VVI limit and the numeric value flashes when the vertical speed exceeds 30m/s.
- The current operational flight mode is indicated in the lower left corner of the HUD.
- The distance to the next waypoint in km is indicated at the bottom of the HUD.

Navigation Mode

The HUD provides navigation data enroute. There are three navigation sub-modes: **МРШ (ENROUTE)**, **ВЗВ (RETURN TO BASE)**, **ПОС (LANDING)**. These submodes are selected automatically at appropriate points along the assigned flight path, and can also be cycled manually by pressing the **[1]** key.



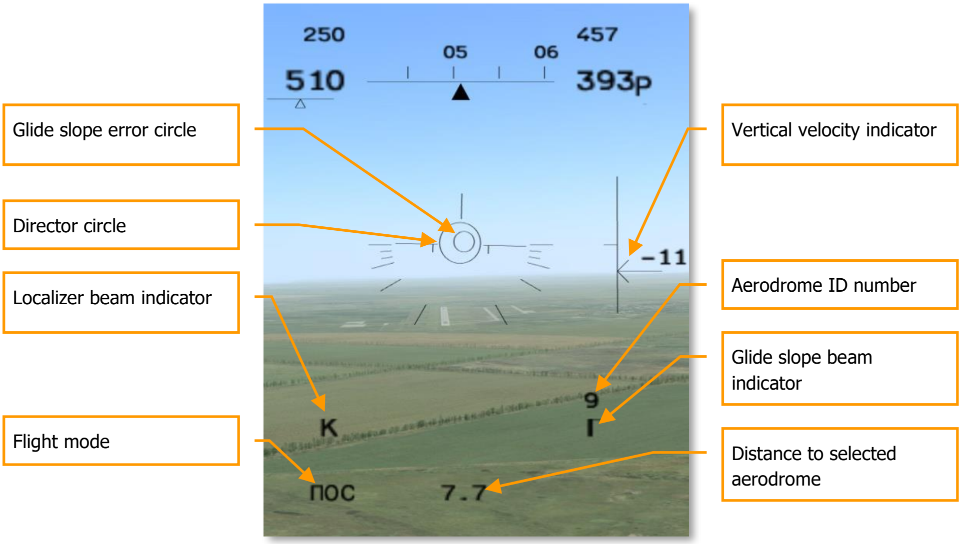
3-56: МРШ (ENROUTE) Navigation Sub-Mode

- The **МРШ (ENROUTE)** sub-mode features a director circle displayed in the HUD. It indicates the direction to the next assigned waypoint.
- The assigned altitude and airspeed enroute to the next assigned waypoint are displayed above the current altitude and airspeed in the HUD.
- The next waypoint number is indicated in the lower right, below the pitch scale. The distance to the next waypoint is displayed at the bottom of the HUD. When the assigned

waypoint is reached, the director circle automatically shows the direction to the one following, and the waypoint number in the lower right will advance.

In the **В3В (RETURN)** sub-mode, the director circle guides the pilot to intercept the runway approach glide-slope.

The landing aerodrome can be cycled by pressing the **[LCtrl-~]** key. The aerodrome ID number is indicated in the lower right, below the vertical velocity indicator. The aerodrome control tower provides voice instructions when the aircraft approaches the runway.



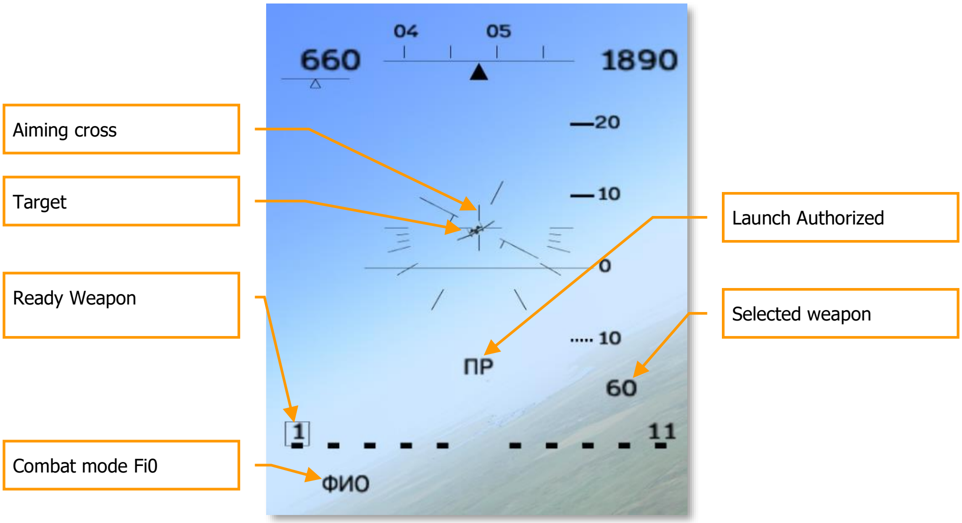
3-57: Landing Sub-Mode

- In the **ПОС (LANDING)** sub-mode, a glide slope error circle appears in the HUD. The aircraft is on the correct approach glide slope when the director and glide slope circles are both centered in the aircraft datum.
- The director circle guides the pilot to intercept the desired glide slope. The aircraft is on the correct approach glide slope when the director and glide slope circles are both centered in the aircraft datum.
- "**К**" and "**Г**" indicate the presence of localizer and glide slope beacons, respectively.

Фи0 (Fi0) - Longitudinal Aiming Close Air Combat Mode

Fi0 (Phi-Zero) is the Su-25T's main "air-to-air" combat mode for use with infrared-homing (IRH) missiles. The aiming principle is very simple - upon activating this mode with the **[4]** or **[6]** key, the available R-60 or R-73 IRH missiles are automatically selected for use, and the HUD appears as shown in figure below.

The missile seeker detects targets within a two degree conical field of view, centered directly ahead along the missile boresight axis. The center of the missile seeker field of view is indicated by the aiming cross in the HUD. The pilot aims by maneuvering the aircraft to place the cross over the target. Launch is authorized as soon as the missile seeker acquires the target, regardless whether it is in range. Since the missile seeker cannot measure the range to the target, the pilot must estimate the range visually before firing, to ensure the shot is within parameters (especially for pursuit intercepts, where the missile needs enough energy to run down the target). In a pursuit intercept against a target flying at a speed of 700 km/h, the R-60 can be fired from 1500-2000 meters range, the R-73 from 3000-4000 meters.



3-58: Фи0 (Fi0) Longitudinal Aiming Mode

- "Фи0" in the lower left corner indicates the longitudinal aiming mode.
- The pilot maneuvers the aircraft to put the target in the crosshairs.
- "ПР" indicates that the infrared-homing (IRH) missile seeker has locked the target.
- The selected weapon is indicated below pitch scale in the lower right: "60" for R-60 (AA-8 "Aphid") missiles, "73" for R-73 (AA-11 "Archer").
- Weapon availability and state of readiness are indicated along the bottom of the HUD. R-60 missiles at weapon stations # 1 and 11, with the flashing rectangle around station 1 indicating that it is locked and ready for launch.

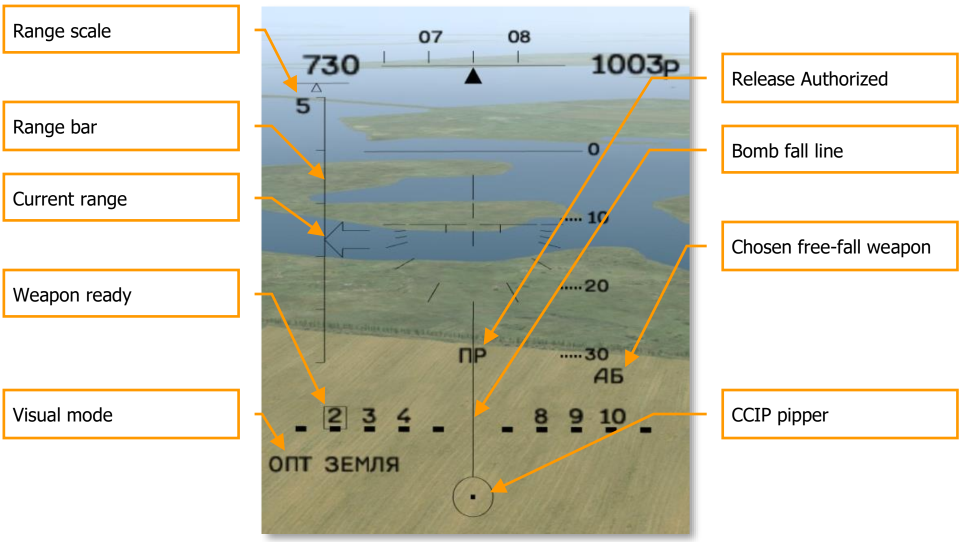
"Air-to-Surface" Weapon Mode

The Su-25T aircraft can employ numerous types of "air-to-surface" weapons. This arsenal includes iron bombs, cluster bombs (CBUs), guided bombs (GBUs), submunition dispensers, aerial rockets, and guided missiles. It is one of only a few aircraft in the Russian Air Force that can employ modern precision weapons such as "Vikhr" antitank missiles with laser beam-riding guidance, Kh-25ML, Kh-29L, and Kh-29T laser- and TV-homing missiles, KAB-500KR TV-guided bombs, and Kh-25MPU and Kh-58 anti-radiation missiles

Free-fall BOMBING

The category of ballistic-trajectory "free-fall" weapons includes all "iron" bombs, e.g. FAB-500, FAB-250, FAB-100, BetAB-500, and ODAB-500, RBK cluster bombs and KMGU dispensers, ZAB-500 incendiary bombs etc.

To employ free-fall weapons against ground targets, the pilot activates the **"ОПТ-ЗЕМЛЯ" (GROUND)** mode **[7]** and chooses the required free-fall bombs, cluster bombs or containers with the **[D]** key. Bombing symbology then appears in the HUD, including the **"ОПТ-ЗЕМЛЯ"** mode indicator in the lower left corner. The selected weapon is displayed in the lower right below the pitch scale, with all free-fall munitions designated as **"АБ"**. The aim and release procedure is effectively the same for all free-fall weapons: the pilot maneuvers the aircraft to superpose the continuously computed impact point (CCIP) pipper over the target and, when all release criteria are satisfied, pulls the trigger in response to the "Launch Authorized" signal displayed in the HUD.



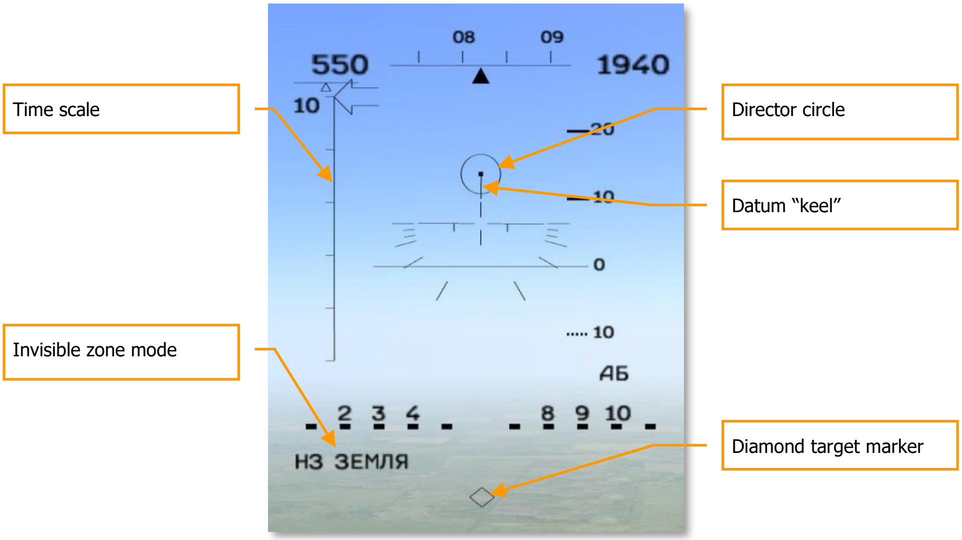
3-59: Free-Fall Bombing Mode (CCIP)

- The continuously-computed impact point (CCIP) pipper indicates the impact point of the next bomb near the bottom of the HUD.
- The bomb fall line extending from the impact point indicates the vertical earth axis from the pipper origin.
- Free-fall ammunition is indicated by **"АБ"** below the pitch scale.

- "Launch Authorized" indicates that all the primary release conditions such as range, altitude and velocity are satisfied and the weapon can be safely released.
- **"ОПТ ЗЕМЛЯ"** in the lower left corner indicates the visual bombing mode.
- Weapon availability and state of readiness are indicated along the bottom of the HUD. Fig. 3-59 illustrates the display when aerial bombs are suspended from the 2nd, 3rd, 4th, 8th, 9th, and 10th hardpoints. The flashing square framing hardpoint 2 indicates the ready weapon.

High drag munitions and some cluster submunitions may follow a strongly curved trajectory that puts their impact point below the lower edge of the visible HUD at almost any angle of dive, so that the CCIP pipper can not be visibly placed onto the target. In this case the continuously-computed release point (CCRP) or "invisible zone" bombing mode is used instead of CCIP.

In the CCRP mode, the pipper is visible at the extreme lower edge of the HUD. The pilot maneuvers the aircraft to place the pipper over the target, pulls the trigger and holds it pressed. The pipper becomes a fixed diamond to mark target. A director circle appears in the upper half of the HUD part to help the pilot fly the aircraft to the release point. The tip of the "keel" of the aircraft datum symbol in the HUD should be kept aligned with the center of the director circle. The pilot flies the aircraft with the trigger held depressed until the bombs are automatically released.



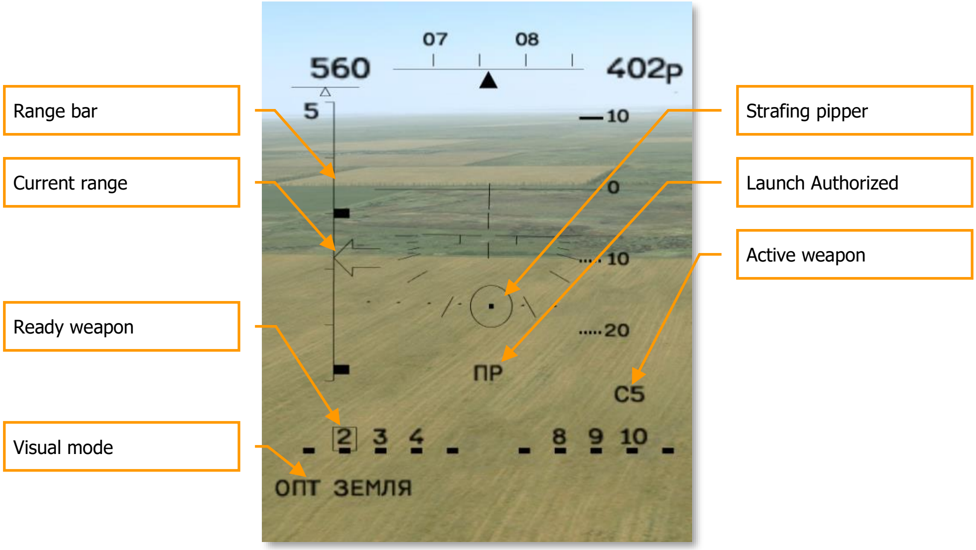
3-60: Free-Fall Bombing in the "Invisible zone" ("H3" or CCRP)

The range bar at the left side of the HUD becomes a time scale, indicating the number of seconds remaining before automatic bomb release. The arrow indicating the time remaining before release doesn't begin moving until 10 seconds before release. Successful automatic release depends on strictly following the assigned flight path with the correct G-loading – the tip of the datum "keel" must be held at the center of the director circle. When the remaining time drops to zero, the bombs are released, and the pilot can let go of the trigger.

Strafing Mode

The phrase "aerial rocket" is usually used to describe any unguided rockets and missiles that lack sensors and are uncontrolled after launch. These include S-5 rockets carried in the UB-32 launcher, S-8 rockets in the B-8 launcher, S-13 rockets in the UB-13, and S-24 and S-25 heavy rockets. The Su-25T's built-in NPPU-8 includes the GSh-20 30-mm twin-barrel cannon with a 200 round ammunition magazine.

Rockets are employed by activating the "**ЗЕМЛЯ" (GROUND)** mode [7] and selecting the desired rocket with the [D] key.

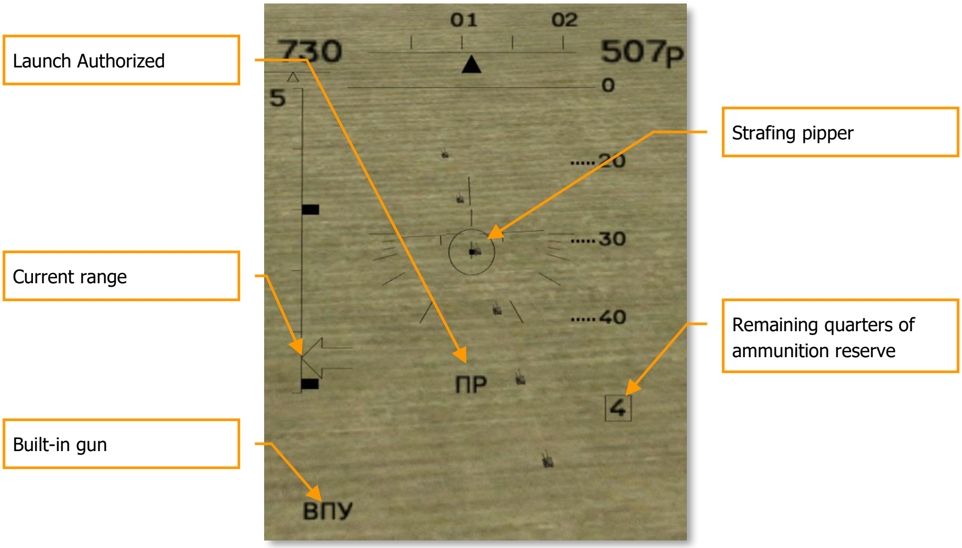


3-61: Rocket Strafing Mode

- The strafing pipper below the aircraft datum symbol indicates the rocket impact point.
- The selected type of rocket will be displayed under the pitch scale. The figure above illustrates the "C5" symbol for the S-5 rocket.
- Available weapons of the selected type are indicated along the bottom of the HUD.
- **ОПТ ЗЕМЛЯ (VISUAL GROUND)** mode is displayed in the lower left corner.

To employ rockets, the pilot detects the target visually and maneuvers the aircraft into a shallow dive, placing the pipper onto the target. The maximum launch range is reached when the arrow in the range bar reaches the upper tick mark and "Launch Authorized" is displayed in the HUD.

Strafing with the built-in gun (internal cannon) is conducted by practically the same procedure. Guns are selected by activating the "**ОПТ ЗЕМЛЯ" (VISUAL GROUND)** mode [7] and the cannon [C].



3-62: ВПУ (Internal Cannon) Cannon Strafing Mode

- The strafing pipper indicating the shell impact point appears under the aircraft datum.
- The remaining ammunition quantity in quarters is displayed beneath the pitch scale. A full magazine is indicated with "4", the last 1/4th of remaining ammunition with "1".
- **"ВПУ"** internal cannon mode is displayed in the lower left corner.

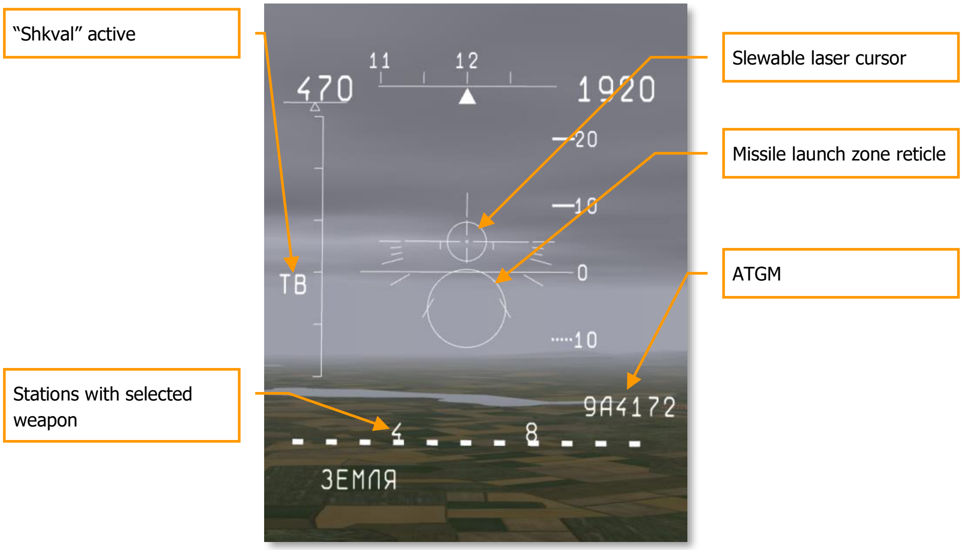
To use the internal cannon, the pilot detects the target visually and maneuvers the aircraft into a shallow dive, placing the pipper onto the target. The maximum firing range is reached when the arrow in the range bar reaches the upper tick mark and "Launch Authorized" is displayed in the HUD.

Precision Strike

Precision "smart" weapons include "Vikhr" antitank guided missiles with laser beam-riding guidance, Kh-25ML and Kh-29L laser-homing missiles, Kh-29T TV-homing missiles and KAB-500KR TV-guided bombs. Bombs and missiles that employ TV guidance are considered "launch-and-leave" ("fire-and-forget"), since they home autonomously and do not require support from the launching aircraft after release. Laser-homing and laser beam-rider weapons require that the target be illuminated with the on-board laser during the weapon's entire time of flight (TOF).

The use of precision weapons is made possible by the onboard I-251 "Shkval" (daytime-only TV) or podded "Mercury" (LLTV for night operations) targeting systems. The image from either system is displayed on the IT-23M TV display in the upper right corner of the Su-25T control panel.

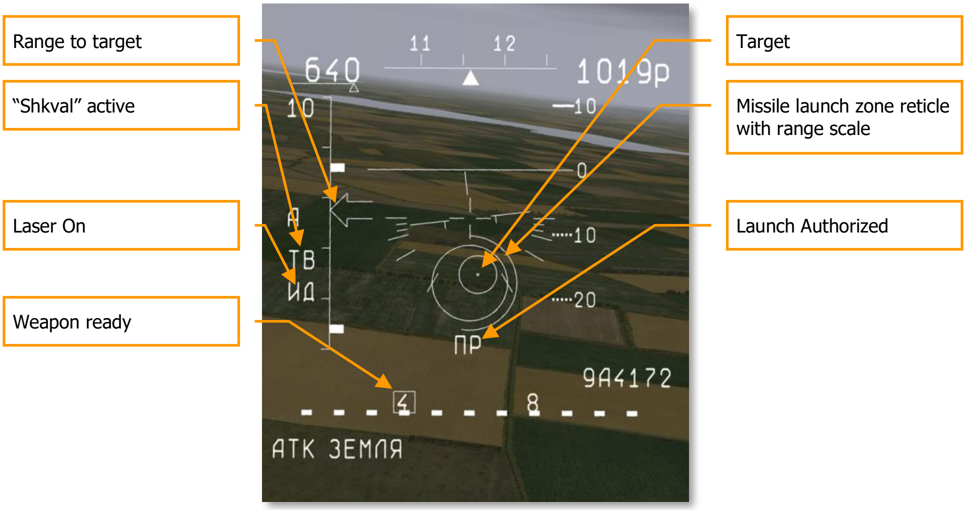
Precision weapons are employed by selecting the "ЗЕМЛЯ" (GROUND) mode **[7]** and activating either the onboard "Shkval" **[O]** or podded "Mercury" **[RCtrl-O]** system. The HUD will then appear as shown in figure below:



3-63: "Shkval" or "Mercury" Targeting System HUD

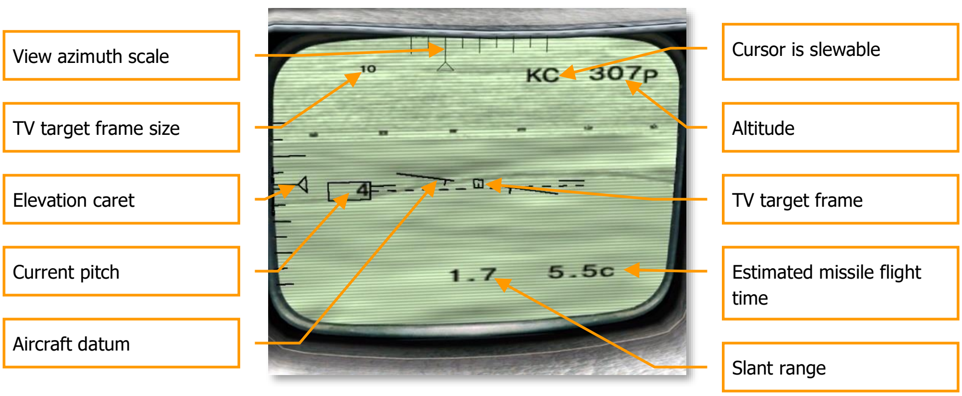
- The circular laser cursor in the center of the HUD indicates the center of the optical field of view shown on the TV display, and can be slewed with the [,], [.], [/], [;] keys.
- **TB** (TV) appears to the left of the range bar, indicating that the "Shkval" targeting system is active (**HTB** (LLTV) indicates the "Mercury" system is active).
- The selected weapon is indicated below the pitch scale. The figure above illustrates the 9A4172 "Vikhr" antitank missile selected. Kh-25ML (AS-10 "Karen") missiles are indicated by 25МЛ, Kh-29L (AS-14 "Kedge") by 29Л, Kh-29T (AS-14 "Kedge") by 29T, and KAB-500KR by 500Kp.
- Weapon availability and readiness state are indicated along the bottom of the HUD.
- **ЗЕМЛЯ** (GROUND) mode is displayed in the lower left corner.

After activating the targeting system, target acquisition is accomplished by slewing the optical sensor field of view (FOV) with [,], [.], [/], [;] keys. The image is shown on the TV cockpit display. The laser cursor in the HUD will move together with the optical sensor FOV.



3-64: ATGM delivery

Upon activating the targeting system, the TV displays the image from the TV camera, together with targeting and attitude information:



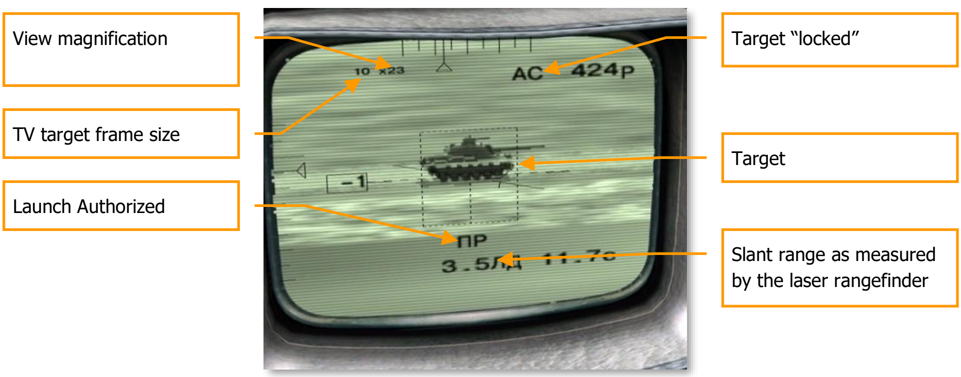
3-65: IT-23M TV Display During Target Acquisition via "Shkval" System

- The TV target frame, the size of which depends on the expected target size, appears in the center of the display.
- The TV target frame size, corresponding to the expected target size in meters, is displayed in the upper left corner. In the figure above the expected target size has been entered as 10 m. Armored vehicles are about 10 meters in size, aircraft may be from 10 to 60 meters, and ships and buildings usually require the 60 meter setting. The target is automatically locked only if the target in the cursor is within 5 meters of the expected target size, with

the exception of targets larger than 60 meters that can still be locked with the maximum setting of 60 m. The expected target size and cursor size are adjusted with **[RCtrl-+]** and **[RCtrl--]**.

- Along the top and extreme left edge of the display are azimuth and elevation scales, respectively. The viewing direction of the currently displayed image is indicated by triangular markers. The upper azimuth scale has graduated markings from -40 to +40 degrees. The elevation scale at left extends from +20 to –90 degrees.
- The aircraft pitch is displayed to the right of the view elevation scale.
- An aircraft datum similar to the one displayed on the HUD is duplicated at the center of the TV display. It informs the pilot about the aircraft bank while performing "head-down" targeting tasks.
- The aircraft altitude above ground level (AGL) is indicated by the radio altimeter in the right upper corner of the display.
- **KC** at the top of the display, to the left of the radio altitude, indicates that the view steering is under manual control, and no target has yet been locked.
- The estimated missile time of flight (TOF) to the target in seconds is displayed in the lower right corner. After missile launch, this number indicates the time remaining until weapon impact.
- The slant range to the target in kilometers, as measured by the laser rangefinder, is displayed at the bottom of the display.

Upon spotting the target, the pilot moves the laser cursor over it, and the targeting system attempts an automatic lock. To aid in target identification, the TV camera field of view (FOV) can be magnified to 23x (0.73x0.97 degrees) or an intermediate value of 8x. View magnification is controlled with **[+]** and **[-]** keys in three steps.



3-66: The IT-23M TV Display; Target Locked With Active Onboard "Shkval" System

After identifying the target to be attacked, the pilot selects the required weapon and observes the maximum launch range scale in the HUD. When the range to the target and other launch criteria are satisfied, the pilot either simply pulls the trigger for TV-guided weapons (e.g. Kh-29T missiles and

KAB-500Kr bombs), or first activates the laser target illuminator for laser-guided weapons (e.g. Kh-25ML, Kh-29L and "Vikhr" missiles) by pressing **[RShift-O]**.

- The current magnification level is indicated in the upper left corner, next to the expected target size.
- AC at the top of the display, next to the radio altitude, indicates that a target has been locked. The targeting system automatically corrects the view direction within the gimbal limits of ±35 in azimuth and from +15 to –85 degrees elevation to keep it pointed at the target, compensating for target and aircraft motion. The boresight direction parallel to the aircraft longitudinal axis is indicated by a long tick mark on the graduated elevation scale and the central tick mark on the azimuth scale.
- With the laser range-finder active, indicated by **ЛД** (LASER), the slant range is shown at the bottom of the display.
- "Launch Authorized" is displayed above the slant range, near the bottom of the display.

After the laser-guided missiles have hit the target, it's necessary to deactivate the laser for cooling. The laser generates high power in the target illumination mode and can only function in this mode for a limited time. The required cooling time is approximately equal to the time the laser was working to illuminate the target. The laser automatically switches off after reaching its maximum allowable temperature. It is not recommended to use the laser for more than 20 minutes total per flight, as exceeding this limit can damage it. The **ЛД** symbol flashes while the laser is still cooling.

"Vikhr" missiles can be launched in pairs with a short delay between each missile, increasing the probability of hitting the target. The supersonic speed of "Vikhr" missiles can also allow multiple targets to be attacked in a single pass.

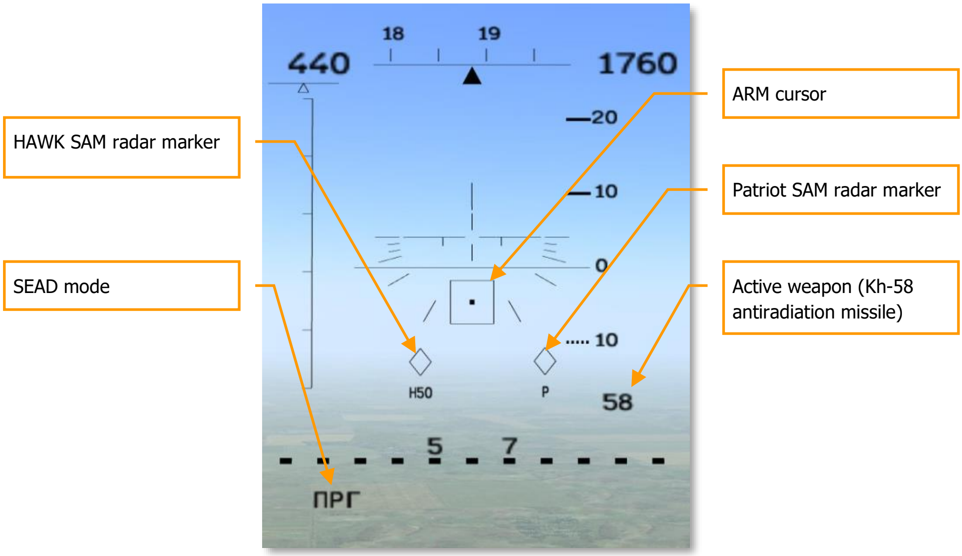
"Vikhr" missiles can also be used against non-maneuvering aircraft such as helicopters and airplanes during target take-off and landing. The procedure for target acquisition is the same for aerial targets as for ground targets, taking into account that the kill probability is much lower.

Suppression of Enemy Air Defenses (SEAD Mode)

The Su-25T aircraft can employ Kh-25MPU and Kh-58 antiradiation missiles (ARMs) against a variety of radio transmitter targets including surface-to-air missile (SAM) search, tracking, and target illumination radars. Since radio transmitters operate over a wide band of frequencies, not all transmitters can be targeted by all ARMs. For example, most antiradiation missiles are not designed for use against mobile anti-aircraft artillery (AAA) which use high frequency radars with short range. For more detailed information on ARM characteristics and targets against which they can be employed, see Chapter 6, "Russian Air Force Air-to-Surface Weapons."

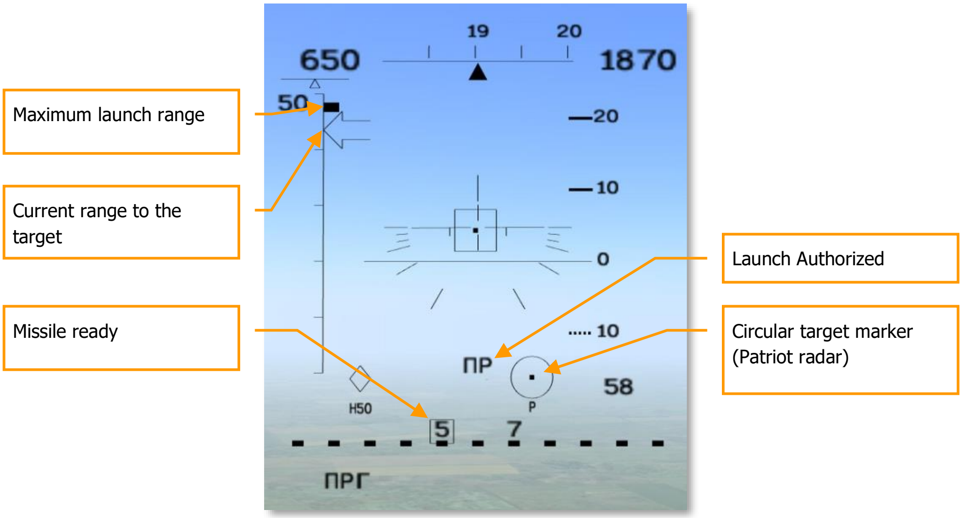
Antiradar missiles require the Su-25T to carry the L-081 "Fantasmagoria" ARM control pod under the aircraft centerline (hardpoint #6).

Antiradiation missiles are employed by selecting the **ЗЕМЛЯ** (GROUND) mode **[7]** and activating passive radar detection with the **[I]** key. The pilot follows indications on the SPO-15 "Beryoza" radar warning receiver (RWR) display to steer the aircraft toward the target emitter. When the target enters the ±30 degree scan zone, a diamond target marker appears in the HUD. If the currently selected weapon is able to lock and attack the detected target, a type indicator appears below the target diamond. The HUD appears as shown in the figure below:



3-67: Suppression of Enemy Air Defenses (SEAD) Anti-Radar Mode HUD

- The square-shaped antiradiation missile (ARM) cursor below the aircraft datum can be slewed over the desired target with the **[,], [.], [/], [;]** control keys.
- The chosen weapon (58 means Kh-58) is indicated below the pitch scale.
- SEAD mode (**ПРГ** for "anti-radiation seeker") is indicated in the lower left.
- Targets are indicated as diamond markers in the HUD. Targets that can be locked and attacked by the currently selected weapon are displayed with a type indicator – **P** for "Patriot" SAM radar, **H50** - for "HAWK" SAM radar, etc.



3-68: SEAD HUD With ARM Locked Target

When target markers are visible in the HUD, the pilot designates the intended target to be attacked. The ARM cursor is moved over the intended target with the **[,], [.], [/], [;]** keys. The target is then locked by pressing **[Enter]**. The target diamond then becomes a circular marker. The range bar displays an arrow indicating the current range to the target and a tick mark indicating the maximum launch range.

- The maximum weapon launch range is indicated as a tick mark on the range bar.
- An arrow indicating the current range to the target moves along the range bar at the left side of the display.
- When an emitting target has been selected, the diamond target marker becomes a circle.
- When all launch criteria have been satisfied, the "Launch Authorized" command is displayed.
- A flashing rectangle around weapon station # 5 indicates that missile is ready for launch.

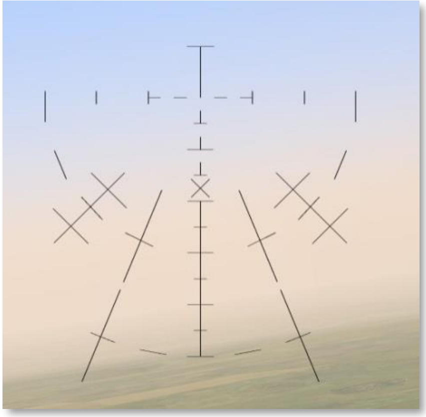
When all launch criteria have been satisfied, "Launch Authorized" appears, and the pilot pulls the trigger to launch the weapon.

Fixed Reticle Sight

The "reticle" is a backup mode, usually used for strafing when the main targeting system is damaged or accurate range data is unavailable. The reticle has calibrated scales along two axes. It is used for aiming together with previously tested and known ballistic characteristics of the selected weapon and the current flight parameters. The center of the reticle is aligned with the aircraft longitudinal axis.

The fixed or "static" reticle can be called up from any combat mode by pressing the **[8]** key. The current mode will be preserved, but the HUD will be replaced by the static reticle. The pilot can toggle the reticle on and off with the **[8]** key.

Aiming corrections in the reticle mode are made by the pilot maneuvering the aircraft to place the expected weapon impact point over the intended target. The cross hairs are positioned above the target by the required angle. Barrage rocket or cannon fire is employed at ranges of 200-400 meters.



3-69: Reticle Sight

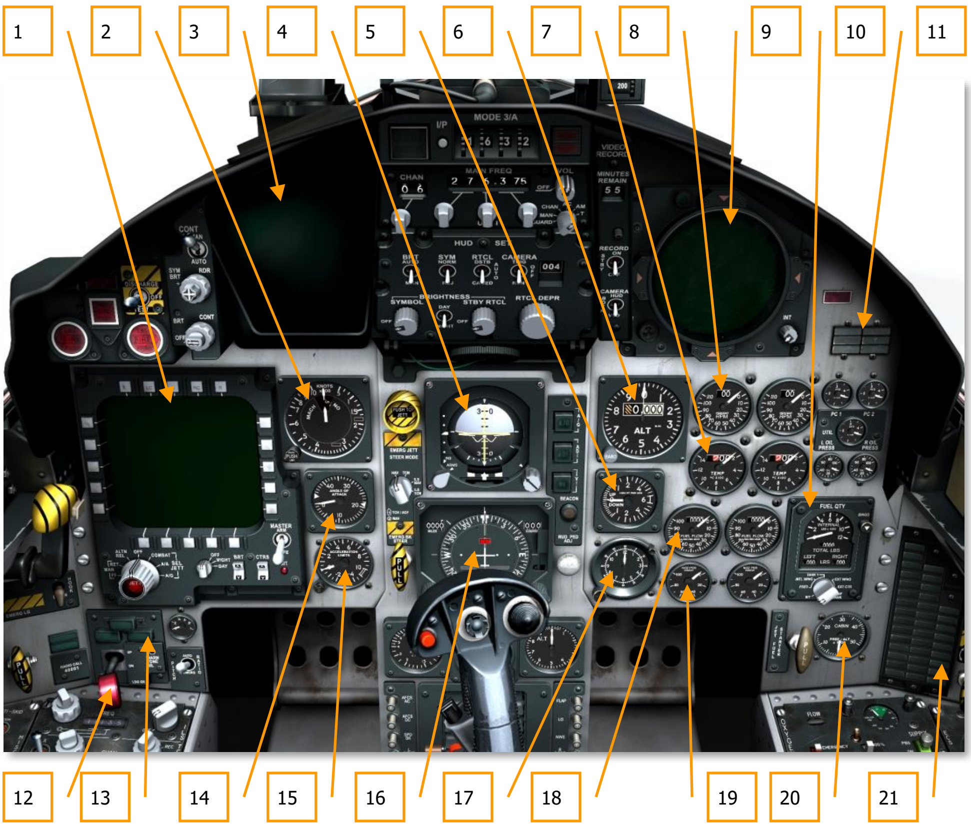
4

COCKPIT INSTRUMENTS FOR U.S. AIRCRAFT

COCKPIT INSTRUMENTS FOR U.S. AIRCRAFT

F-15C Cockpit Instruments

The F-15C is an air superiority fighter. That's why its cockpit instruments are focused around the radar indicator and TEWS display, which are positioned a little lower than the HUD. The lower section of the instrument panel consists of instruments for engine control, navigation, weapon availability, fuel amount and countermeasures.



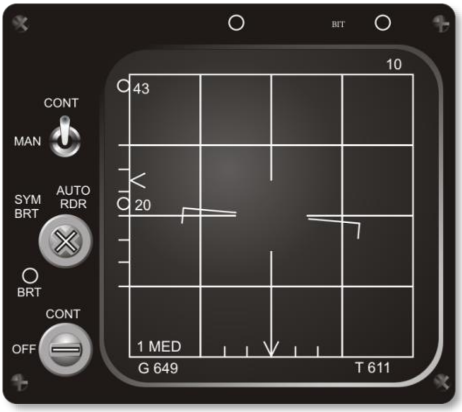
4-1: F-15C instrument panel

1. Multi-Purpose Color Display (MPCD)

2. IAS and Mach meter
3. Vertical Situation Display (VSD)
4. Attitude Director Indicator (ADI)
5. Vertical Velocity Indicator (VVI)
6. Altimeter
7. Fan turbine inlet temperature indicators (FTIT)
8. Engine tachometers
9. TEWS display unit
10. Fuel quantity indicator
11. Chaff, flare lights
12. Landing gear control handle
13. Landing gear position indicator
14. Angle of attack indicator
15. Accelerometer
16. Horizontal Situation Indicator (HSI)
17. Clock
18. Engine fuel flow indicators
19. Engine exhaust nozzle position indicator
20. Cabin pressure altimeter
21. Caution lights panel

Vertical Situation Display (VSD)

The Vertical Situation Display (VSD), which is also called the "radar scope", takes up the upper left corner of the instrument panel. The VSD shows the air situation in front of the aircraft, detailing information on other aircraft detected by the radar. Detailed information regarding radar use is dealt with in the corresponding chapter.



4-2: VSD

TEWS Display Unit

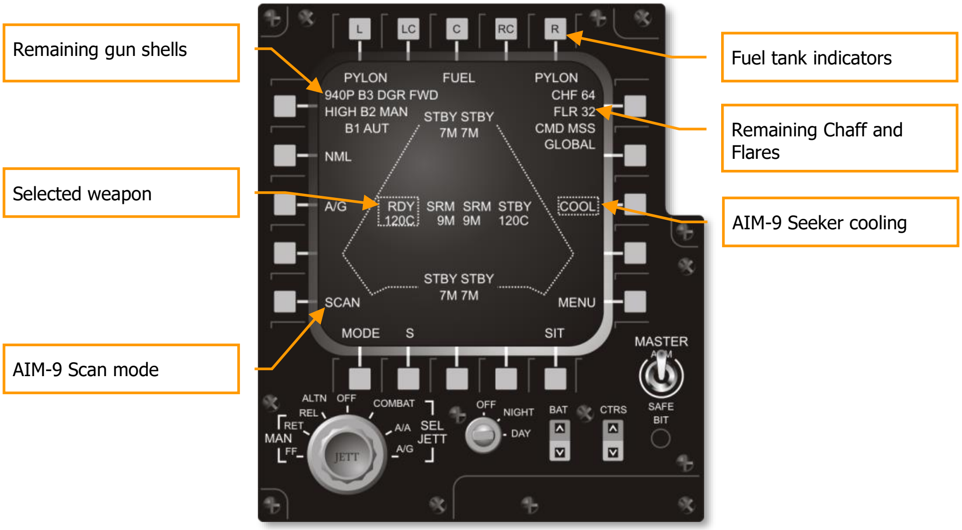
The TEWS (Tactical Electronic Warfare System) is positioned in the upper right corner of the instrument panel. It displays information on radars illuminating your aircraft. The information is presented as symbols that indicate radar type and direction, also self-protected jammer activity. Detailed information on workings of the TEWS can be found in the corresponding chapter.

4-3: TEWS

Multi-Purpose Color Display (MPCD)

Weapon Control Panel

The Weapon control panel, which is positioned in the lower left portion of the instrument panel, displays the current state of weapons, countermeasures and number of external fuel tanks.



4-4: Weapon control panel

In the upper part of the display, the number of external fuel tanks is indicated. The "**L**", "**C**" and "**R**" indicators show the availability or absence of external fuel tanks under the left, central and right "wet points" respectively. If the fuel tank is loaded, the "**FUEL**" indicator is lit. If the fuel tank is not installed, "**PYLON**" indicator is lit.

In the left part of the display, information on the aircraft internal gun system state is shown. The number under the indicator determines the remaining quantity. During firing of the cannon, this quantity is reduced by units of 10.

The SCAN framed indicator indicates that the seeker of the AIM-9 is selected and will operate in SCAN mode. In the Weapon Delivery section you can find more information on how to use this mode.

The right side of the display indicates weapon readiness and number of remaining flares and chaff. The "**CHF**" and "**FLR**" indicators show the number of remaining flares and chaff. The aircraft can be equipped with 64 bundles of chaff and 32 flare cartridges.

The "**COOL**" indicator informs the pilot of the AIM-9 readiness for use. If the Master Arm switch is set in ARM position, the COOL indicator is boxed. It will disappear when the Master Arm switch is set in the "**SAFE**" position.

In the central part of the display, information on the types of loaded missiles and their readiness state is shown. The aircraft has eight external weapon stations – four of them are under the fuselage and two are on each wing pylon. "Air-to-air" missiles are subdivided into two categories. Different variants of the AIM-9 are indicated by the SRM (Short Range Missiles) indicator; variants of AIM-7 and AIM-120 are indicated by the MRM (Medium Range Missiles) indicator. The type and state of each missile is shown on the corresponding pylon.

If you choose the MRM type, the weapon station of the chosen missile will appear as "**RDY**"; all other missiles of that type will be indicated as "**STBY**".

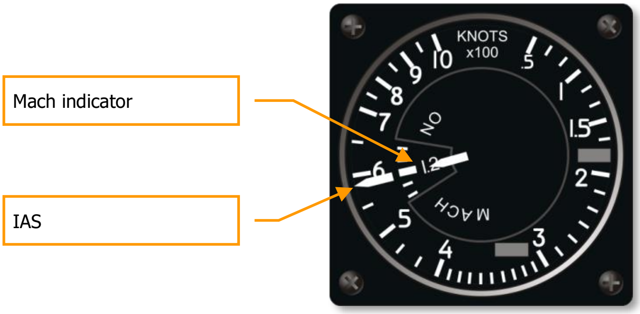
If you choose the SRM type, the station of the selected missile will appear as "**RDY**"; all other missiles of that type will be indicated as "**STBY**".

The following table shows the different missiles that the F-15C can use.

Designation	Missile type	Class
7M	AIM-7M	MRM
120B	AIM-120B	MRM
120C	AIM-120C	MRM
9M	AIM-9M	SRM

Indicated Airspeed (IAS) and Mach Meter

The IAS and Mach meter is positioned to the right of the MPCD. It shows the indicated airspeed and the Mach number. The fixed scale of the indicated airspeed is graduated within the limits of 50 to 1,000 knots. The moving scale of the Mach number shows the value of Mach number within the limits of the operating altitudes and speeds. Mach numbers are shown starting from the indicated speed value of 200 knots.



4-5: IAS and machmeter

Angle-of-Attack (AoA) Indicator

The AoA indicator is positioned on the instrument panel under the IAS and Mach meter. It is used for indicating the current AoA value within the limits of 0 to 45 units. The AoA indicated values do not correspond to actual degrees. In the area of the landing AoA (20-22 units) there is a corresponding index on the indicator.

4-6: Angle-of-attack indicator

Accelerometer

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

4-7: Accelerometer

Attitude Director Indicator (ADI)

The ADI is positioned in the central portion of the instrument panel. The rotating sphere shows the current pitch and bank angles. The pitch scale is graduated at five degrees; the bank scale is graduated for 10 degrees. On the front part of the indicator are the vertical and horizontal bars that show the aircraft's deviation from the preplanned course.

4-8: ADI

In the lower part of the indicator, the turn and slip indicator is positioned. When not centered, apply rudder towards the needle to center the indicator. This allows you to coordinate your turns.

Horizontal Situation Indicator (HSI)

The HSI shows a top-down view of the aircraft superimposed on a compass. The aircraft's heading always appears at the top of the display. The course arrow, on the outer edge of the display, shows the direction of the next waypoint.

In the center of the display is the course deviation indicator. The course deviation dots show the deviation of the current aircraft position from the required course line. Each dot represents a 5-degree deviation from the set course. During an Instrumented Landing System (ILS) landing, the bars show the aircraft deviation from the landing course. In this situation it is identical to the ADI ILS bar indicator. Bear it in mind that these bars will move in opposite directions.

In the upper right corner of the instrument, the set course numerical indicator is shown. In the upper left corner, the range to the selected waypoint is indicated in nautical miles.

4-9: HSI

Altimeter

The Altimeter shows the barometric pressure altitude and is displayed in units of 20 feet.

4-10: Altimeter

The altimeter scale consists of a numeric counter showing the current altitude.

Vertical Velocity Indicator (VVI)

The VVI is used for indicating the vertical aircraft speed, i.e. the climb and sink rate in thousands feet per minute. When the indicator arrow moves in a clockwise direction, it indicates that the aircraft is increasing its flight altitude. When the indicator arrow moves in a counter-clockwise direction, it indicates that the aircraft is descending.

4-11: Vertical velocity indicator

Tachometer

This pair of tachometers indicates engine RPM. They show percentages of maximum RPM, and the red zone corresponds to the "afterburner" zones.

4-12: Tachometer

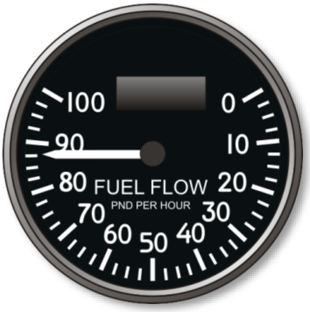
Fan Turbine Inlet Temperature Indicators

The two Fan Turbine Inlet Temperature Indicators are positioned below the tachometer. The indicator scale is graduated for each 100 degrees Celsius. The indicator arrow in the red zone shows dangerously high turbine gas temperature.

4-13: Fan turbine inlet temperature indicators (FTIT)

Engine Fuel Flow Indicators

The Engine Fuel Flow Indicators are used for measuring and showing the current values of the fuel flow for each engine. Fuel flow is measured in pounds per hour.



4-14: Engine fuel flow indicators

Engine Exhaust Nozzle Position Indicator

These indicators are positioned in the lower left corner of the instrument panel. The two indicators show the nozzle position (opening rate) of each engine in percents from the fully opened position. In afterburner mode, the nozzles are fully opened.

4-15: Engine exhaust nozzle position indicator

Fuel Quantity Indicator

The fuel quantity indicator is intended for indicating fuel quantity in the aircraft's fuel tanks. The fuel level needle shows the fuel quantity in the internal fuel tanks. The three digital indicators in the lower part of the instrument show the total amount of fuel (both in internal and in external fuel tanks) and the amount of remaining fuel in the left and right external fuel tanks respectively. Fuel amount is measured in pounds.

4-16: Fuel quantity indicator

Cabin Pressure Altimeter

The Cabin Pressure Altimeter shows the altitude at which atmospheric pressure is equal to the current cockpit pressure. In the case of cockpit damage, the cockpit pressure will be decreasing; i.e. indicated altitude value will be increasing. If cockpit pressure has dropped to the value corresponding to atmosphere pressure at the altitude of 10 000 feet, you should immediately descend.

4-17: Cabin pressure altimeter

Chaff and flare lights

Chaff and flares lights indicate the chaff and flare releases and minimum quantity warning.

4-18: Chaff and flare lights

The CHAFF light flashing about 3 seconds when chaff releasing.

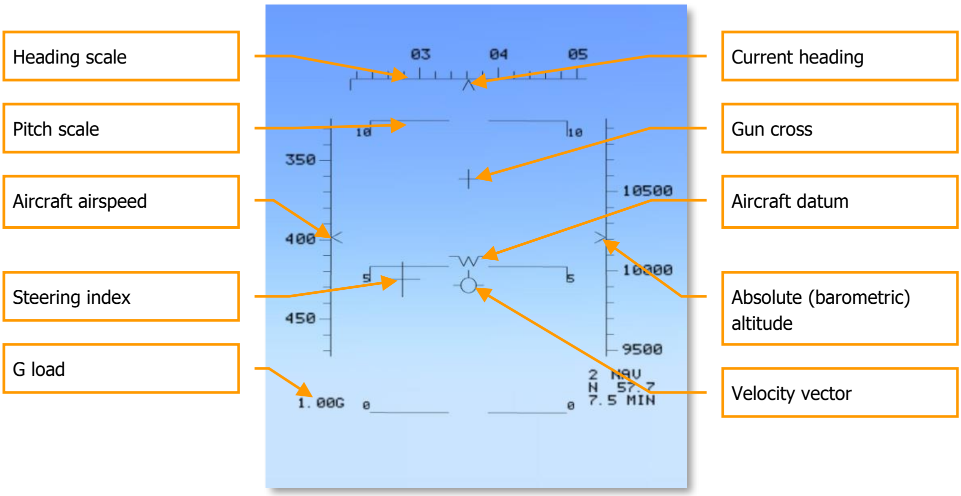
The FLARE light flashing about 3 seconds when flare releasing.

The MINIMUM warning lights when quantities of chaff or flares are low.

F-15C HUD Operating Modes

Basic F-15C HUD Symbols

There is a set of HUD symbols that remain unchanged in HUD operating modes.



4-18: Basic F-15C HUD symbols

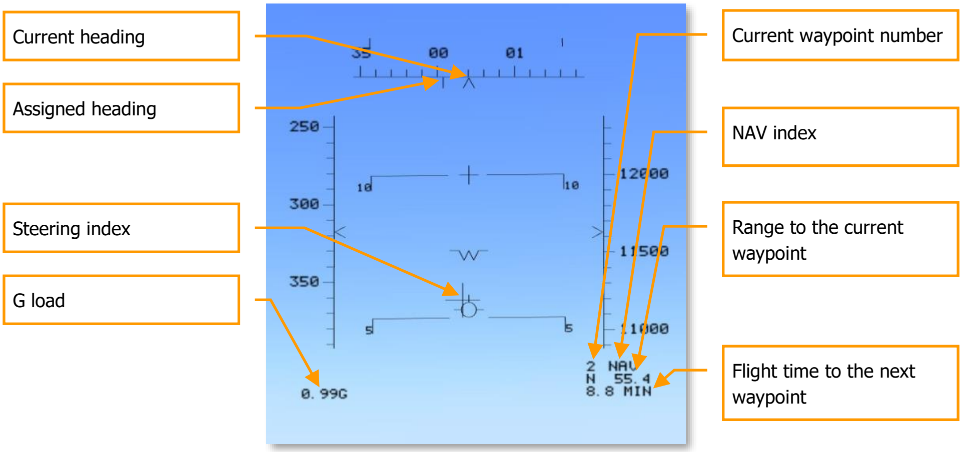
- In the center of the HUD is a fixed aircraft datum "W", which shows the position of the aircraft's longitudinal axis.
- The current heading scale is positioned in the upper part of the HUD. The inverted caret along the scale indicates the aircraft's current heading. (For example, 04 corresponds to the value of 40 degrees).
- On the airspeed scale, which is positioned along the left side of the HUD, the indicated aircraft airspeed is shown in indicated knots. Speeds less than 150 knots are not indicated. The caret position on the scale indicates the aircraft's current speed.
- On the altitude scale, along the right side of the HUD, absolute (barometrical) altitude is shown in feet. The caret position on the scale indicates the aircraft's current altitude.
- The aircraft's total velocity vector (aka flight path marker) indicator is positioned in the HUD but can move all around depending on the maneuvering of the aircraft. It indicates the current aircraft flight direction.
- The pitch scale is positioned in the central portion of the HUD and is linked with the velocity vector indicator. The scale is graduated for 5 degrees. Depending on the banking direction, the scale moves either to the right or to the left, indicating the aircraft's banking direction and value. In fact, it backs up the bank indicator on the ADI.

Navigation Mode

In HUD navigation mode, various types of information are shown. In the main navigation mode (NAV), the direction to the selected waypoint is shown on the HUD. In the landing mode, (ILSN), information necessary for landing the aircraft is provided.

Navigation Mode (NAV)

In this mode, steering directions to the selected waypoint are provided. In addition to the primary set of indicators, additional indicators are shown on the HUD. These include:



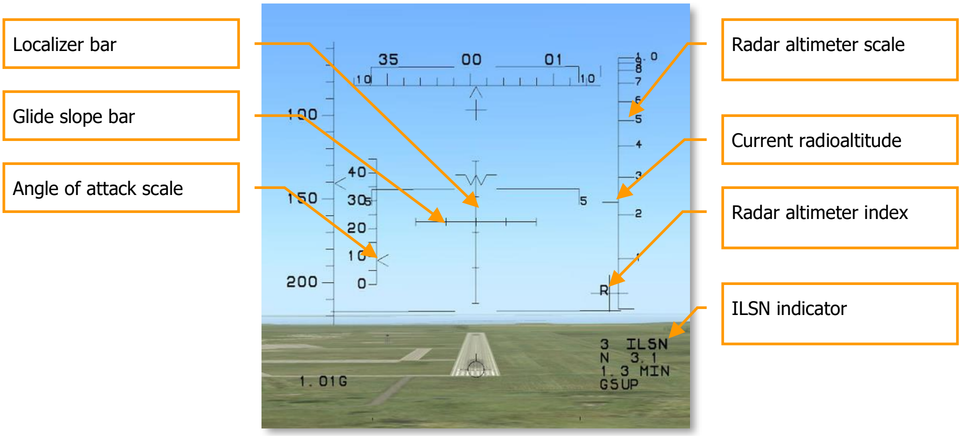
4-19: HUD navigation mode

- In the lower right corner of NAV HUD, the current NAV mode and selected waypoint number are displayed. (2 NAV)
- Beneath the HUD mode indication, the range to the selected waypoint in nautical miles is shown. (N 55.4)
- At the bottom of this data block, the time to reach the selected waypoint (if the current speed is maintained) is shown. (0.0 MIN)
- In the lower left corner of the HUD, the current G loading value is indicated.
- In the central area of the HUD, the steering index is situated, in the form of a "+". This indicates the bearing to the selected waypoint. It indicates angle position of the route point in the vertical and horizontal planes. For an accurate flight to the next waypoint, you should keep the velocity vector on the steering index.
- Along the bottom of the heading scale, a vertical line that represents your assigned heading is displayed. When the assigned heading is aligned with the heading scale caret, you are flying directly to your selected waypoint.

Instrument Landing System Navigation (ILSN)

In the ILSN mode, the additional indicators are shown:

- In the lower right corner of the HUD, the ILSN index is shown and informs you of the current mode and waypoint number. (3 ILSN)
- In the lower right corner of the HUD, below the time to the next waypoint indicator, there is the landing gear position indicator. When the landing gear is retracted, the GSUP index is shown. When the landing gear is extended, GDWN index is shown.
- At an altitude of less than 1,000 feet, along the right side of the HUD, there appears a radar altimeter scale, graduated in hundreds of feet. The current radar altimeter bar moves along the left side of this scale.
- Just to the right of the speed scale, a smaller AoA scale is displayed. This scale shows the current AoA, which is measured in units and not degrees. You should land at approximately 22 units.
- In the central portion of the HUD, the ILS needles, or bars, are drawn. The horizontal bar represents the desired glide slope, and the vertical bar the desired heading (localizer). Steer towards the bars until they are in the center, and you will be following the glide slope to the runway.



4-20: Instrument landing mode

Gunnery Modes

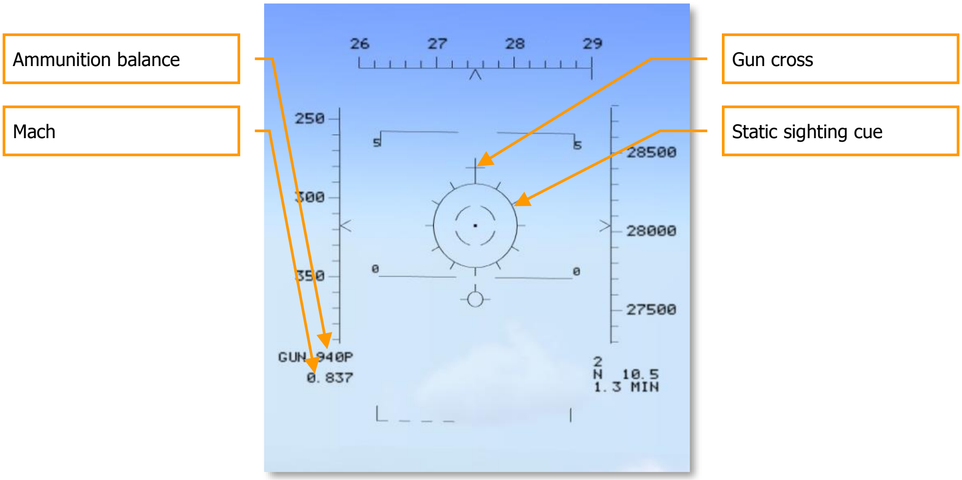
There are two gunnery modes; one requires a radar lock and the other does not.

Gun Use Without Radar Lock

To select the M-61 cannon, without first locking a target, press the **[C]** key.

In this case, the HUD displays the following information:

- Under the gun cross appears a static sighting cue in the form of a pipper dot, framed by two concentric circles.
- The **GUN** indication appears in the lower left corner of the HUD. Next to it, the number of remaining cannon rounds in indicated. The **GUN 940P** indication, for example, means that the cannon has 940 PGU-38 shells remaining.
- Next to the gunnery mode indication, the aircraft's current Mach number is displayed.



4-21: Gun firing without target lock-on

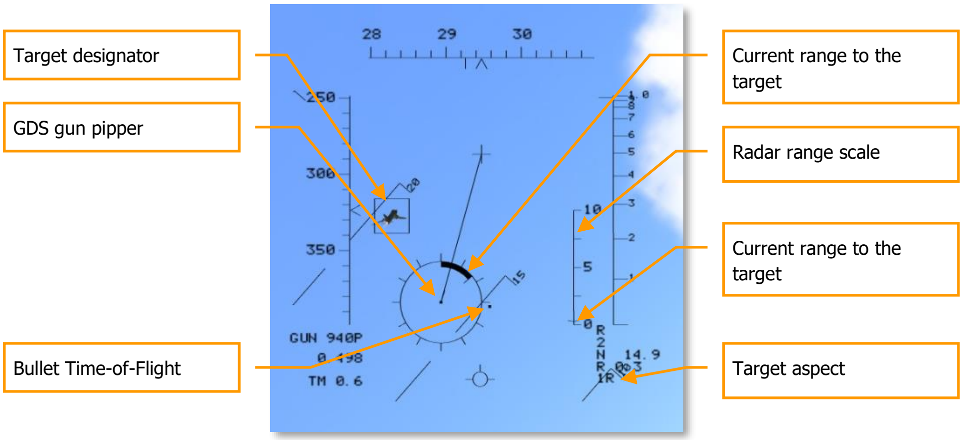
Gun Director Sight (GDS)

When a target has been locked on by radar and Gun is selected, the HUD will enter GDS mode. The GDS HUD displays the information:

- Around a locked radar target, a target designation (TD) box is displayed that denotes the location of the locked target in the HUD field. If the gun pipper is placed over the locked target, the TD box is removed.
- Along the right side of the HUD, the target range scale is shown. The scale ranges from zero to 10 nautical miles. The vertically sliding bar shows the current range to target.
- The GDS gun pipper shows the point where the shells intersect target trajectory. In order for the shells to hit the target, you should place the pipper over the target.
- The inscribed circle in the GDS indicates the range to target. Each scale tick corresponds to 1,000 feet. As range to the target decreases, the range scale unwinds counter-clockwise. There is also the Bullet Time-of-Flight dot that indicates the effective gun firing range.
- A range to target digital display is located in the lower right portion of the HUD. The range value is shown as a number, following the **R** symbol.

- The target aspect indicator is located under the current range digital display. This shows the angle off the target's longitudinal axis and line of the target sighting. The **T** (Tail) symbol is displayed when the target is tail on and **H** (Head) when the target is head on. The **R** and **L** symbols with digital values correspond to the left and right target aspect.
- In the lower left portion on the HUD, three data items are listed when a target is locked: the selected weapon, ownship Mach, ownship G-load, and target Mach.

ATTACKING A TARGET ON A PURSUIT COURSE INCREASES YOUR HIT PROBABILITY



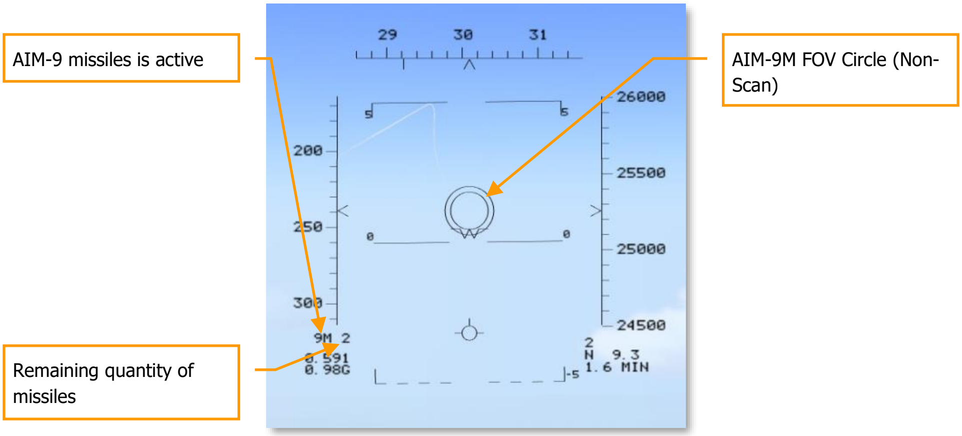
4-22: Gun GDS Mode

AIM-9M Sidewinder "Air-to-Air" Short Range Missile (SRM) Modes

The following section discusses the HUD modes used when employing the AIM-9M Sidewinder. The missile's infrared homing (IRH) seeker works independently of the radar. The seeker can lock onto targets with and without the assistance of a radar lock. After launch, the missile does not require any assistance from the launch aircraft. It is truly "fire and forget."

Cage Mode (Non-Scan)

To lock targets with just the IRH seeker, press the **[6]** key to cage the seeker. Once caged, press the **[D]** key to select the AIM-9M missile. A "9M" indication will appear on the HUD when selected. A reticule will appear in the HUD center. The seeker head position is rigidly aligned along the aircraft's longitudinal axis within this reticule. If the target is within the reticule limits and the seeker has enough thermal contrast from the back ground, you can lock on to the target. If however the target strays outside the reticule, you will lose the lock.

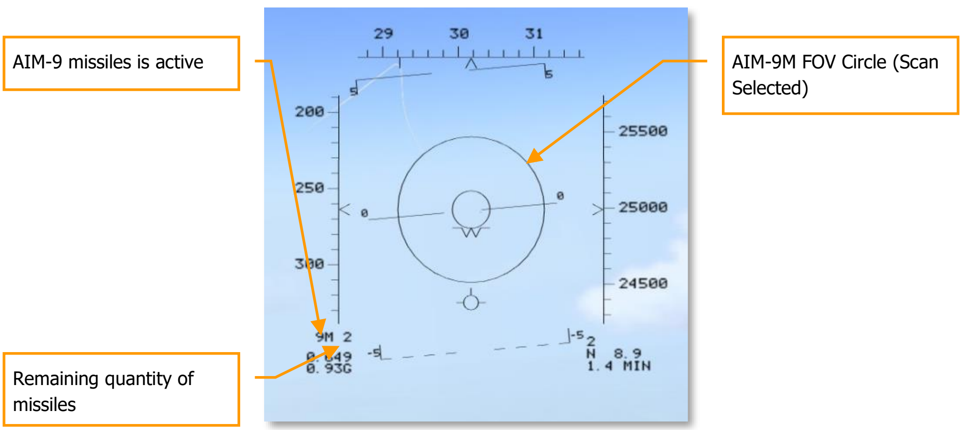


4-23: Cage mode AIM-9M

When caged, the seeker will not follow the target outside the reticule, even if locked. This mode is useful in locking onto specific targets in a tight group.

Uncage Mode (Scan Selected)

Pressing the **[6]** key cycles between caged and uncaged mode. This setting is indicated on the MPCD. When uncaged (not boxed), two reticules with different diameters will appear. The larger diameter reticule represents the missile's field of view and the smaller reticule is the where the seeker is currently looking.



4-24: Uncage Mode (Scan Selected)

The outer reticule size is always fixed. This reticule disappears after the missile seeker locks a target. Once locked, the smaller reticule will frame the target and follow it within its seeker's gimbal limits across the HUD. When the missile seeker starts to track the target, the pilot hears the high pitched lock tone.

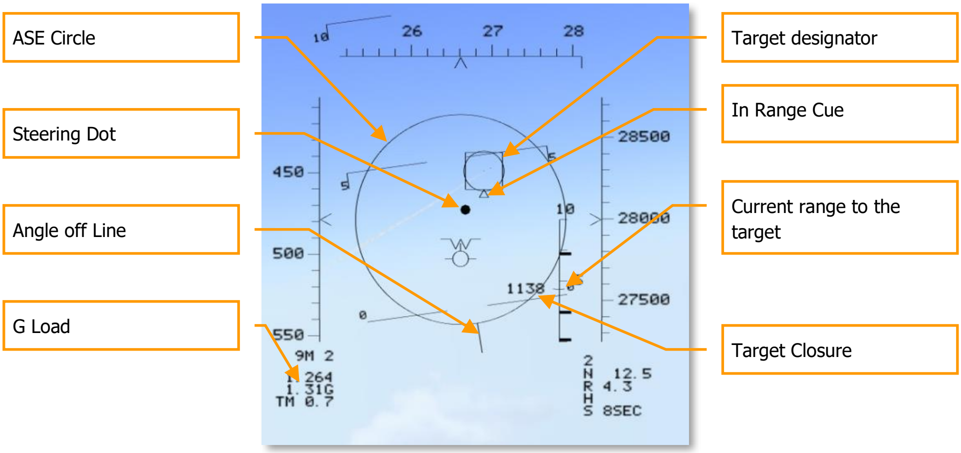
Locking targets through the IRH seeker is a good tactic for stealthy attacks (the emission cannot be picked up by enemy RWS systems). The enemy will be unlikely to detect your attack from the rear hemisphere, and accordingly, will not take defensive measures.

Radar-Slaved Mode

In the Vertical Scan [3] or Boresight [4] air combat maneuvering (ACM) modes, the inclusion of radar lock slaving of the IRH seeker provides additional targeting information on the HUD. If the distance to the target is more than 12,000 feet (outside of AIM-9M missile effective range), the following symbols and indications will appear on the HUD:

- The ASE Circle shows the maximum steering error angle. The steering error value is proportional to the steering dot deviation from the ASE circle center.
- The ASE Circle shows the zone in which the steering dot should be positioned and angular limits to engage a target. The ASE circle increases in size when the distance to the target decreases or the aspect angle increases. This means that as target distance decrease, the missile can be launched with a larger steering error.
- The angle off tail line is located on the ASE circle. This shows target aspect angle in relation to your aircraft in a plan view. If it is located at the top of the circle, then the target is moving directly away. If it is located at the bottom of the circle, the target is flying directly towards you.

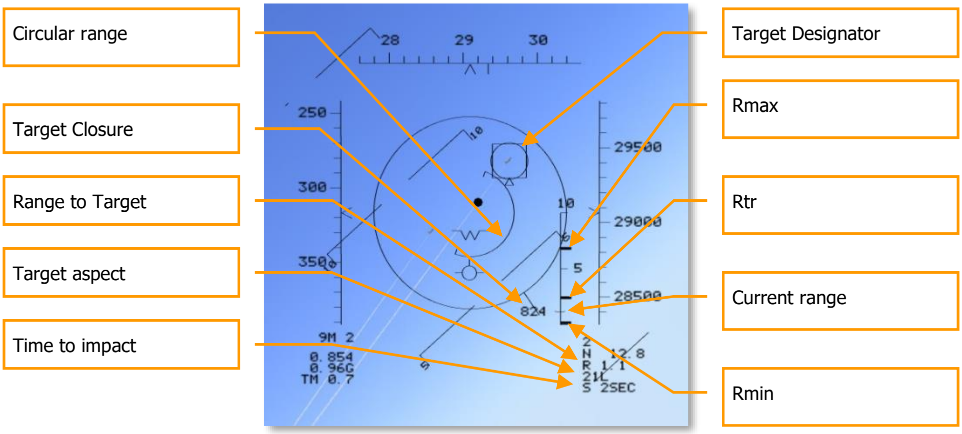
THOUGH THE AIM-9 MISSILE IS AN ALL-ASPECT MISSILE, YOU SHOULD ATTACK THE TARGET FROM THE REAR HEMISPHERE SIDE. THIS WILL INCREASE THE PK



4-25: STT mode. Radar lock on target greater than 12,000 feet away

- The target designator (TD box) shows the target position in the space relative to your aircraft.
- The target range scale is located along the right portion of the HUD. The range values go from zero to 10 nautical miles. Along this fixed scale, a sliding bar indicates the target's current range. The number next to the bar shows target closure rate. There are also bars for Rmax, Rtr, and Rmin for an AIM-9M launch. When the current range to target is between the Rmax and Rmin range bars, the target is in the valid launch zone.
- Additional data is located in the data block in the lower right portion of the HUD. A digital range value in nautical miles to the target is shown after the "R" symbol. Under the range value, target aspect angle is located. This shows the angular difference between the target longitudinal axis and line of sight to the target. At the bottom of the data block, the Time To Intercept (TTI) is provided.

If the distance to the target is less than 12,000 feet, the additional information appears on the HUD:



4-26: STT mode. Radar lock on target less than 12,000 feet away

- The circular range to the target scale appears within the ASE Circle. When target range decreases, the range scale will unwind counter-clockwise. There is a minimal launch range bar on the scale. When a target less than this range, a large "X" flashes across the HUD.
- Below the TD box, a flashing triangle is displayed when the target is locked and within valid shot parameters.
- In the lower left portion on the HUD, three data items are listed when a target is locked: the selected weapon, ownship Mach, ownship G-load, and target Mach.

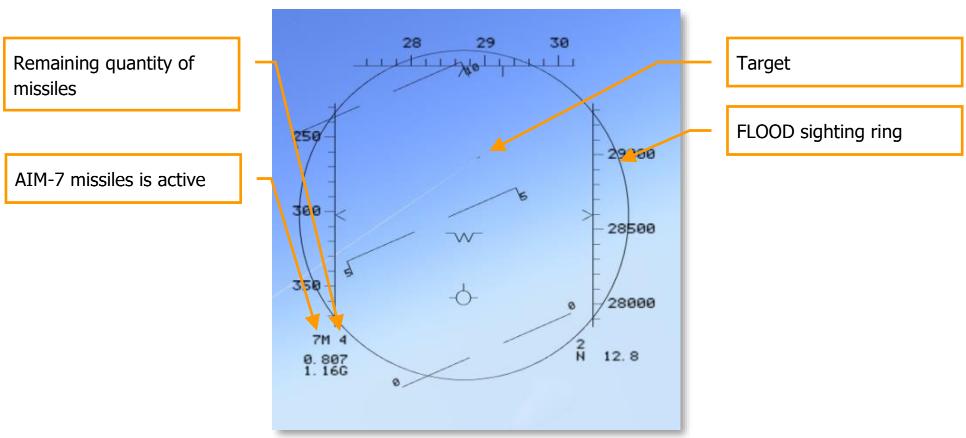
AIM-7M Sparrow "Air-to-Air" Medium Range Missile (MRM) Modes

The AIM-7M missile is one of the two medium-range, air-to-air missile types employed by the F-15C, The missile's semi-active radar homing (SARH) seeker requires constant target illumination by the radar in STT mode during the missile's entire time-of-flight.

The following HUD symbology is used with the AIM-7M:

Flood Mode

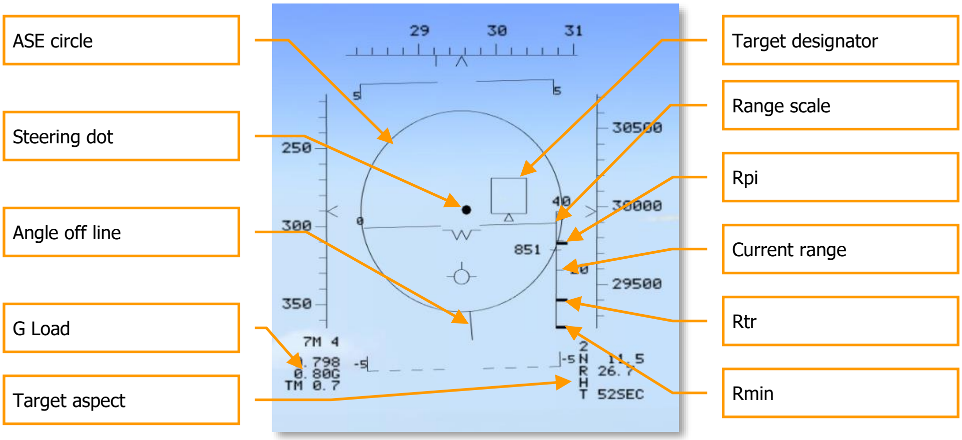
Flood mode is most often used in the close combat arena when a radar lock is unattainable. Flood mode is accessed by pressing the **[6]** key and is indicated by a large, 12-degree reticule on the HUD. When in this mode, the radar is simply emitting a steady beam of energy that is focused within the FLOOD reticule. By launching an AIM-7M, the missile will attempt to intercept a target within the reticule that is reflecting energy back to the missile's seeker. As such, you do not have to lock the target with radar before engaging. The "FLOOD" mode indication is displayed on the lower center portion of the HUD and on the VSD. If several targets come into the reticule, the missile will attempt to intercept the target with the largest RCS or closest range. If the target is too far away or leaves the confines of the reticule, the missile will lose tracking and go ballistic.



4-27: FLOOD mode

Target Tracking Radar Mode

This is the basic long-range combat mode for the AIM-7M. After locking the target from long range search (LRS) acquisition mode **[2]** key, the radar automatically transfers the track file to STT mode if it is designated to be locked. Additional information will appear on the HUD:



4-28: STT mode

- The target designation (TD) box shows the position of the target in relation to your aircraft.
- The ASE circle shows the maximum, angular steering error probability. The steering error value is proportional to the steering dot from the ASE circle center.
- The ASE circle shows the zone in which the steering dot should be located prior to launch to hit the target with a given probability kill. The circle increases in size when the distance to the target decreases, which means that as the distance decreases, the missile can be launched with greater steering error. It is necessary, by maneuvering your aircraft, to ensure that the steering dot is located as close to the ASE circle center as possible.
- The angle off tail bar is located on the ASE circle. This shows the target aspect angle in relation to your aircraft in a plan view. If it is located at the top of the circle, then the target is heading away. If the bar is located at the bottom of the circle, then the target is heading towards you.
- Along the right portion of the HUD, the target range scale is displayed. The scale's upper limit corresponds to the radar's current range setting. Three elongated bars on the scale display the missile's minimal range (Rmin), maximum range to a maneuvering target (Rtr) and maximum range against a non-maneuvering target (Rpi). The sliding bar displays the current range to the designated target. The number next to the range bar displays the combined closure speed.
- In the lower right portion of the HUD, the data block provides additional data. This includes current range to target digital display. The range value is shown as a number, following the **R** symbol.
- The target aspect indicator is located under the current range digital display. This shows the angle the target's longitudinal axis and line of the target sighting. The **T** (Tail) symbol is displayed when the target is tail on and **H** (Head) when the target is head on. The "R" and "L" symbols with digital values correspond to the left and right target aspect.

- Below the target designator box, a flashing triangle is displayed when the target is locked and within valid shot parameters. Valid shot can be determined by having the target within range of the selected weapon and the steering dot within the ASE circle.
- In the lower left portion on the HUD, three data items are listed when a target is locked: the selected weapon and remaining number, ownship Mach, ownship G-load, and target Mach.

RAERO - Range with Optimal Steering, including aircraft lofting. This is the maximum aerodynamic range the missile can fly out to and still kill a target. It assumes a non-manouvering target that maintains a constant velocity, and represents the earliest opportunity at which a target intercept can be computed.

ROPT - Max Range Probability of Intercept with Optimum Steering. Requires steering dot to be centred and also assumes non-manoeuvring, constant velocity target.

RPI - Max Range Probability of Intercept with Current Steering. Assumes non-manouvering target with constant velocity.

RMNVR - Max Range against a Manoeuvring Target. Assumes target executes a 4g, level turn to face away from the missile at the moment of launch.

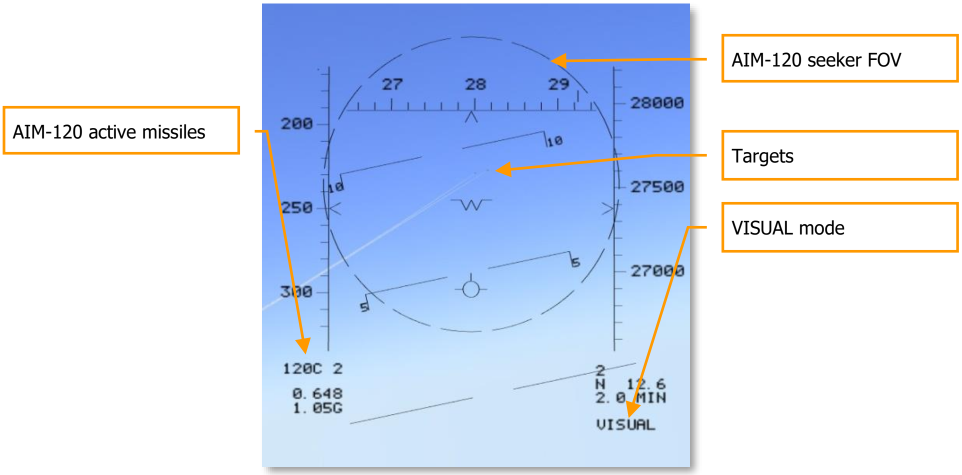
RTR - Range Turn and Run. Indicates the maximum launch range against a target executing an evasive turn and run maneuver at launch and is calculated using current steering. If steering closely approaches optimal steering, RPI approaches ROPT. Once the dot is centred, RPI and ROPT are the same.

AIM-120 AMRAAM "Air-to-Air" Medium Range Missile (MRM) Modes

The AIM-120 air-to-air missile is the F-15C's primary medium range weapon. In contrast to the AIM-7M, the AIM-120 has an active radar homing (ARH) seeker. When launched from long range, the missile initially uses inertial guidance with data link corrections received from the launch aircraft. At the terminal stage, the active radar seeker automatically switches on and completes the intercept by itself.

Visual MODE

This engagement mode is used in visual range combat arena when a radar lock can not be achieved or a quick shot must be taken. With AIM-120 selected as the active weapon, press the **[6]** key to enter the Visual mode. Visual permits the launching of AIM-120s, nicknamed Slammers, without using the aircraft's radar to first lock the target. It should be noted that to lock a target with the seeker, it is required that the target be within 10 nautical miles and it should be in the missile seeker FOV as displayed on the HUD.



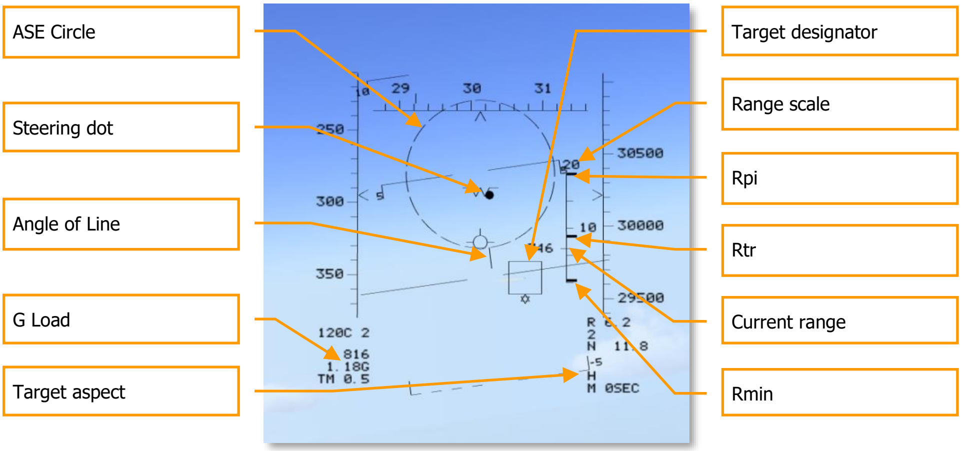
4-29: AIM-120 missiles in VISUAL mode

The **VISUAL** indication appears in lower right portion of the HUD. In the lower left of the HUD are the indications for how many AIM-120 are loaded on the aircraft. Below this field, the aircraft's Mach and G-loading are displayed.

Before launching an AIM-120 in Visual mode, it is necessary to maneuver your aircraft so that the target is positioned inside the dashed-reticule. The missile will not give a readiness indication for launch. Two seconds after launch, the missile's active radar homing (ARH) seeker is switched on and Slammer will search for targets within its seeker's field of view. If several targets are detected, the ARH seeker will attack the closest target. If two targets are of equal distance from the missile, it will attack the target with the larger radar cross section (RCS).

Radar Target Tracking Mode

Designating one or more targets with the aircraft's radar is the primary method of engaging targets at long range. Designating a target from LRS **[2]** mode or designating the target twice from TWS **[RAlt-I]** mode, will command the radar to initiate a single target track (STT). This focuses all the radar's attention on that one target. When in this engagement mode, the symbology is similar to that of the AIM-7M mode described above. Additional information that appears on the HUD includes:



4-30: AIM-120 STT mode

- The target designation (TD) box shows the position of the target in space in relation to your aircraft.
- The ASE dashed-circle shows the maximum, angular steering error probability. The steering error value is proportional to the steering dot from the ASE circle center.
- The ASE circle shows the zone in which the steering dot should be located prior to launch to hit the target with a given probability kill. The circle increases in size when the distance to the target decreases, which means that as the distance decreases, the missile can be launched with greater steering error. It is necessary, by maneuvering your aircraft, to ensure that the steering dot is located as close to the ASE center as possible.
- The angle off tail bar is located on the ASE circle. This shows the target aspect angle in relation to your aircraft in a plan view. If it is located at the top of the circle, then the target is heading away. If the bar is located at the bottom of the circle, then the target is heading towards you.
- Along the right portion of the HUD, the target range scale is displayed. The scale's upper limit corresponds to the radar's current range setting. Three elongated bars on the scale display the missile's minimal range (Rmin), maximum range to a maneuvering target (Rtr) and maximum range against a non-maneuvering target (Rpi). The sliding bar displays the current range to the designated target. The number next to the range bar displays the combined closure speed.
- In the lower right portion of the HUD, the data block provides additional data. This includes current range to target digital display. The range value is shown as a number, following the **R** symbol.
- The target aspect indicator is located under the current range digital display. This shows the angle the target's longitudinal axis and line of the target sighting. The **T** (Tail) symbol is displayed when the target is tail on and **H** (Head) when the target is head on. The **R** and **L** symbols with digital values correspond to the left and right target aspect.

- Below the target designator box, a flashing five-pointed star is displayed when the target is locked and within valid shot parameters. Valid shot can be determined by having the target within range of the selected weapon and the steering dot within the ASE circle.
- In the lower left portion on the HUD, three data items are listed when a target is locked: the selected weapon and remaining number, ownship Mach, ownship G-load, and target Mach.

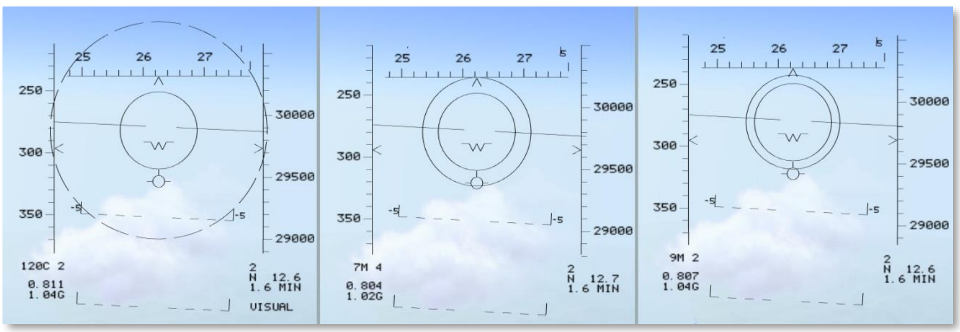
Auto ACQuisition (AACQ) Radar Modes

The F-15C can employ three short-range, radar auto acquisition modes. These modes are used to automatically radar lock enemy aircraft during an ACM engagement. The maximum lock range for these modes is 10 nautical miles.

IN THE AUTOMATIC LOCK-ON MODES, THE RADAR WILL TRACK THE FIRST TARGET DETECTED

Boresight AACQ Mode

The BORESIGHT **[4]** key mode permits automatic lock of targets within a narrow cone ahead of you. In this mode, the radar field of view (FOV) is directly ahead of the aircraft, and the outer reticule shows this scan area. The radar locks on to the first target entering the FOV.

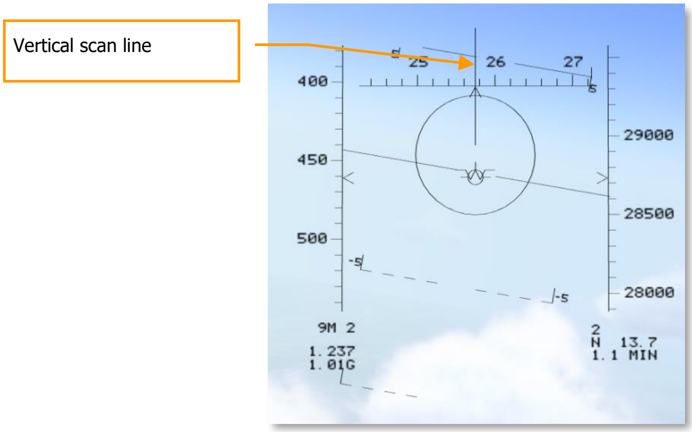


4-31: Boresight mode AIM-120C, AIM-7M and AIM-9M

After locking onto the target, the radar changes to STT mode.

Vertical Scan AACQ Mode

The VERTICAL SCAN **[3]** key mode enables you to lock up targets that are in the same vertical plane with your aircraft. It allows you to lock on to the targets during air combat maneuvering (ACM) with high-G automatically. In this mode, the radar scans an air space 7.5 degrees wide and –2 to 50 degrees vertically. Two vertical lines are displayed on the HUD. To lock up a target, it is necessary to position the target between these two lines or along your lift vector. The maximum vertical scan range is about two HUD heights above your upper HUD frame.



4-32: Vertical scan mode (VS)

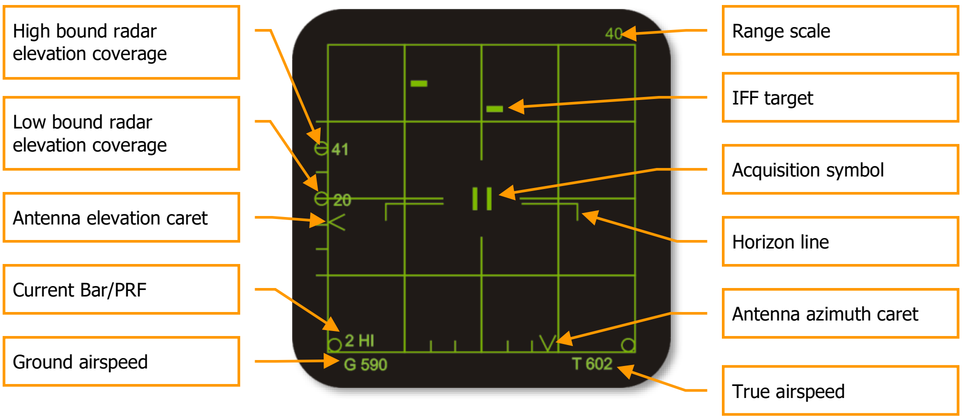
After locking onto the target, the radar automatically changes to STT mode.

AN/APG-63 Radar Modes, VSD

Long Range Search (LRS) Mode

The LRS [2] key mode is the primary radar mode for the F-15C for long-range acquisition and engagement. The pilot can set the acquisition range (10, 20, 40, 80, or 160 nautical miles) and change the azimuth width and elevation. The information regarding radar contact locations is displayed on the vertical situation display (VSD), but no information regarding the contacts speed, altitude and bearing are provided.

The VSD shows the radar picture as a plan-view from above your aircraft, matching the chosen distance scale. The target contacts, also referred to as hits, are located on the VSD according their range from your aircraft. The nearest hits are located at the lower edge of the VSD and the more distant ones at the top. The radar can track up to 16 targets simultaneously. The radar will also interrogate friend or foe (IFF) all the targets automatically. Friendly hits are shown as circles and hostile as rectangles.



4-33: VSD LRS mode

In the upper right corner of the VSD, the current radar range setting is displayed (10, 20, 40, 80, or 160 nautical miles).

The radar's elevation scan area is displayed on the left side of the VSD. The digits close to the small circles show the high and low elevation coverage limits of the target designation cursor (TDC) at its current range on the VSD. Because the radar beam is a cone that grows larger the further it is from the antenna, the elevation coverage will widen as TDC range increases. You can tilt the radar elevation coverage 60 degrees up and down with the [RShift+;] and [RShift+.] keys. The elevation coverage circles will move up and down accordingly. Each bar scan angular coverage is 2.5 degrees. By moving the TDC to the upper and lower limits of the VSD, you may automatically "bump" the range up and down.

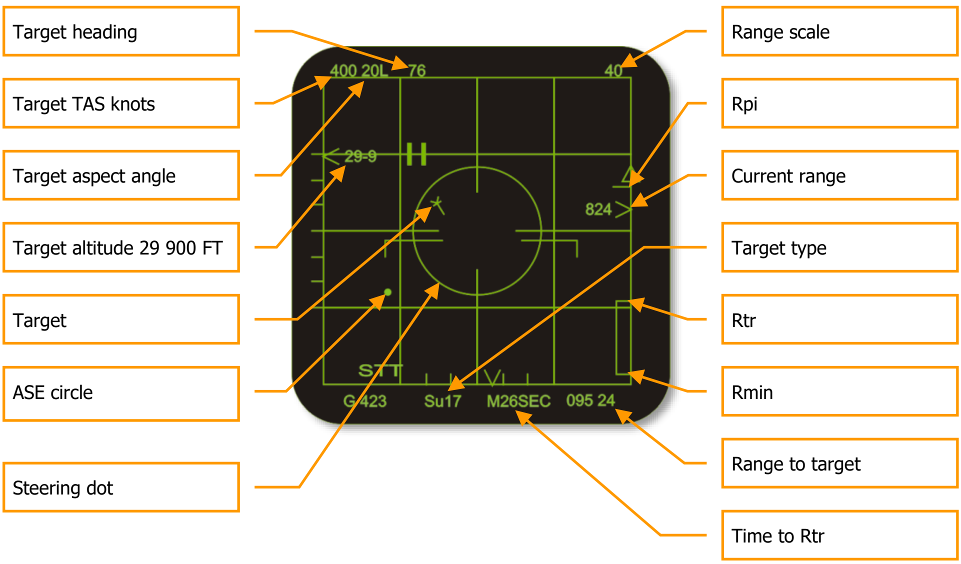
The ground speed "G" and true speed "T" values are displayed at the lower edge of the VSD. The constantly changing elevation bar and the pulses repetition frequency (PRF) value is displayed in the lower left corner. The constantly alternating of HI - MED PRF is required to detect targets flying at different aspects to you. The "HI" High PRF frequency mode permits detection of head-on targets at great distance. "MED" Medium PRF has less range but is better at detecting targets will less closure (Vc). This is termed interleaved mode and is the standard LRS mode for the F-15C in game.

Along the bottom of the VSD is a horizontal scale that reflects the selected azimuth scanning zone width. The width defaults to - ±600, but by pressing the **[RCtrl+-]** key, - ±300 can be selected. The two circles along the scale represent the azimuth scanning limits of the antenna, and inside this zone is a moving caret that displays the antenna's current azimuth position. While the ±600 setting provides a larger scan area, the ±300 provides faster target updates.

To have the radar lock on to a contact, move the TDC over a contact using the **[;], [,], [.], [/]** keys, and press the **[Enter]** key. If all lock conditions are met, the radar will automatically transfer to a single target track (STT) mode.

Single Target Track (STT) Mode

After you have locked the target from LRS mode, the radar will change to STT mode. The radar now focuses all of its energy on a single target and provides constant updates. However, the radar will no longer detect other contacts and the enemy may be alerted by this radar lock. The VSD display in STT mode remains much the same as LRS mode. The STT indicator appears in the lower left corner of the VSD. The locked radar target is displayed as a star with a flight vector line coming from it, which indicates it is the primary designated target (PDT).



4-34: VSD. STT mode

TO LAUNCH THE AIM-7, IT IS REQUIRED TO ENTER THE STT MODE OR SWITCH ON THE FLOOD MODE AT CLOSE RANGE

The non-cooperative target recognition (NCTR) system automatically attempts to identify (print) the locked target. The system stores in memory a library of different aircrafts radar signature samples and tries to compare it with the locked target. The signature identification method is based on the radar return, which is partly determined by the target's first stage compressor blades. If the signature matches a library entry, the name of target is displayed near the bottom center of the VSD. Such a method does not ensure a 100% guarantee of successful target identification. Target range, elevation difference, and target aspect can all influence an NCTR print.

A target's speed, aspect angle and heading are displayed along the upper left portion of the VSD. The target's altitude is in displayed in relation to sea level along the elevation scale. An altitude of 29,900 feet would be displayed as 29-9. Additionally, target range and combined closure are displayed in the lower right portion of the VSD.

Missile employment data is provided in STT mode that provides you cues of when to take a shot. The large circle on the VSD is the allowable steering error (ASE) circle. This operates the same way as we reviewed with the HUD. The larger the circle, the larger the permissible steering error and probability of kill (Pk, pronounced P sub K). The ASE's size depends on the selected missile, target maneuvers, target aspect, speed, etc. To ensure a higher Pk, try to remember the simple rhyme, "Center the dot for before taking the shot."

Along the right side of the VSD, a vertical scale is displayed that shows the selected weapon's dynamic launch zone (DLZ) in relation to the locked target. Horizontal bars along the scale provide launch cues. From the bottom to top: Rmin – minimal launch range, Rtr – maximum launch range assuming high-G target maneuvering, Rpi – maximum launch range against a non-maneuvering target. At the top of the scale is a triangle that represents Raero. Raero symbolizes the missile's maximum ballistic range regardless of target.

Below the scale, in the lower right portion of the VSD, target bearing and a digital readout of target range are displayed.

After missile launch, the missile flight timer appears at the top of the VSD. When launching an AIM-7M, a "T" appears on the VSD and an adjacent number counts down until target impact. The same time to intercept (TTI) counter appears with the AIM-120, but the timer is preceded by an "M" instead.

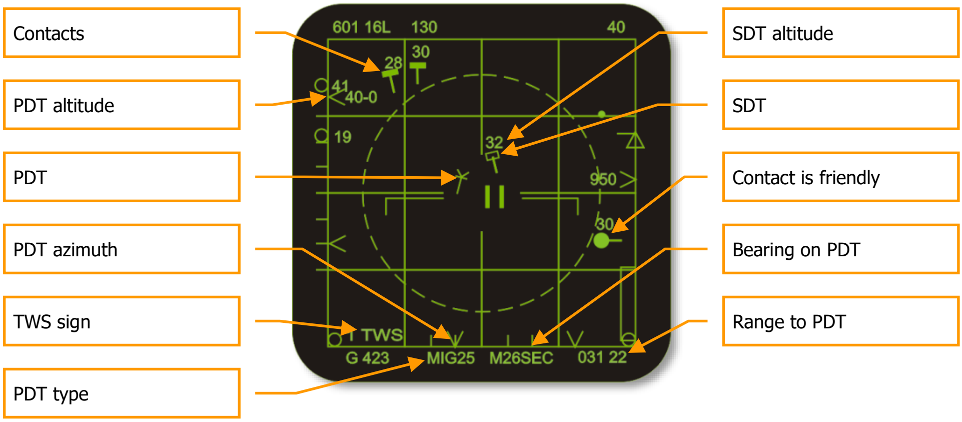
Along the lower center of the VSD, the AIM-7M shoot cue will appear when the fire control system determines a valid shot. This cue looks like a triangle. To the right of the shoot cue, a count down timer is displayed that indicates how long it would take for the missile to reach the locked target if launched now. This only applies to missiles still on the rails; it is not a TTI timer.

Track While Scan (TWS) Mode

The TWS mode is a very informative mode, but is more complex than LRS. This mode combines the information unique to LRS and STT modes. It permits having detailed target data on a contact while still being able to scan for other targets. When TWS mode is initiated with the **[RAlt-I]** key, the mode indicator in the lower left corner of the VSD will change to "TWS." Generally, the TWS VSD display is very similar to the LRS VSD. However, each contact has a vector line that points in the direction of the contact's heading and a digital altitude indication beside it.

> YOU CAN USE TWS MODE FOR SIMULTANEOUS FIRING OF AIM-120 MISSILES AT MULTIPLE TARGETS.

In contrast to LRS where designating a contact transitions the radar to STT mode, an initial designation of a contact in TWS sets the contact as the primary designated target (PDT) but continues to search for and display additional contacts within the scan area. Further, by designating other contacts, these are set as secondary designation targets (SDT). SDT targets are indicated as hollow rectangles, whereas the PDT is displayed as a star-shape (as in STT mode). By designating either a PDT or SDT second time, an STT track on that target will be initiated. When multiple AIM-120 missiles are launched in volley, the first will go to the PDT and the following missiles will intercept the SDTs in the order they were designated. Time to intercept timers will be in regards to the PDT.



4-35: TWS Mode

You can not launch an AIM-7 while in TWS mode. To launch such a missile, you must to transition to STT mode by designating a target twice

TWS has several restrictions. The radar will attempt to build track files for each contact, but given a large scan volume, there will be a sizable refresh time between scans. During each scan the radar will try to predict the position of the contact for the next scan. If however the target takes evasive, high-G maneuvers and quickly changing its trajectory and speed, the radar can lose the track by making an incorrect track file prediction. Using such a defensive tactics, the hunter can quickly become the hunted.

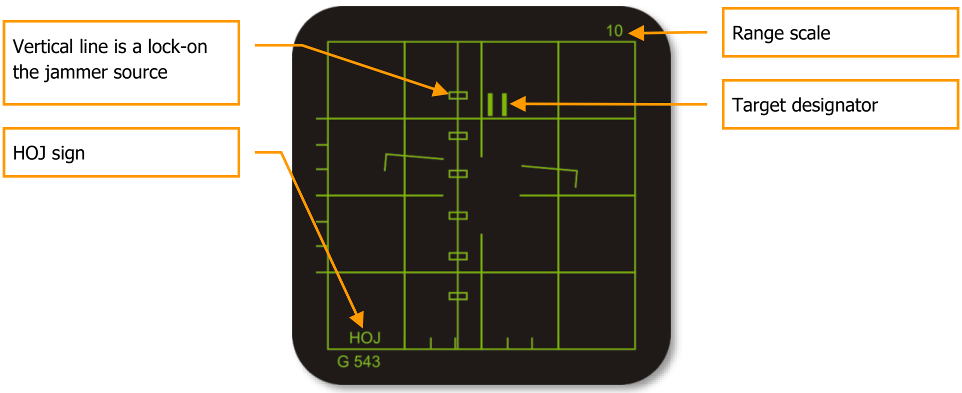
TWS, when combined with the AIM-120, provides a powerful ability to engage multiple targets simultaneously. Nevertheless, the target tracking reliability is less than that of LRS and even more so than STT. Unlike STT though, a TWS launch with AIM-120 will not provide the enemy aircraft with a radar lock and launch indication. As such, the first warning the enemy pilot will likely get is when the active radar seeker of the AIM-120 goes active near the target.

Home On Jam (HOJ) Mode

When the radar and radar warning receiver (RWR) detects active electronic countermeasures (ECM), it displays on the VSD a vertical series of hollow rectangles along the azimuth of the jammer. This

ECM indication is that of a noise jammer and is termed a strobe. In order to lock the target using its own ECM strobe, place the TDC on any of the hollow rectangles and press the **[Enter]** key to designate. Note that you are not locking a target on radar. Once the ECM emitter is locked, the series of rectangles will have a solid, vertical line running through them; the ECM emitter is along that azimuth.

The VSD is now in home on jam mode, the HOJ indicator appears on the VSD and HUD. The AIM-120 and AIM-7M missiles can both be launched in this mode when a radar lock is not possible due to enemy ECM. Note that when fired in this mode, the missile will fly a less efficient pure-pursuit trajectory and the probability of kill is much less. Also note that no range information is provided. As such, a call to a friendly AWACS is suggested to get ranging information. Attacking in such a mode provides the enemy with no warning because a HOJ attack is a completely passive attack.



4-36: HOJ Mode

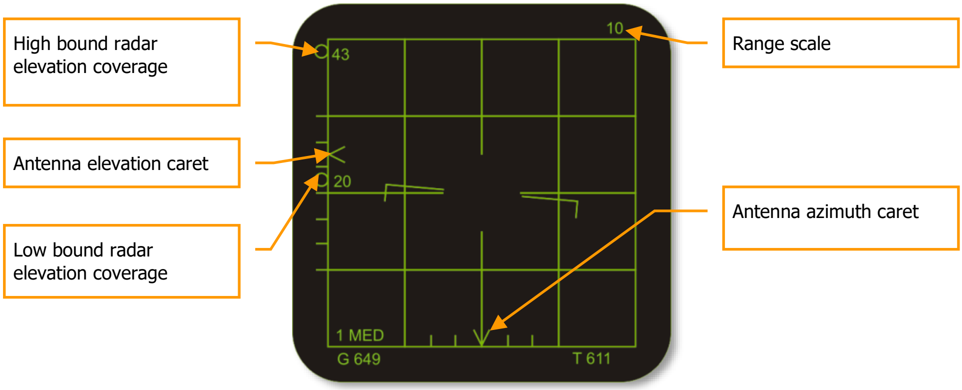
> HOJ MODE PROVIDES THE AZIMUTH OF THE TARGET BUT GIVES NO TARGET DATA REGARDING RANGE, ASPECT, SPEED, OR ALTITUDE

At the short ranges, the radar's energy overcomes the energy output of the noise jammer and the radar gets enough radar reflected energy back from the target to form a track. This is termed "burn through." At burn through, the radar will automatically transition to STT mode regardless of prior designation mode (LRS or TWS). ECM burn through is generally 15...23 nautical miles.

Vertical Scan (VS) AACQ Mode

In the vertical scan mode, **[3]** key, the radar searches an area with 2.5 degrees in width and -2 to +55 degrees in the vertical. The lock range is 10 nautical miles. The radar automatically locks on to the first and closest target this zone. When locked, the target is automatically tracked in STT mode.

This mode is most often used during air combat maneuvering (ACM) dogfights. During such fights, you are often trying to place the target on the lift vector and "pull" the target into the HUD. When in VS mode, you can often lock on to the target earlier, even when it is well above the HUD frame.

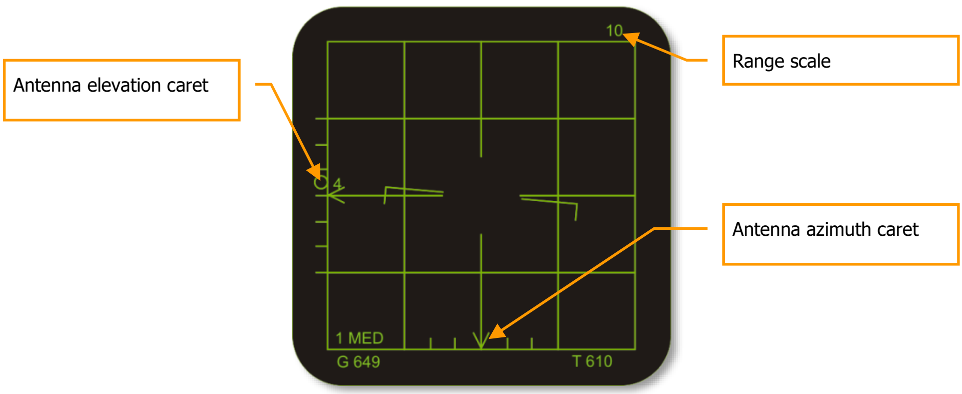


4-37: VS Mode

The high and low radar elevation markers show the scanning zone. The fixed antenna azimuth caret, in the azimuth scale center, shows that the radar antenna does not scan on the azimuth.

Bore Sight (BORE) AACQ Mode

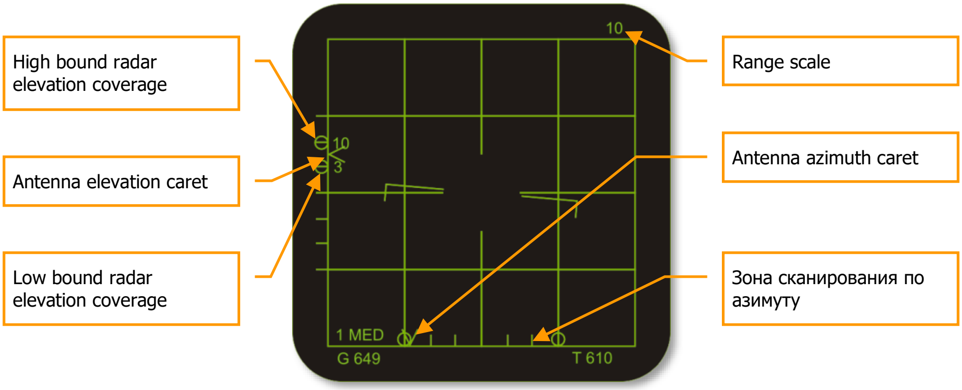
In BORE mode, the **[4]** key, lock of the target occurs automatically when the target is within the Bore reticule and is within 10 nautical miles. Bore is useful for quickly locking a target within visual range (WVR) and allows a degree fine control as to the target being locked.



4-38: Bore

AUTO GUNS (GUN) AACQ Mode

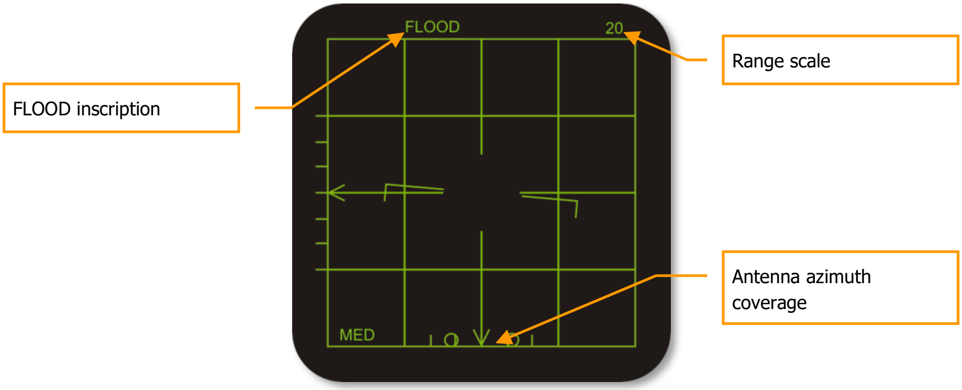
Auto Gun mode is used expressly for close range combat with the M61 20mm cannon. The radar scanning zone is centered on the fixed gun reticule and is 60 degrees in width (±30 degrees) and 20 degrees in height. Maximum lock on range is 10 nautical miles. After the target is locked, the radar transitions to STT.



4-39: Auto Guns mode

FLOOD Mode

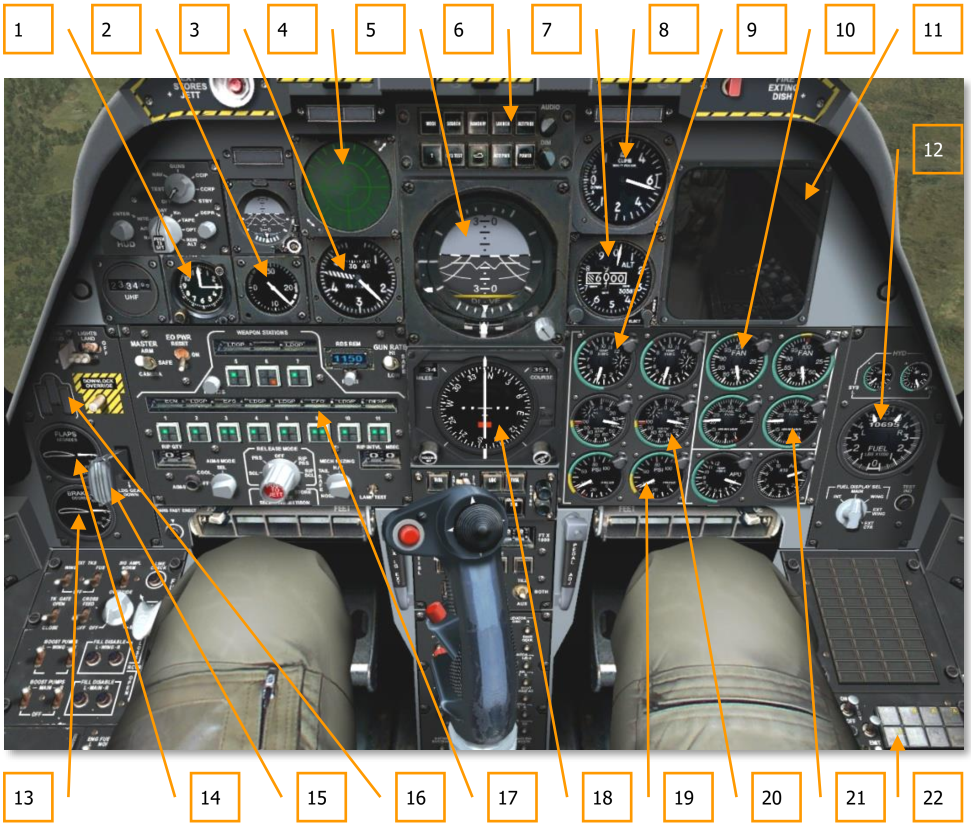
Flood, [6] key, mode is used in the close-range combat with the AIM-7M. The antenna is limited to a 12 degrees cone that is flooded with continuous wave (CW) energy. In Flood mode, the radar never actually locks onto the target; rather, the seeker in the missiles homes in on the target within the Flood reticule with the largest radar cross section (RCS). Flood engagement range is limited to 10 nautical miles. "FLOOD" is displayed on the VSD and HUD.



4-40: Flood Mode

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.



4-41: A-10A Instrument Panel

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. Airbrake Position Indicator
14. Flap Position Indicator
15. Landing Gear Handle
16. Landing Gear Position Display
17. Armament Control Panel
18. Horizontal Situation Indicator (HSI)
19. Engine Oil Pressure Indicator (L & R)
20. Engine Core Speed Indicator (L & R)
21. Fuel Flow Indicators
22. ECM Panel

4-42: Upper instruments

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.

4-43: TV Monitor AGM-65

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.

4-44: RWR Display

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.

4-45: Airspeed indicator

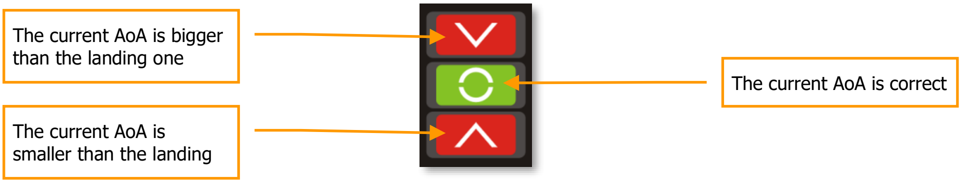
Angle-of-Attack (AoA) Indicator

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.

4-46: Angle-of-attack (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.



4-47: Angle-of-attack 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.

4-48: ADI

Horizontal Situation Indicator (HSI)

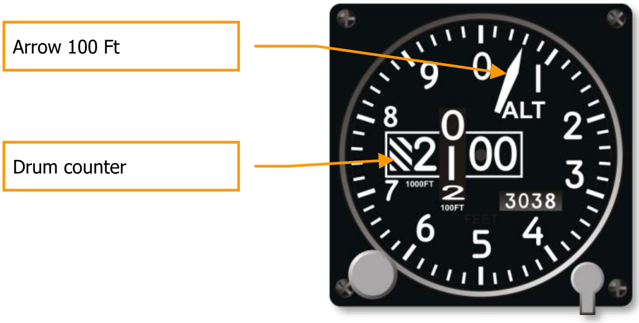
The HSI is intended to assist you in providing proper heading and alignment of your flight path on the planned route. This is done by using radio beacons and inertial navigation (INS) when enroute and approach. The rotating compass shows the current aircraft heading relative to the upper lubber line. 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.

4-49: HSI

Altimeter

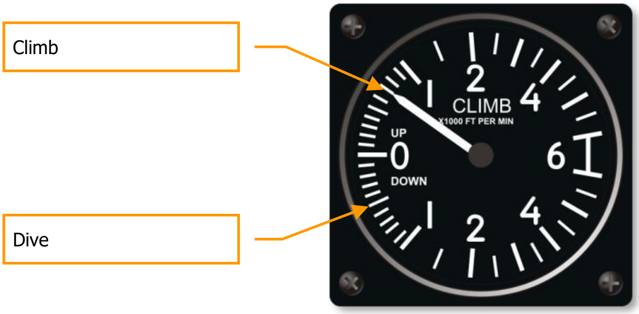
The altimeter is intended for barometrical altitude measurement. The scale factor is 20 feet. A digital altitude indicator is also displayed on the indicator.



4-50: 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.



4-51: Vertical velocity indicator

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.

4-52: Accelerometer

Interstage Turbine Temperature Indicator

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.

4-53: Interstage turbine temperature indicator

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.

4-54: 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.

4-55: Engine 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.

4-56: 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.

4-57: Fuel flow indicator

Flap Position Indicator

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

4-58: Flap position indicator

Airbrake Position Indicator

The A-10A is equipped with splitting ailerons that are used as air brakes. The air brake position indicator shows the deflection angle of upper and lower surfaces of the split ailerons.

4-59: Air brake position indicator

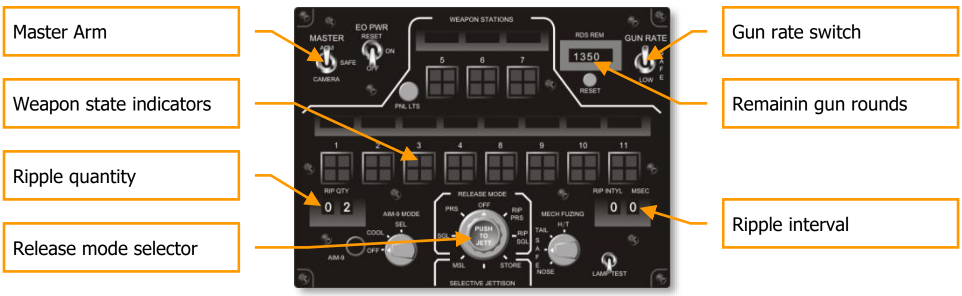
Indicator

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.

4-60: Fuel quantity indicator

Armament Control Panel (ACP)

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

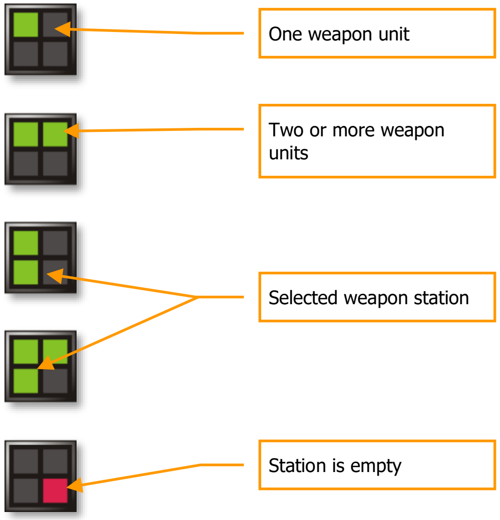


4-61: Armament Control Panel

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.



4-62: Weapon state indicators

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

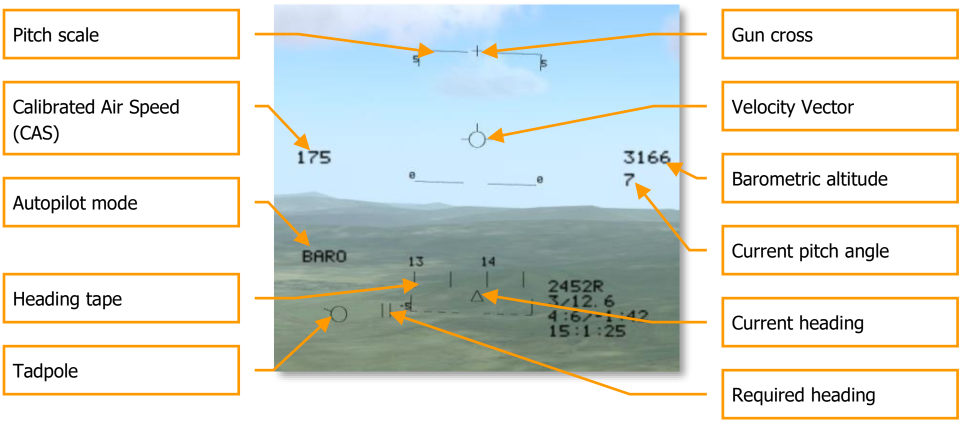
Two upper green indicators indicate the number of weapons on that station. Both indicators are lit when there are two or more weapons loaded on that station. If only one weapon is loaded on the station, then one indicator will be lit. If the station is empty, one lower, red indicator is lit.

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 Symbology

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

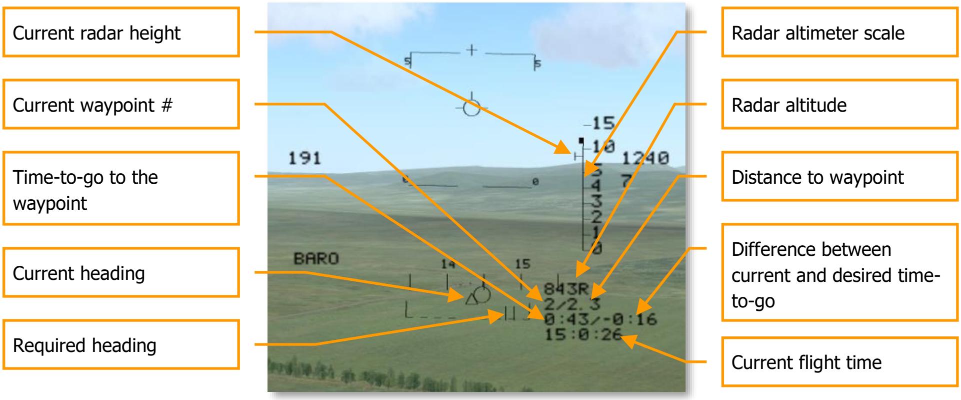


4-63: A-10 Basic HUD Symbology

- 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.



4-64: Navigation mode with radio altimeter scale HUD symbology

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

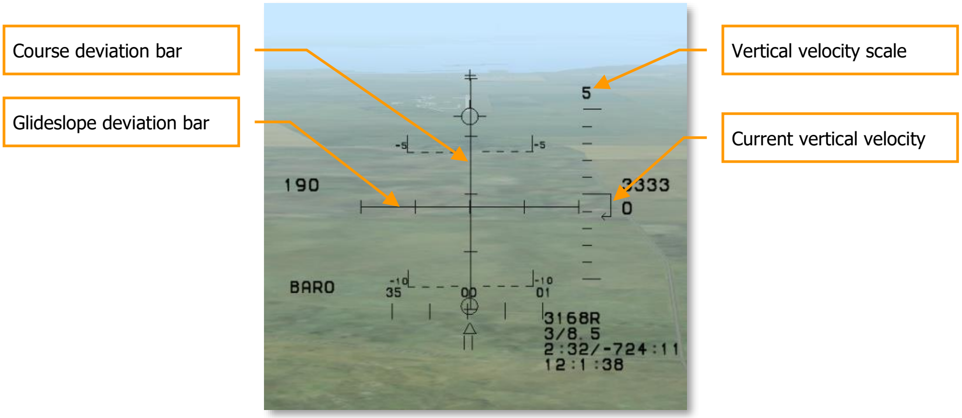
BARO	Autopilot is off

Instrumental Landing System (ILS) Mode

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 radar altimeter is displayed. The indicator moves along the vertical scale and shows radar flight altitude above if it's current value is less than 1,500 feet.

The course and glideslope deviation bars are displayed in the HUD center 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.



4-65: Instrumental landing mode HUD symbology

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

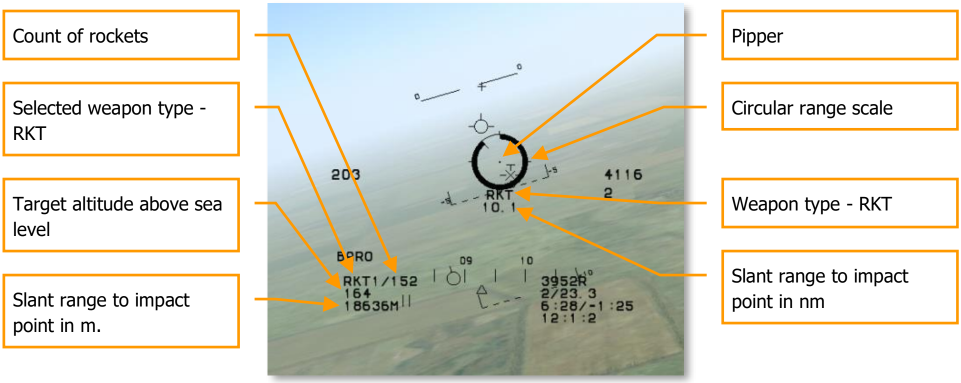
Internal Gun and Unguided Rocket (RKT) Delivery Mode

Gun and rockets use a common set of HUD symbology.

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 or cycle the **[D]** key until rockets are selected. When in this 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.

With rockets selected, the "RKT" indicator will be shown under the reticule.

The pipper is considered a continuously computed impact point (CCIP). This means that the weapons will hit the area under your pipper when you fire the weapon, assuming range requirements are met. Note though that rockets are an area weapon and will generally impact around the aim point.



4-66: GAU-8A and RKT delivery mode HUD symbology

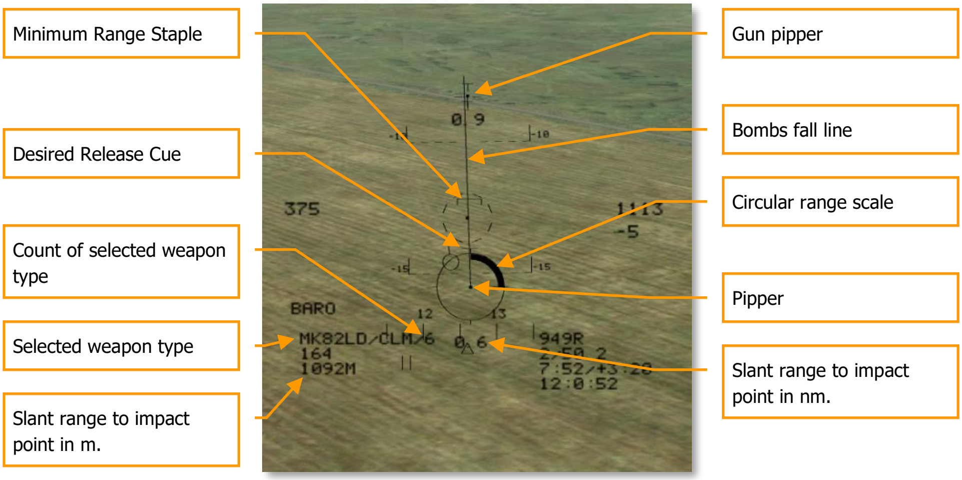
When in a weapon mode, a data block in the lower left corner of the HUD is displayed. This consists of three lines. The top line indicates the selected weapon and the quantity of the weapon remaining. The second line indicates the barometric elevation, in meters, of the terrain below the weapon pipper.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



4-67: CCIP delivery mode HUD symbology

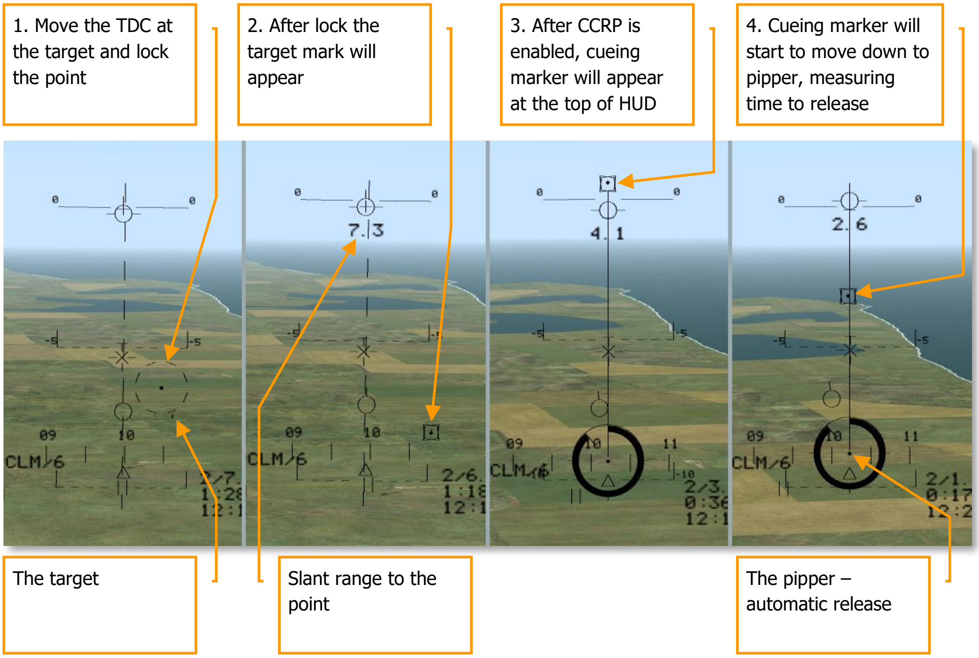
- The constantly displayed gun pipper shows the current shells impact point. The slant range to the impact point in miles is displayed under the pipper. When an "X" is drawn through the pipper, the impact point is not accurate.
- The bomb fall line shows the line on which bombs will fall in a ripple 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 target designator cursor (TDC) and the fire control computer (FCC). The TDC 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 target.

The TDC can be moved with the **[,], [.], [/], [;]** keys. Once the TDC 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.



4-68: CCRP bombing mode HUD symbology

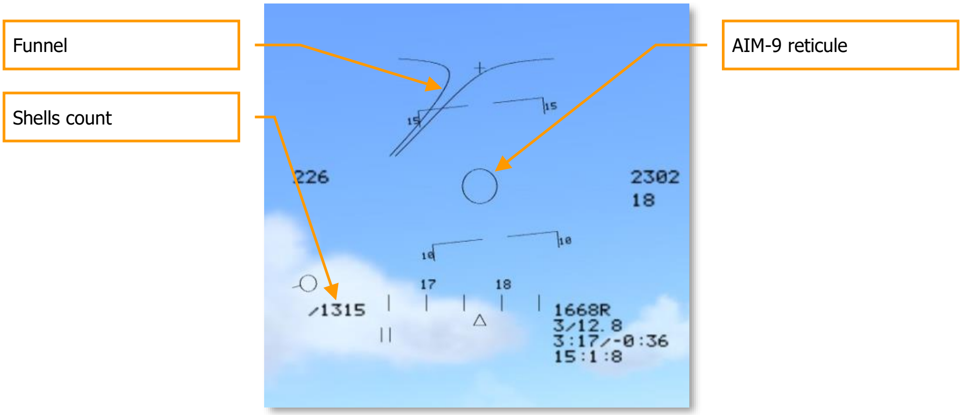
As soon as the target is marked by the target designator, the slant range to the target is displayed under the velocity vector indicator in miles.

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.

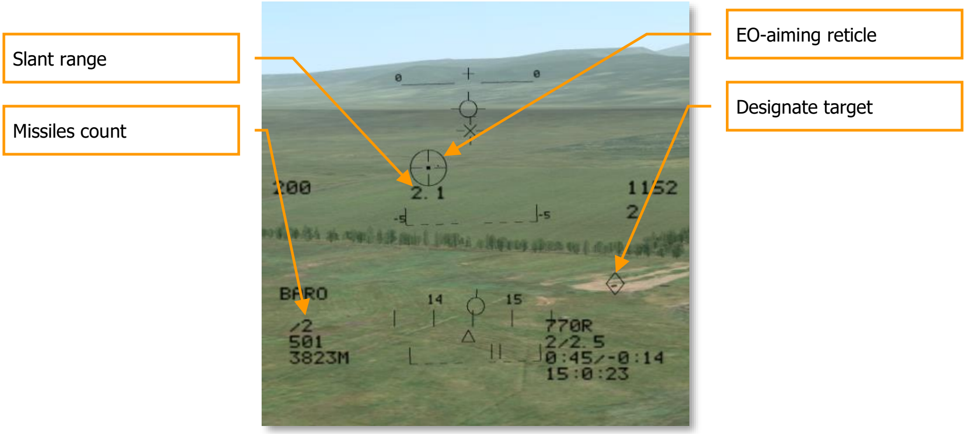


4-69: AA mode (Gun – Missiles)

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-65 with daylight TV-guidance and with imaging infrared guidance.

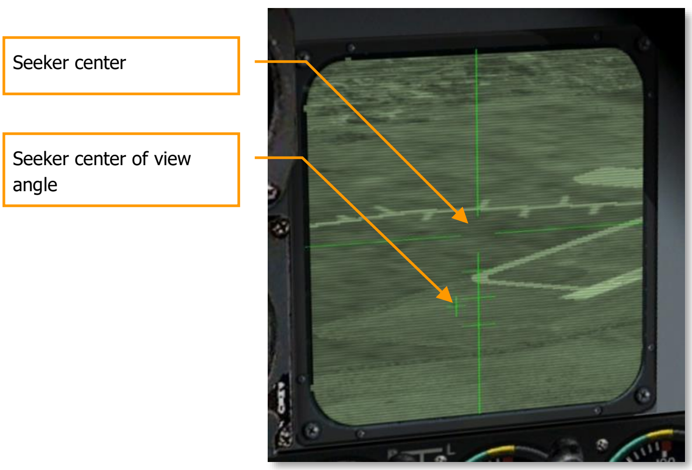
The AGM-65 delivery modes provide the pilot with an aiming reticule that shows seeker position on the HUD and TVM, seeker gimbal limits, and the slant range to target. The AGM-65K can lock on to a target from three nautical miles away and the AGM-65D can lock a target from eight nautical miles.



4-70: AGM-65 delivery mode

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. AGM-65K images look like a black-and-white TV, whereas AGM-65D images appear in 16 gray-green scale shades.

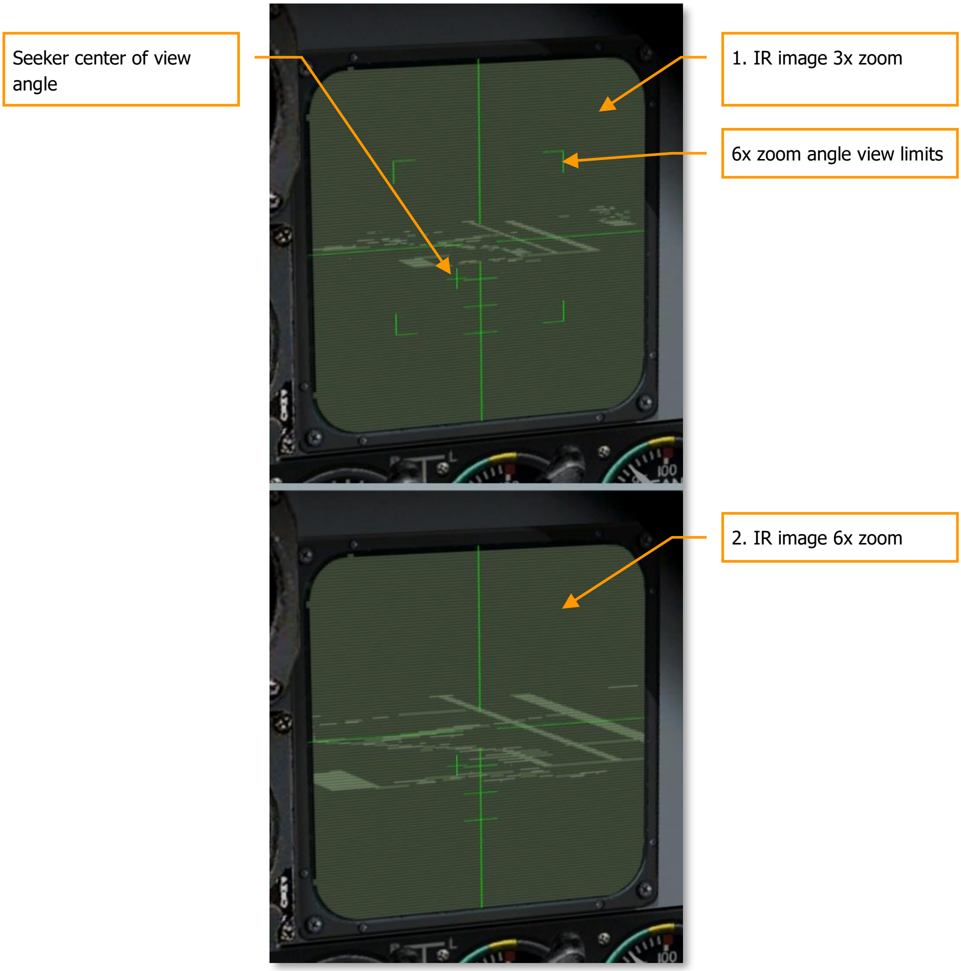
Both the AGM-65K and AGM-65D have a 3x magnification level; however, the AGM-65D also has a 6x magnification level. Using the **[-]** and **[=]** keys, you may toggle between AGM-65D magnification levels. You can determine when you are in the AGM-65D 6x magnification level by the lack off field of regard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



4-71: AGM-65 Mechanization

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 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.



4-72: AGM-65 TVM

On the TVM, the seeker's position is in regards to the longitudinal axis of the aircraft, and is displayed as a cross. When the 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.

5

TARGETING SYSTEMS

TARGETING SYSTEMS

Modern technologies enable the detection of air and ground targets from a distance of tens and even hundreds kilometers. Radars, electro-optical sighting systems, infrared systems and laser range-finders - target designators - are all included in the arsenal of modern combat aircraft. Despite some conceptual differences, the radars presented in game, the AN/APG-63 (F-15C), N-001 (Su-27, Su-33), and N-019 (MiG-29), are Pulse-Doppler radars that share the same operational principles and limitations.

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 tarets.

5-1: A-10 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.

The Russian Su-25 CAS aircraft uses a simple gunsight that is linked to a laser range finder and illuminator. This system calculates the impact point for unguided munitions and laser illuminates targets for missiles with passive laser homing seekers.

5-2: Laser range-finder target designator "Klen" on Su-25

The Su-25T is a more complex CAS aircraft and includes the optical-television targeting system "Shkval", which enables it to detect, recognize and track small, moving ground targets at distances over 10 km. Like the A-10A, the Su-25T is very adept at destroying armor vehicles such as tanks.

To target surface radars, like surface-to-air missile radars, the Su-25T can employ anti-radiation missiles (ARM) that receive targeting data from Emitter Targeting Systems (ETS) – "Fantasmagoria". Unlike the A-10A, this allows the Su-25T to destroy air defense threats before entering the target objective area.

Radar

Since the Second World War, the defining feature of an "all-weather fighter" has been its onboard air intercept radar set. By virtue of the ability of radio waves to penetrate clouds, this powerful sensor provides the fighter with the ability to detect and direct weapons against aerial targets day or night, independent of weather conditions that can degrade visual or infrared detection. Radar can also provide a very long detection range, making it the sensor of choice for modern beyond-visual-range (BVR) air combat.

The F-15C fighter has been fitted with several variants of the APG-63 radar during its operational career. The majority of these are "X-band" (10 GHz) radars with mechanically-scanned flat-plate slotted array antennas. The MiG-29 and Su-27 carry the N019 and N001 radars respectively, which operate in the same frequency band but employ twin-reflector "twist-Cassegrain" antennas similar to those of earlier Soviet fighters.

The features and limitations of these air intercept radars largely dictate the tactics employed during the BVR phase of an aerial duel. Although many details remain secret, enough information has become available to create an interesting portrait of the dynamics of BVR combat, in which each adversary seeks to gain advantage by exploiting the hardware limitations of the other.

5-3: N019 radar MiG-29

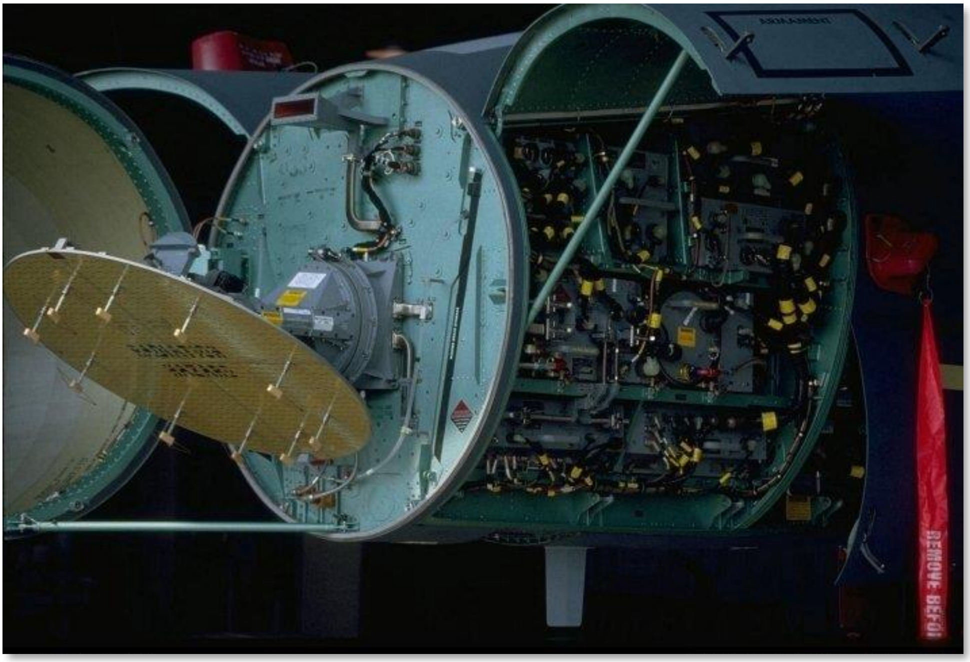
Radar operates by focusing radio waves into a narrow beam and transmitting them into space, then receiving any signals that are reflected from the target. This focusing is accomplished by the radar antenna, and the narrowness of the beam affects the radar's maximum detection range and target resolution. In order to save space and fit the largest possible antenna with the best focusing power onto a fighter, a single antenna is used in a pulsed mode, rapidly switching between time-shared transmit and receive functions thousands of times per second. This modulating pulse repetition frequency (PRF) is distinct from the much higher operating frequency (e.g. X-band) of the radio waves themselves.

During the Vietnam War, North Vietnamese fighters learned to employ low altitudes to remain hidden from pulse radar-equipped American fighters. By flying at a lower altitude than the opponent, they ensured that the enemy radar antenna would have to be steered to face a downward angle, toward the earth. In this "look-down" geometry, radar signals reflected from the target were drowned out by reflections from the surrounding background of the earth, making it practically impossible for the radar to detect or track the target. The defensive advantages afforded by the look-down geometry spawned an entire generation of NATO strike aircraft, including the F-111 and Tornado, designed to penetrate air defenses safe from interception at very low altitude.

5-4: AN/APG-65 radar F/A-18C

Modern pulse-Doppler radars like the APG-63, N019 and N001 employ stable, coherent oscillators that allow them to integrate multiple reflected signals to detect small variations in frequency. The Doppler effect causes the reflected signals from approaching and receding air targets to exhibit a frequency shift different from that of reflections bouncing off the earth. Pulse-Doppler radars thus feature "look-down/shoot-down" capability, able to detect, track and engage most air targets regardless of relative altitude. The appearance of the MiG-29 in Soviet forces led to a change in NATO doctrine away from low-altitude penetration and towards "stealth" and multirole fighters.

Pulse-Doppler radar thus depends on "closure" (i.e. target approach velocity) to discern low-altitude targets against the background of the earth. Aircraft on the defensive can often break a pulse-Doppler radar lock by a tactic called "beaming" or "flying the notch," which consists of flying on a trajectory perpendicular to the hostile radar beam. The defensive pilot observes the threat radar on the aircraft's radar warning receiver (RWR) display and flies to place that threat at the "three-" or "nine-o'clock" position. The defensive fighter is then flying neither towards nor away from the threat, and its closure is the same as that of the surrounding terrain in a look-down geometry, or any deployed chaff countermeasures in a look-up geometry.



5-5: AN/APG-70 radar F-15E

The rate of closure of the surrounding terrain effectively generates a primary "notch" in the radar's sensitivity, due to ground-reflected signals ("clutter") received along the axis of the main radar beam. Target signals in this "look down clutter notch" are rejected by filtering as if they were ground clutter, allowing beaming targets to break a radar lock. Antenna focusing is never perfect, however, and some transmitted energy also spills out in unintended directions called sidelobes. This energy can also be reflected from the ground, and re-enter the antenna from the sidelobe directions. If a fighter is flying at low altitude, signals reflected from the ground may enter the radar and appear on the scope as additional clutter, with a closure equal to the fighter's rate of climb or descent, and a range equal to the fighter's altitude. If the fighter is in pursuit against a fleeing target travelling at the same speed and range, the target signals may become lost in sidelobe clutter, breaking the lock. This can create a secondary "notch" in the fighter's radar sensitivity.

Sidelobe clutter is usually filtered out ("compensated") with the help of a small "guard" horn antenna. The guard antenna is designed to be more sensitive than the main antenna in sidelobe directions, but less sensitive along the axis of the main beam. Signals received on the main and guard channels are then compared and rejected as sidelobe clutter if they are stronger on the guard channel.

The guard horn is attached to the slotted array in flat-plate radar antennas like the APG-63 and scans together with it for good compensation in all scan directions. In Russian Cassegrain radars like the N019 and N001 however, the guard horn is not attached to the scanning reflector but is rather fixed and aimed in a downward direction. Banking the fighter at low altitude during a radar lock on a fleeing target can thus rotate the compensation horn away from the ground, degrade the sidelobe compensation and break the lock due to ground clutter. During normal scanning operation in search mode, the entire radar Cassegrain antenna housing is roll-stabilized on a rotating gimbal to keep it oriented with the horizon. In this mode, search targets can be lost from the scope if the fighter roll exceeds the limits of the rotating gimbal (110-120 degrees angle of bank). MiG-29 and Su-27 pilots thus need to make careful decisions about operating altitude during an engagement, since high altitudes reduce sidelobe clutter to maximize their radar performance, but also allow look-down targets to more easily break lock by notching. F-15C pilots enjoy fewer restrictions in radar performance, and might make such decisions based instead on the effect that altitude has on missile performance.

This is a table of some of the technical characteristics of modern Russian airborne radars.

Name		BRLS-8B	N-001	N-019	N-019M Topaz
Radar system		SUV "Zaslon"	SUV S-27	SUV S-29	SUV 29S
Aircraft		MiG-31	Su-27	MiG-29	MiG-29S
Antenna type		Phased array	Cassegrain	Cassegrain	Slot array antenna
Target detecting range at a high altitude, km.	Forward hemisphere	180...200	100	70	90
	Rear henisphere	60...80	40	40	40
	Target RCS, sq m	19	3	3	5
Tracking zone, degrees	Azimuth	±70	±60	±60	±70
	Elevation	-60 +70	±60	-45 +60	-40 +50
The number of simultaneously tracked targets		10	10	10	10
The number of simultaneously attacked targets		4	1	1	2
Transmitter average power, watt		2500	1000	1000	
Consumed energy, kilowatt		31			
Weight, kg					380
Reliability, hours to failure		55	100		

All modern combat aircraft are equipped with radar warning systems (RWS). An RWS identifies the azimuth and type of radar system that is radiating. Having identified the type of the radar system, it is generally safe to assume the type (or class) of the weapon system that is carrying the radar.

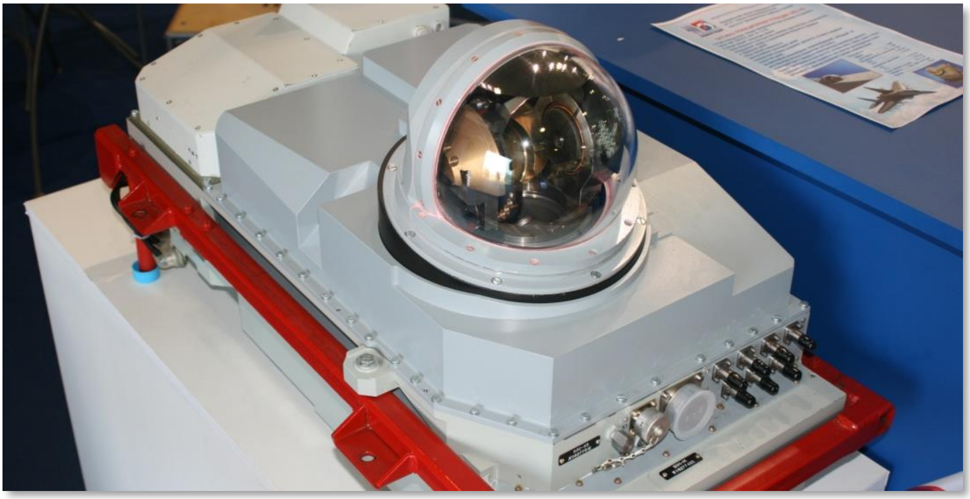
Modern radars can operate in a great variety of modes, with different pulse repetition frequencies (PRF) and different scan zones. PRF is the number of radar pulses per second. Changing the PRF is used to increase the radar's sensitivity when detecting targets flying at different aspect angles. High PRF is used to detect targets flying towards your aircraft (high aspect), medium PRF is used for targets with low closure rate or you are behind. In the default operation mode, the radar cycles between high and medium PRF to provide all target aspect detection. This is termed an interleaved mode. In search modes the radar operates in wide scan zones. In target track modes the radar operates with narrow azimuth zones. The radar changes to track mode after target lock on.

Many modern radars have a form of track while scan (TWS) mode. It provides simultaneous tracking of several targets. The main advantage of this mode is that it provides detailed information on a wide zone of the air space. However, no information is provided about targets outside of the scan zone. Target movements in this mode are often tracked through prediction. Although the scanning period is relatively short, high speed and maneuvering targets can perform a quick maneuver and leave the scan zone. On the radar display, the predicted trajectory of the target will be shown. The next update of the position is made only after a defined period of time and a track file has been built.

In track while scan mode there is detailed information on a great number of targets. However target position prediction in the time during the scan periods is used in this mode. The target can leave the survey zone by performing an unexpected maneuveur.

Infrared Search and Track (IRST), Electro-Optical targeting Systems (EOS)

Aircraft engines radiate heat that can be detected. This fact was used by weapon systems developers when working on infrared (IR) targeting systems. Early IR-systems detected jet aircraft only from the rear hemisphere where the engine nozzles are located. Modern, highly-sensitive systems detect IR-contrast from any aspect angle. Infrared search and track (IRST) systems are installed on many aircraft. Unlike radar systems, IRST systems are passive, i.e. will not alert the enemy. The enemy cannot detect aircraft tracking them with an IRST system and significantly increases the chances of a successful, stealthy attack.



5-6: Russian IRST (EOS)

Electro-optical systems are widely used on attack aircrafts and fighters. Various search and track systems that incorporate day television, low-level night television and infrared sensors enable aircraft to strike ground targets at any time. Like optical systems though, they can be ineffective due to foul weather, fog, smoke and dust.

Laser Rangefinder/Target Designator System

A laser rangefinder is intended to measure the distance between the aircraft and ground, naval or air targets. Measuring is performed with high accuracy but at a relatively short distance. Laser systems are often used to provide greater accuracy for air-to-ground missiles. The system provides enough accuracy to target tanks and other mobile ground units.

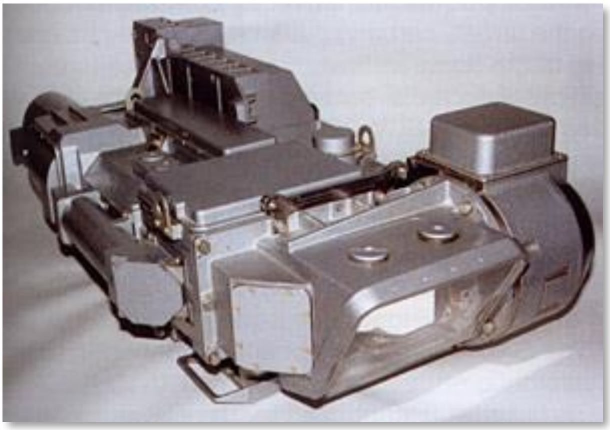
Laser systems are most effectively used in good meteorological conditions. Clouds, fog, rain and dust decrease their efficiency.

5-7: Su-25 laser rangefinder/target designator system "Klen-PS"

The Su-25 and Su-17M4 use the "Klen-PS" laser rangefinder/target designator.

Optical-Television Targeting System

The Su-25T is equipped with the SUV-25T "Voskhod" weapon control system. It is, intended for acquisition and automatic tracking of small, moving targets such as tanks, trucks, ships, etc. Gun and unguided rockets can also be used with the system. The system incorporates the day-night, "Shkval" automated targeting system. The I-251 is positioned in the nose of the aircraft and includes a television monitor connected to an automated target tracking gate and laser rangefinder/target designator. It also provides the pilot valuable information such as the information display system (IDS), central digital computer, attitude and heading reference system (AHRS), velocity and Doppler measurement set, radar altimeter, short-range and long-range navigation systems. For operations at night, the "Mercury" low-light level television system is installed under the aircraft's fuselage



5-8: Optical-Television Targeting System I-251 "Shkval"

6

AIR-TO-AIR MISSILES

AIR-TO-AIR MISSILES

All modern fighters, and most attack aircraft, are equipped with air-to-air missiles (AAM). Though possessing significant advantages over cannons, they have many operational limitations. For the successful launch of any missile, one has to strictly follow defined sequences. There are unique, pre-launch steps for each type of a missile.

AAMs are a collection of integrated components that consist of the seeker, the warhead, and the motor. Motor burn can only last for a limited amount of time. This usually ranges from 2 to 20 seconds, depending on the missile type.

At launch, the missile accelerates to its maximum flight speed. After the motor is depleted, the missile consumes the energy acquired in the acceleration. The higher the initial airspeed at the moment of the missile launch, the greater the airspeed of the missile and the longer its launch range will be. An increase in launch aircraft speed corresponds to a longer missile range.

The missile launch range, or missile employment zone (MEZ), is greatly influenced by the aircraft's altitude at the moment of missile launch. This is due to the much denser air at lower altitude. If the flight altitude is increased by 20,000 feet, the maximum launch range is about doubled. For example, the AIM-120's launch range at of 20,000 feet is twice as great as when launched at sea level. When attacking a target higher or lower than one's aircraft, the maximum missile launch range is equivalent to the maximum launch range of the average altitude between the two aircraft.

> TO INCREASE A MISSILE'S MAXIMUM LAUNCH RANGE, YOU SHOULD LAUNCH FROM HIGH ALTITUDES

Target aspect angle can also greatly influences a missile's MEZ. The launch range increases when you and the target are flying towards each other. This is termed a high aspect engagement. When you attempt to attack a target from behind, the target is flying away from you and greatly reduces a missile's MEZ. This is termed a low aspect engagement. To increase the range of your attacks, attempt high aspect intercepts.

> YOU SHOULD TRY TO ATTACK ONCOMING TARGETS. THIS WILL INCREASE YOUR MISSILE LAUNCH RANGE.

Missiles fly according to the same physical laws as aircraft. When maneuvering, the missile consumes energy when it pulls G. A maneuvering target can make the missile make significant course corrections and thereby consume the missile's energy. This can lead to the missile being incapable of continuing the intercept.

> AT LONG RANGES. SLOW MANEUVERING TARGETS ARE MORE EASILY HIT.

Air-to-air missiles are intended to destroy aircraft. They are divided into several classes, according to their range and guidance principles. According to the range:

- Short range missiles. Less than 15 km. (R-73, R-60, AIM-9 and others)
- Medium range missiles. From 15 km up to 75 km. (R-27, R-77, AIM-7, AIM-120, and others)
- Long range missiles. Over 75 km. (R-33, AIM-54, and others)

These missiles use a variety of guidance systems:

- Passive infrared. Infrared target seeker (R-60, R-73, R-27T, AIM-9)
- Passive radar. Radar emitter targeting, is usually combined with semi-active or active targeting. It is a targeting mode modern missiles such as AIM-7M, AIM-120, and R-27R can use. This is sometimes referred to as Home On Jam (HOJ) mode.
- Semi-Active Radar Homing (SARH). Such seekers home in on the reflected radar energy from the launch aircraft's continuous wave radar. (R-27R/ER, AIM-7, R-33)
- Active Radar Homing (ARH). Active systems have their own radar seekers built into the missile. (R-77, AIM-120, AIM-54)

Medium and long range missiles are often fitted with an inertial navigation systems (INS) and a command-guidance transmitter/receiver (data link). This enables such systems to be launched towards a target's position that is further than the supporting radar can lock and illuminate.

Passive radar and infrared homing systems do not radiate an active signal. Instead, they guide to the target by locking on to the target's radar or infrared emissions. These are "fire-and-forget" missiles, i.e. they are fully automated after launch.

Semi-active missiles home in on the reflected radar energy of a target. For such missiles, it is necessary that the supporting aircraft retain radar lock until the missile hits the target. This can often lead to "jousting" of SARH armed aircraft.

Active missiles at long ranges have the same features as semi-active systems; i. e. the launch aircraft must track the target and provide guidance to the missile. Once the missile is within 10 to 20 km of the target, the onboard radar seeker activates and continues the intercept without need of support from the launch aircraft's radar. Such systems have only recently been introduced into service.

AAMs fly according to the same aerodynamics laws as aircraft. They are affected by the same gravitational and drag force that affect aircraft. For a missile to fly, it must also generate lift forces. Due to the small size of AAM wings though, lift is generally generated by speed rather than wing form.

After launch, the missile is accelerated by its motor. This is generally a solid propellant motor that operates from 2 to 15 seconds. During this period, the missile accelerates up to Mach 2 -3 and then continues flight based on the stored kinetic energy to overcome drag and gravity. As airspeed decreases, it becomes increasingly difficult for the missile to maneuver due to the decreased efficiency of its control surfaces. When the missile's speed falls below 1,000 – 800 km/h, it becomes almost uncontrollable and will continue to fly ballisticly until it hits the ground or self destructs.

Maximum missile launch range is not a constant value; it depends on a number of variables: initial median flight altitudes, combined air speeds, and target aspect angle. To attain a missile's maximum launch range, it is best to launch at high altitude, at high airspeed, in a high aspect intercept. Note that launch range does not necessarily equate to missile flight range. For example, in a high aspect encounter where the missile is launched at 50 km, the missile will only travel about 30-35 km. This is because the target is flying towards the missile. Near ground level where the air density is very high, the launch range is more than halved.

When attacking an enemy from the rear, the launch range significantly decreases because the missile has to catch up with a target that is flying away. Rear hemisphere, low aspect, launch ranges are usually two to three times less than high aspect launch ranges. For example, these are the launch ranges of the R-27ER at different aspects and altitudes:

- Maximum forward hemisphere launch range at the altitude of 10 000 m. – 66 km.
- Maximum forward hemisphere launch range at the altitude of 1000 m. – 28 km.
- Maximum rear hemisphere launch range at the altitude of 1000 m. – 10 km.

Maximum launch range is calculated with the assumption that the target will not take any maneuvers after missile launch. If the target begins to maneuver, the missile will also need to maneuver and quickly lose energy. This is why it is more practical to use a different gauge of maximum range – maximum launch range that takes into account target maneuverability (Rpi in western terminology). The weapon control system constantly calculates the maximum launch range to a non-maneuvering target, as well as the Rpi. Rpi is at a much shorter range than the maximum launch range but ensures a much higher probability of kill. In game, these ranges are indicated on the HUD and HDD/VSD.

Missiles Operated by the Russian Air Force

Long Range Missiles

R-33

The R-33's appearance is widely associated with the visually similar American AIM-54 Phoenix. Moreover, the diameter of the missiles is the same down to the millimeter. Knowing the history of K-13 missile development, one could assume that this is another example of a successful copy of a foreign weapon. However, the R-33 is of purely Russian development, the resemblance to the AIM-54 is quite natural, taking into account the similar requirements for flight performance and technical characteristics.

The missile's development had begun before work on the P-40 and MiG-25P weapon systems were complete.

In accordance with a resolution dated May 24, 1968, it was decided to develop the E-155МП aircraft, which was a modernized version of the MiG-25 fighter. This would become the MiG-31. The MiG-31 was to be equipped with the new "Zaslon" radar. Missiles were to be developed with a maximum launch range of at least 120 km. A contest was organized that would pit offerings from "Vympel" chief designer A. Lyapin's K-33 missile against PKPK chief designer M. Bisnovat's K-50 missile. The "Vympel" entry was chosen. The K-33 designation continued the tradition of the earlier achievements of this design group – the K-13 and K-23. The development was headed by deputy chief designer V. Zhuravlev and later – deputy chief designer Y. Zakharov.

6-1: R-33 missile

Initially, a "canard" scheme was approved for the missile. It was planned to position the missile on the pylons under the wing, as was done for the K-40 on the MiG-25. Later however, the designers changed the design to the more "traditional" aerodynamic scheme. This provided better aerodynamic qualities, which is very important for a long-range missile. Development was carried out in close cooperation with the Mikoyan designer bureau. To decrease aerodynamic resistance when suspended beneath the aircraft and to reduce skin friction heating, it was decided to semi-recess the missiles into the fuselage. To provide a sufficient number of missiles, it was planned to position four missiles, in pairs, along the aircraft's fuselage. Such a scheme imposed strict limitations on the missile length. This resulted in an unusually short missile body. Another factor contributing to such an arrangement was the desire to include a semi-active radar homing seeker with a large diameter antenna. Based on the K-33 semi-recessed position under fuselage, the two upper sections of the missile's control surfaces would be folded. This decreased the wing span from 1100 mm to 900 mm. With a recessed carry, a catapult launch system would have to be used.

It should be noted that in the course of development, different K-33 variants were considered: a semi-active radar seeker, an active radar seeker, an infrared seeker, and a combination infrared semi active radar seeker. However, due to technical, tactical and economic reasons, the missile development was focused on the semi active radar variant.

Unlike a mechanically scanned antenna, like that of the AWG-9 radar for the F-14A, the radar installed in the MiG-31 would be a phased array antenna build by "Zaslon." Such a radar provides very rapid steering of the beam in addition to simultaneous targeting several missiles using semi-active seekers. This allows the radar to engage multiple targets without the need for missiles with active radar homing seekers. This allowed the P-33 to be less expensive than the AIM-54 by using less expensive equipment.

The first third of the P-33's flight is accomplished with a gyro stabilized navigation system that uses an angle speed sensor.

Besides the new operational characteristics, the R-33 differed from R-40 by its passive heat-protection system. During the course of development, and more experience with MiG-25 operations, more data was gathered regarding true altitude and speed profiles that missiles are exposed to. As a result, the R-33 designers decided not include a coolant system; this would have only complicated missile carry and construction.

In accordance with classic missile layout, the missile consists of four sections that are connected by clamps. The first section of the missiles contains a semi-active radar homing seeker, a contact warhead, and a radio proximity fuse. The second section consists of the autopilot systems, and a blast-fragmentation warhead with safety-and-arming device. The third section includes a single-compartment, dual-mode solid propellant motor with a prolonged gas-passage and nozzle cluster.

The fourth section is grouped around the motor and contains gas generators, a turbo generator with a control block and hot gas-operated servo units.

In the course of flight tests from 1975 to 1980, tail control surface construction was worked out and removed all aerodynamic flutter. The designers also developed the missile's control system, seeker jamming protection, control systems and radio proximity fuse when operating at low altitudes. The first target aircraft (a MiG-17 drone) was shot down on March 26, 1976. Prior to this, only PRM-2 parachute targets had been used in live-fire tests.

The P-33 went operational as part of the MiG-31-33 weapon system on May 6, 1981 under the name of R-33. It then entered serial production at the Dolgoprudny machinery plant. This same plant had already worked with "Vympel" on "Kub" SAM missile production. In western countries, the R-33 is known as the AA-9 Amos.

Medium Range Missiles

R-40

K-40 missile development began after the transition from single-engine, heavy fighters of the E-150 family, armed with K-9 and K-8 missiles, to twin-engine MiG-25 S-155 interceptor and E-55P reconnaissance variants. This followed Resolution 131-62 dated February 5, 1962. This government document also defined the terms of when the systems had to be introduced for joint state tests – the end of 1964. The development of the interceptor missile system was assigned to the OKB–4 design bureau, headed by M. Bysnovat. The semi-active radar seeker was developed by research institute №648; the infrared seeker was developed by central design bureau TZKB-589; the autopilot was developed by design bureau OKB-3; the combined radio-optical explosive device was developed by research institute №571; and the solid propellant motor was developed by design bureau KB-2 of plant №81.

The aircraft's weight was increased twice, which allowed for missile whose weight and dimensional characteristics were close to MiG-25P with R-40T and R-40R missiles. Simultaneous to this, the K-80 missile for Tu-128-80 was being developed. It was planned to use the "Smerch-A" radar on E-155P. This radar was developed on the base of "Smerch" radar installed in the Tu-128-80.

However, complications arose when a new design element was introduced. The S-155 interceptor was intended for a flight lasting over 10 minutes at speeds almost twice the speed of sound. The components of both aircraft and missile positioned the missile on the outer under-wing suspensions. At high Mach speeds, this area could heat up to 300 degrees Celsius. Aside the problems connected with material heating, it was necessary to solve the problems of equipment efficiency and to avoid fuel load heating. Stable engine internal ballistic parameters could only be achieved in a relatively narrow temperature range. It was vital to provide satisfactory dynamic parameters in a wide flight and altitude range.

Consequently, the development had to start from scratch with virtually no commonality with the K-80. In 1962, a conceptual model of the K-40 missile was released ("production 46"). It presented in two layout variants. As development continued, a canard scheme was selected, rather than the standard scheme as used with the K-80. The motor was positioned in the central portion of the missile, which provided it a narrower, dynamic parameter range of missile control. A large wing-area provided the missile better capacity at altitude and contributed to decreasing synchronous errors influence. The primary section of the missile's avionics was positioned in the forward section; the warhead and the on-board electric power supply source were positioned in the rear part. For the first time, a narrow, blast directed explosive was realized for KU-46 warhead. To ensure accurate warhead detonation, a command and jam-resistant fuse was combined with the "Aist-M" radio-optical explosive fuse.

In accordance with the approved scheme for the PRD-134, the engine was double-nozzled. For the first time in the history of Russian-made "air-to-air" missiles, high-energy metal-infused fuel was used. To protect from heating, the titanium body was covered by outer thermal blankets.

To keep temperatures within operational limits, a special freon cooling system that is powered from a container positioned on the launcher, was used. This is in addition to covering some compartment surfaces with thermal blanket. High temperatures entailed use of glass-ceramic materials in the radar seeker TSD nose cone. The same design was used for the optical ceramics in T-40A1 infrared seeker.

6-2: R-40T missile

The development of the R-40T was slowed due to the adoption of a number of changes at the beginning of the project. To start with, a government Resolution dated May 25, 1964 included the design bureau OKB–3 (the autopilot developer) into the "Chelomey Empire" – design bureau OKB-52. Vladimir Nikolaevich was known for being a great project manager and uniting staff of outside organizations to solve assigned tasks. The autopilot development for K-40 missile was transferred to plant №118. Soon afterwards, radar seeker development was transferred from research institute №648 to radar "Smerch-A" developer, institute №131. In this institute, a group of designers headed by E. Genishta carried on developing the K-40 seeker missile. Missile development slowed. Project managers even considered the possibility of starting S-155 flight tests with equipment on based on the K-80, developed for Tu-128. Work began on improving the "Smerch-A" radar and K-80 on the E-152 family of aircraft. However, even work on other parts of the project we late in development and it was clear that the original project terms would not be met.

A number of new technical solutions were applied in the first Russian-made mono-pulse semi-active radar guided seeker, PARG-12. This was developed by chief designer E. Genishta. One of these solutions was to form a four main lobe antenna pattern with the angle of diversion up to 70 degrees. A Cassegrainian antenna was used for this. In the seeker they used a computer on the base of sine-cosine rotating transformer, range-finder with two integrators, original schemes of microwave oscillator and receiver with logarithmic characteristic excluding the threat of "jamming" at high jamming power delta. Special measures designed to increase anti-countermeasures protection were taken and included in the infrared seeker.

Development of the "Smerch-A" on-board radar and missile equipment was carried out with the use of a flying laboratory – a modified Tu-104 42736.

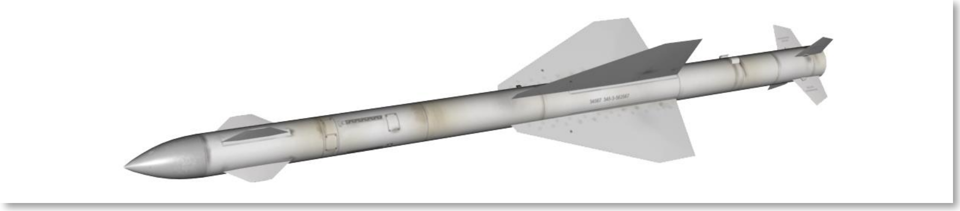
The first flight of MiG-25 with the reconnaissance modification took place on March 15, 1965. The first interceptor variant flew on October 26, 1965. The third interceptor prototype was fully equipped with radar and started flight tests on April 16, 1967. Weapon tests were carried out at the Vladimirovka Air Force facility from August 1968 to February 1970. A resolution dated February 12, 1971 confirmed the acceptance of the weapon system into operation under the name of MiG-25-40. The radar was named RP-SA and the missile, R-40.

6-3: R-40R missile

R-40 serial production took place at the Kiev "Named after Artem" plant. In the early 1970s, a Soviet documentary film of modern military equipment was shown in public. Some shots taken from the film show the MiG-25P with missiles. These same images were reproduced in western periodicals and the R-40 has henceforth been termed the AA-6 Acrid in the west.

R-24

During the course of K-23 development, new guidance systems were developed that could significantly increase launch ranges. In fact, a trajectory target locking system was developed for the K-23 missile. However, due to targeting errors characteristic of aircraft radar systems, the actual launch ranges were only slightly greater than the target distance at target lock ranges. It could at closer ranges, but in this case, the missile's autonomous control had to be set during the previous phase. In this case, the launch range was represented as a sum of the autonomous flight phase distance and maximum target lock on distance of the seeker in tracking mode that would determine engagement ranges. The radar's illumination power and seeker sensitivity would also affect this.



6-4: R-24R missile

Along with the R-23 going operational with the MiG-23M, a resolution dated January 9, 1974 provided for further aircraft weapon development by "Vympel" under the supervision of Pustovoitov. In 1975, a draft design of the enhanced K-24 missile variant was released. The missile was equipped with a new semi-active seeker with increased jamming resistance and lock on range, RGS-24 (9B-1022). Moreover, the autonomous flight time was increased up to 10 seconds due to the implementation of a so called "pseudo-kinematic link" with an analogue calculating unit. Disregarding aiming errors, it enabled it to hit targets positioned 30% further than the maximum seeker target lock on range. For autonomous guidance, kinematic acceleration integration is carried out that provides inertial control during this phase of flight. .For the first time they ensured that hovering helicopter and aircraft at low altitude could be engaged in close groups. The engineers increased kill probability maneuvering and low-flying targets while increasing protection against combined and spaced diversity jamming.

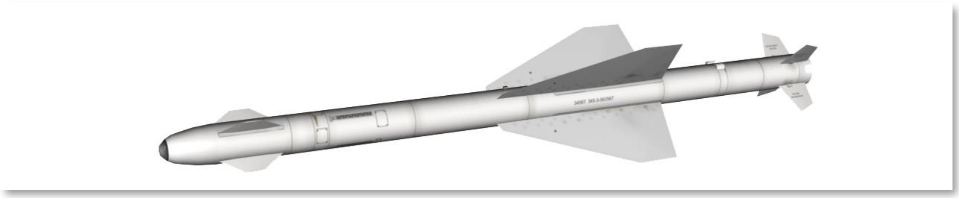
The initial intention to create only a new "Topaz-M", but that was not to be. To achieve maximum efficiency they applied a new warhead, a more powerful engine and significantly altered the missile layout.

The most noticeable difference in appearance from the previous missile was the introduction of swept-forward wings on the trailing edge. The internal layout was also changed, the number of sections decreased from eight to five. The first section was used for the seeker. The second section contained a radio proximity fuse "Skvorets", autopilot and a turbo generator that operated from a special powder pressure accumulator. The third section contained an expanding rod-type warhead with blast radius of 10 m and a safety-and-aiming device. A solid propellant motor, PRD-287, formed the forth section. The fifth section contained a gas generator block that provided the power supply for control surfaces actuators.

An infrared-guided variant of the R-24 ("production 160") was also developed. This variant uses a modified TGS-23T4 seeker.

The R-24 is fitted to a modified APU-23M launcher.

The maximum launch range: 50 km – R-24R, 35 km – R-24T. G: 5-8 g. Target altitude envelope: 0.04-25 km.



6-5: R-24T missile

R-24 development and flight tests were performed ahead of time, but further operational developments delayed the formal approval of the missile to be authorized for the MiG-23ML and MiG-23P until 1981.

In 1982, The R-24 was successfully used on the MiG-23ML in the armed conflict in Southern Lebanon. According to Syrian, official statements, MiG-23ML fighters managed to shoot down three F-15C and one F-4E aircraft. This has never been confirmed however and other information contradicts this.

More recently, the R-24 was modernized with a seeker with improved jamming resistance. This is termed the R-24M.

An important event connected with the history, development and operation of the R-23/R-24 family of missiles was the rapid development of new radar and missile equipment for the MiG-25 after a famous episode with Russian pilot Belenko that defected and landed in Japan. As a result, Russian air defense interceptors were soon re-equipped with "Sapfir-25" (RP-25) seekers that were developed on

"Sapfir-23". They also re-equipped with the R-40D with the RGS-25 radar seeker, unified with RGS-24.

On the whole, K-24 missile development became an important milestone in the history of Russian missile production. Due to implementation of the original operational scheme, the designers managed to achieve superiority in maximum launch range over the American analogue, AIM-7F.

R-27

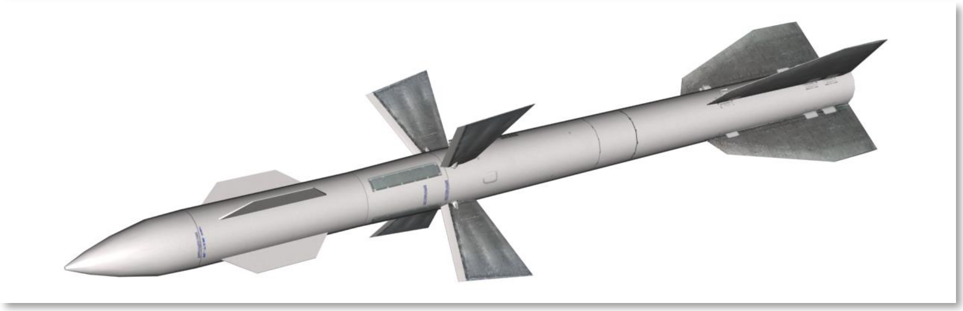
The R-27 medium range missile family is intended for the interception and destruction of all types of aircraft, helicopters, unmanned aerial vehicles (UAV) and cruise missiles. The missiles can be employed in medium and long range air combat independently or as part of a group of aircraft at day or night. The R-27 is effective in all meteorological conditions and is very capable against low flying and maneuvering targets.

The R-27 is manufactured in several variants that differ according to their seekers – semi-active radar or infrared – and two types of propulsion systems – standard and extended. The variants with the semi-active radar homing seeker are termed the R-27R and the R-27ER. Variants with the infrared seeker are termed the R-27T and R-27ET. Both the R-27ER and R-27ET have the extended, longer-burning motors.

The primary material of the missile body is a titanium alloy, and the engine body is made mostly of steel.

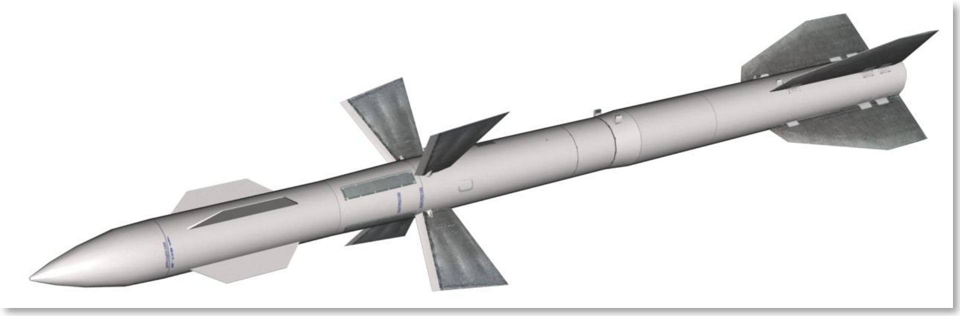
The same rail and ejector launchers are used for both size variants of the R-27, the standard and extended range. The APU-470 rail launcher is intended for missiles loaded under the wings and the AKU-470 catapult device is used for missiles loaded underneath the fuselage or wings.

In addition to the seekers, the missile control system also includes an inertial navigation system with radio correction. The all-aspect R-27 attacks the target at its any initial position within a 50 degree gimbal limit for the semi-active radar seeker and 55 degrees for infrared. Maximum aircraft G loading at the launch can be up to five units. The R-27 can intercept targets flying at speeds up to 3500 km/h and altitudes from 20 m to 27 km. Maximum target and launch aircraft altitude difference can be up to 10 km. Maximum target G is eight. The combined launch of R-27 missiles with different seeker variants increases the resistance to target counter measures. The R-27 family of missiles was developed by the Vympel design bureau and went into operational service between 1987 and 1990. Today, all versions of the MiG-29 and Su-27 fighters are equipped with these missiles.



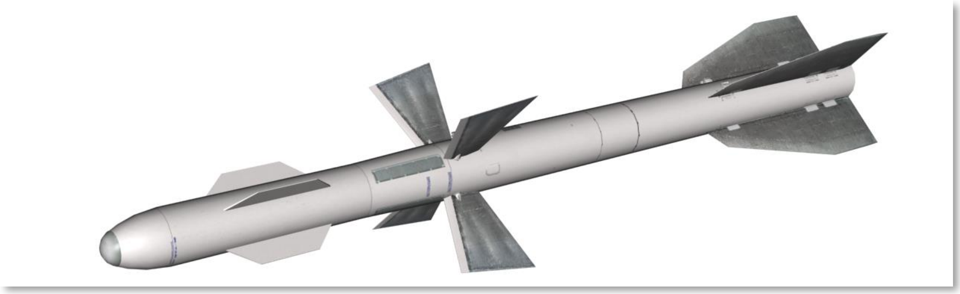
6-6: R-27R missile

R-27R. "Product 470R" (AA-10A Alamo) is a radar-guided, medium-range "air-to-air" missile that went into operational service in 1987. The missile has inertial navigation guidance system with radio correction. For terminal guidance, the R-27R has a semi-active radar seeker. The maximum launch range is 30-35 km. The maximum target speed is 3600 km/h, the maximum target G is eight, and the initial weight of the R-27R is 253 kg. It has a length of 4 m, a maximum body diameter of 0.23 m, and a wing span of 0.77 m. The cruciform control surfaces span 0.97 m and the expanding rod warhead weighs 39 kg.



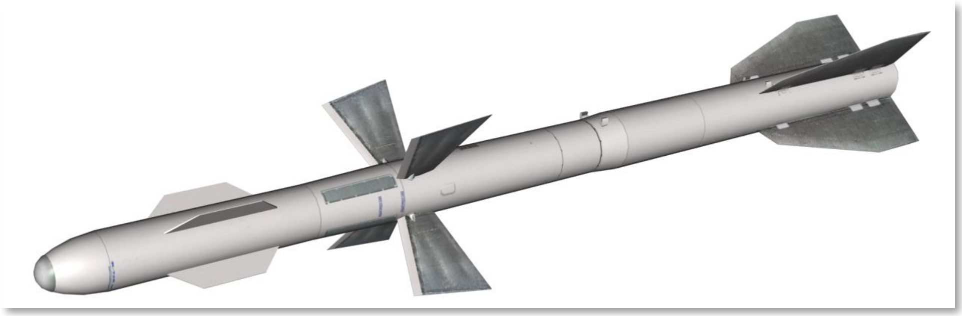
6-7: R-27ER missile

R-27ER. "Product 470ER" (AA-10C Alamo) is a radar-guided, medium-range missile that is a modification of the R-27R with a larger motor. The missile has inertial navigation guidance system with radio correction. For terminal guidance, the R-27ER has a semi-active radar seeker. The maximum, effective launch range is 66 km. The maximum target altitude is 27 km. The R-27ER's initial weight is 350 kg; the length is 4.78 m; the maximum body diameter is 0.26 m; and the wing span is 0.8 m. The control surfaces span 0.97 m. The expanding-rod warhead weighs 39 kg. The Su-27 and its variants can be equipped with this missile.



6-8: R-27T missile

R-27T. "Product 470T" (AA-10B Alamo) is a medium range "air-to-air" missile and became operational in 1983. This version of the R-27 uses an infrared seeker. The R-27T must have infrared seeker lock on the target before launch. The maximum, effective launch range is 30 km and can engage targets up to 24 km in altitude. The launching weight is 254 kg; missile length is 3.7 m; and maximum body diameter is 0.23 m. The wing span is 0.8 m. The expanding-rod warhead weighs 39 kg. Su-27, MiG-29 and their variants can be equipped with this missile.



6-9: R-27ET missile

R-27ET. "Product 470ET" (AA-10D Alamo) is a medium range "air-to-air" missile and became operational in 1990. This version of the R-27 uses an infrared seeker. The R-27T must have infrared seeker lock on the target before launch. Like the R-27ER, the R-27ET also has a larger motor that provides it greater range. The maximum launch range is 60 km (on the condition of the target lock on with the infrared seeker). The maximum target altitude is 27 km. The R-27ET's weight is 343 kg. The missile's length is 4.5 m. The maximum body diameter is 0.26 m. The wing span is 0.8 m. The expanding-rod warhead weighs 39 kg. The Su-27 and its variants can be equipped with this missile.

R-77

The development missiles for fourth-generation Russian fighters was completed with the introduction of the MiG-29 and Su-27. By this time, the technical outlines of fifth-generation Russian fighters was being defined. Just as important, the United States began practical implementation of a new medium-range missile with an active radar seeker, the AMRAAM (AIM-120A) development program.

The R-27 design was perfected with the implementation of a "canard" scheme that required no aileron control surfaces. Instead, this was achieved with the large rudder span. As a result, it was difficult to position a significant number of weapons in internal carriage. Internal carriage was preferable due to the reduced radar cross section that was to be a feature of Russian fifth-generation fighters. The AMRAAM turned out to be more compact than and twice as light as the R-27ET. The new American missile even weighed one-third less than AIM-7M.

Therefore, from the beginning of the 1980s, the Soviet Union began designing a medium-range missile weighing no more than 160-165 kg and equipped with an active radar seeker. The missile also had to be compatible with new radar being developed for Su-27M and MiG-29M. This new Soviet missile, afterwards shown at numerous exhibitions as the RVV-AE, was very different than AMRAAM because of its lattice tail control surfaces. This was the first use of such surfaces in an "air-to-air" missile.

R-77, also known as the RVV-AE, development was carried out by the united group of designers that included "Vympel" and "Molniya", headed by G.Sokolovsky under direct supervision of V.Pustovoitov. The work was completed under the supervision of V.Bogatskiy, who is now a chief designer.

Instead of traditional use of triangular wings, they introduced short, tapered wings – "strakes". Such a wing-type was applied earlier to American naval surface-to-air missile systems, starting with "Tartar". The RVV-AE's unique feature as an air-to-air" missile was its folding lattice tail control surfaces. In the folded position they do not go beyond the missile's lateral dimension defined by the wing span. Along with a light weight and a relatively short length, it provides the ability to load a great number of these missiles underneath the fuselage of a fighter aircraft. Moreover, due to the small chord of the tail fins, the hinge moment is short and is only slightly dependent on flight speed, altitude and angle of attack. The required moment does not exceed 1.5 kGm. This allows the R-77 to use small-sized and light weight, electrical actuators to move the control surfaces. The control surfaces are aerodynamically efficient at angle-of-attacks up to 40 degrees, and they possess high rigidity that assists the control parameters. Naturally, there are also some shortcomings of lattice control surfaces – a greater aerodynamic drag and increased cross-section efficiency. Nevertheless, it is compensated for when in its folded position in recessed fuselage weapon stations.

6-10: R-77 (RVV-AE) missile

The missile development under strict weight guidelines and required the unconditional fitting of sub-units, components, and systems into the planned dimensions of the fuselage. This resulted in the implementation of a unique design plan. The so-called "directive" missile engineering draft was submitted for approval to not only the primary manufacturers, but it was personally approved by the Minister for Aviation Industry.

The R-77 construction includes five sections, each connected by wedge-type clamps. The first section includes the active-radar seeker; the second section contains an active laser fuse with adjustable parameters according to target size; contact pickups; and an autopilot. The third section contains an expanding-rod warhead with a safety-and-fusing device. When the warhead detonates, a solid ring of rods with micro-cumulative elements is formed. The blast radius is seven m. The fourth section is formed by a single-mode solid propellant motor. The tail section contains a heating electrical battery in front of the control surfaces actuators block.

The missile is delivered fully assembled and can be launched from the APU-170 and AKU-170 rails. Starting in May 1984, the R-77 was tested as a part of MiG-29C weapon system. In 1984, the new missile went into serial production. State tests were completed in 1991, and on February 23, 1994, the R-77 was made officially operational.

The maximum, effective launch range against bomber-sized targets at a high altitude is 50 km; for fighter-sized targets, the range is reduced to 45 km. The minimum launch range is 300 m. The launch weight is 177 kg. The warhead weight is 21 kg. The missile length is 3.6 m. The maximum body diameter is 0.2 m. The wing span is 0.4 m. The control surfaces span is 0.7 m. The maximum flight speed is Mach 4. The maximum target speed is 3500 km/h. Target altitudes can range between

20 m and 25 km. The maximum G is 12. MiG-29C, Su-30, Su-35 fighters are equipped with this missile system.

In the 1990s, the R-77 was repeatedly shown at international exhibitions. In western countries, the R-77 is known as the AA-12 Adder.

Short Range Missiles

R-60

In scenarios of intense aerial battles using beyond visual range engagements, the task of Identification of Friend or Foe (IFF) became almost unsolvable. Reliable, visual identification could be performed at several kilometers, but more often, identification is only made at a distance less than the launch zone of the American AIM-7 "Sparrow" medium range missile.

Even western and eastern missiles – American AIM-9B "Sidewinder" and the Soviet K-13A -- turned out to be ineffective in the high-G, air combat maneuvering (dogfight). The stringent launch G limitations of these missiles of about two units did not allow pilots to fully use their fighter's maneuvering capabilities. Even after launch, these early missiles maneuvered poorly and could not hit maneuverable targets. For most such missiles, the acceptable launch cone was limited by the target rear hemisphere.

For short-range missiles, it is necessary to include an autopilot that adjusts to in-flight parameters. The process of locking a target with the K-13 missile infrared seeker was rather time-consuming process and the angles at which a target could be locked were small. This required exception flying skills to attain a lock and keep it. During the Vietnamese war, these faults in early missiles led to the early deaths of the pilots deprived of a gun in the MiG-21PF and F-4C family of "pure missile-carriers".

As a result, the USA, the USSR and in France near simultaneously conceived of a new, small-sized missile in the late 1960s. Such a missile was intended for close air combat. They were not to have long launch ranges, and this allowed small weight and size. Given their launch envelope and the possibility to attack multiple target with a pass, the new missiles were closer to the traditional gun rather than their predecessors, from a tactical point of view. In the USSR, a great contribution to the development of close air combat missile conception was made by the scientists of the Minaviaprom scientific-research institute №2, R.Kuzminskiy and V.Levitin in particular.

Also in the late 1960s, a rather small anti-aircraft missile, 9M31, had been developed for the self-propelled, surface-to-air (SAM) "Strela-1" system. This missile was 1.5 times shorter than the K-13A and almost three times as light. This was largely due to the light warhead (4 times lighter). The new, close combat "air-to-air" K-60 missile was planned to perform as the 9M31 as a basis.

However, a number of 9M31 qualities did not meet the requirements of an effective aviation weapon. The 9M31 was equipped with a photo-contrast target seeker that can be only be successfully used against targets with no back ground clutter. Besides, close air combat made aiming by the missile body axis very difficult. In such conditions, the missile was to be aimed in accordance with target designation from the weapon control systems. The 9M31 engine's limited engagement of targets up to trans-sonic speeds.

It is important to note that K-60 development was entrusted not to 9M31 missile designers of the Minoboronprom design bureau headed by A.Nedelman, but rather to the Minaviaprom PKPK (former design bureau OKB-4). Along with chief designer M.Bysnovaty and his first deputy V.Elagin, the development was headed by A.Kegeles, G.Smolsky and I.Karabanov. As a consequence, and contrary to the original plan, the only thing the K-60 inherited from "Strela-1" was the caliber – 120 mm and warhead size. The K-60 launch weight is 1.5 that of the 9M31.

When reviewing the primary technical solutions for K-60 missile, its developers, who had been successful at designing relatively large medium and long range missiles such as the K-8 and K-80, could not help considering their colleague's experience in developing the K-13 family missiles. However, the K-60 had a number of fundamental differences from missiles produced by "Vympel".

6-11: R-60M missile

Like in K-13, the first section of K-60 was an infrared seeker. Kiev "Arsenal" design bureau designers headed by S.Alekseenko developed a target seeker device termed "Komar" (OGS-60TI) with a low-inertial gyrostabilizer that enabled it to detect targets up to 12 degrees off bore sight. To increase control surface efficiency at high angles-of-attack and to straighten oncoming air flow, they applied small de-stabilizers fixed on the seeker's outer body.

The small warhead capacity defined a number of layout solutions. A proximity-fused warhead provided target damaging within a 2.5 m blast radius; however, a direct hit was necessary to ensure target destruction. The heaviest damage was caused when the warhead penetrated the skin of the target. Therefore, the expanding-rod warhead of the K-60 was moved as far forward as possible, to the second section behind the target seeker. With its light weight and relatively large caliber, the warhead was made with a large internal channel. In the third section, the safety-and-fusing mechanism, the actuators, autopilot are located. The autopilot was particularly important to meet the more strict requirements for maneuverability as compared with K-13. On the outer surface of this section are the aerodynamic control surfaces. In the fourth section, the radio proximity fuse is installed next to its power source – two electro-generators operated from a turbine that is actuated by combustion of a pressure accumulator.

The fifth section contains a solid propellant PRD-259 engine with a time-altering thrust diagram. On the engine body, swept, triangular wings are affixed. The small wing length provides a sufficient area for maneuverability and is compact enough for loading on an aircraft in large numbers. Along the wing's trailing edge, rollerons are installed.

The K-60 ("product 62") was developed in an extremely short time. In 1971, full-scale tests began – the missile was launched from the ground launcher at a heat source positioned on a tower. Soon afterwards, tests on a MiG-21 began. On December 1973, which is two years before the French "Magic" missile, K-60, under the name R-60, became operational.

After the appearance of Soviet client state MiG-23s loaded with R-60, the new Soviet missile got a codename, AA-8 Aphid.

The R-60 can be used to engage targets out to 7.2 km. Such distances can only be attained when launched at an altitude above 12 km. Near the ground, the distance is one third that. The missile can be launched with the aircraft performing up to seven G. The infrared seeker has a detection angle limit of 5°; after locking on, the seeker can track a target to the seeker's gimbal limits of 30-35 degrees.

The missile can engage targets that are maneuvering with an eight G. By using two missiles, salvo attack, a 0.7-0.8 of success is estimated.

Taking into account the missile's small size and weight, several launchers have been developed for three, two or one missiles. PU-62-I is a single rail and PU-62-II has two rails. The PU-62-II has a right and left wing version.

The R-60's good performance has led to it being fielded with many types of Russian combat aircraft: MiG-21, MiG-23, MiG-27, MiG-29, MiG-25 and MiG-31, Su-15, and Su-17. As a defensive weapon, it is also used on the Su-24 and Su-25. The modified APU-60-I and APU-60-II launchers also contributed to this (APU-60-II enables to suspend two missiles at the same time). They can be positioned on ordinary weapons stations and have mechanical locks and a sole electrical connector point to transmit interface commands to the missile. The R-60 export variant is termed the R-60K. The R-60's good qualities were confirmed in combat between Syrian and Israeli aircraft over Lebanon in 1982. Several Israeli aircraft took R-60 hits to their engine nozzles.

Almost simultaneously with the K-60 entering operational service, work on the R-60 modernization program began. The enhanced seeker – "Komar-M" (OGS-75) was installed on R-60M variant. Gimbal limits were increased to 17° and provided possibility to engage a target from its forward hemisphere due to IR seeker IR cooling. The warhead weight was increased 17% due to the use of more efficient warhead sub-elements. Consequently, the missile's weight also increased and its length increased 43 mm. The minimum launching range was reduced by one third and the maximum engagement range was increased by 500 m.

The R-60 and R-60M have been widely used on fighters for the past 30 years. More recently, they have been used as a "secondary weapon" combined with more powerful, longer ranged systems. When loaded on such aircraft as the MiG-31, that can reach 3000 km/h, additional modifications have been added to cope with the extreme heating.

R-73

Following poor combat results in Vietnam at the end of the 1960s, the United States began developing its fourth generation fighters, the F-14 and F-15. Like the F-16 and F/A-18 light fighters, these aircraft were intended gain air superiority; this would include close range air combat. At the beginning of the 1970s in the USSR, a sort of "symmetrical answer" to the western countries resulted in the design of new front line fighters, later called the Su-27 and MiG-29.

Estimated requirements for a new missile to arm the new generation of Soviet fighters, showed that even a specially enhanced version of the R-60M (its development was coming to an end in those years) would not fully satisfy the new requirements. According to the analysis, missiles of the new generation were to be highly maneuverable and have all-aspect engagement capabilities.

At first, these requirements were distributed between two different design bureaus. Reviewing the results and preliminary developmental work performed in the framework of the avanproject, a resolution dated July 26, 1974 defined the requirements of the future Su-27 and MiG-29, entrusted "Molniya" design bureau with development of a highly-maneuverable, small, close air combat missile

- the K-73. The missile was first envisioned as an enhanced P-60, but taking into account the high maneuverability requirements, it was allowed to increase its weight to be between the R-60 and R-13.

6-12: R-73 missile

The same day, another resolution entrusted "Vympel" design bureau with development of an all-aspect short-range missile. This K-14 was a further development of K-13 family and included an infrared seeker and superb aerodynamic performance.

The "Super-maneuverability" requirements defined the necessity of K-73 operations at extremely high angles-of-attack (about 40°). At such angles, the efficiency of traditional A-A missile control surfaces are completely lost. A transition to gas-dynamics control units in such conditions was inevitable. Wing surfaces changes was also considered inefficient with regard to a relatively short launching range.

Given the assumption of the first K-73 variant's small size and weight, an all-aspect seeker was not envisioned. Nevertheless, at Kiev "Arsenal" design bureau, which earlier worked with the Moscow "Geophisica" design bureau, developed a rather compact seeker "Mayak" (OGS MK-80) with a new seeker. The new seeker provided target acquisition up to 60°, which was 12 times greater that the corresponding seeker for the R-60. Later, the K-73 gimbal limits were increased to 75° with a maximum angle speed of up to 60 degrees per second. "Mayak" seeker also included new, efficient anti-countermeasures (flares) implemented. In addition to an increased sensitivity range for the photo-detector array, a pulse-time signal modulation was applied, and a digital signal processing unit with several independent channels was introduced. To increase engagement efficiency, the steering point logic was adjusted to aim for a point forward of the targets engine nozzles. This allowed the warhead to damage more critical parts of the aircraft system, such as the pilot.

Despite the formal absence of an all-aspect engagement requirement, K-73 developers pursued the "Mayak" seeker because it was evident that sooner or later this requirement would be demanded. Providing these capabilities required that the K-73 size and weight increase.

The initial, wingless design had limited maneuverability. High angle of attack is generally required when dog fighting, and this is generally not favorable for such a design. For a time, the designers considered a missile variant without aerodynamic control surfaces but instead use six, large six-cantilevers.

However, the use of gas-only control units limited the flight time by motor operation time. This significantly decreased tactical employment flexibility. When reviewed at a headed by G.Dementiev, it was decided to adopt a aerodynamic design similar to that of the K-60. However, unlike the prototype, they had to provide bank stabilization when the missile was equipped with an autopilot with traditional gyroscopes. Use of kinematically connected ailerons rather than rollerons was not accompanied by a missile weight increase. This was because earlier variants had surfaces actuators elements for gas-dynamic control units operation in the tail section. For control routines, the autopilot used information from the angles-of-attack and sideslip sensors that are positioned in front of destabilizes. Like the P-60, this also ensured air flow straightening before the aerodynamic control surfaces.

A set of sensors, destablators and control surfaces form the characteristic "pine cone" on the first missile section. Aerodynamic control surfaces, along with a pair of aerodynamic connectors, are used by the steering motors in the forward part of the second section. This is located behind the autopilot and active radio proximity fuse. The third section is occupied by a solid propellant gas generator. The produced actuating fluid is sent to the actuators of aerodynamic controls and through the gas pipeline coming through the fairing. This in turn actuates the ailerons and exhaust vanes positioned in the missile's tail section. The fourth section contains an expanding-rod warhead; inside the warhead is a safety-and-fusing device. The warhead blast radius is about 3.5 m. The fifth section is a single-mode solid propellant motor. In the missile's tail section are the actuators of the ailerons and gas-dynamic vanes.

Except for the steel engine body, most of the airframe is made of aluminum alloys. The sections are joined by bayonet joints, except for the end sections that are connected by flange joints. The fully assembled missile is delivered in a hermetically sealed in a wooden packing crate. The missile is suspended from the aircraft by the P-72 or P-72D launchers (APU-73-1 or APU-73-1D).

As a result of the joining of two "air-to-air" missile design teams, the K-73 development was completed at "Vympel" design bureau. The missile went into operational service as the R-73 by Resolution June 22, 1984. The maximum launch range of the R-73 is 30 km in the forward hemisphere and high altitude. On the whole, missile's performance characteristics exceeded the initial goals, but at the same time the missile's weight was 1.5 the initial design specification.

The R-73 was exported abroad as the K-73E variant; the first deliveries were made to East Germany in 1988. The missile was named AA-11 Archer in western terminology. The R-73, when combined with helmet mounted cueing device "Shel-3UM", enables a pilot to achieve air superiority in close air combat. This was confirmed during initial joint trainings of the former Warsaw Pact countries (in particular, East Germany) with NATO pilots who flew some of the best western fighters.

In the 1990s, "Vympel", in the course of international exhibitions, displayed various enhancements of the of R-73, In particular, photos of attack aircraft using a backwards launching version that could attack threats approaching from the rear hemisphere were shown.

The launch range of the R-73 is between 0.3 and 20 km and engage targets as high as 20 km. The initial weight is 105 kg. The missile length is 2.9 m. and the maximum body diameter is 0.17 m. The wing span is 0.51 m. The control surfaces span .0.38 m. Maximum speed of the target is 2500 km/h. The warhead weight is 7.4 kg. The maximum target G is 12 units. MiG-29, Su-27 and their variants are equipped with this missile system.

The table below compares the characteristics of several modern, Russian missiles types.

Parameters	R-27R/T	R-27ER/ET	R-77	R-33
Parameters	R-27R/T			
The year it entered service	1987	1990	1994	1981
Aircraft/number carried	MiG-29/4; MiG-29SMT/4; Su-27/4; Su-35 /4; Su-34/4; Su-33/6		MiG-29S/6-8; MiG-29SMT/6-8; Su-35/10-14; Su-34/12; Su-33 /10-14	MiG-31/4
Weapon control system	SUV S-29; SUV S-29M; SUV S-27; SUV S-27M		SUV S-29M; SUV S-27M	SUV "Zaslon"
Aerodynamic design	Canard with destabilizers		Standard with tapered wings	Standard
Weight, kg	253	354	177	520
Warhead weight, kg	39		21	47
Warhead type	Rod-type		Multicumulative rod-type	Blast fragmentation
Body diameter, m	0,23	0,23/0,26	0,20	0,38
Length, m	3,96	4,56	3,60	4,15
Control surface span, m	0,77	0,8	0,7 (folding)	1,12
T/W ratio, Kgs/Kg	62	94	79	73
Motor type	single-mode	double-mode	single-mode	double-mode
Seeker gimbal limits	±50° for radar TSD; ±55° for IR TSD		±60°	±60°
Guidance system type	Inertial guidance with radio correction; self-guidance with semi-active TSD with lock-on after launch; infrared TSD cooled by nitrogen		Inertial guidance with radio correction; self-guidance with active radar TSD with lock-on after launch	Inertial guidance with radio correction; self-guidance with semi-active radar TSD with lock-on after launch
Guidance method	Proportional guidance			

Target maximum speed, km/h	3500		3600	3700
Target maximum range, km	0,03 - 25	0,03 - 27	0,02 - 25	0,05 - 28
Maximum launch range in forward/rear hemisphere, km	45/18	70/30	55/20	120/40
Minimum launch range in rear hemisphere, km	0,5		0,3	2,5
Maximum target G, units	8		12	3 – 4

Figure 4

Missiles in NATO Service

Medium Range Missiles

AIM-120 AMRAAM

The medium-range AIM-120 AMRAAM (Advanced Medium-Range Air-to-Air Missile) "air-to-air" missile was is replacing the AIM-7 "Sparrow" and went into operational service by the US Air Force in 1991. Compared to the "Sparrow", the AIM-120 is considerably lighter, smaller in size, increased flight efficiency, and both can engage high-flying highly-maneuverable targets as well as low-flying targets in intense electronic countermeasure environments. This became possible due to modern achievements in the missile control theory, radar and computer engineering, propulsion systems, and arming.

Today, the AIM-120 is operated by the United States, Germany, Great Britain and a number of other NATO members.

6-13: AIM-120C AMRAAM

The AIM-120 is made according to standard aerodynamic designs and consists of three sections: forward, warhead and tail. It has a small, cruciform wing that provides good maneuverability low and high speeds and cruciform tail fins in the tail section. The missile body is made of steel, painted gray, and can endure considerable skin heating.

The forward section contains the autopilot navigation systems. The missile's autopilot combines several sub routines to aid the missile in reaching its target with out continuous wave illumination from the launch aircraft: corrected-inertial navigation at the first and second flight trajectory legs and active radar at the terminal leg. The corrected-inertial system contains non-gimbal, inertial platform and command line receiver positioned in the nozzle block of the missile's tail section. The platform weight, in which miniature speed gyroscopes are installed, is less than 1.4 kg. The high-performance micro-computer, working at 30 MHz, is used for inertial and radar systems. It performs all functions of control, including: data link, radar equipment, warhead/fuse signal processing, and built-in control of the main sub-systems and components. The introduction of such a micro-computer enabled the engineers to increase the number of parameters used to calculate the most efficient flight trajectory, depending on the missile and target intercept point, their flight speeds and bearings. For example:

on the basis of measured range, target's sight-line angle, and speed of their change, the micro-computer can calculate the target's acceleration. If the missile's own acceleration is known (it is received with the help of the inertial systems); the micro-computer can then calculate possible intercept maneuvers. This can allow the computer to choose the optimal trajectory that will ensure a hit on the target.

The data link is used when there is a necessity to correct the missile's flight trajectory during the mid-flight leg. An active radar seeker, which provides fully independent missile guidance after a safe target lock, turns on the radar and uses high and medium pulse repetitions to detect and track the target. The radar antenna is positioned behind a radio-transparent radome (the length is 530 mm and the base diameter is 178 mm), which is made of ceramics reinforced by glass fiber.

The warhead section contains the warhead, a non-contact radio proximity fuse, and safety-and-arming mechanisms. The blast directional warhead uses blast fragmentation and ensures fragment dispersion in a narrow field or limited sector. The latter is only possible when the missile intercepts the target at a definite aspect angle. When the missile directly hits a target, the contact fuse detonates the warhead. The propulsion system represents a double-stage solid-propellant rocket motor, with high specific impulse. It uses a smokeless, aluminum-free fuel weighing 45 kg.

The typical missile trajectory is divided into three parts: corrected-inertial, independent inertial and active radar. Target detection is performed with the help of the launch aircraft's on-board radar. The AN/APG-70 radar, on the F-15C, can use target characteristics such as range and closure rate to pick the ten most important targets and simultaneously track them in TWS mode. After the pilot has designated the targets, their positional data is automatically sent to the missile's inertial system. Until the moment of launch, the aircraft's radar is providing the missile with intercept calculations. After the missile launched, the current target position data is only tracked in the launch aircraft's radar. If the target does not maneuver, the missile's inertial guidance will bring the missile close to the target at which time the missile's active radar seeker will take over.

When a target maneuvers, a positional data correction is performed. The position data is entered into the missile's inertial navigation system before the launch. The corresponding correction commands are sent through the aircraft's radar antenna side lobes with periodicity of antenna orientation diagram scanning. These data link commands are received by the missile's data link receiver. Detailed data link guidance is possible for up to eight AIM-120 missiles simultaneously, if they are launched at different targets. The remaining time until the missile activates its onboard radar is indicated the aircraft cockpit. This enables the pilot to end the supporting data link connection to the missiles, which is now in self-guidance mode. Data link commands may cease if the target stops maneuvering and the missile is able to be guided to the target with its own inertial navigation system. The guidance methods described above can only be used if there is no active jamming. If the target uses active jamming, the missile's on-board systems can repeatedly switch into the Hom-On-Jam (HOJ) guidance mode when in the middle and final trajectory legs. In close air combat when the target is visible active radar guidance mode is used.

The AIM-120 can be loaded on two different launch-type devices: rail guides and forced ejection with the help of squibs. The first is constructed such that even AIM-9 "Sidewinder" can be loaded on them. The second type of device requires a modified to the existing LAU-17 and LAU-92 launchers. The F-15 and F-18 are equipped with such launchers. The can be used for both AIM-7 "Sparrow" and AIM-120 loading. Thee devices allow six missiles on F-15, F-16, F-18 and Tornado F.2, and four on the Phantom F-4F.

6-14: AIM-120B missile

6-15: AIM-120C missile

Today, there are three AIM-120 models:

- AIM-120A is the first version of the missile; it was produced until 1994.
- AIM-120B is a modernized version of the A model with greater programmability via the cable jack in the transport container.
- AIM-120C has been in production since 1996, and has been modified to be loaded on the F/A-22A. The C model has a reduced size, improved speed, better maneuverability and greater range than earlier models.

A small number of F/A-18 fighters, equipped with the AIM-120, were transferred to the Persian Gulf region as part of operation "Desert Storm." However, the missile did not see use in combat. The first combat use of the AIM-120 (nicknamed the Slammer) happened in December 1992 when an American F-16C shot down a MiG-25 of Iraqi Air Force.

The AIM-120 is perhaps the most effective air-to-air missile of NATO air force. It has long range, high energy retention, good maneuvering characteristics, and has an unmatched guidance system.

AIM-7 Sparrow

Sparrow III (AIM-7C) development began in 1954, and became operational with American forces in 1958. The missile was initially loaded on Demon (F3H and F3H-2) and Phantom II (F-4B, F-4C, F-4M) fighters. Six missiles could be loaded and they had a range of 12 km.

All Sparrow III missiles models use the same aerodynamic design with an all-moving cross-wing and stabilizer system. The missile consists of four sections: nose, wing, warhead and engine. Each model is loaded the same way and has a consistent size. This allows an aircraft to load multiple model types on the same aircraft. The AIM-7 uses a proportional navigation system and is equipped with a semi-active radar homing (SARH) seeker. Radar energy reflected from the target is received by seeker's antenna; and a signal is sent back to the launch aircraft from the tail antenna. The actuating mechanism is installed in the wing section, and it deviates from the wing panel as per control signals.

6-16: AIM-7M Sparrow

An expanding-rod warhead is in installed in the AIM-7. Such a warhead creates an expanding ring of steel rods designed to destroy an aircraft within this ring. The warhead uses both a radar proximity fuse (when passing close to the target) and an impact fuse (when a direct hit is achieved).

The solid-propellant motor has two levels of thrust- a boost phase and the sustainer phase. The solid fuel has a star-like channel that runs through the center of the motor. This allows maximum efficiency of fuel burn.

AIM-7D entered service in 1961 and its range is 15 km. It is equipped with a semi-active radar seeker that required continuous wave illumination from the launch aircraft. The solid-propellant LR44-RM2 motor, which was installed on AIM-7C as well, was later changed to the Roketdyne Mк.38/39 motor (both engines had one level of thrust). AIM-7D missile production stopped ended in 1963 when the new AIM-7E went into production.

AIM-7E had a more sophisticated seeker than the D model and a new Aerojet Mк.52.Mod.2 motor. The motor weight was 68.5 kg, with a burn time of just 2.8 sec, and a range of 25 km. For this new motor, a polybutadiene was used as the fuel and ammonium perchlorate was used as the oxidizer. Thanks to the new motor, the missile could develop high speeds and greater ranges than older models of the AIM-7. The extended range was also due to the improved seeker.

Based on the AIM-7E, the navalized "Sea Sparrow" was developed, which has been used as a defensive system for ships of the United States and several other countries. Later, the AIM-7E was included as the basis for several NATO air defense systems: "Spada" (ground) and "Albatros" (ship-borne). Many countries have also developed their own "air-to-air" missiles based on the AIM-7E. Successful ground tests and good publicity brought world fame to AIM-7E missile.

However, the positive press did not match combat results. In Vietnam, from 1965 to 1969, only one AIM-7E launch out of ten hit their target. Combat experience revealed several deficiencies such as a large minimum range and the time-consuming process of locking a target. These missiles were particularly inefficient at hitting highly maneuverable targets. Given that AIM-7E was designed to engage lumbering, Soviet bombers at long range, these results are not surprising.

Following the Vietnam War, combat analysis spawned the development of a new Sparrow model began: the AIM-7E2**.** This modification went into operation in 1968 with a maximum engagement range of 50 km at high altitude.

When designing this model, great attention was paid to achieving the necessary characteristics needed in a within visual range engagement. They reduced the fuse device arming time, improved the seeker and enhanced the control system and control surface actuators. As a result, the new model was more maneuverable and had a reduced minimum engagement range.

By 1973, AIM-7F became operational. The maximum engagement range at high altitude was 50-70 km. Its seeker could operate in two modes: pulse-Doppler and continuous wave, which enabled the missile to be compatible with a multitude of radars.

The improved expanding-rod warhead had a greater blast range. Unlike previous modifications, the missile's warhead is installed between the nose and the wing section. This became possible by reducing the space needed for instruments that previously used vacuum tubes with single computer chips to control the seeker, control systems and warhead. Additionally, this increased missile reliability – the equipment mean-time-between-failures amounted to 470 hours, which is eight times higher than AIM-7E.

The missile is equipped with a new two-level thrust motor, the Hercules Mk.58 Mod.2. With a significant increase of the range compared to the AIM-7E2, AIM-7F is better adapted for close range combat.

One shortcoming however was the AIM-7F's low jamming resistance to radar signals reflected from the ground. This is especially important when attacking targets at low altitude in a look-down shoot-down situation. To solve this, work began in 1975 on an enhanced model of the AIM-7F. This new model would be equipped with a mono-pulse target seeking with better jamming resistance.

In 1976-77, the new AIM-7M under went flight tests. The maximum range at high altitude was 50-70 km. Nevertheless, in AIM-7M missile still had the shortcoming of relying on a semi-active radar homing (SARH) seeker. Such a seeker considerably limits the launch aircraft's maneuverability by requiring target illumination (for 20-60 seconds if the target is beyond visual range and for 10-20 seconds if the target is visible) up to the moment of target impact. The SARH seeker is also quite vulnerable to modern electronic countermeasures. In fact, this prevents the realization of one of the main requirements of modern weapons – "fire-and-forget", i.e. independent guidance after launch.

The F-4, F-15, F-14, F-16, F/A-18 aircraft are equipped with this missile.

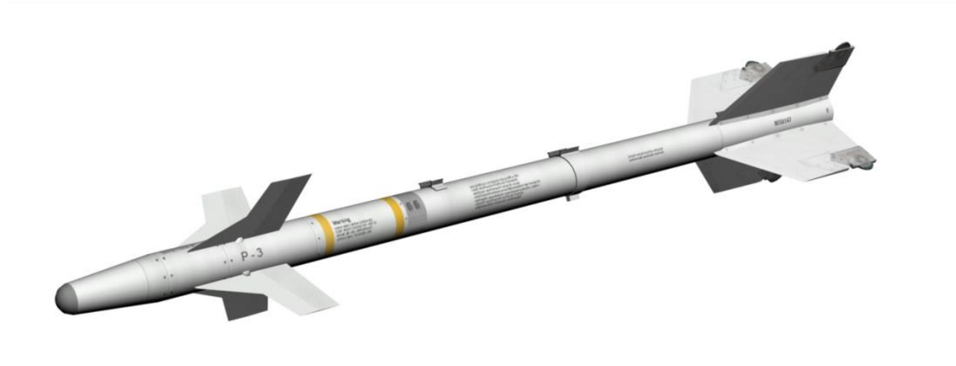
Close Combat Missiles

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.



6-17: AIM-9P Sidewinder missile

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).

6-18: AIM-9M Sidewinder missile

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.

AIM-9X -- Today, work continues on America's next generation of infrared-guided, short-range missiles. This missile, the AIM-9X, will be competing with other similar systems such as the R-73 and AIM-132 on the world market.

The AIM-9X is to provide superiority within visual range air combat and engage targets from any aspect angle. The guidance system is resistant to all existing active and passive countermeasures due to its imaging infrared seeker. The missile motor is equipped with a thrust vector system; the approximate cost for each such missile $84,000. In 2004, the AIM-9X entered operational service with the United States Air Force. Like the R-73 helmet mounted sight system, the AIM-9X can be cued with the new helmet mounted display system.

7

AIR-TO-SURFACE WEAPONS

AIR-TO-SURFACE WEAPONS

"Air-to-Surface" weapons can be divided into two categories: guided and unguided. Guided air-to-surface weapons include both powered air-to-surface missiles (AGMs and ASMs) and guided bombs (GBUs). Unguided weapons include free-fall ("dumb," "gravity" or "iron") bombs and unguided aerial rockets.

Free-fall bombs are basic weapons of strike aviation that have been widely used in all the large-scale armed conflicts of the last 80 years. Due to their low cost and availability, they can often be cost-effective even when compared to more accurate (and expensive) modern guided munitions.

Free-fall bombs are not highly accurate. They follow a ballistic trajectory after release without any ability to maneuver. To improve aiming accuracy, the bombing aircraft should be flying a straight-line trajectory at the moment of release. Even small amounts of pitch and bank error can degrade the aiming accuracy, as can the wind. Free-fall bombs can't be used against pinpoint targets (i.e. when high aiming accuracy is required) or "surgical strikes" in which "collateral damage" around the vicinity of the target cannot be tolerated.

> EVEN INCORRECT AIRCRAFT YAW AT THE MOMENT OF RELEASE CAN DEGRADE THE HIT ACCURACY OF FREE-FALL BOMBS.

The horizontal distance that a free-falling bomb will travel before hitting the ground depends primarily on two factors: aircraft speed and altitude at the moment of release. If the aircraft speed and altitude are increased, the bomb trajectory will be extended, but this also degrades hit accuracy.

The size and destructive power of a conventional free-fall bomb is expressed in terms of its weight, and is usually somewhere between 50 to 1500 kg. Unlike general-purpose bombs, which have a single warhead, cluster bombs contain a large number of explosive sub-munitions that spread their destructive power out over a larger area after release.

> THE RANGE OF FREE-FALL BOMBS DEPENDS ON THE AIRCRAFT SPEED AND ALTITUDE AT THE MOMENT OF RELEASE.

Unguided folding-fin aerial rockets are widely employed against lightly armored enemy vehicles and personnel. A rocket's hit accuracy depends heavily on the conditions at the moment of launch. A small aircraft aiming error at the moment of launch can lead to a significant rocket deviation from the target. Wind can also degrade the hit accuracy. Rockets are usually used in volleys, en masse. Using a large number of rockets can spread destructive power over a significant area, and help ensure hitting the intended target.

> UNGUIDED ROCKETS ARE LAUNCHED IN SALVOS TO ENSURE HITTING THE TARGET.

Guided weapons can more reliably ensure destruction of a target, but they are also more expensive. Guided bombs and missiles with infrared (IR), laser and TV guidance have very high accuracy and can ensure hits against tank and building targets with a single shot. The actions of the pilot when using guided bombs (GBUs) or missiles vary with the exact type of weapon.

Russian Air Force Air-to-Surface Weapons

Most Russian fighter jets have some limited ground attack capability, often being able to carry free-fall bombs and/or unguided rockets in place of air-to-air missiles. This is not their primary role however, and Russian fighters are seldom assigned to such a task. The primary aircraft for attacking ground targets are tactical bombers and close support aircraft, such as the Su-25 and Su-25T. This chapter describes various air-to-surface weapons that can be employed by the player-controlled aircraft. Additional information may be found in the online encyclopedia.

Each weapon type is designed for a specific task or type of target. Antiradar missiles, for example, are useless against tanks, and attempting to attack a modern warship with conventional free-fall bombs would be suicidal. Before starting any mission, careful consideration should be given to the choice of weapons as according to the combat objective.

Air-to-Surface Missiles

"Air-to-surface" missiles, like "air-to-air" missiles, vary in terms of launching range and type of target. The warhead and guidance system are usually tailored for a specific task, such as the anti-radar or anti-armor mission, but there are also "general purpose" missiles useful for a variety of tasks.

The Kh-25 (AS-10 "Karen") and the heavier Kh-29 (AS-14 "Kedge") are the primary "general purpose" guided tactical missiles. These weapons can destroy fortifications, bridges and railroad facilities, aircraft shelters, surface-to-air missile (SAM) sites, slow moving armored vehicles and small ships. They are equipped with solid propellant rocket motors, which accelerate the missile supersonic speed with only a few seconds of burn time.

Tactical Missiles

"Air-to-surface" missiles employ a variety of different guidance systems. Non-emitting "passive" systems include television (TV) and imaging infrared (IIR) homing. Such optically guided weapons make use of a television display in the cockpit. The pilot locates, identifies and locks the target via a magnified optical image seen by the missile seeker. "Active" systems include radar homing, in which the missile illuminates the target with radio waves and homes on reflected signals. "Semi-active" laser guidance systems home on reflected laser signals instead of radar. The laser illuminator used to designate the target is located either on board the shooting aircraft, or on the ground (e.g. with a Forward Air Controller or "FAC"). In the first case the pilot selects the target and provides laser illumination during the missile's entire time of flight (TOF). In the second case an off-board system (e.g. another aircraft, helicopter or FAC) selects the target and provides illumination, affording free maneuver to the shooting aircraft after launching the missile.

The Russian "Vikhr" anti-tank missile employs laser "beam-rider" guidance. Unlike the Kh-25L and Kh-29L missiles, which are equipped with semi-active laser homing seekers in the nosecone, the 9A4172 "Vikhr" does not have any seeker in the nose. Instead, sensors are mounted in the tail of the missile, near the rocket motor nozzles. These sensors detect the laser beam emitted by the carrier aircraft and follow it directly to the target.

Kh-25 (AS-10 "Karen")

The Kh-25 guided missile began development in the early 1970s as "product 71" of the "Zvezda" Design Bureau. The design was based on that of the earlier Kh-23 (AS-7 "Kerry") fighter-bomber missile. The new weapon was intended for the destruction of enemy fortifications, command and control (C2), weapon emplacements, antiaircraft artillery (AAA) and SAM sites.

The Kh-25L laser-guided variant is designed for the destruction of small targets such as radars, command centers, and tactical missile launchers. Targets can be illuminated by an aircraft or from the ground. The missile's maximum speed is 3200 km/h. The Kh-25MP (AS-12 "Kegler") is the antiradar variant.

Kh-25 missiles are carried on APU-68U/UM/UM2/UM3 pylons, which may be installed on MiG-27, Su17M, Su-24 and Su-25 aircraft.

Variants:

The Kh-25L "Projector" ("product 71" or AS-10 "Karen") is a general-purpose missile with a 24N1 semi-active laser seeker and SUR-71 control system.

The Kh-25ML (AS-10 "Karen") is a modernized variant, also using laser guidance. It is equipped with a 24N1 semi-active laser seeker and SUR-73 control system. The engine, body, warhead, autopilot, and power unit are the same as for the Kh-27 missile. It entered service in 1981.

The Kh-25MP ("product 711" or AS-12 "Kegler") is an antiradar missile (ARM). It is equipped with a PRGS-1VP or PRGS-2VP passive radar guidance system (depending upon the intended target). It entered service in 1981.

The Kh-25MR ("product 714" or AS-10 "Karen") is a variant using a radio-command guidance system. It entered service in 1981.

7-1: The Kh-25ML (AS-10 "Karen") Tactical Missile

Missile	TSD type	Warhead, kg	Launch effective range, km
Kh-25MR	Radio-command	90	2-20
Kh-25ML	Semi-active laser	90	2-10
Kh-25MP	Passive antiradar	90	20-40

Figure 5

Kh-29 (AS-14 "Kedge")

The Kh-29 (AS-14 "Kedge") guided missile began development at the "Molniya" design bureau, under the direction of M.P.Bisnovat. It entered service in 1980. From 1981 onward, further development of the missile continued at the "Vympel" State Machine-building Office. The missile is equipped with a high-explosive penetrating warhead and is designed for use against concrete shelters, bridges and ships. It is carried on an ejector pylon.

The Kh-29L variant has a semi-active laser seeker and is used together with onboard target illuminators, such as the "Kaira" or "Klyon" optical-electronic systems, or ground-based laser target designators.

7-2: The Kh-29L (AS-14 "Kedge") Tactical Missile

The Kh-29T variant uses TV guidance, and is designed to destroy ships of up to 10,000 tons displacement, hardened concrete shelters, concrete runways, bridges and industrial targets. The optical seeker is locked onto the target before launch, with the help of a magnified TV image displayed in the cockpit. This variant is "fire-and-forget" - it guides itself to the target autonomously after launch.

7-3: The Kh-29T (AS-14 "Kedge") Tactical Missile

At present, the Su-25TM (Su-39) close support aircraft, MiG-27M, Su-17M3, Su-17M4, Su-24M and Su-34 fighter-bombers, and Mig-29CMT, MiG-33, and Su-35 multirole fighters can be equipped with this variant.

Missile	TSD type	Warhead, kg	Launch effective range, km
X-29L	Semi-active laser	317	8-10
X-29T	TV	320	20-30

Figure 6

9K121 "Vikhr" (AT-16) ANTITANK Weapon System

The "Vikhr" antitank weapon system is designed for use against armored vehicles, including those equipped with reactive armor, and air targets flying at speeds of up to 800 km/h. The system began development in 1980 at the "Tochnost" Design Office for Instrument-making (Scientific and Production Combine) under the direction of chief designer A.G.Shipunof. It entered service in 1992. By the beginning of the year 2000, the complex was carried on the Su-25T antitank close support aircraft (up to 16 missiles can be carried on two APU-8 launchers) and the Ka-50 "Akula" combat helicopter (up to 12 missiles carried on two APU-6 launchers). The NATO missile designation is AT-16. The "Vikhr" missile system includes:

- Supersonic laser beam-riding 9A4172 missiles
- The I-251 "Shkval" electro-optical fire control system
- APU-8 or APU-6 launchers.

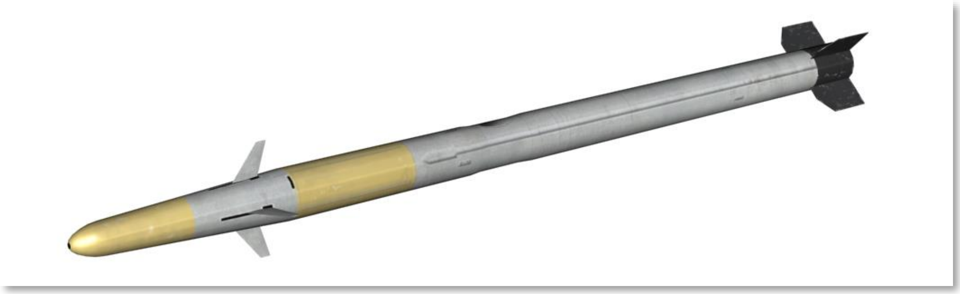
7-4: The APU-8 "Vikhr" (AT-9) Launcher

The system allows missiles to be fired singly or in pairs. The missile's high supersonic speed (up to 610 m/s) decreases the shooting aircraft's vulnerability during the attack, and can allow quick sequential attacks against multiple targets in one pass. The missile covers up to 8 km effective range with a flight time of 23 seconds.

The missile is designed according to the canard aerodynamic layout and features folding fins. Aiming is done with the help of the "Shkval" automated targeting system. Upon identifying the target image in the TV display, the pilot places a cursor over the target and commands lock-on by pressing a button. The display provides target data when it is locked, and authorizes the pilot to shoot when the target is in range.

The missile is tube-launched with the help of an ejection charge before rocket motor start-up.

The laser beam-riding guidance together with the electro-optical target lock ensures high accuracy practically regardless of target range. In addition, laser beam-riding guidance provides more reliable performance in the presence of environmental clutter (e.g. dust, smoke) and/or enemy countermeasures (e.g. smokescreens).



7-5: The 9A4172 "Vikhr" (AT-9) Missile

In the Su-25T aircraft, the "Prichal" laser target designator/rangefinder is integrated with the on-board "Shkval" fire control system and the podded "Mercury" low-light television (LLTV) night system. The "Shkval" system automatically tracks a locked target and illuminates it with the laser target designator. The missile detects the laser beam and attempts to keep it centered between two receiving sensors in the tail while flying towards the target. The missile has only one servo motor for steering, so it rolls around its longitudinal axis in flight, continuously correcting pitch and yaw in turn. This rotating motion gives the missile a distinctive spiral trajectory.

The missile storage, transportation and launch is all performed with the same tubular transport-launch container, ensuring reliable missile performance for up to 10 years without any maintenance.

The missile achieves 1,000 mm rolled homogeneous armor (RHA) penetration. The "Vikhr" missile features both contact and proximity fuses. The kill probability against moving tanks is 80%.

S-25L

The S-25L laser-guided rocket was designed in the "Tochmash" Central Scientific and Research Institute, famous for its airborne infantry weapons and unguided aerial rocket designs. Among the latter was the 400 kg S-25 heavy rocket – a very reliable weapon popular the armed forces. The rocket had a modular structure that simplified its further development. The plastic nose cowling was replaced by a laser seeker, which turned the rocket into precision ordnance. The idea was proposed by A.Nudelman, the head of the Institute's Design Office. The design team was headed by B.Smirnov (today the Institute's General Designer). A 42 kg control module comprising a 24N1 laser seeker, autopilot, control surfaces, actuators and 20 second battery power supply was added to the simple, mass-produced rocket. The S-25 rocket was stabilized in flight by rotation, spinning up to 600 rpm, which would not allow the laser seeker or autopilot to work properly, threatening to overload the gyroscope and cause loss of control. The problem was solved in a simple way – the whole control module was mounted on a rotating bearing to allow it to remain steady while the missile body rotated. A field upgrade kit includes the control module and new electrical connections for the launch tube and weapon pylon, which can be installed by two people. The updated disposable launch tube is designated O-25L, and the 150 kg blast-fragmentation warhead in a thick-walled penetration casing is increased by an auxiliary 21 kg warhead. The S-25L missile is equipped with an electromechanical contact fuze with optional delay for concrete penetration. The S-25L missile entered service in 1979. The S-25L missile range is 7 km with 4 – 7 meter hit accuracy. There is an updated S-25LD version with rage up to 10 km, which entered service in 1984.

7-6: The S-25L Laser-Guided Rocket

When designing the S-25L, the "Tochmash" Institute completely lived up to its name (Tochmash means "accurate machine-building" in Russian). The weapon's range doubled from 3 to 7 km compared to the original S-25 rocket, and its hit accuracy improved by a factor of six – from 20-30 m for the S-25 at 3 km range to 5-7 m for the S-25L at 7 km range. The precision S-25L also distinguished itself by its low cost, ease of use, reliability and low maintenance. The modified S-25L retained similar weight and dimensions while improving performance: when used from the Su-25T fighter the probable circular hit error (CEP) does not exceed 1.2 m and the majority of armored vehicle targets were destroyed by direct hits.

Antiradiation Missiles

From a technical perspective, anti-radiation or antiradar missiles (ARMs) are passively guided weapons that home on radio emissions from the target. Anti-radiation missiles can work against a variety of target radars including early warning, search and tracking radars used by SAM fire control systems.

In practice, the destruction of enemy radar systems has proven a complex task. Many radar systems are able to detect incoming missiles. In this case they usually shut down, thus denying guidance signals to the hostile missile and causing it to miss the target. Modern ARMs like the Kh-31P and AGM-88 HARM can remember the direction towards the emission source and continue to fly by inertial guidance, but their hit accuracy in this mode is degraded. Nevertheless, the task of suppressing and/or destroying radar-based enemy air defenses (SEAD or DEAD) is very important, especially when this is done to ensure the safety of friendly strike aircraft.

Different combat radars operate over a wide spectrum of possible frequency bands. It is difficult to design a single passive homing warhead covering this entire spectrum, due in part to antenna physical limitations. Until recently, the accepted practice was to design several replaceable seeker modules for the same missile, each of which operated over a different part of the radio spectrum, selected before takeoff according to the anticipated threat. Even modern ARMs may be optimized to counter a particular priority threat. For example, the Kh-58 and Kh-31P ARMs were designed for use against the Patriot system's multifunction AN/MPQ-53 radar. As a result of this optimization, there may be some threat radars that a given ARM may be unable to detect.

Kh-25MP/MPU (AS-12 "Kegler")

The Kh-25MP (AS-12 "Kegler") variant of the Kh-25 tactical missile has a passive anti-radiation homing seeker, and was designed for use against Hawk, Improved Hawk, and Nike Hercules SAM radars. Roland and Crotale SAM radars were added to the threat library in a modernized variant called Kh-25MPU.

7-7: The Kh-25MPU (AS-12 "Kegler") Antiradiation Missile

The modernization consisted of increasing the frequency range of the passive radar seeker and the addition of an inertial guidance system, which kept the missile flying towards the target to re-acquire if the homing lock was broken mid-flight. The missile's range was increased to 40 km, and maximum speed increased to Mach 2.5.

The missiles are launched from APU-68U pylons installed on MiG-27K, Su-17M4, Su-24M, Su25T and Su-25TM aircraft.

Kh-58 (AS-11 "Kilter")

The Kh-58U (AS-11 "Kilter") missile was designed with an extended range to allow the launching aircraft to attack "HAWK", "Nike Hercules" and "Patriot" SAM systems from a "stand-off" distance, without entering threat missile launch zones.

The Kh-58U missile has a normal aerodynamic layout with fixed wings and moving control surfaces in the tail. The large-area wing provides a long flight range, and the solid-propellant rocket motor uses an axial exhaust nozzle to avoid the propulsive losses inherent to side-mounted nozzles, like those of the Kh-25. To ensure a launch range of 100 km from high altitudes and launch velocities, the rocket motor features a 3.6 s boost phase with about 6 tons of propulsive force (exceeding the launch mass by an order of magnitude), followed by a 15 s sustain phase for cruising flight. The sustain motor uses an inhibited grain propellant with lower burning temperature, providing the thrust profile with an "economical" drop to about one-sixth of the boost phase thrust. In this way the Kh-58U is comparable to air-air missiles in its rocket performance (by comparison: its thrust-to-weight ratio is double that of the Kh-23 and Kh-25 AGMs). The control surfaces use electromechanical actuators mounted around the tail, which are unusual for this class of weapon. They were chosen to ensure longer range and flight time than air- or gas-generating power supplies could provide. The onboard high-capacity nickel-cadmium rechargeable battery ensures system operation and steering controllability for a flight time of at least 200 s (more than twice as long as the Kh-27). 30KhGSA chromansil and OT4-1 titanium were used as the main construction materials to resist the 4000 - 5000C kinetic heating during high-speed flight. The wing and empennage, including the wing skin and ribs, are welded titanium. The body is welded steel, and other parts made from light alloys use non-traditional heat shielding, including heat-resistant joint sealants.

7-8: The Kh-58 (AS-11 "Kilter") Anti-radiation Missile

The launch range from high altitude and high speed reaches up to 100 km. The maximum flight speed is more than Mach 3.0 when carried on AKU-58 pylons installed on Su-17M4, Su-24M and Su-25T(M) aircraft.

SEAD Notes for Mission Designers

The bandwidth and threat library capabilities of different anti-radiation missiles (ARMs) may become apparent during play, as certain ARMs may not be usable against radars of overly high or low operating frequency. By popular request, Figure 7 has been provided to help mission designers ensure that player- and computer-controlled aircraft assigned to suppress enemy air defenses (SEAD) are suitably armed. The ranges provided (in km) have a different meaning depending on whether they apply to player- or to computer-controlled aircraft. Computer-controlled aircraft are able to detect ground vehicle radars from very long range, so the quoted range indicates that of weapon launch. The radar warning receiver (RWR) and "Fantasmagoria" ARM datalink pod are more realistically modeled for the player-flown Su-25T. The ranges shown for the player indicate the range at which ground radars can be detected and locked by this equipment. The actual weapon launch range may be longer or shorter than this, depending on the speed and altitude at which the player chooses to fly. The equipment may be able to detect and lock some radars but not actually shoot at them – in these "lock only" cases, the range is shown in parentheses. The provided ranges were valid at the time of writing, but may change without notice as new unclassified radar and weapon data becomes available and incorporated into future products.

Class	Name	Computer-Controlled Artificial Intelligence (AI) Aircraft					Player-Controlled Su-25T		HUD symbol	Notes
		Kh-25MPU (AS-12 "Kegler")	Kh-58 (AS-11 "Kilter")	Kh-31P (AS-17 "Krypton")	AGM-88 HARM	ALARM	Kh-25MPU (AS-12 "Kegler")	Kh-58 (AS-11 "Kilter")		
EWR	1L13	/	/	/	/	/	(100 km)	(100 km)	none	
	55G6	/	/	/	/	/	(100 km)	(100 km)	none	
AAA/CIWS	ZSU-23-4 Shilka	/	/	/	85 km	45 km	(4.1 km)	(4.1 km)	none	
	2S6 Tunguska	60 km	100 km	110 km	85 km	45 km	15.1 km	15.1 km	2C6	
	Vulcan	/	/	/	/	/	/	/	/	no radar
	Gepard	/	/	/	/	/	(12.5 km)	(12.5 km)	none	
MANPADS	Igla	/	/	/	/	/	/	/	/	no radar
	Stinger	/	/	/	/	/	/	/	/	no radar
Low Altitude IRH SAM	Strela-1	/	/	/	/	/	/	/	/	no radar
	Strela-10	/	/	/	/	/	/	/	/	no radar
	Dog Ear rdr	60 km	100 km	110 km	85 km	45 km	(30 km)	(30 km)	none	
	Avenger	/	/	/	/	/	/	/	/	no radar
Low Altitude Radar SAM	Osa 9A33 ln	60 km	100 km	110 km	85 km	45 km	25 km	25 km	OCA	
	Osa ld	/	/	/	/	/	/	/	/	no radar
	Tor 9A331	60 km	100 km	110 km	85 km	45 km	21 km	21 km	TOP	
	Roland ADS	60 km	100 km	110 km	85 km	45 km	10 km	10 km	R	
	Roland rdr	/	/	/	/	/	(30 km)	(30 km)	none	
Medium Altitude Radar SAM	Kub STR	60 km	100 km	110 km	85 km	45 km	60 km	60 km	КУБ	
	Kub LN	/	/	/	/	/	/	/	/	no radar
	Buk SR	60 km	100 km	110 km	85 km	45 km	85 km	85 km	БУК	
	Buk LN	60 km	100 km	110 km	85 km	45 km	30 km	30 km	БУК	
	Hawk SR	60 km	100 km	110 km	85 km	45 km	80 km	80 km	H50	
	Hawk TR	60 km	100 km	110 km	85 km	45 km	36 km	36 km	H46	
	Hawk LN	/	/	/	/	/	/	/	/	no radar
Long Range Radar SAM	S-300PS 64H6E sr	60 km	100 km	110 km	85 km	45 km	170 km	170 km	300	
	S-300PS 40B6MD sr	60 km	100 km	110 km	85 km	45 km	100 km	100 km	300	detected only below 3000 m alt
	S-300PS 40B6M tr	60 km	100 km	110 km	85 km	45 km	57 km	57 km	300	detected only after missile launch

	S-300PS C ln	/	/	/	/	/	/	/	/	no radar
	S-300PS D ln	/	/	/	/	/	/	/	/	no radar
	Patriot STR	60 km	100 km	110 km	85 km	45 km	170 km	170 km	P	
	Patriot LN	/	/	/	/	/	/	/	/	no radar

Figure 7: ARM Target Lock Performance (for Mission Planning)

Anti-Ship Missiles

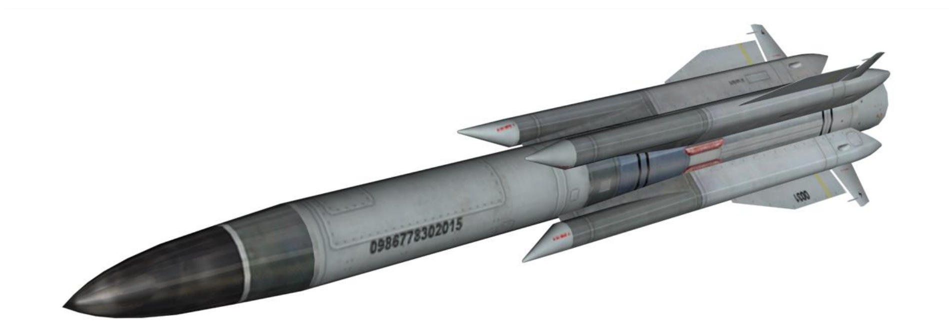
Anti-ship missiles (ASMs) are designed for use against ships and surfaced submarines. They usually have a long standoff flight range and high speed, to help them penetrate ship air defenses. ASMs are often launched in volleys to effectively saturate ship defenses and permit some missiles to hit the target. Different guidance methods may be used on the same missile, including inertial guidance during the cruise phase and active radar homing during the final approach.

Kh-31A (AS-17 "Krypton")

In 1977, the "Zvezda" Separate Design Office began designing the Kh-31P antiradar missile, for use against prospective enemy antiaircraft defenses, under the leadership of V.Bugaisky. The missile was designed to have longer range and high supersonic flight speed, thanks to a solid propellant ramjet engine and booster motor.

In 1980s, it was decided to create an anti-ship variant, capable of penetrating multi-layered warship air defenses, using the ARGS-31 active radar seeker. The anti-ship missile (ASM) received the new designation Kh-31A (product 77a). It was intended for use by Su-24M, Su-27K, "MZ" system-equipped Su-27IB (export Su-32FN), Su30MK, MiG-29K, Mig-29M, MiG-29SMT and Yak-141 aircraft. "Zhuk", "Kopyo" or other air-to-surface aircraft radars are used for target acquisition, and the missiles are carried on standard AKU-58 (AKU-58M, AKU-58E) ejector pylons.

The Kh-31A has an electronic countermeasures (ECM)-resistant seeker and can reach a speed of Mach 4.5 at high altitude. The ARGS-31 seeker also has the ability to isolate the desired target from within a group. In this case the hit probability is 55%. The Kh-31A missile can conduct a steep "gorka" climb maneuver of up to 10G before diving onto its target. The maximum launch range is 70 km at high altitude.



7-9: The Kh-31A (AS-17 "Krypton") Anti-ship Missile

The missile is made of titanium alloys and high-strength stainless steel. The radio-transparent dielectric antenna fairings are made of new generation plastics. The 9M2120 penetration warhead is designed to be effective against destroyer, frigate, and missile boat warships, and also against hydrodynamic vessels such as hydrofoils, air cushion and ground effect vehicles. Two to three hits are sufficient to destroy a destroyer-sized warship, whereas for a missile boat 1 hit is enough.

Due to changes in the political and financial situation of the country, the Kh-31A anti-ship missile did not enter service with Russian Naval Aviation, but rather was proposed for export in 1991. At the end of the 1990s, India purchased 90 Kh-31A missiles to equip Su-30MKI fighters. Discussions were also held with Vietnam, concerning the use of this missile by the Su-27SK. All Kh-31 missile variants are manufactured at the Bolshevo factory.

Kh-35 (AS-20 "Kayak")

In contrast to the high-speed, high-altitude Kh-31, the Kh-35 (AS-20 "Kayak") anti-ship missile was designed according to the principle of a long range, "stealthy" subsonic cruise toward the target at sea-skimming altitude, to avoid detection by enemy air defenses. This approach makes the Kh-35 an analog to the American AGM-84 "Harpoon" anti-ship missile. The main challenge in developing the air-launched Kh-35 on the basis of the 3M 24 "Uran" ship-launched cruise missile was to provide over-the-horizon range capability. This required an economical small-size solid-fuel jet engine and an aircraft-like aerodynamic layout, including a cylindrical frame with fuselage air inlet, large area wings, and all-moving empennage. To reduce weight, the frame was made of welded aluminum alloys and is not modular, but rather fully integrated.

The active radar seeker covered by a radio-transparent fiberglass plastic cover, power supply, 145 kg warhead, jet fuel tank, cruise engine, and onboard automated control system with inertial guidance unit, computer, radio altimeter and autopilot are all installed in the missile frame.

Jet engine turbine spool-up is accomplished after launch with the help of a pyrotechnic starter. The Kh-35 missile has a 47.5 kg ARGS-35 active radar seeker that scans +450 to -450 in azimuth and +100 to –200 in elevation with target lock-on at ranges up to 20 km.

7-10: The Kh-35 (AS-20 "Kayak") Anti-ship Missile

To ensure penetration of the ship hull, bulkheads and equipment and delivery of the payload to the ship interior, where its destructive potential is greatest, the blast fragmentation warhead is encased in a hardened shell. Interestingly, the latest anti-ship missiles don’t require shaped charges, since armored battleships are now a thing of the past. The Kh-35 can be launched in the general direction of an enemy ship, after which it flies a zigzag search pattern to locate the target with its onboard radar seeker. The missile then approaches at sea-skimming altitude before conducting a "pop-up" diving attack, especially effective against maneuvering targets.

The Kh-35 flies at a subsonic 240 – 270 m/s cruise speed, avoiding defenses rather by its low flight altitude of 5 – 10 m during cruise and 3 – 5 m during the final approach to the target. Two Kh-35 hits are enough to sink a destroyer, or one for smaller ships. The Kh-35 was planned to enter service with most Navy strike aircraft, including the MiG-29K carrier borne fighter, Su-25TM close support aircraft, Tu-142 long-range patrol aircraft (carrying up to 8 missiles) and Ka-27, Ka-29 and Ka-31A-7 helicopters.

Guided missiles of the Russian Air Force and Naval Aviation

Missile (NATO Designation)	Launching Platform (number of missiles)	Weight, kg	Effective launch range, km	Targets
Kh-25ML (AS-10 "Karen")	Su-25 (4) MiG-27 (2) Su-17 (4) Su-39 (4)	300	10-12	Fortifications, strong points, bridges, command and control centers, artillery and missile emplacements.
Kh-25MPU (AS-12 "Kegler")	MiG-27(2) Su-25T (4) Su-17 (4) Su-24 (4) Su -39 (4)	300	40	"Hawk", "Roland", "Crotale" SAM radars.
Kh-29T/L (AS-14 "Kedge")	MiG-27(2) Su-24(2) Su-39(2) Su -34(4)	680	10-13	Fortifications, strong points, bridges, command and control centers, artillery and missile emplacements, boats.
Kh-31P (AS-17 "Krypton")	MiG-27(2) Su-24(2) Su-39(2) Su -34(6)	600	100	"Patriot", "Nike Hercules", "Improved HAWK" SAM radars.
Kh-31A (AS-17 "Krypton")	MiG-27(2) Su-39(2) Su -34(6)	600	70	Ships up to 8 000 t.
Kh-35 (AS-20 "Kayak")	MiG-27(2) Tu-142(6) Su-34(6) Tu-142 (6)	600	130	Ships up to 5 000 t.

Figure 8

Bombs

Aerial bombs are versatile and inexpensive weapons. Different types of bombs are designed for different tasks. Aerial bombs are divided into two main classes: free-fall ("dumb", "gravity" or "iron") bombs and guided ("smart") bombs. Bombs are employed for attacking a variety of different ground targets including equipment, personnel, aircraft shelters, command and control centers, missile launchers, underground bunkers, bridges, roads and runways. A typical bomb consists of a body with stabilizing fins, an explosive and a fuse. There are blast, blast-fragmentation, concrete piercing, incendiary, fuel-air explosive, dispenser, illumination and other types of bombs.

Free-fall Bombs

Free-fall bombs lack any guidance or control system. They follow a ballistic trajectory that is affected by the releasing aircraft's speed and dive angle.

FAB-100, FAB-250, FAB-500, FAB-1500 - General Purpose Bombs

This is a family of high-explosive bombs of varying caliber. The number in the designation refers to the bomb's approximate weight (in kilograms). These bombs are effective against ground objects, equipment, defensive installations, bridges and fortifications. The airspeed at the moment of bomb release may be 500 – 1000 km/h.

7-11: The FAB-500 High-Explosive Bomb

7-12: The FAB-250 High-Explosive Bomb

7-13: The FAB-100 High-Explosive Bomb

BetAB-500ShP Concrete Piercing Bomb

This special bomb is effective against hardened shelters and concrete runways. It has a parachute and solid propellant rocket motor. First the parachute retards the bomb, giving the aircraft time to egress, and orients the bomb vertically over the target. Then the rocket motor ignites, accelerating the warhead to a speed sufficient to pierce concrete. The bomb has a stronger casing than ordinary high explosive bombs that allows it to be buried into the concrete before detonation. This bomb is best dropped from an altitude of 150 – 1000 meters and airspeed 550 to 1100 km/h.

7-14: The BetAB-500ShP Concrete Piercing Bomb

SAB-100 Illumination Bomb

7-15: The SAB-100 Illumination Bomb

This 100 kg-caliber flare-bomb is used to illuminate a target area after dark. The dispensing container is released from an altitude of 1000 – 3000 m, after which illuminating flares are ejected in sequence. Each flare element is equipped with a parachute to decrease the rate of fall. The illumination time lasts 1 – 5 minutes.

RBK-250, RBK-500 Cluster Bomb

RBK cluster bombs are thin-walled canisters that contain multiple antipersonnel or antitank mine, or fragmentation, antitank or incendiary bomblet sub-munitions. The cluster bomb has about the same dimensions as a general purpose high explosive bomb with caliber 100 – 500 kg and are designated according to caliber and ammunition type (e.g. RBK-250 AO-1 for a 250 kg antipersonnel bomb). The different RBK types are also distinguished from each other by the method of dispersing sub-munitions.

7-16: The RBK-250 Cluster Bomb

The nose of the canister contains a black gunpowder dispersal charge triggered by a time-delay screw fuse. The time-delay fuse starts spinning after bomb release and the cluster bomblets are then ejected in mid-air. The expanding gases split the canister casing in two, scattering the independent bomblets. The area over which sub-munitions are distributed is called the bomb's footprint. Depending on the bomb's fall angle at the moment of sub-munitions dispersal, the footprint may be circular or elliptical, and its dimensions determined by the canister speed and altitude. The canister may also feature internal mechanisms to increase the footprint area of bomblet dispersal by ejecting them with a greater speed or time interval.

There are several types of RBK cluster bomb.

The RBK-250 AO-1 is equipped with 150 fragmentation bomblets. Canister length is 2120 mm, diameter 325 mm, weight 273 kg, including 150 kg of sub-munitions. The maximum footprint area is 4,800 m^2.

7-17: The RBK-500 Cluster Bomb

The RBK-500 AO-2.5RTM bomb is equipped with 108 AO-2.5RTM bomblets. Canister length is 2500 mm, diameter 450 mm, weight 504 kg, including 270 kg of sub-munitions. A single AO-2.5RTM sub-munition (bomblet) weighs 2.5 kg, with 150 mm length and 90 mm diameter. RBK-500 AO-2.5RTM cluster bombs are dropped from an airspeed of 500 to 2300 km/h and altitudes between 300 m to 10 km.

KMGU-2 Submunition Dispenser

The KMGU-2 ("General Container for Small-Sized sub-munitions") is designed to dispense small caliber bomblets and air deployed mines. The sub-munitions are placed in the dispenser in cartridges (BKF – "container blocks for frontal aviation"). The KMGU-2 consists of a cylindrical body with front and rear cowlings and contains 8 BKF cartridges filled with bomblets or mines, carried in specialized slots. The dispenser doors are pneumatically actuated to dispense the sub-munitions.

7-18: The KMGU-2 Sub-munitions Dispenser

The KMGU-2 electrical system ensures a regular time interval of 0.005, 0.2, 1.0 or 1.5 seconds between each cartridge release. BKF cartridges carried by Su-25 aircraft are usually equipped with 12 AO-2.5RT fragmentation bombs of 2.5 kg caliber, 12 PTM-1 1.6 kg antitank mines, or 156 PFM-1C 80 g high explosive mines. KMGU-2 dispensers are suspended singly on universal BDZ-U beam bomb racks. Cartridges are released from altitudes of 50-150 m and airspeeds of 500–900 km/h. Authorization for release is provided by cockpit indications.

Guided Bombs

Guided bombs are useful against the stationary ground targets, including command and control centers, weapon depots, railway bridges and fortifications, and may feature either high explosive or armor-piercing warheads. Similar to missiles, guided bombs may use TV, IIR or laser guidance. Adverse weather conditions and visibility degrade their performance.

KAB-500KR TV-guided Bomb

The KAB-500KR is a TV-guided bomb used during good daytime visibility conditions. The warhead can be either high explosive or armor piercing. The seeker includes a TV camera and microprocessor. The TV camera's field of view is $2^0 – 4^0$. After target lock-on and bomb release, the bomb guides fully autonomously to the target. Small controls surfaces steer the bomb in flight to hit the target with a circular error probable (CEP) of 3 – 4 m. The bomb is designed for use against high-contrast surface targets, such as railroad bridges, concrete shelters and airfield runways. It is employed by front-line strike aircraft, from altitudes of 0.5 – 5 km and airspeeds of 550 – 1100 km/h. There are no known direct foreign analogues to this TV-guided bomb of 500 kg caliber.

7-19: The KAB-500KR TV-Guided Bomb

KAB-500L, KAB-1500L Laser-guided Bombs

The KAB-500L and KAB-1500L laser-guided bombs are designed for use against stationary surface targets, including hardened or underground facilities such as fortifications, command and control centers, tunnel entryways, runways, bridges, and dams. Their laser guidance system is semi-active, requiring target illumination during the bomb's time of flight. The bomb warhead may be either high explosive or penetrating. The bomb is carried on the BD universal beam bomb rack.

7-20: The KAB-500L Laser-Guided Bomb

A special laser target illumination system is required, onboard the aircraft or on the ground, to use these bombs.

Unguided Aerial Rockets

Despite the existence of precision guided weapons, unguided rockets continue to see widespread use as air-to-ground weapons, combining effectiveness, reliability and ease of use with low cost. The unguided rocket has relatively simple design, consisting of a fuse, warhead, body, rocket motor and stabilizing fins. Unguided rockets are usually carried in special containers or launch tubes. The rocket motor usually burns for 0.7 to 1.1 s after launch, accelerating the rocket to speeds of 2100 – 2800 km/h. After motor burnout, the rocket flies a ballistic trajectory like an artillery shell. To ensure directional stability, the rocket stabilizing fins, located at the tail, unfold from their stowed position. Some rockets are further stabilized by gyroscopic rotation around the longitudinal axis. An aircraft can be equipped with unguided rockets of different calibers (from 57 mm to 370 mm) and/or warheads, depending on the mission. The fuse can be contact- or proximity-detonated to achieve the desired dispersal of blast fragments.

Hit accuracy is dependent on the rocket's flight range, which in turn varies according to rocket type and caliber. Error accumulates with longer ranges, since the rockets fly without any trajectory guidance. The permissible launch zone for each type of unguided rocket is defined between its maximum range, and the minimum safe blast distance. The minimum safe distance depends on the warhead type and weight, and protects the firing aircraft from exploding fragments. Rockets are usually fired at airspeeds of 600 – 1000 km/h with a dive angle of 10^0 – 30^0. The pilot maneuvers the entire aircraft to put the aiming pipper on the target before firing.

S-8 rocket

The S-8 is a medium caliber (80 mm) unguided rocket. Twenty rockets are carried per weapon station in B-8 multiple launchers. For improved aiming accuracy, the rocket features 6 stabilizer fins, which are unfolded at launch by a piston driven by the rocket motor exhaust gases. The fins are then locked in the unfolded position. The fins are held in the folded position by a covering that is discarded at the moment of launch. The impulse and burn rate of the S-8 rocket motor was increased with respect to the S-5 rocket, to provide the heavier S-8 with rapid acceleration and rotation; the motor burn time was decreased to 0.69 sec. S-8 dispersion during flight and circular error probable (CEP) is 0.3% of the range. The maximum effective launch range is 2 km.

7-21: The B-8M1 Rocket Launcher

The S-8TsM is a smoke rocket variant, used to designate targets for friendly strike aircraft. The signal smoke indicates the position of the target.

S-13 rocket

These 132 mm unguided rockets are carried in B-13 launchers containing 5 rockets each. They are designed for strikes against fortified and hardened objects (pillboxes, shelters, airport aprons and runways). The Russian Air Force also uses 122 mm "type-013" unguided rockets. The S-13 preserves the layout of the smaller S-8 rocket (folded stabilizing fins located between the rocket nozzles with exhaust pressure actuation), with improved ballistic characteristics and hit accuracy.

7-22: The UB-13 Rocket Launcher

S-13 rockets can be fitted with different types of warheads. The rocket has the ability to penetrate up to 3 meters of earth or 1 meter of concrete. Its effective range is 3 km. The S-13T variant has two-stage action, and detonates inside the target after penetrating (up to 6 m earth or 2 m concrete). It can create runway craters with an area of 20 sq. meters.

The S-13OF blast-fragmentation variant generates 450 fragments weighing 25–35 g each, and is effective against unarmored targets.

All of the S-13 rocket variants are designed to be fired from aircraft speeds of 600 – 1200 km/h.

S-13 rockets are fired from B-13L 5-rocket launchers. The launcher has a length of 3558 mm and a diameter of 410 mm. The empty launcher weight is 160 kg.

Su-17M4, Su-24, Su-25, Su-27, MiG-23, Mig-27 aircraft and Mi-8, Mi-24, Mi-28 and Ka-50 helicopters can be equipped with S-13 rockets.

S-24 rocket

The ARS-240 rocket entered service in 1964 as the S-24.

The rocket has a length of 2330 mm. The wingspan with 4 stabilizing fins is about 600 mm. The launch weight is 235 kg, including a 123 kg blast-fragmentation warhead. The warhead contains 23.5 kg of explosive.

7-23: The S-24 Rocket

The rocket achieves a speed of 413 m/sec in flight, despite a rail-launch muzzle velocity of only 3.6 m/sec. The motor burns for 250 m of the flight path before burnout. Time of flight to a 1 km range is 3 seconds, with a maximum effective range of 2 km. The S-24 circular error probable (CEP) is within 0.3 – 0.4% of the flown distance.

The surface of the warhead is grooved to facilitate fragmentation. Detonation of the warhead generates 40,000 fragments reaching a blast radius of 300 – 400 m. Nevertheless, the construction is quite robust, able to penetrate 25 mm armor or layered brick or wood without damaging the fuse or warhead. Tests revealed that a contact fuse caused up to 70% of the shell fragments to embed in a shallow crater, so immediately upon the rocket’s service entry, it was fitted with the RV-24 "Zhuk" airburst proximity fuse, for detonation at an altitude of 30 meters.

Contact fuses with 3 different time delays continue to be used against hardened targets. The structure walls are penetrated by the encased warhead, which then explodes inside the target.

Stability in flight (and thus accuracy of aim) are ensured by the tail fins. The rocket spinning during flight compensates rocket motor irregularities.

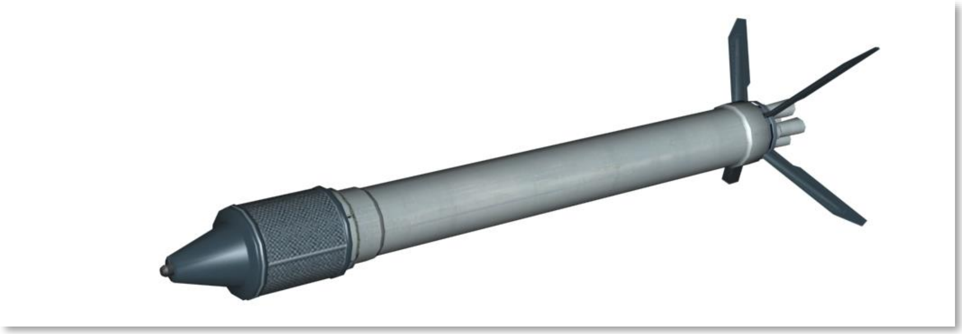
The rocket motor consists of seven solid propellant blocks with a star-shaped burn cavity, arranged in a circle around the rocket longitudinal axis. The pipes are angled so as to immediately spin the rocket after launch to a rotation rate of 450 rpm. The rocket motor contains 72 kg of propellant and has a burn time of 1.1 s. The rocket is stabilized in flight after burnout by the tail fins, which are canted to preserve the rocket’s spin.

Dependent upon the mission task, the Su-17 fighter-bomber may carry up to 6 S-24 rockets and the Su-25 close support jet up to 8. Some Mi-24 helicopters were also upgraded to enable them to employ the S-24.

S-25 Rocket

The S-25 unguided heavy rocket was produced in two versions, one with the S-25-0 fragmentation warhead and the other with the S-25-F high explosive warhead.

The 340 mm caliber S-25-F has a length of 3310 mm and launch weight of 480 kg. The high explosive warhead weighs 190 kg, including 27 kg of explosive, and is equipped with a contact fuse of varying time delay.



7-24: The S-25 Rocket

The S-25-0 rocket has the same caliber as the S-25-F, a full length of 3307 mm and a launch mass of 381 kg. The warhead weights 150 kg and is equipped with an adjustable radio proximity fuse for detonation at altitudes of 5 to 20 m above the ground. The warhead explodes into 10 thousand fragments.

7-25: The S-25 Unguided Rocket in its Launch Tube

The fins of the S-25 rocket are folded between four motor exhaust nozzles, which are slanted as on the S-24 to impart spin to the rocket at the moment of launch. The S-25 rocket solid propellant rocket motor consists of a mono-block high-energy fuel mixture weighing 97 kg. A smoke tracer is provided between the exhaust nozzles for observation and photo-record of the rocket flight path.

The S-25 has an effective launch range of 4 km. At the end of 1973, development work began on a laser-guided variant, designated the S-25L and equipped with a 2N1 laser-homing seeker, power unit, actuators and control surfaces. This variant was carried in the PU-0-25-L launcher.

The specifications of some unguided rockets are shown in table below.

Unguided rocket	Effective range, km	Weight, kg	Warhead type
S-8OFP	2,2	15,2	Blast-fragmentation
S-8TsM	2,2	15	Smoke (target designation)
S-13-OF	2,5	68/67	Blast-fragmentation
S-24B	2	235	Blast-fragmentation
S-25-OF	4	480	Blast-fragmentation

Figure 9

Gun Pods

SPPU-22-1 Gun Pod

The SPPU-22-1 gun pod was designed at the MAZ "Dzerzhinets" enterprise. It is armed with a GSh-23 twin-barrel gun, featuring 3400 rpm rate of fire and a magazine of 260 shells. The SPPU-22-1 pod can tilt the gun barrels down to -30o elevation, allowing it to be used against ground targets even in level flight.

7-26: The SPPU-22-1 Gun Pod

The Su-25 and Su-25T can carry up to 4 SPPU-22-1 pods on BDZ-25 pylons, for fire in the forward hemisphere.

The barrel tilt mechanism is integrated with the aircraft fire control system (FCS), which controls the elevation angle. The system can lock onto a point on the ground terrain from the moment the trigger is pulled.

NATO Air-to-Surface Weapons

Tactical Missiles

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.

7-27: The AGM-65K Maverick Missile

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.

7-28: The AGM-65H Maverick Missile

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.

7-29: The AGM-65D Maverick Missile

7-30: The AGM-65G Maverick Missile

The modern AGM-65K is an upgraded daytime variant using a charge-coupled device (CCD) EO seeker and a larger 136 kg blast-fragmentation penetration warhead with delayed-action fuze, which is more effective against fortified installations.

Anti-Radiation Missiles

AGM-88 HARM

The new AGM-88 High-speed Anti-Radiation Missile (HARM) entered service with the United States Navy (USN) and Air Force (USAF) in 1983. Unlike the earlier Shrike and Standard-ARM, the AGM-88 could attack lower-band early warning (EWR) and ground control (GCI) radars. According to official data, the missile can home on continuous-wave (CW) and pulsed emissions, as well as radars employing frequency modulation (FM) ranging.

The AGM-88 was developed on the basis of the semi-active radar homing (SARH) AIM-7 Sparrow air-to-air missile (AAM) and retains its basic aerodynamic layout, including cruciform moving wing control surfaces attached near the midpoint of the missile body. Four fixed stabilizing fins are mounted at the tail.

The missile is equipped with a Thiokol-780 boost-sustain solid propellant rocket motor. This motor burns a reduced-smoke propellant to prevent enemy forces from visually detecting the launch.

The blast-fragmentation warhead employs a proximity laser fuse.

7-31: The AGM-88 HARM Anti-radiation Missile

The missile's passive seeker can detect enemy radar emissions in the 3, 5, 10 and 25 cm wavelength bands (NATO bands D through I/J). It compares detected radar signals to a threat library of stored samples for rapid target identification. The missile also features a strap-down inertial guidance system, for use as a backup in case the target radar ceases transmissions while the missile is in flight.

The missile has three (3) operation launching modes. If the target type and position are known before takeoff, these can be programmed into the AGM-88 for launch in the "pre-brief" (PB) mode. In this mode, the AGM-88 can be fired from its maximum range under inertial guidance, and lock onto the target in flight (the HARM will self-destruct if no target is detected). "Target of opportunity" (TOO) mode is used against targets detected in flight by the HARM's seeker while it is still on the pylon. The missile flies a non-lofted profile directly at the target emissions in this mode. "Self-protect" (SP) mode is similar, but used against "pop-up" threats detected by the aircraft's radar warning receiver (RWR).

At the end of 1980s, efforts began to modernize the HARM missile. The AGM-88B variant had a new programmable seeker head, allowing its threat library to be updated in the field on short notice.

The AGM-88C modernization introduced a new wider-bandwidth passive radar seeker that was more sensitive than the original, and a more destructive warhead with twice the blast radius. The new warhead explodes into 12,845 cubic-shaped tungsten alloy fragments of 5 mm size. The fragments can penetrate a 12.7 mm thick sheet of soft steel, or 6.35 mm thick armor plate.

The US Navy first used the AGM-88 in combat in 1986, against Libyan air defense installations in the Gulf of Sidra (when 80 missiles were used). Since then, it has also been employed in large numbers by coalition aircraft in Operation Desert Storm (1991) and NATO aircraft over Kosovo (1999).

ALARM

The Air-Launched Anti-Radar Missile (ALARM) is a British-made ARM employed by Tornado aircraft of the Royal Air Force (RAF). It features similar performance and operational modes to the American AGM-88 HARM, with the added ability to be suspended over the target area on a parachute, waiting for threat radars to resume transmitting after a defensive shutdown.

Free-fall Bombs

Mk-82 and Mk-84 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.

7-32: The 500 lb Mk-82 Bomb

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.

7-33: The 2000 lb Mk-84 Bomb

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.

7-34: The Mk-20 Rockeye Cluster Bomb

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.

Unguided Rockets

LAU-10 and 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.

7-35: The LAU-61 Rocket Launcher

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.

7-36: 2,75' Hydra 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.

8

ELECTRONIC COUNTERMEASURES

ELECTRONIC COUNTERMEASURES STATION

Electronic warfare (EW) is a deep and complex topic that covers a long history of opposing and rapidly evolving sensors, tactics, weapons and other equipment from numerous countries. In this section, we consider only a few active radar jamming electronic countermeasures (ECM) - or as it has been more recently called, "electronic attack" (EA) - systems that are designed to protect the aircraft on which they are installed. When the player-flown aircraft is equipped with such an ECM system (internally, or carried on a weapon station as a pod), it can be toggled on and off during a mission by pressing the **[E]** key. The active jammer will then work to reduce the tracking range of enemy radars and degrade the performance of incoming radar-guided missiles. The player's use of such active ECM may come at a price, however. The ECM may interfere with the player's own radar-guided missiles during or after launch, hostile radars experiencing reduced tracking range may nevertheless enjoy increased detection range, and hostile missiles may see active ECM as a beacon, and pursue it in a secondary "Home On Jam" (HOJ) mode. For the best defense against missiles, active ECM is best combined together with passive jamming (chaff) and perpendicular ("beaming") maneuvers at low altitude.

Electronic Countermeasures (ECM) Stations of the Russian Air Force

"Sorbtsiya" and "Gardenia" ECM Stations

The Flanker's SPS-171 "Sorbtsiya" active ECM station is an analogue of the American AN/ALQ-135 station employed by the F-15C. The system is carried in two wingtip pods that replace a pair of R-73 missile pylons, thus decreasing the maximum missile carriage of the Su-27 or Su-33 aircraft by two (2). In normal usage, one pod acts as a receiver and the other as a transmitter, so that enemy radar signals can be continuously analyzed, manipulated and retransmitted with distortions, even if the threat radar frequency or bearing are changed. It employs steerable-beam antennas to organize jamming by sector and frequency band, and has several advanced operating modes, significantly decreasing the tracking and lock range of hostile radars.

The "Gardenia" active jamming station is mounted internally in the "humped" fuselage spine of the MiG-29S "Fulcrum C" variant, and thus does not decrease the available aircraft payload. It employs some similar operating modes and principles as the SPS-171, but with non-steerable transmitting and receiving antennas mounted at the wingtips.

Su-25 ECM Suites

The Su-25 close support aircraft is equipped with the SPO-15LM "Beryoza" radar warning receiver and the ASO-2V(M) chaff/flare dispenser, and can carry the SPS-141MVG "Gvozdika" active ECM pod (replacing the earlier "Siren") from one of the weapon stations. The SPS-141MVG "Gvozdika" ECM pod is interchangeable with the "Siren" pod and distinguished by more effective jamming in the rear hemisphere.

8-1: The SPS-141MVG "Gvozdika" Active ECM Pod

The appearance of modern threat radars capable of rapid frequency hopping, however, required the creation of new ECM system based on digital technology and possessing higher technical characteristics for advanced close support aircraft such as the Su-25T/TM.

The new system includes a new radar warning receiver, active jamming station and chaff/flare dispenser fully integrated under the name "Irtysh" and installed in the Su-25T/TM aircraft.

The SPO-15LM "Beryoza" was replaced by the L-150 "Pastel" receiver, the SPS-141MVG "Gvozdika" by the "Gardenia" active ECM station, and the ASO-2VM by the UV-26S chaff/flare dispenser.

The active ECM station development, constantly reacting to new threats and available technologies, continued to evolve in a progression: "Siren" – "Gvozdika" – "Gardenia" – "Omul" – "MSP" according to the aircraft type and variant. Today, the most up-to-date "MSP" and MSP-410 "Omul" active ECM stations are designed for installation on the Su-25T, Su-25TM and Su-25SM aircraft.

Whereas "Siren", "Gvozdika" and "Gardenia" stations are each carried as a single pod, the "Omul" station is realized as two pods carried on the wingtip pylons, much like the SPS-171 "Sorbtsiya."

8-2: The MPS-410 "Omul" Active ECM Pod

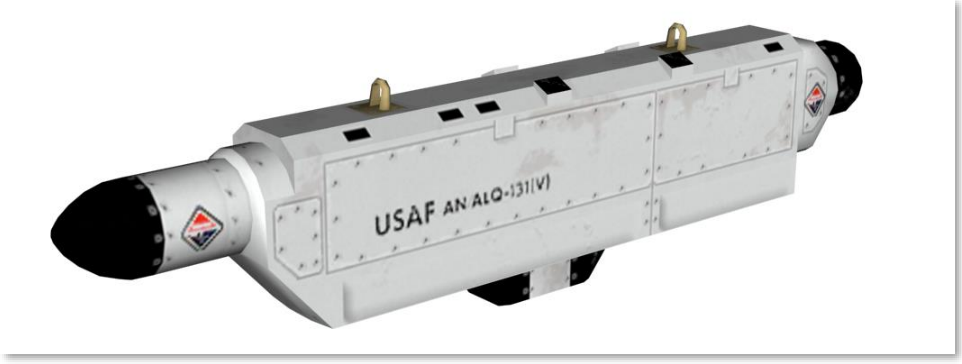
The MPS-410 "Omul" ECM is design to counter modern and prospective threats, and is currently at the prototype stage of development.

The Su-25T and Su-25TM aircraft further include a flashing "Sukhogruz" IR jammer mounted at the base of the tail fin above the engine exhausts, to confuse the tracking of conical-scan infrared homing (IRH) missile seekers. This equipment can be activated during a mission by pressing **[LShift-E]**.

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.



8-3: The AN/ALQ-131 Active ECM Pod

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

AN/ALQ-135 ECM station

The AN/ALQ-135 internal ECM station entered service as an integrated element of the F-15 Eagle's Tactical Electronic Warfare System (TEWS), making the Eagle the first air superiority fighter designed from the start with internal space reserved for an active jamming suite.

The system is capable of producing both noise barrage and deception jamming signals to counter a variety of both fixed- and variable-frequency threat radars operating in the bands of 2 to 20 GHz (NATO E through J bands). The transmitting antennas provide 360° coverage for protection against radar guided "surface-to-air" (SAM) and "air-to-air" (AAM) missiles. The system features 20 re-programmable processors working in parallel, to ensure fast and flexible responsiveness to changes in the threat environment.

The AN/ALQ-135 jammer tunes itself according to threat data received from the AN/ALR-56C radar warning receiver, which is similarly integrated into the Eagle's TEWS.

In its original configuration, the AN/ALQ-135 consisted of six line-replaceable units (LRUs or "black boxes") - three oscillators and three amplifiers that generated the jamming signals for coverage in its overlapping Band 1 (NATO E through G) and Band 2 (NATO G through I).

The F-15C later received some of the F-15E Strike Eagle's AN/ALQ-135B equipment as an upgrade, providing coverage in Band 3 (NATO H through J) against modern short-range SAM, AAA and interceptor aircraft radars. Two new transmitting antennas were installed ahead of the windshield and ventrally, both behind the nose radome, together with a horn antenna installed in the starboard fuselage tail boom for rear hemisphere coverage. These were in addition to the existing "Band 1.5" (replacing Bands 1 and 2) transmitting blade antennas installed under the fuselage nose.

Despite the high operational tempo during Operation Desert Storm in 1991, no F-15 fighter equipped with the AN/ALQ-135 was shot down by radar guided SAMs or AAMs (two F-15E Strike Eagles, still lacking the F-15C's Band 1.5 coverage at the time, were lost to ground fire).

Work on the AN/ALQ-135 and TEWS system continued through the mid-1990s. After their operational evaluation in 1994 the US Air Force Command noted that the "technical requirements required of modern ECM systems were met or surpassed."

9

RADAR WARNING SYSTEMS

RADAR WARNING SYSTEMS

Radars that are installed on aircraft, ships and ground vehicles are used for acquisition and weapons guidance to various types of targets. Most modern aircraft are equipped with radar warning systems (RWS) that detect the illumination of enemy radar. Although companies and bureaus have their unique approaches to the designing of such systems, all RWS have common operational principles.

RWS is a passive system, i.e. it does not emit any energy into the environment. It detects radar emitters and classifies them according to a database of the known radar types. RWS can also determine the direction to the emitter and its operational mode. For example, the establishing a single target track file. However, RWS cannot define the distance to the emitting radar.

The RWS systems included in game are similar in their functional capabilities. Each system can detect the unique radar emissions, detect continuous wave (locked warning) illumination, and missile command data link signals (launch warning).

For better situational awareness, it is recommended to use the RWS mode selection. Mode selection enables the RWS to identify only radars operating in the target track mode, or radars that are transmitting command guidance signals for a SARH missile launch or Active Radar Homing (ARH) missile seeker track.

Note that the RWS does not have Identify Friend-or-Foe (IFF) capabilities.

The RWS can use priority logic to determine a primary threat and a list of secondary threats in descending order:

1. The threat is either an ARH missile or if the missile command guidance signal is detected (missile launch);
2. The threat radar is transmitting in Single Target Track (STT) mode (or any other lock mode);
3. The threat has a priority based on a 'common type' of the threat. Here is the list of the types:
    - The threat is airborne radar;
    - The threat is a long-range radar;
    - The threat is a mid-range radar;
    - The threat is a short-range radar;
    - The threat is an early warning (EW) system;
    - The threat is an AWACS.
4. The threat is at maximum signal strength.

RWS DOES NOT DEFINE THE DISTANCE TO THE EMITTER

Radar Warning Receiver of Russian Aircraft

The RWS model implemented in game is very close to the actual system installed in the MiG-29A and MiG-29S (production 9-12, 9-13).

The system provides detection of radar signals at the following angles: Azimuth - +/- 180, and Elevation Range - +/- 30.

The maximum number of threats on screen: Unlimited.

The threat history display duration time: 8 seconds.

Function modes: All (acquisition) or Lock (the "ОБЗОР/ОТКЛ" switch in MiG-29 cockpit).

Symbology. Threats types:

П – airborne radar

З - long-range radar

Х - medium-range radar

Н - short-range radar

F - early warning radar

С - AWACS

"Relative elevation" lights, "power of emission" gauge lights and "Lock/Launch" lights are only in regards to the primary threat.

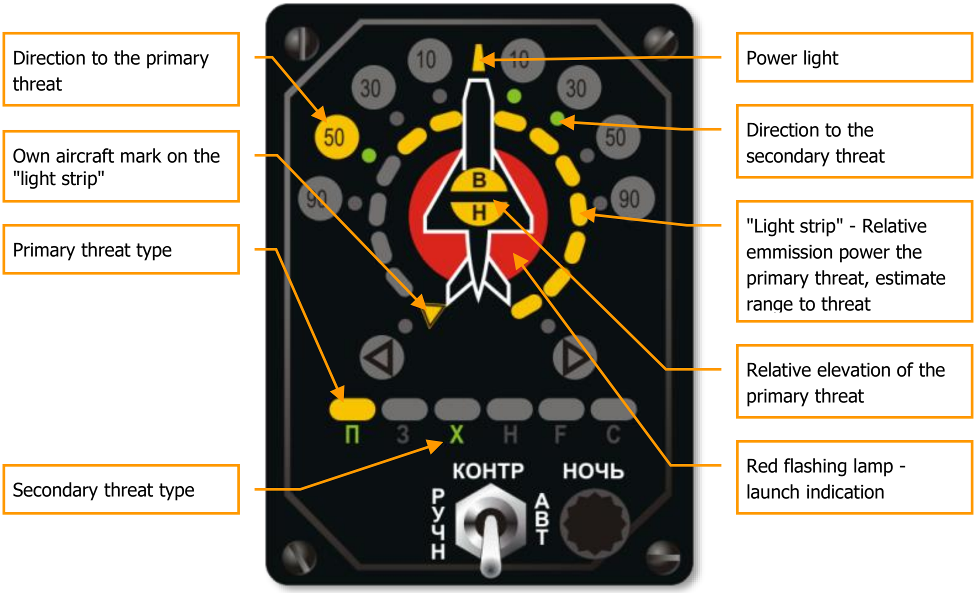
If the time between radar spikes of threat radar is eight or more seconds, the azimuth lights will not blink.

In the case of an acquisition-type spike, the low frequency audio tone will sound.

If a radar is in lock mode, the "Lock/Launch" indicator will light up, along with a steady, high frequency audio tone.

If a radar-guided missile launch is detected, the "Lock/Launch" light will flash, along with a high pitched audio tone.

An ARH missile can be detected by the system after a missile establishes a lock using its own radar seeker. In this case, the missile will become the primary threat. The cue to recognize an ARH missile is the rapid increase in signal strength ("power of emission" lamps).



9-1: "Beryoza" SPO-15LM indicator

The ability to correctly interpret the information indicated on RWS panel is vital in combat.

As an example, let's take a look at the situation shown in picture above.

As is seen in the picture, two threats are indicated on RWS panel:

1. The primary threat at 50 degrees left (10 o'clock) is indicated in the form of a large yellow lamp. The lamp above "**П**" symbol, which means "interceptor", is lit. This type of threat includes all fighters. The circular scale of signal power ("light strip") consists of yellow segments that show the relative emission power of the primary threat's radar. The large red circle under the aircraft symbol indicates that your aircraft has been locked by the primary threat radar. The lit, yellow hemispheres marked as "**В**" and "**Н**" in the center of the aircraft silhouette, indicates the threat's relative altitude to yours. In this situation, the primary threat is at the same altitude as your own, within 15 degrees in elevation. Consequently, the display can be interpreted in the following way: your primary threat is a fighter approaching from 10 o'clock; it is near co-altitude with you; and judging by the signal strength and lock light, it is ready to launch a missile.

2. The secondary threat is positioned at 10-30 degrees azimuth (1-2 o'clock right), and this is indicated by the two green lamps. The green "**Х**" symbol in the threat types line indicates that your being targeted by a medium-range radar. There is no additional data on secondary threats.

In a complex threat environment, it is often difficult to define the threat type and direction. In this case it is recommended to use the RWS mode filter **[RShift-R]** that removes all emitters operating in acquisition mode.

The RWR can produce multiple audio alerts. You can adjust their volume by pressing **[RAlt-,]** – **[RAlt-.]** keys.

Radar Warning Receivers of USA Aircraft

The A-10A and F-15C Radar Warning Receivers (RWR) are a different in appearance but operate much the same way. On the 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-56C RWR is a part of TEWS (Tactical Early Warning System) for the F-15C/D Eagle.

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 implemented of these systems in game is very close to the actual system installed in the A-10A/OA-10A and F-15C.

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.

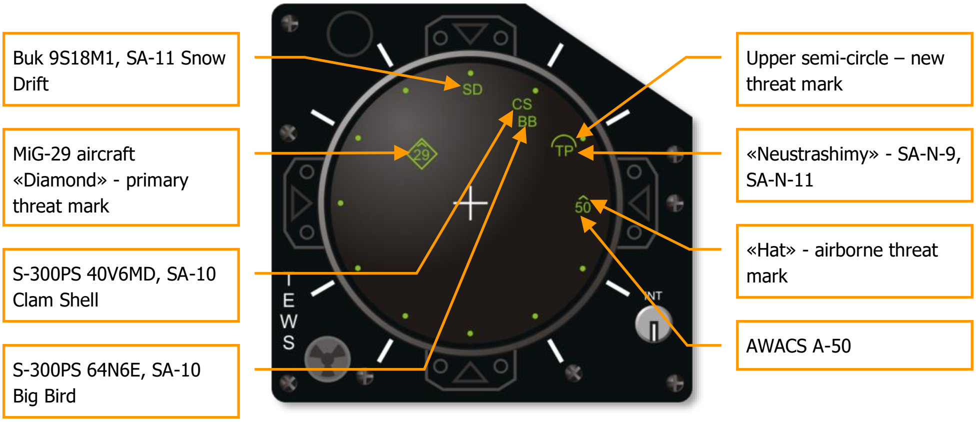
The AN/ALR-69 (A-10A) has azimuth marks on the scope (at 15 grad intervals) and two zones (or "rings") divided by a circle. A threat in the inner ring is an immediate threat to your aircraft.

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.



9-2: F-15C TEWS display symbology

The above image shows an example situation on the TEWS display.

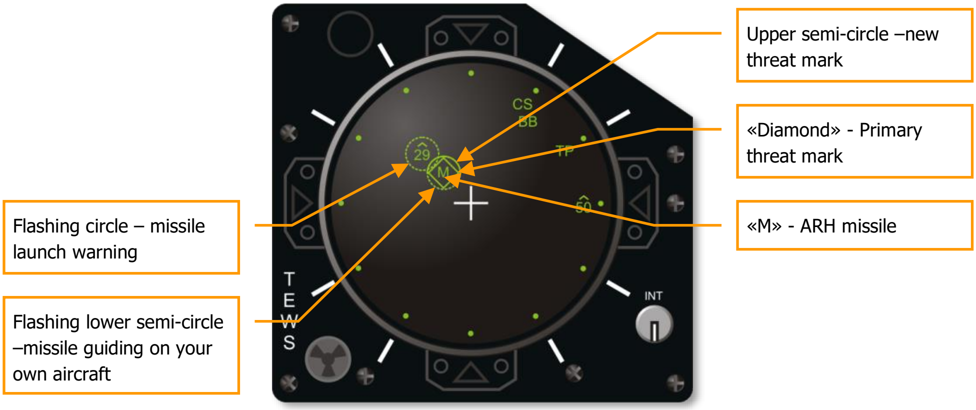
- At 12 o'clock, your aircraft is being illuminated by the acquisition radar (Snow Drift) of a "Buk" SAM system.
- From 1 o'clock, your aircraft is being illuminated by an 64N6E (Big Bird) acquisition radar and a 40V6MD (Clam Shell) low-altitude acquisition radar tower. Both of these radars are part of a S-300PS SAM (SA-10C) battery.
- From 2 o'clock, your aircraft is being illuminated by a ship-borne radar of a "Neustrashimy"-class patrol ship. Because it is a newly detected emitter, it has the semi-circle above it.
- From 3 o'clock, your aircraft is being illuminated by an A-50U AWACS.
- The primary threat, enclosed in a "diamond", is a MiG-29 between 10 and 11 o'clock.

From above analysis, we can draw the conclusion that the primary threat is MiG-29 that can employ a weapon any time. Consequently, it is necessary to either go offensive against this threat, or exit the area and deny the MiG a shot. An attack on the MiG could be performed independently or with the help of wingmen.

In addition to the MiG-29, the S-300 complex presents a potential threat. It is located at 1 o'clock, relative to your aircraft. When planning future maneuvers, the possibility of entering into the SAM's launch zone must be considered.

If a missile launch is detected, an audio launch warning will be heard. It will repeat itself every 15 seconds until the threat is gone.

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.



9-3: TEWS display symbology, ARH missile launch

The above image shows an example situation on the TEWS display, picture 9-3.

- At 12 o'clock, your aircraft is being illuminated by the acquisition radar (Snow Drift) of a "Buk" SAM system.
- From 1 o'clock, your aircraft is being illuminated by an 64N6E (Big Bird) acquisition radar and a 40V6MD (Clam Shell) low-altitude acquisition radar tower. Both of these radars are part of a S-300PS SAM (SA-10C) battery.
- From 2 o'clock, your aircraft is being illuminated by a ship-borne radar of a "Neustrashimy"- class patrol ship. Because it is a newly detected emitter, it has the semi-circle above it.
- From 3 o'clock, your aircraft is being illuminated by an A-50U AWACS.
- MiG-29 aircraft positioned between 10 and 11 o'clock had launched a missile – a blinking circle around the symbol.
- The primary threat, "M" symbol, is enclosed by a "diamond" symbol. This is an ARH missile launched from the MiG-29. It is marked as a new threat – the semi-circle. As the primary threat, a "diamond" symbol surrounds it. The lower, blinking semi-circle indicates that the missile is on the way to intercept your aircraft.

In this case, there is little time to think and you must react quickly – perform an aggressive, high-G maneuver perpendicular to the missile's flight path while expending chaff **[Insert]**.

Given the effectiveness of modern ARH missiles, the probability of being hit still remains high, even after proper counter-missile tactics. In any case, it is better to deny the shot to begin with than trying to avoid being shot down a missile launched at you.

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

9-4: A-10 RWR control 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 TEWS (F-15) and RWR (A-10) displays.

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.

9-5: TEWS (F-15) and RWR (A-10) symbols

It should be noted that symbols and marks can be combined. Ror 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

TEWS ECM Indication

The self-protected ECM activity dysplayed in the center of TEWS screen as open X.

9-6: TEWS ECM indication

10

RADIO COMMUNICATIONS AND MESSAGES

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-air missile.	**"Fox from (x),"** if an American aircraft or **"Missile away from (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 detected on radar	**"(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 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	**"(x), Tower, orbit for spacing,"** where (x) is the callsign of

	approach point and has been handed over to Tower control. However, an aircraft is already in the pattern.	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"

11

THEORETICAL TRAINING

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. Modern, highly maneuverable aircraft like F-15C can fly at high angles-of-attack (AoA) - when the aircraft flies in one direction but the longitudinal axis is directed in another.

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

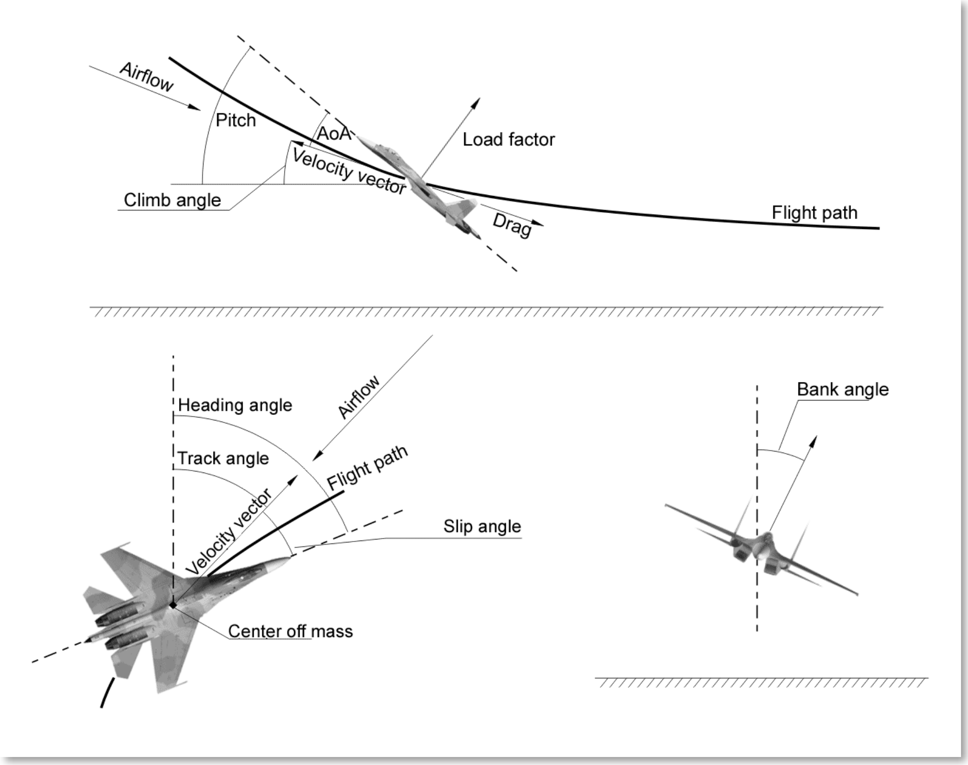
When aircraft AoA is increased up to a critical value, the airflow becomes disrupted over the wing and the wing ceases to generate lift. Asymmetrical air-mass separation from the left and right wings can induce side movement (yaw) and stall the aircraft. The stall may happen when the pilot exceeds the 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

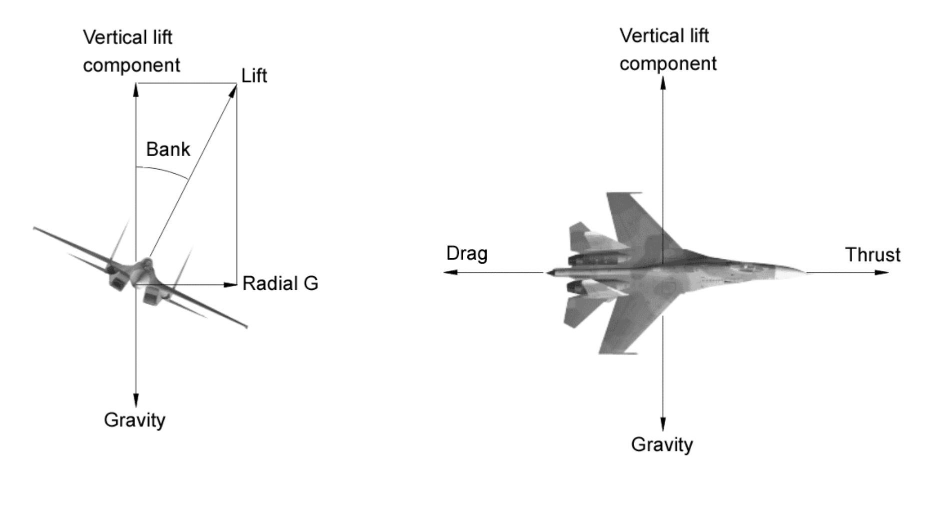
Turn Rate and Radius of Turn

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.



11-1: 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.



11-2: The forces acting at the aircraft maneuver

Turn Rate

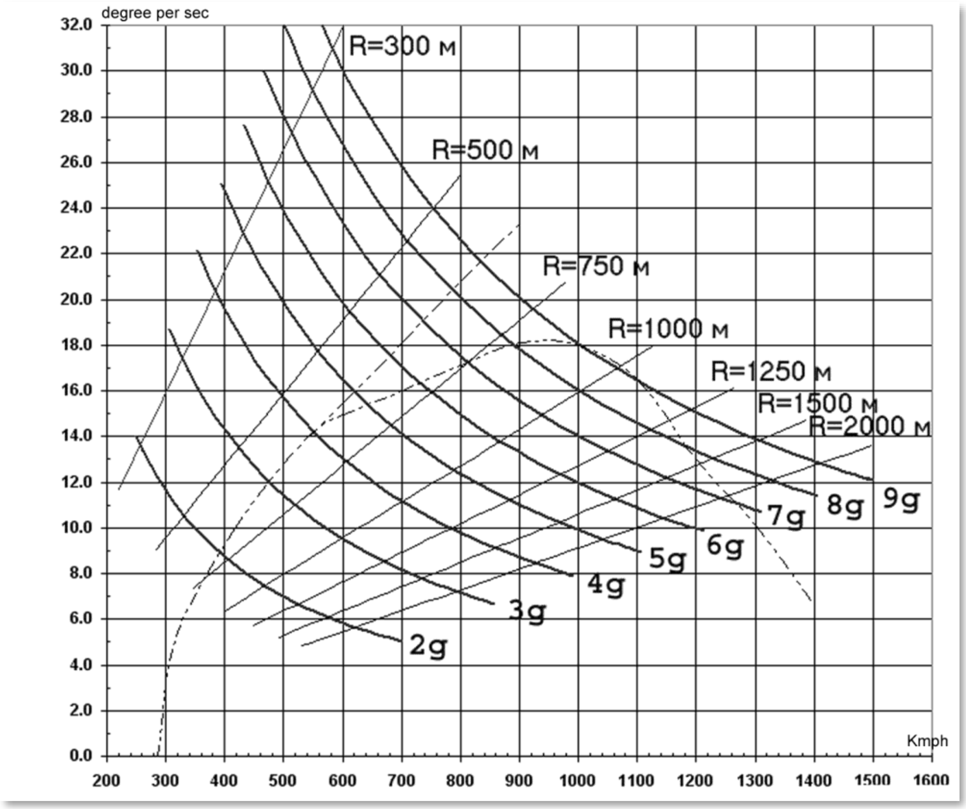
When G-load increases: turn rate increases and radius of turn decreases. There is an optimal balance at which maximum possible turn rate is achieved with the smallest possible turn radius.

> 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.



11-3: 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

12

FLIGHT SCHOOL

FLIGHT SCHOOL

During a mission, the majority of flight time is taken up with taking off, flying the assigned route, acquiring the target, returning to base, and landing. Actual combat with the enemy is generally a small fraction of the total mission time.

IF YOU FAIL TO FIND THE TARGET OR FAIL TO RETURN TO BASE, YOUR CAREER AS PILOT WILL SOON BE OVER

Using the Horizontal Situation Indicator (HSI)

For many modern aircraft, navigational information is presented on HUD. What is the pilot to do if the HUD fails? The HSI provides much of the same navigation information that is provided on the HUD; in some ways, more. Both Russian and American HSI indicators perform the same functions and include the following features:

- Course to the next waypoint (needle and digital readout)
- Distance to the next waypoint
- Current heading
- Course and altitude deviation bars

The course to the selected waypoint is shown in relation to the aircraft's current location. Waypoints are automatically set before the flight and can be used to reach the target objective along the best route.

Landing

Landing is one of the most difficult and potentially dangerous elements of flight. Pilots of high and low qualification differ by their landing skills.

FOR A GOOD LANDING, LINE UP YOUR APPROACH EARLY ON

The landing approach is performed at a defined angle-of-attack. Your current AoA can be viewed on the AoA indicator in the cockpit. If the aircraft is equipped with an AoA indexer, you can perform landing approaches while keeping an eye on this indexer. If the upper index is lit it means that the aircraft is flying at too high of an AoA or the airspeed is too low. If the lower index is lit it means that the aircraft is flying at too low an AoA or the flight speed is too high. If the middle indicator is lit it means that all landing approach parameters are met.

WHEN LANDING, USE SMOOTH, SMALL CONTROL INPUTS AND REMEMBER THAT CONTROL INPUTS CAN HAVE A DELAYED IMPACT ON THE FLIGHT OF YOUR AIRCRAFT. THINK AHEAD OF YOUR AIRCRAFT

In the process of landing, you should maintain the proper AoA. If the flight speed is too high, you should pull the control stick back a little. This will decrease the flight speed to the appropriate value. In the opposite case, you should push the control stick a little forward; this will increase the flight speed. If your altitude is decreasing too fast you should increase engine thrust by pushing the throttle control forward. If the altitude is too high you should pull the throttle back.

On the HUD and dash, some aircraft will include a vertical velocity indicator; this can be used to assure a safe touch down rate. The aircraft's velocity vector can also be used to confirm that the touch down point is at the start of the runway.

In the table below, you can find landing approach and touch down speeds.

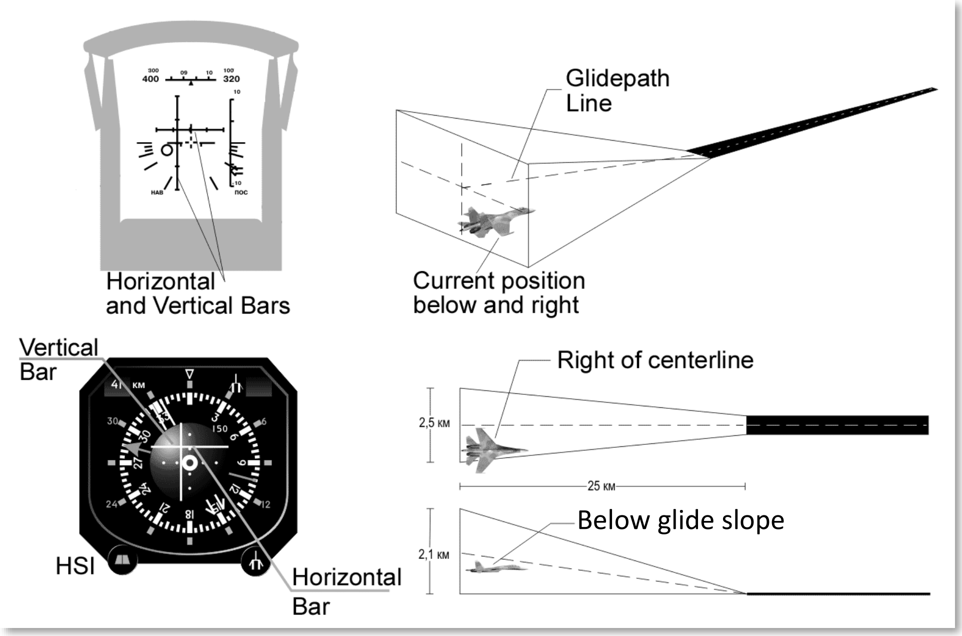
Aircraft	Landing approach speed	Runway contact speed
Su-25	280 km/h	235 km/h
Su-27	300 km/h	250 km/h
MiG-29A	280 km/h	235 km/h
F-15	175 knots	120 knots
A-10	150 knots	110 knots

IF FLAPS ARE RETRACTED YOU SHOULD INCREASE THE INDICATED AIR SPEED ABOUT 10 KNOTS/20 KM/H. IF THERE ARE EXTERNAL PAYLOADS OR A CONSIDERABLE AMOUNT OF FUEL YOU SHOULD INCREASE YOUR AIR SPEED TO ALLOW THE DESIRED ANGLE OF ATTACK.

You should always approach a landing along the longitudinal axis of the runway.

Instrument Landing System (ILS)

Russian and American aircraft are equipped with instrument landing system equipment. Steering bars are used to indicate deviation from the landing glideslope and course. The horizontal bar shows the deviation of the aircraft's flight path from the proper glideslope. The vertical bar (also called the localizer) indicates the deviation of the aircraft's flight course from the required course. The planned course will align the aircraft on the runway's longitudinal axis. A centering of these two bars to form a cross indicates that the aircraft is flying along the proper glideslope down the runway's axis.



12-1: Instrument landing system

Landing with a Crosswind

Landing in a crosswind is more difficult than the landing with no wind. A crosswind causes the aircraft to drift away from the runway's longitudinal axis. Therefore, it is necessary to compensate for aircraft drift with the help of rudders and ailerons during the landing approach. Landing in such conditions requires great attention from the pilot and well-coordinated stick and rudder movements.

AVOID LANDINGS WITH A TAIL-WIND; IT CONSIDERABLY INCREASES THE TOUCHDOWN SPEED AND MAY LEAD TO A ROLL OUT BEYOND THE RUNWAY

Su-25 and Su-25T Advanced Flight Dynamics Model Description

Advanced flight dynamics model was created for the Su-25 and Su-25T. This section describes some of the many remarkable features of the advanced flight model.

Aircraft dynamics are calculated on the basis of the same physics equations describing translational and rotational motion of a solid body under the influence of external forces and moments, disregarding the nature of their origin.

- Trajectory and angle movements look more natural due to correct modeling of the aircraft's inertial properties.
- Transitions between the flight modes in a smooth manner without abrupt changes of angle rotational speeds and attitude (for example: after a tail-slide or when landing with an angle of roll on one landing wheel).
- Gyroscopic effect with the aircraft's rotation taken into account.
- The asymmetric effect of external forces is taken into account, along with the effect of external forces not going through the center-of-gravity (for example: engine thrust, drag chute forces). These forces are correctly modeled at any flight mode and cause an adequate rotary moment.

The center-of-gravity can change its location within the speed axis system.

- The modeling of lateral and longitudinal center of mass has been introduced. This can change depending on fuel load and weapon loads.
- The asymmetrical loading of weapon and fuel pylons, which influence the characteristics of lateral control (depending on flight speed, regular overload, etc), is also modeled.

When calculating aerodynamic characteristics, the aircraft is represented as a combination of airframe components (fuselage, outer wing panel, stabilizer, etc). Separate calculations for the aerodynamic performance of each of these components are performed. This is done over the entire range of local angles of attack and slip (including supercritical), local dynamic pressure and Mach number. This takes into consideration the change and level of destruction of control surfaces and various airframe components.

- Aerodynamics are accurately modeled in the entire range of angles of attack and glide.
- The efficiency of lateral control, and degree of lateral and static lateral stability, now depend on the angle of attack, longitudinal and lateral center-of-gravity.
- The wing autorotation effect when performing a rolling rotation at high angles of attack is modeled.
- Kinematic, aerodynamic and inertial interaction of longitudinal, dihedral and lateral channels (yaw movement when performing a rolling turn, rolling motion at rudder pedal forward, etc).
- Angle of glide availability is determined by the pilot's efforts and the plane's position.

- When an airframe component is destroyed, the plane's motion is modeled in a natural way. The damaged component's aerodynamics can be fully or partially removed from the aircraft's aerodynamic calculations.
- The flight model guarantees a realistic implementation of stalls (rocking wings with simultaneous course oscillation).
- Various characteristics of aerodynamic shaking depending on the flight mode have been introduced. This occurs due to store loading, exceeding allowable angle of attack, Mach number, etc.

The jet engines are represented as a complex model of the main components: compressor, combustion chamber, turbine and starter-generator.

- Idle RPM depends on the speed mode: altitude and Mach number, weather conditions: pressure and temperature.
- Low RPM over-speeding is modeled.
- Engine throttling and its controllability depend on rotation speed.
- Gas temperature behind the turbine is dependent on engine operating mode, flight mode and weather condition.
- Specific fuel consumption is non-linearly dependent on engine operating mode and flight mode.
- The dynamics of engine operating parameters (gas speed and temperature) during engine start and shut down is accurately modeled. The mode of engine autorotation from ram airflow, engine seize (accompanied by continued temperature rise) in case of engine start at the incorrect throttle position, engine restart and windmill air restart.

The left and right hydraulic system model includes models of sources and consumers of hydraulic pressure.

- Each hydraulic system supplies its own group of hydraulic pressure users (landing gear, aileron actuator, flaps, wing leading edge flaps, adjustable stabilizer, nose wheel steering, brake system, etc).
- Pressure in the left and right hydraulic systems depends on the balance of hydraulic pump efficiency and operating fluid consumption by hydraulic pressure users (boosters, actuators, etc). Hydraulic pumps efficiency depends on the right and left engines speed respectively, operating fluid consumption depends on their work intensity.
- Both catastrophic and partial hydraulic actuators failure when pressure drops in a corresponding hydraulic system is modeled.

The control system includes models of the primary components: trimming mechanism and trimming effect, hydraulic boosters in roll channel, and yaw dampener.

- Pitch trimming, the yawing model and the aileron trimming mechanism model are all based on a different logics. In particular, the pitch trimming position does not influence rate controller position at near-zero flight speed. Trimming tab serviceability depends on electrical power in the aircraft electrical system.

- In the event of a pressure drop in the left side of the fuselage, lateral control worsens with the rise of indicated flight airspeed. Longitudinal control does not depend on fuselage pressure.
- The extension and retraction speed of high-lift wing and adjustable stabilizer surfaces depends on fuselage pressure.
- The extension of high-lift wing devices for a more maneuverable configuration at a high indicated airspeed can lead first to partial and then to complete hydraulic actuator blocking. This causes fuselage pipe damage, hydraulic fluid leakage and fuselage pressure drop.
- Landing gear extension at a high indicated airspeed can first lead to partial and then to complete hydraulic actuator blocking. This causes fuselage pipe damage, hydraulic fluid leakage and fuselage pressure drop.

Cold Engine Start Procedure From the Parking Ramp

1. Turn on the auxiliary power unit (APU) with the **[RShift-L]** key and confirm that all instrument indications on the dash and HUD are operating normally.
2. Set the throttles to the idle position.
3. Start both engines with the **[RShift-Home]** key, or sequentially start the right engine - **[RCtrl-Home]** key and then the left engine - **[RAlt-Home]** key.
4. Check engine compressor fans turning on the tachometer indicator and engine RPM stabilizes at 33%.
5. Check the turbine gas temperature on the exhaust gas indicator. The exhaust gas temperature should be around 440 degrees.

If you start the engine with the throttles not set to idle, the engine will be flooded with fuel and the engine will be held-up in an intermediate position. An uncontrollable engine temperature rise may also result and start an engine fire.

In such a situation, immediately stop the engine(s) - **[RShift-End]**. After a full engine shut-down, wait one to five minutes for the engine to cool off, and then try to repeat the startup procedure.

To speed up the engine start procedure it is also possible to perform an engine relight. To do this, wait for the second stage of the engine spin-up to reach at least 16% RPM; then move the throttles to their maximum thrust position.

In Air Automatic engine start

If the engines cease to function (flame out) while in the air, you can perform an automatic restart. To do so, the airspeed must exceed 150 km/h; set the throttle to the idle position; then increase to the maximum thrust; and then back to idle. If all conditions are met, the engine will begin the restart process.

A windmill start is only possible when engine speed is at or above 12%.

Special Considerations for Flying the Su-25 and Su-25T

Taxi

Nosewheel turns should be performed at no faster than 5-10 km/h in order to avoid rolling the aircraft onto its wing or damaging the nose gear pneumatics.

Take-off

The wheel brakes will hold the aircraft at no greater than 80% of engine RPM. When powering up the engines for take-off, release the wheel brakes as the RPM climb through 70-75% and increase thrust to full military power as the aircraft begins to roll for take-off. Maintain heading straight down the runway with soft pedal input. As the speed climbs to 160-180 km/h for normal take-off weight or 200-220 km/h for maximum take off weight, pull the stick back about 2/3 of the way to raise the nose for take-off. A good take-off pitch angle can be approximated by placing the ends of the two pitot tubes along the horizon. The aircraft will take-off almost immediately as you raise the nose to a proper take-off angle. If the aircraft is not carrying external stores, it will have a tendency to increase pitch dynamically, which can be countered by carefully pushing the stick forward.

Retract the gear at 10 m. above the ground and the flaps as the airspeed climbs to 320-340 km/h at an altitude of no less than 150 m. As the gear is raised, the hydraulic pressure may temporarily drop in the second hydraulic system, activating the "ГИДРО 2" ("HYDRO-2") warning light.

Crosswind Take-off

One of the peculiar features of the Su-25/25T is the short span and base of the landing gear, which makes crosswing take-offs and landings quite challenging. Nevertheless, the aircraft can be held steady while rolling in a crosswind of up to 11-14 m/s, provided the ruway is dry. When rolling in a crosswind, the aircraft will tend to bank with the wind, which can be corrected by counter stick force against the wind. The aircraft will also have a tendency to turn into the wind, which can be corrected with smooth pedal input in the opposite direction.

Landing

On approach, the gear should be extended once the airspeed falls below 400 km/h. When extending the flaps, the aircraft will have a tendency to "balloon". The aircraft balance in the Take-off/Landing Configuration is almost identical to normal Flight Configuration. If the aircraft becomes unbalanced in either its longitudinal or lateral axis when configured for landing, the gear or flaps may not have fully extended or extended asymmetrically. In this case, retract the flaps to perform the landing in normal Flight Configuration. Adjust all approach and landing speeds to increase by 40-60 km/h.

Careful speed management is required on final approach to perform a proper landing. Reduce speed to 290-310 km/h by setting the aircraft into Takeo-off/Landing Configuration at the start of your glideslope descent. Reduce speed to 260-280 km/h by the time you reach the Inner Marker Beacon. Begin to flare as you approach the runway, at approximately 5-8 m. altitude, 250-270 km/h and 100 m. before the runway threshold. After final line up at approximately 1 m. above the ground, reduce thrust to Idle and as the aircraft slows down, increase pitch by holding the stick back so that the pitot tubes line up with the horizon. Touchdown should occur at 220-240 km/h. Proceed to lower the nose wheel by carefully pushing the stick forward, release the brake chute and engage the wheel brakes. Maintain heading down the runway centerline with smooth pedal inputs. If the aircraft veers when braking, release the brakes, correct heading and only then reapply the brakes. If the aircraft risks running off the runway at a speed of greater than 50 km/h, retract the gear, open the canopy, and perform an emergency shut down.

Crosswind Landing

When performing a crosswind landing, estimate a lead angle directly to the runway threshold such that the approach can be flown with no bank or yaw. As you flare the aircraft just before touchdown, eliminate the lead angle to align the aircraft with the runway and push the stick into the wind. This will ensure that touchdown is performed with no sideslip and is corrected for the crosswind bank tendency when rolling on the runway. Once the main gear is in contact with the ground, release the pedals to center the nose wheel and quickly, but carefully lower the nose to touchdown the nose wheel. Once stabilized down the runway centerline, engage the wheel brakes. In a crosswind of greater than 4-5 m/s, the brake chute is not used as it would make it practically impossible to maintain the aircraft on the ruway. If the aircraft veers when braking, release the brakes, correct heading and only then reapply the brakes.

Common Landing Errors

Overshoot

An overshoot will occur if speed was mismanaged and the approach performed too fast or if the touchdown point was miscalculated. This will often happen when the flare is performed late, such as over the runway threshold instead of ahead of it. A significant overshoot can be dangerous and the landing should be aborted as a missed approach ("go-around").

Landing Short

A landing short will occur if the approach speed was too low, the flare maneuver started too early, or the aircraft was allowed to fall below the glidepath on final appoach. To correct this, increase engine thurst until optimum approach speed is reached and the aircraft is on the glidepath.

Flare Too High

A flare too high will occur if the flare altitude is misjudged or the stick is pulled back too much during the flare. To correct this, hold the stick steady to allow the aircraft to descend to the proper flare altitude and then pull the stick again to perform a proper flare. In a flare too high, the aircraft will likely loose airspeed and drop onto the runway, resulting in a rough touchdown and high vertical velocities stressing the airframe.

Stalls and Spins

If airspeed is lost in level flight, the aircraft will stall without entering a spin. It will begin a "parachute" descend while oscillating in yaw and roll. If the stick is pulled during the stall, oscillations may increase in roll to the point of causing a wing-over, where the aircraft will roll violently toward one side. To correct this and counteract the stall, push the stick forward.

When flying in normal Flight Configuration and Maneuvering Configuration, a spin can only be induced intentionally. In normal Flight Configuration and Maneuvering Configuration, the spin will be alleviated once the stick is placed into its neutral position. To expedite the recovery out of the spin, the standard technique is to push the stick forward and apply opposite rudder.

When flying in Take-off/Landing Configuration, a spin can be entered unintentionally if the angle of attack reaches beyond critical limits, especially if the aircraft's center of gravity is aft of center. The CG will shift aft in an Su-25 if the cannon ammunition has been expended and is always aft in the Su-25T. Once the aircraft has entered a spin in this configuration, it is practically impossible to recover.

13

COMBAT OPERATION BASICS

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

Modern fighters like the Su-27, MiG-29 and F-15C were designed to achieve air superiority over the battlefield. Although they can carry a limited number and types of air-to-surface weapons, air combat is their priority task. During air combat, it is better to kill the enemy at long range, and only engage within visual range if necessary. With the advent of the Russian R-73 and helmet mounted sight, this is particularly true for western aircraft. For interceptors such as the Su-27 and F-15C, it is important to start an engagement with the enemy at long-range, before the enemy can bring weapons to bear. Ideally, the enemy aircraft will be damaged or destroyed and won't be able to carry out its mission. It is often more important to deny the enemy from completing its mission that actually destroying the enemy aircraft.

Target Search

Modern fighters often have powerful radars that are able to detect targets at long range. In addition to onboard radar, it is also helpful to have an airborne warning and control system (AWACS) aircraft in the air or ground early control intercept (GCI) radar stations that can monitor the airspace and vector friendly assets against enemy forces. Using AWACS and GCI, it is possible to conduct covert missions that enter enemy airspace with the onboard radar in standby mode (not emitting energy that could be detected by the enemy). If the radar is in standby, the chance of being detected by the enemy decreases (enemy aircraft can detect your radar emissions at a range twice of what you can detect them). Additionally, during a covert attack, Russian aircraft can use IRST systems that cannot be detected by radar warning systems. If an enemy aircraft is using onboard jamming systems, you can use AWACS and GCI to determine ranging information.

If an AWACS or GCI is not available, the fighter will need to use its own sensors during the mission. When there are multiple aircraft within a flight, the flight leader should order "line abreast" formation to increase the volume of air space that the flight's radars are scanning.

Pilots must be aware that detection range depends on a target's radar cross section (RCS). The simple rule is that the larger the RCS, the greater the range at which it can be detected by radar. RCS has no affect on non-radar sensors such as IRST. For example: an Su-27 flying at high altitude can detect a strategic bomber-class target with an RCS of 70 – 100 sq. m at distance of 130 – 180 km. A modern fighter with an RCS of 3 sq. m can only be detected at 80 – 100 km. At low altitudes, detection ranges are reduced significantly due to the side lobe feedback noise from the ground being received back into the antenna. This noise forces the radar to decrease gain levels and thereby lowering its sensitivity. For example: an Su-27 flying at 200 m has a maximum detection distance of only 35 – 40 km against high targets aspect and 20 – 25 km against low targets aspect. This same restriction applies to detecting targets at lower altitudes than your own. In such a "look down" situation, the radar sensitivity is reduced due to the excessive ground clutter. The following conclusion can be made: –long-range air combat is severely restricted at the low altitudes and weapon and radar performance will be greatly reduced. The best engagement profile is to be flying above 3,000 m with the target slightly above you at a high aspect angle.

Beyond Visual Range (BVR) Combat

You have detected an enemy aircraft and you are ready to attack it with medium or long range missiles. However, the enemy has the same intentions and is equipped with missiles similar to your own. In such a situation, victory is not obvious and depends greatly on several factors such as maintaining a stable target lock and the missile's maximum launch range. When such factors are equal, the adversaries have an equal chance of victory. In order to gain an advantage, one must use BVR tactics to gain the upper hand.

The most common tactic is called the tactical turn away. The maneuver calls for launching a missile at long-range and then turning away from the target while keeping the target within the outer gimbal limits of the radar. While maintaining radar lock on the target and supporting the launched missile, the rate of closure with the target decreases. With a reduced closure rate, the enemy's fire control computer may delay allowable launch or at least delay the enemy pilot from launching until he reaches Rpi. When both you and the enemy launch at the same time, a tactical turn away will cause the enemy's missile to fly a less efficient, longer flight path and use more energy. If the enemy missile still manages to reach you, a high-G maneuver should easily defeat a missile low on energy.

Maneuvers

If both you and the enemy manage to survive the BVR joust and enter 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

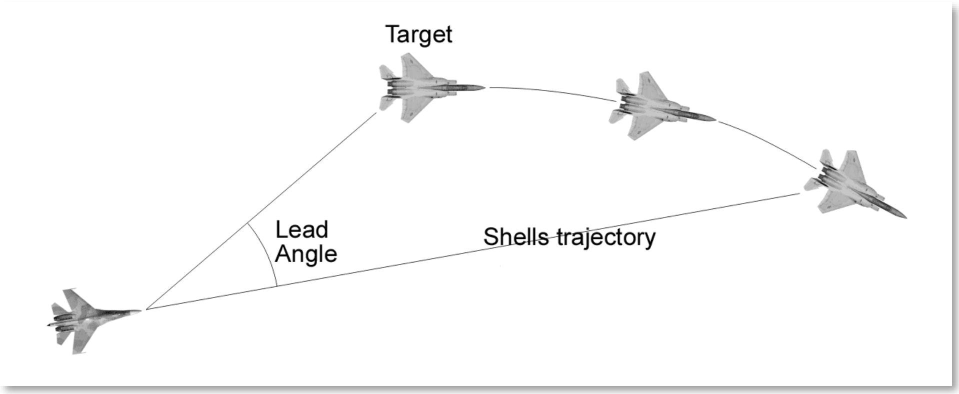
The "Hi Yo-Yo" maneuver is similar to a combat turnaround. First execute a steep climb perpendicular to the target's flight path. During this maneuver, it is important that you do not lose sight of the enemy; always know his location. This maneuver should be accomplished a bit behind and higher than 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.



13-1: 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

Good combat pilots know which missiles are best used for within visual range combat and which to use for beyond visual range. The employment of these missile systems is described in detail in the corresponding chapter, as are reference to different aircraft types.

Before a radar-guided missile can be launched, it is generally required to establish a radar lock and select the best missile according to the targets distance. For a Russian aircraft, missile launch is impossible until the "Launch Authorized" WCS command is given. When it is given, the WCS calculates if it is safe to launch the missile and if the missile has a high probability of a kill. In an emergency though, this authorization consent can be overridden. The F-15C on the other hand can launch missiles at any time. However, to give the pilot cues as to the probability of kill, there are three indicators: minimum permitted launch range (Rmin), maximum permitted launch range to maneuvering target (Rtr), and the maximum permitted launch range to non-maneuvering target (Rpi).

Launching a missile at long ranges decreases hit probability; the shorter the distance the missile has to fly to the target, the higher the hit possibility.

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.

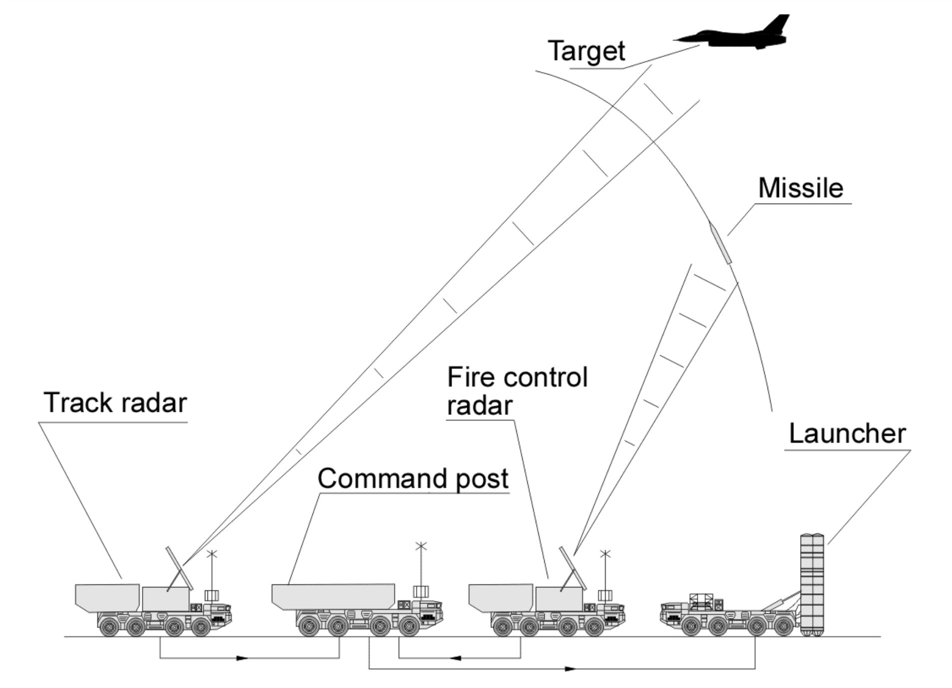
Air defense missiles consist of the following elements: seeker head, fuse, warhead, and rocket motor. Over the air frame of the missile, the wings and control surfaces are attached.

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.

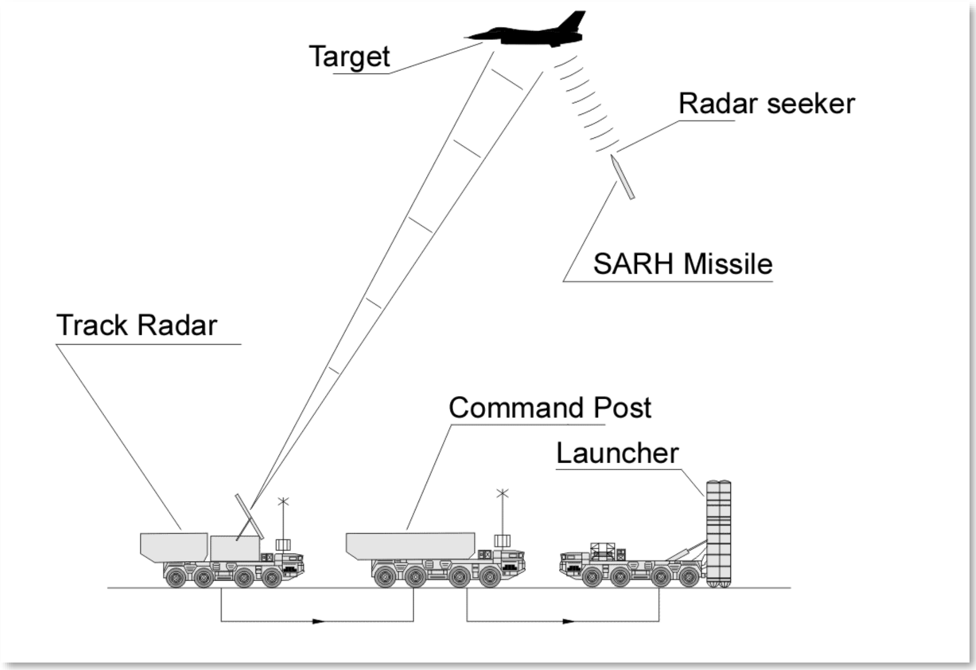


13-2: Command guidance

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

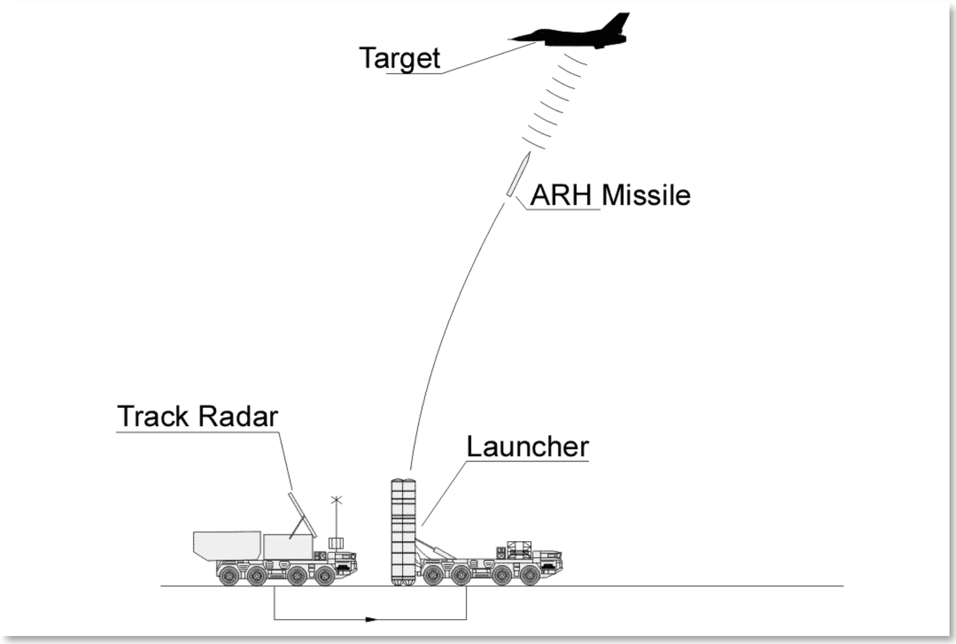
The semi-active guidance method is based on the missile guiding itself to the target based on the reflected radar energy off the target into the missile's antenna. The source of this radar energy is a SAM system's fire control radar. All control commands are calculated onboard the missile. This guidance 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.



13-3: 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.



13-4: 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.

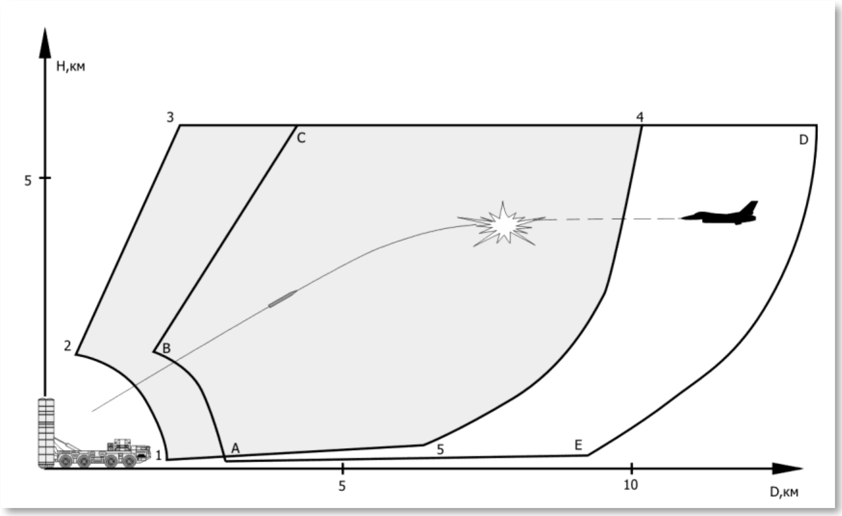
Combined Guidance

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.



13-5: 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

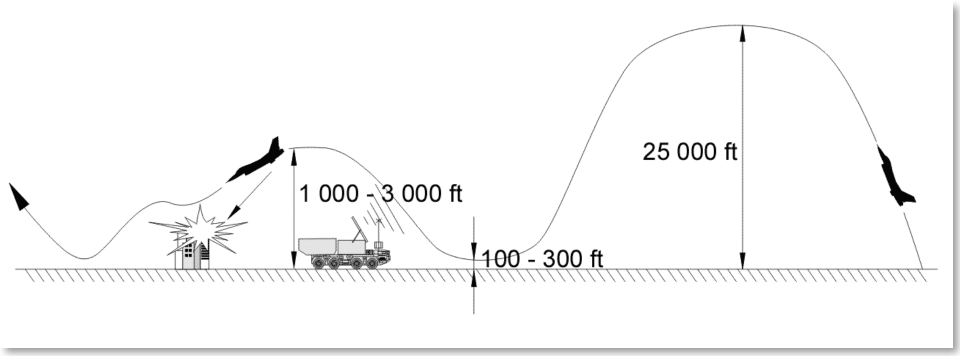
Penetrating an IADS is a very difficult task. The following recommendations will help you reach your initial attack point, detect and destroy your target, and return home.

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.

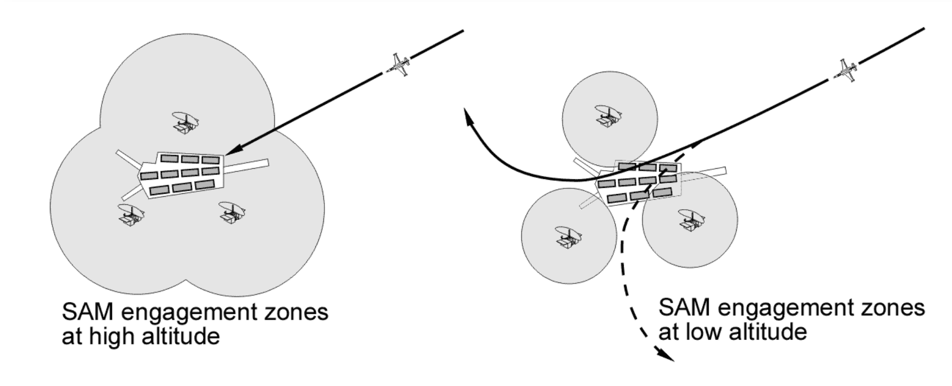
Supression of Enemy Air Defences (SEAD)

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.



13-6: 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.



13-7: 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."

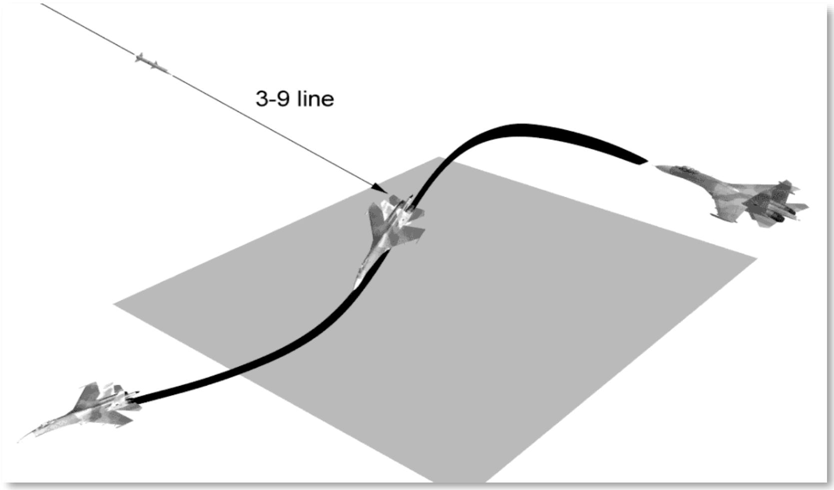
ECM systems have one, large shortcoming: by emitting, it shows its presence to enemy aircraft in the area. Imagine a person screaming at the top of his lungs during a meeting. The noise volume forces the others to keep silent, but it also attracts attention to the screaming person. The same happens to 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.



13-8: 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.

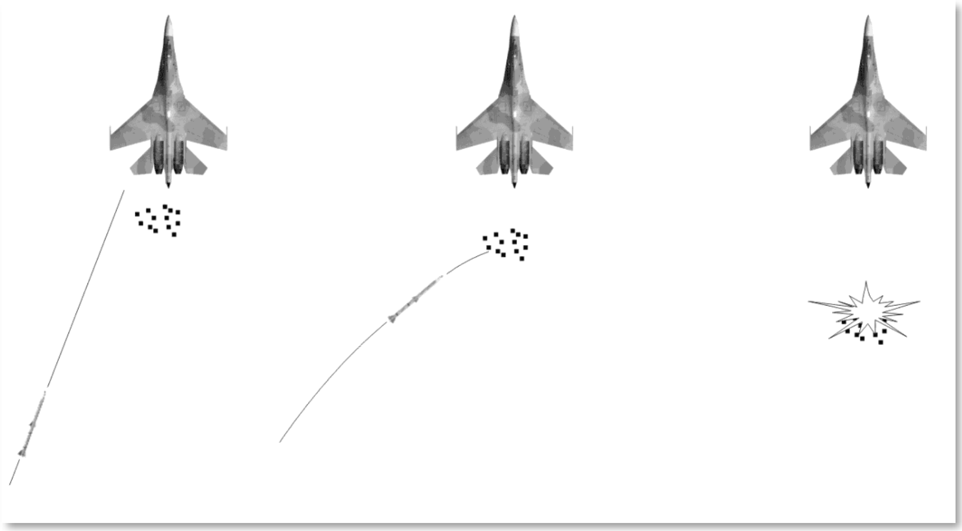
If the missile has a radar seeker though, the missile may continue the intercept.

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.



13-9: 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.

14

WEAPONS DELIVERY

WEAPONS DELIVERY

Each of the flyable aircraft featured in game has a unique weapons control systems (WCS), and the interface mechanization between pilot and WCS differ greatly between American and Russian aircraft. This section provides instruction on the steps needed to successfully deliver many types of weapons.

To employ a weapon, the pilot needs to execute the following steps:

- Detect the target
- Lock or designate the target
- Deploy weapon

MiG-29A, MiG-29S, Su-27 and Su-33

The weapons delivery procedures for the MiG-29, Su-27 and Su-33 are very similar to each other. Below are descriptions of the procedures needed to employ air-to-air weapons. This begins with long-range weapons and concludes with short-ranged systems.

Long-Range Combat

Long-Range Missile Engagement With Radar as the Active Sensor

Depending on the mission, target type, and jamming environment, you can use two primary radar acquisition modes **SCAN** and **TWS** for long-range missile employment. The **TWS** mode provides more detailed target information, permits a tactical situation picture to be displayed on the Head Down Display (HDD), and can lock targets in an automated mode. However, it cannot be used to detect targets in a heavy ECM environment or simultaneously detect high and low targets aspect. In such a situation, it's best to use **SCAN** mode. To search for both high and low targets aspect, use the **AUTO** sub-mode. Using AUTO however incurs about a 25% reduction in detection range compared to the **HI (PPS)** and **MED (ZPS)** sub-modes. If you already know the target aspect, it is recommended to that you enter the appropriate sub-mode with the **[RShift-I]** key.

Target acquisition, locking and launching a missile consists of the following steps:

Step 1

To search for targets at long range, select the long range **[2]** mode, activate the radar with the **[I]** key and to set the appropriate range scale on the HUD and HDD in km with the **[+]** and **[-]** keys. If the situation permits, you may choose to enter TWS mode by pressing the **[RAlt-I]** key. Select the best missile for the range and target by cycling the **[D]** key and confirm the selection on the HUD.

Step 2

Orient the radar azimuth scan zone in the direction of the target. On Russian fighters, the azimuth scan zone moves discretely and has three positions: central ±30 degrees, left –60 - 0 degrees and right 0 - +60 degrees. If the target is out of the central ±30 degrees zone, then it is required to move the scan zone to the left or right with the **[RShift-,]** or **[RShift-/]** keys.

Step 3

Orient the radar elevation scan zone in the direction of the target. There are two ways to do this.

The first method is to set the zone elevation by the data coordinates: range and elevation. To do this you first need to know the range to target (coming from the AWACS or GCI) in kilometers, which can be entered on the HUD with the **[RCtrl-+]**, **[Ctrl--]** keys. To set the target elevation in relation to your own, use the **[RShift-;]** and **[RShift-.]** keys. Doing this will center the scan zone on the target.

The second method is to use the scan elevation caret along the left, vertical axis of the HDD. Control of this setting can be assigned to a game controller axis. The elevation scan zone setting will correspond to the reading on the HUD.

Step 4

After you have oriented the scan zone in the direction of the target, you may have to wait up to six seconds before the target is detected. This is only accomplished after the radar has completed several scanning cycles. After the radar has detected a target, a contact icon is displayed on the HUD and HDD if TWS mode is active. Aircraft that return a friendly identify friend or foe (IFF) return are double-marked. Hostile aircraft return only a single mark. On the HDD, friendly contacts have a circular mark and hostiles have a triangular mark. The number of dashes in the contact represents the RCS size of the target. Generally, the larger the contact mark is, the larger the contact is.

Step 5

Upon target detection, the next step is to lock it up.

To do so in SCAN mode, place the Target Designation Cursor (TDC) over the contact and press the **[Enter]** key. If range, target RCS, and jamming permit, the target will be locked and framed with a circular target marker. The radar will now be in STT mode.

When in **TWS** mode, place the TDC near the contact with the **[;], [,], [.], [/]**, keys and the TDC will automatically "snap to" the target mark. This indicates that the radar is now tracking this particular contact and receiving additional data about the contact. To enter a full STT lock, press the **[Enter]** key. If an STT lock is initiated over 85% of the selected missile's maximum range, the STT lock will not take place. However, once at or under 85%, then an STT lock will be initiated automatically.

Step 6

Once in STT mode and the distance to target is 85% or less than that of the maximum range of the selected missile, the LA – "launch authorized" message will appear on the HUD. With this authorization you may launch the missile by pressing the launch weapon button on your joystick or by pressing the **[Space]** key.

It should be mentioned that launching from maximum range on a maneuvering targets is not very effective because the target can avoid the missile by performing a simple missile avoidance maneuver. If the situation permits, wait until Rpi range is reached; this will greatly increase your probability of kill. However, launching at, or over maximum range with launch override, can be used to put the enemy on the defensive early.

In regards to SARH missile (R-27R, R-27ER) employment, it is required to maintain an STT lock on the target during the missile's entire time of flight. If the target breaks lock, and you are able to quickly re-acquire lock, the missile will continue homing in on the target. However, the R-77 with its active seeker does not require an STT during its entire flight. Once within 12 to 15 km of the target, the active seeker takes over the intercept and support from the launch aircraft is no longer required.

> TO USE SARH MISSILES, YOU MUST LOCK THE TARGET IN STT MODE THE ENTIRE TIME OF MISSILE FLIGHT. WITH ACTIVE MISSILES, THEY WILL CONTINUE THE INTERCEPT AUTOMATICALLY ONCE THEY ARE WITHIN 15 KM OF THE TARGET.

Long-Range Missile Engagement With IRST as the Active Sensor

Using the infrared search and track (IRST) system for long-range missile combat allows covert attacks. The IRST is immune to active jamming, but it has much less target detection range than radar. The R-27ET, R-27T, R-73 and R-60 can all be used with the IRST system.

IRST works the in the infrared spectrum and detects targets by their thermal contrast. The "hottest" aircraft section is the jet engines that expel hot gases and heat up the surrounding metal fuselage. This is why infrared detection is more effective from the rear of the aircraft than the front.

Because the IRST system does not provide any range information, target information on the HUD is presented in the form of azimuth in the horizontal and target elevation in the vertical. The IFF interrogator does not operate with the IRST, so be absolutely sure that the target is an enemy aircraft before attacking.

Target acquisition, locking, and launching a missile consists of the following steps:

Step 1

To search for targets at long range, select the long range **[2]** mode, activate the IRST with the **[O]** key and set the appropriate range scale on the HUD and HDD in km **[+]** and **[-]**. Select the best missile for the range and target with the **[D]** key and confirm the selection on the HUD.

Step 2

Orient the radar azimuth scan zone in the direction of the target. On the Russian fighters, the azimuth scan zone moves discretely and has three positions: central ±30 degrees, left –60 - 0 degrees and right 0 - +60 degrees. If the target is out of the central ±30 degrees zone, than it is required to move the scan zone to the left or right by the **[RShift-,]** and **[RShift-/]** keys.

Step 3

Orient the IRST elevation scan zone in the direction of the target.

To do so, move the scan zone up or down depending on the possible target elevation with the **[RShift-;]** and **[RShift-.]** keys. Elevation indicators are shown along the left side of the HDD. The optimal way to search for targets is to scan along the vertical axis in small increments.

Step 4

After you oriented the scan zone in the direction of the target, you should allow the IRST to search each increment for four to six seconds; this allows the IRST to properly search that portion of sky. The number of dashes that comprise a target marker on the HUD corresponds to the size of the infrared signature. Generally, large aircraft have larger infrared signatures. The exception would be an aircraft in afterburner.

Step 5

Once the target has been detected, you next need to lock it up.

To do so, place the TDC over the contact and press the **[Enter]** key. If the target distance and infrared signature permit, the IRST will initiate an STT lock. The target will then be framed by a circle on the HUD.

Step 6

Once in STT mode and the distance to target is 85% or less than that of the maximum range of the selected missile, the LA – "launch authorized" message will appear on the HUD. With this authorization, you may launch the missile by pressing the launch weapon button on your joystick or by pressing the **[Space]** key.

It should be mentioned that launching from the maximum range on a maneuvering targets is not very effective because the target can avoid the missile by performing a simple missile avoidance maneuver. If the situation permits, wait until Rpi range is reached; this will greatly increase your probability of kill.

Missiles with IR seekers are "fire-and-forget" and do not require any additional support from the launch aircraft. Once launched, the pilot can immediately begin engaging in other tasks.

THE R-27T/ET MEDIUM RANGE MISSILES MUST HAVE AN INFRARED SEEKER LOCK ON A TARGET BEFORE FIRING. THESE SYSTEMS ARE IR-HOMING ALL THE WAY AND DO NOT USE A DATA LINK SYSTEM.

Close Air Combat

Close air combat (CAC) is combat with the enemy at visual distances. This leads to fast, hard turning fights with each side looking for an advantage that will enable them to get the first shot.

CAC ranges are usually limited by the targeting and weapon system's maximum detection and engagement ranges in CAC modes; this equates to about 10 km.

In CAC, highly-maneuverable missiles are often used, such as R-73 and R-60. These have wide-angle IR seekers that are optimized to attack maneuverable targets performing high G tactics. These missiles are often used in conjunction with guns.

Several targeting modes used in CAC are described below:

Close Air Combat – Vertical Scan Mode

The vertical scan mode is perhaps the most convenient and useful mode when performing high-G combat maneuvers. In this sub-mode, the radar and IRST are scanning a zone three degrees wide and form–10 to +50 degrees in the vertical. Two vertical lines are displayed on the HUD that illustrates the scan zone azimuth limits. When you are trailing a maneuvering target, but it is still above your HUD on the same lift-line, the VS mode allows you to lock the target without "over-pulling" to place the target in the HUD.

The lock and launch steps are as follows:

Step 1

When an air target is visually detected, activate **VS** mode by pressing the **[3]** key. The IRST sensor will become active automatically; this allows an attack without active sensors. If you then select a SARH-type missile, you will need to manually activate the radar by pressing the **[I]** key. Select the desired missile by cycling the **[D]** key or select the internal gun by pressing the **[C]** key. Your active weapon will be displayed on the HUD.

Step 2

Maneuver your aircraft to place the target between the two vertical lines on the HUD. Note that the actual scan zone extends two HUD lengths above the top HUD frame. As such, it is possible to lock on to targets far above your HUD.

With the target in the scan zone and either sensor active, the target will be automatically locked on to. Once locked, the IRST or radar will automatically transition to an STT lock. If the internal gun is then selected, the LCOS gun mode will be active.

Step 3

Once in STT mode and the distance to target is 85% or less than that of the maximum range of the selected missile, the LA – "launch authorized" message will appear on the HUD. With this authorization, you may launch the missile by pressing the launch weapon button on your joystick or by pressing the **[Space]** key.

If in the LCOS gun mode, you must place the gun pipper on the target and press the weapon release button on your joystick or the **[Space]** key on your keyboard.

To increase the probability of kill, try to minimize your aiming error by flying a collision course with the target prior to missile launch. This will reduce the amount of G the missile must pull at launch.

PASSIVE TARGET DETECTION SYSTEMS LIKE IRST PROVIDE LESS WARNING TO ENEMIES, THEREBY HAVING THE ELEMENT OF SURPRISE

Close Air Combat – STROB (BORE) Mode

BORE mode is similar to VS mode, the only differences being that the sensors scan along the longitudinal axis (a 2.5-degree cone) of the aircraft and not along the lift vector as VS does and that you must manually lock the target. The scan zone is shown on the HUD as a 2.5-degree reticule and it can be moved with the **[;], [,], [.], [/]** keys.

The lock and launch steps are as follows:

Step 1

When an air target is visually detected, activate **BORE** mode by pressing the **[4]** key. The IRST sensor will become active automatically; this allows an attack without active sensors. If you then select a SARH-type missile, you will need to manually activate the radar by pressing the **[I]** key. Select the desired missile by cycling the **[D]** key or select the internal gun by pressing the **[C]** key. Your active weapon will be displayed on the HUD.

Step 2

By either maneuvering your aircraft or using the **[;], [,], [.], [/]** keys, place the BORE reticule over the target. When the target is in the reticule, you must manually initiate a lock by pressing the **[Enter]** key. Once locked, STT mode will be automatically selected. If the internal gun is selected, the LCOS gun pipper will be displayed on the HUD.

Step 3

Once in STT mode and the distance to target is 85% or less than that of the maximum range of the selected missile, the LA – "launch authorized" message will appear on the HUD. With this authorization, you may launch the missile by pressing the launch weapon button on your joystick or by pressing the **[Space]** key.

If in the LCOS gun mode, you must place the gun pipper on the target and press the weapon release button on your joystick or the **[Space]** key on your keyboard.

To increase the probability of kill, try to minimize your aiming error by flying a collision course with the target prior to missile launch. This will reduce the amount of G the missile must pull at launch.

Close Air Combat – Shlem (Helmet) Mode

This is a unique close air combat mode. With the Schel-3UM helmet-mounted cueing system (HMCS), a pilot turning his head can control the aircraft targeting systems and direct weapons to the target placed in his monocle reticule. By turning his head and placing the reticule over a target, the pilot can lock sensors and weapons on the designated target. The reticule is not like a symbol reflected on the HUD, but instead is always shown in the center of the screen. This mode is used in close air combat to lock and engage targets at high off-bore sight angles.

The lock and launch steps are as follows:

Step 1

When an air target is visually detected, activate **SHLEM** mode by pressing the **[5]** key. The IRST sensor will become active automatically; this allows an attack without active sensors. If you then select a SARH-type missile, you will need to manually activate the radar by pressing the **[I]** key. Select the desired missile by cycling the **[D]** key or select the internal gun by pressing the **[C]** key. Your active weapon will be displayed on the HUD.

Step 2

Panning your in-cockpit view using the number pad keys, you can place the HMCS reticule over a target and press the **[Enter]** key. Alternatively, you can first padlock the target with the **[NumPadDel]** key and then activate SHLEM mode and press the **[Enter]** key. After locking the target, STT mode will automatically be initiated. If the internal gun is selected, the LCOS gun pipper will be displayed on the HUD.

Step 3

Depending on the form of the reticule, you can determine three conditions:

The reticule is attached to the target – you have a good target lock but not ready to launch a weapon.

The reticule is attached to the target and it blinks with the frequency of 2 Hz – launch is authorized. This means that conditions for the missile launch have been met. The "LA" message will be displayed on the HUD and you can launch a missile by pressing the weapon release button on your joystick or by pressing the **[Space]** key on your keyboard.

If the reticule has an "X" through it, it indicates that launch is not permitted, and a lock on is not possible. This will be seen when the HMCS reticule is beyond the permitted designation angles.

If in the LCOS gun mode, you must place the gun pipper on the target and press the weapon release button on your joystick or the **[Space]** key on your keyboard.

To increase the probability of kill, try to minimize your aiming error by flying a collision course with the target prior to missile launch. This will reduce the amount of G the missile must pull at launch.

Fi0 (Longitudinal) Mode

Longitudinal mode is a reserve mode in case the WCS fails. This mode is used for the infrared-guided (R-27T, R-27ET, R-73, R-60) missiles, which able to lock on the target without help of the aircraft's WCS. In this mode, target lock is aided only by the missile's onboard seeker, which has the scan zone of about two degrees in the longitudinal axis. For the seeker to lock a target, the target must enter the scan zone of the seeker, which is in the center of the aircraft symbol on the HUD.

The lock and launch steps are as follows:

Step 1

When you detect an air target visually, activate longitudinal mode by pressing the **[6]** key. If the WCS system is damaged and there is no indication on the HUD, switch to the SETKA (Reticle) mode. Select the desired missile by cycling the **[D]** key or select the internal gun by pressing the **[C]** key. Your active weapon will be displayed on the HUD.

Step 2

Maneuver the aircraft to position the center of the HUD aircraft symbol over the chosen target. When the target is in the missile seeker's field of view, the "launch authorized" message will be given.

Step 3

You will need to visually determine the distance to the target and if it is less than the missile's maximum launch range. Launch the missile by pressing the weapon release button on your joystick or press the **[Space]** key on your keyboard.

Note that an "LA" notification does not factor range to target. There is a strong probability that the missile will not have enough energy to reach the target. As such, you will need to gauge range by eye and factor in aspect angle.

Air-to-Ground Weapons

The MiG-29, Su-27 and Su-33 can carry limited types of air-to-surface weapons. This arsenal includes free-fall bombs and unguided rockets.

General Purpose, Low-Drag Bombs

This category of bombs includes the FAB-100, FAB-250 and FAB-500 freefall bombs. They have low drag indexes and have flat trajectories. This often allows you to release a bomb at a target while it is still visible.

Step 1

Visually identify the target.

Step 2

Select the air-to-surface mode by pressing the **[7]** key.

Step 3

When the CCIP aiming pipper starts moving from the HUD lower portion of the HUD, place the pipper on the target and press the weapon release button on the joystick or the **[Space]** key on the keyboard when the "LA" appears on the HUD.

> THE BOMBS CAN BE RELEASED AFTER THE LA SYMBOL APPEARS ON THE HUD. BEFORE RELEASE A STEADY DIVE TOWARDS THE TARGET ASSURES A GOOD RELEASE. TRY TO AVOID CHANGES IN BANK, PITCH AND YAW AND SIGNIFICANT AIRSPEED CHANGES DURING THE BOMBING PASS. SUCH CONTROL INPUTS MAY LEAD TO REDUCED ACCURACY.

General Purpose, High-Drag Bombs

This bomb category includes bombs with aerodynamically high drag such as PB-250, ODAB-500, various RBK types, KMGU-2 containers, and BetAB concrete-piercing bombs. They have high drag values and have a curved trajectory that significantly complicates that targeting of visible targets.

It is recommended to use the continuously calculated release point (CCRP) delivery mode when using this type of bomb. To drop a high-drag bomb, follow these steps:

Step 1

Identify the target visually.

Step 2

Select air-to-surface mode by pressing the **[7]** key.

Step 3

Place the CCRP pipper on the intended target and press and hold the weapon release button on your joystick or the **[Space]** key on your keyboard. The WCS will initiate the release point calculation, and on the HUD will appear a diamond symbol that represents the designation point. In the upper portion of the HUD, a steering ring will be displayed. Fly the aircraft such that the aircraft symbol "tail" is placed in the center of this ring. The range scale on the right side of the HUD turns into a time-to-release scale that is graduated in seconds. The arrow indicating time-to-release will appear on the scale only 10 seconds before the bombs release. For accurate bombing it is best to minimize changes in bank and yaw. When the timer reaches zero, the bomb(s) will automatically be released and you can release the trigger.

Step 4

Press the trigger on your joystick or press the **[Space]** key.

Unguided Rockets and Internal Gun

Unguided rockets include all the rockets and missiles that are not equipped with guidance system. These include the S-5 in the UB-32 rocket launcher, the S-8 in the B-8 rocket launcher, the S-13 in the UB-13 rocket launcher, and the S-24 and S-25. The internal gun is the GSh-301 30-mm gun with 150 rounds.

Step 1

Identify the target visually.

Step 2

Select air-to-surface mode by pressing the **[7]** key and cycle the **[D]** key until the rocket of choice is selected. Or, select the **[C]** to make the gun the active weapon. Confirm that the correct weapon is selected on the HUD. Maneuver into a shallow dive towards the target.

Step 3

When the aiming pipper is over the target and launch conditions are satisfied, the "LA" message will appear on the HUD. Fire the rocket(s) or guns by pressing the weapon release button on your joystick or by pressing the **[Space]** key on your keyboard.

> UNGUIDED ROCKETS CAN BE LAUNCHED ONCE THE "LA" MESSAGE APPEARS ON THE HUD. BEFORE FIRING THOUGH, ASSUME A SHALLOW BANK WITH MINIMAL BANK, PITCH, AND YAW DEVIATIONS. SUCH DEVIATIONS CAN LEAD TO AN INACCURATE ROCKET PASS

Su-25

The Su-25 is designed to strike ground targets, but it is not equipped with a radar. To determine distance to target and illumination for laser-guided missiles, it has the "Klen-PS" laser range-finder/target designator. The Su-25's air-to-air combat abilities are quite limited.

Air-to-Air Weapons

R-60 short range missile

Step 1

Select air-to-air mode with the **[6]** key. In either case, longitudinal aiming mode will be activated; this is the only air-to-air missile mode for the Su-25.

Step 2

Maneuver your aircraft to place the center of the HUD aircraft symbol over the target. When the missile seeker is in lock range, the aiming will jump to the target; the yellow launch authorized lamp will flash; and lock audio signal will sound. The lock range depends greatly on the target's IR-signature. The maximum signature for an aircraft is when flying at high-altitude, at full AB, and you are in the target's rear-hemisphere. Note that helicopters have minimal IR signatures and it may be difficult to acquire. When the missile seeker achieves a lock and the "LA" message is displayed on the HUD, this is only an indication that the target has been locked; it does not mean that the target is within range of the missile. Launching a missile too early may lead to a miss because the missile has insufficient energy to intercept the target. It is recommended that you not launch until the target's shape is visible or 2 km.

Step 3

Press the trigger on your joystick or press the **[Space]** key to launch the missile. The missile is "fire and forget" and requires no additional support from the launch aircraft.

Internal Gun and Gun Pods Against Air Targets

The internal gun and gun pods are generally used against ground targets, but they can be used against air targets with limited accuracy.

Step 1

Identify the target visually.

Step 2

Select air-to-air mode with either the **[6]** key. To select the internal gun or gun pods, press the **[C]** key. On the aiming sight collimator (ASP-17) the aiming mark will appear. The fixed reticle can also be displayed by pressing the **[8]** key.

Step 3

Maneuver your aircraft and properly lead the target. Press the trigger on your joystick or press the **[Space]** key to fire the gun(s).

The effective gun fire is generally less than 800 meters. Judge the range visually before opening fire.

Air-to-Ground Weapons

For the Su-25, air-to-ground weapon delivery modes are rather basic. We will review the different types of unguided weapons and their employment procedures below.

Unguided, Low-Drag Bombs

This category of bombs includes the FAB-100, FAB-250 and FAB-500 freefall bombs. They have low drag indexes and have flat trajectories. This often allows you to release a bomb at a target while it is still visible.

Step 1

Identify the target visually.

Step 2

Switch to the air-to-ground mode by pressing the **[7]** key. Select the weapon to be released using the weapon control panel and the **[D]** key. The ripple quantity should be selected on the panel with the **[LCtrl-Space]** key and the release interval with the **[V]** key.

Step 3

Turn on the laser range-finder/target designator by pressing the **[RShift-O]** key; the green lamp will light. Using a wings-level dive, maintain your speed between 500 and 600 km/hour.

Step 4

When the aiming mark starts moving up from the lower portion of the HUD, fly the aircraft to place the aiming mark on the target. When the aiming mark is showing the true impact point underneath it and the bomb can be dropped, the orange lamp will light. To release a bomb, press the weapon release button on your joystick or press the **[Space]** key. If a bomb ripple setting has been made, keep the weapon release button held down until the pulse ends.

Step 5

Turn off the laser range-finder by pressing the **[RShift-O]** key. Remember that the range-finder/target designator has a limited, continuous duration time, which is about one minute. After that, the device needs time to cool down or risk damage. During this cool-down time, a green lamp will flash at 2 Hz; when the device has sufficiently cooled, the lamp will extinguish. The cooling time is nearly equal to the work time, and it depends on environment temperature conditions.

Unguided, High-Drag Bombs

This bomb category includes bombs with aerodynamically high drag such as the PB-250, ODAB-500, various RBK types, KMGU-2 containers, and BetAB concrete-piercing bombs. They have high drag values and have a curved trajectory that significantly complicates that targeting of visible targets.

It is recommended to use the continuously calculated release point (CCRP) delivery mode when using this type of bomb. To drop a high-drag bomb, follow these steps:

Step 1

Identify the target visually.

Step 2

Switch to air-to-ground mode by pressing the **[7]** key. Select the weapon to be released using the weapon control panel and the **[D]** key. The ripple quantity should be selected on the panel with the **[LCtrl-Space]** key and the release interval with the **[V]** key.

Step 3

Turn on the laser range-finder/target designator by pressing the **[RShift-O]** key; the green lamp will light. Fly the aircraft to place the aiming mark on the desired target and press and hold the weapon release button on your joystick or the **[Space]** key on your keyboard. The WCS will then calculate the release point. You must then fly the aircraft in level flight without any bank angle. The bank should be controlled by the triangle index – the bank indicator on the aiming mark. The circular range scale in this mode indicates the time-to-release. When the time scale reaches zero, the bomb(s) will be released automatically.

Step 4

Release the trigger once the release pulse is complete. Turn off the laser range-finder by pressing the **[RShift-O]** key.

Unguided Rockets, Internal Gun and Gun Pods

Step 1

Identify the target visually.

Step 2

Switch to air-to-ground mode by pressing the **[7]** key. Select unguided rockets by cycling the **[D]** key or internal gun/gun pods with the **[C]** key. The weapon control panel reflects weapon changes and status. Turn on the laser range-finder/target designator by pressing the **[RShift-O]** key; the green lamp will light. During a wings-level dive, fly the aircraft to place the aiming mark on the target.

Step 3

When all weapon release conditions are met, the orange lamp will light; press the weapon release button on your joystick or the **[Space]** key on your keyboard to fire.

Step 5

Turn off the range-finder/target designator by pressing the **[RShift-O]** key.

> UNGUIDED ROCKETS CAN ONLY BE LAUNCHED WHEN ALL CONDITIONS ARE MET (WHEN THE ORANGE LAMP LIGHTS). BEFORE FIRING, ENTER A WINGS-LEVEL DIVE AND PLACE THE AIMING MARK OVER THE TARGET. THE DEVIATIONS IN BANK, PITCH, AND YAW CAN ADVERSLY AFFECT IMPACT DISPERSION

Kh-25ML, Kh-29L, and S-25l Air-to-Surface Missiles

Step 1

Identify the target visually.

Step 2

Switch to air-to-ground mode by pressing the **[7]** key. Select guided missiles by cycling the **[D]** key. Weapon status and selection is indicated on the weapons control panel. Turn on the laser range-finder/target designator by pressing the **[RShift-O]** key; the green lamp will light. Place the aiming mark on the target by slewing the aiming mark with the **[;], [,], [.], [/]** keys. Once over the target, press the **[Enter]** key. The range-finder/target designator will now be ground-stabilized over that selected point on the ground (not necessarily the target). You can then further refine the aim point by slewing the aiming marker over the target or move the marker to a nearby target.

Step 3

If launch conditions are met, the orange lamp will light and you can launch the missile by pressing the weapon release button on your joystick or the **[Space]** key. During the missile's flight you can further move the aiming marker. Wherever you move the marker, the missile will attempt to impact the ground at that spot. Thereby, you will need to continually move the aim point if the target is moving. Remember not to move the aiming marker too fast or the missile may not be able to retain lock on the designated spot.

Step 4

Turn off the laser range-finder by pressing the **[RShift-O]** key when the attack is finished to let the device cool down.

> THE S-25L MISSILE'S MANEUVERABILITY IS VERY LIMITED AND SHOULD ONLY BE LAUNCHED FROM A WINGS-LEVEL DIVE, AS IF PERFORMING AN UNGUIDED ROCKET ATTACK

Su-25T

The Su-25T is the perfect tactical attack aircraft for the Russian Air Force. It can strike small, mobile targets with pinpoint accuracy in all weather conditions and at all times of day.

The Su-25T is equipped with the I-251 "Shkval" TV targeting system, combined with the "Prichal" laser range-finder/target designator. For nighttime operations it can be equipped with the "Mercury" low light level TV (LLTV) targeting system.

For self protection, the Su-25T can also carry the R-73 and R-60 short range missiles.

Air-to-Air Weapons

R-73 and R-60 short range missiles

The Su-25T can carry the R-73 and R-60 short range air-to-air missiles in the longitudinal aiming mode. When this mode is activated, the missile's seeker has a scan zone of 2 degrees that is directed forward along the aircraft's longitudinal axis. The target must enter this seeker field of view, which is represented by the center of the aircraft symbol on the HUD, to automatically lock the target.

The target lock and launch procedures consist of the following steps:

Step 1

Select air-to-air mode with the **[6]** key. In either case, longitudinal aiming mode will be activated.

Step 2

Maneuver your aircraft to place the center of the HUD aircraft symbol over the target. When the missile seeker is in lock range, the aiming will jump to the target; the yellow launch authorized lamp will flash; and a lock audio signal will sound. The lock range depends greatly on the target's IR-signature. The maximum signature for an aircraft is when flying at high-altitude, at full AB, and you are in the target's rear-hemisphere. Note that helicopters have minimal IR signatures and they may be difficult to acquire. When the missile seeker achieves a lock and the "LA" message is displayed on the HUD, this is only an indication that the target has been locked; it does not mean that the target is within range of the missile. Launching a missile too early may lead to a miss because the missile has insufficient energy to intercept the target. It is recommended that you not launch until the target's shape is visible or 2 km.

Step 3

Press the trigger on your joystick or press the **[Space]** key to launch the missile. The missile is "fire and forget" and requires no additional support from the launch aircraft.

Internal Gun and Gun Pods Application Against Air Targets

The internal gun and gun pods can be used against air targets, but it has limited accuracy in application.

Step 1

Identify the target visually.

Step 2

Select air-to-air mode by pressing **[6]** key. Select internal gun or gun pods by pressing the **[C]** key. Now in gun mode, the funnel will appear on the HUD - graphically it represents the shell's flight trajectory vs. target wingspan. By pressing the **[RAlt--]** and **[RAlt-+]** keys, you can set the target wingspan (also known as "target base") in meters. The target's set wingspan is indicated in the upper portion of 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 weapon release 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 Su-25T can carry a wide variety of weapon types, including unguided bombs, sub-munitions containers and dispensers, unguided rockets, TV-guided missiles, laser and beam-riding homing missiles, TV-guided bombs, and gun pods.

Unguided, Low-Drag Bombs

This bomb category includes the FAB-100, FAB-250 and FAB-500 unguided bombs. They have low drag indexes and flat trajectories. This often allows you to release a bomb at a target while it is still visible.

Step 1

Identify the target visually.

Step 2

Switch to air-to-ground mode by pressing the **[7]** key. Select the weapon to be released using the weapon control panel and the **[D]** key. The ripple quantity should be selected on the panel with the **[LCtrl-Space]** key and the release interval with the **[V]** key.

Step 3

When the aiming mark starts moving up from the lower portion of the HUD, fly the aircraft to place the aiming mark on the target. When the aiming mark is showing the true impact point underneath it and the bomb can be dropped, the orange lamp will light. To release a bomb, press the weapon release button on your joystick or press the **[Space]** key. If a bomb ripple setting has been made, keep the weapon release button held down until the pulse ends.

> BOMBS CAN BE RELEASED ONCE THE "LA" MESSAGE APPEARS ON THE HUD. 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

Unguided, High-Drag Bombs

This bomb category includes bombs with aerodynamically high drag, such as various RBK types, KMGU-2 containers, and BetAB concrete-piercing bombs. They have high drag values and have a curved trajectory that significantly complicates that targeting of visible targets.

It is recommended to use the continuously calculated release point (CCRP) delivery mode when using this type of bomb. To drop a high-drag bomb, follow these steps:

Step 1

Identify the target visually.

Step 2

Select the air-to-surface mode by pressing the **[7]** key.

Step 3

Place the CCRP pipper on the intended target and press and hold the weapon release button on the joystick or the **[Space]** key on the keyboard. The WCS will initiate the release point calculation, and on the HUD will appear a diamond symbol that represents the designation point. In the upper portion of the HUD, a steering ring will be displayed. Fly the aircraft such that the aircraft symbol "tail" is placed in the center of this ring. The range scale on the right side of the HUD turns into a time-to-release scale that is graduated in seconds. The arrow indicating time-to-release will appear on the scale only 10 seconds before the bombs release. For accurate bombing it is best to minimize changes in bank and yaw. When the timer reaches zero, the bomb(s) will automatically be released and you can release the trigger.

Step 4

Press the trigger on your joystick or press the **[Space]** key

TV Targeting Aided Bombing

Unguided bombs can be used in conjunction with the "Shkval" TV targeting system or the "Mercury" low-light level TV targeting system.

Bomb delivery using these sensors is done as follows:

Step 1

Select air-to-ground mode by pressing the **[7]** key. Select the desired bomb by pressing the **[D]** key. Confirm the selected bomb type on the HUD. To detect and identify targets, you must turn on the "Shkval" TV targeting system by pressing the **[O]** key, or the "Mercury" system by pressing the **[RCtrl-O]** key. Search for your target by moving the scan zone center with the **[;], [,], [.], [/]** keys. Upon target acquisition, ground-stabilize the sensor by pressing the **[Enter]** key. For positive target identification you can increase the sensor's magnification level by pressing the **[+]** and **[-]** keys.

Step 2

Place the acquisition frame on the target. Fly the aircraft in the direction to the target and turn on the laser range-finder/target designator by pressing the **[RShift-O]** key.

Step 3

Press the weapon release button on your joystick or the **[Space]** key on your keyboard. The WCS will initiate the release point calculation and a diamond symbol that represents the designation point will appear on the HUD . In the upper portion of the HUD, a steering ring will be displayed. Fly the aircraft such that the aircraft symbol "tail" is placed in the center of this ring. The range scale on the right side of the HUD turns into a time-to-release scale that is graduated in seconds. The arrow indicating time-to-release will appear on the scale only 10 seconds before the bombs release. For accurate bombing it is best to minimize changes in bank and yaw. When the timer reaches zero, the bomb(s) will automatically be released and you can release the trigger.

Step 4

Turn off the laser range-finder by pressing the **[RShift-O]** key. Remember that the range-finder/target designator has a limited, continuous duration time, which is about one minute. After that, the device needs time to cool down or risk damage. During this cool-down time indicated by **"Л"**, a green lamp will flash at 2 Hz; when the device has sufficiently cooled, the lamp will extinguish. The cooling time is nearly equal to the work time, and it depends on environment temperature conditions.

The KMGU-2 sub-munitions dispensers differ in that it’s required to offset the aiming point from the target to allow the container’s rotary clam-shell time to open.

Unguided Rockets and Internal Gun

Unguided rockets include all the rockets and missiles that are not equipped with guidance system. These include the S-5 in the UB-32 rocket launcher, the S-8 in the B-8 rocket launcher, the S-13 in the UB-13 rocket launcher, and the S-24 and S-25. The internal gun is the GSh-301 30-mm gun with 150 rounds.

Step 1

Identify the target visually.

Step 2

Select the air-to-surface mode by pressing the **[7]** key and cycle the **[D]** key until the rocket of choice is selected. Or, press **[C]** to make the gun the active weapon. Confirm that the correct weapon is selected on the HUD. Maneuver into a shallow dive towards the target.

Step 3

When the aiming pipper is over the target and launch conditions are satisfied, the "LA" message will appear on the HUD. Fire the rocket(s) or guns by pressing the weapon release button on your joystick or by pressing the **[Space]** key on your keyboard.

Gun Pods

The Su-25 can carry SPPU-22-1 gun pods that can operate in zero depression angle mode, fixed depression angle mode, and programmed (point tracking) mode.

Because the zero depression mode does not differ from the internal gun, we shall only review two modes: fixed depression and programmed.

THE FIXED DEPRESSION MODE IS USED WHEN FIRING IN HORIZONTAL FLIGHT ALONG A LINE OF TARGETS

Step 1

Identify the target visually.

Step 2

Switch to the air-to-ground mode by pressing the **[7]** key. Select internal gun mode by pressing the **[C]** key.

Select gun pods by pressing the **[RCtrl-Space]** key and confirm weapon selection on the HUD and WCS panel; two gun pods will be selected. Set the ripple interval/gun pods mode to **FIX** mode and the ripple quantity switch to **PO2**.

If the aircraft has four gun pods loaded onboard, press **[RCtrl-Space]** once more. Set the ripple interval/gun pods mode to **FIX** mode and the ripple quantity switch to **PO2**.

Step 3

Using the **[RAlt--]** and **[RAlt-+]** keys, alter the barrel depression angle by moving the aiming mark along the vertical axis on the HUD.

Step 4

Align your flight path with the target and maintain the level flight. When the aiming mark on the HUD overlays the target, press the weapon release button on your joystick or press the **[Space]** key on your keyboard to fire.

While firing, you use rudder input to cover a larger area with fire. Note though that any deviations in bank angle can lead to significant shell deviation.

THE PROGRAMMED MODE IS USED FOR THE PINPOINT ATTACKS AGAINST LIGHTLY ARMORED TARGETS.

Step 1

Identify the target visually.

Step 2

Switch to the air-to-ground mode by pressing the **[7]** key. Select internal gun mode by pressing the **[C]** key.

Select gun pods by pressing the **[RCtrl-Space]** key and confirm weapon selection on the HUD and WCS panel; two gun pods will be selected. Set the ripple interval/gun pods mode to **FIX** mode and the ripple quantity switch to **PO2**.

If the aircraft has four gun pods loaded onboard, press **[LCtrl-Space]** once more. Set the ripple interval/gun pods mode to **FIX** mode and the ripple quantity switch to **PO2**.

Step 3

Using the **[RAlt--]** and **[RAlt-+]** keys, alter the barrel depression angle by moving the aiming mark along the vertical axis on HUD.

Step 4

Turn on the laser range-finder by pressing the **[RShift-O]** key. Set the interval/gun pods mode switch to **PROGR** mode.

Step 5

In a wings-level dive, place the aiming mark on the target and, when "LA" message appears, open fire by pressing the weapon release button on your joystick or by pressing the **[Space]** key on your keyboard. Avoid roll, pitch, and yaw changes while firing for better accuracy.

Step 6

Turn off the laser range-finder/target designator by pressing the **[RShift-O]** key.

TV-Guided Bombs and Missiles

The Su-25T is equipped to carry the KAB-500Kr bomb and Kh-29T missile with the "Tubus" optical seeker. Such weapons allow "fire-and-forget" attacks that do not require the launch aircraft to continue locking the target after the weapon has been launched. These unguided weapons are designed to destroy buried command centers, control centers, reinforced concrete shelters and other well-protected targets. The Kh-29T missile can also be used to destroy ships.

The most significant limitation of TV-guided weapons is the inability to use them at night or during poor weather conditions.

The delivery procedure for such weapons is as follows:

Step 1

Select air-to-ground mode by pressing the **[7]** key. Select the desired bomb by pressing the **[D]** key. Confirm the selected bomb type on the HUD. To detect and identify targets, you must turn on the "Shkval" TV targeting system by pressing the **[O]** key, or the "Mercury" system by pressing the **[RCtrl-O]** key. Search for your target by moving the scan zone center with the **[;], [,], [.], [/]** keys. Upon target acquisition, ground-stabilize the sensor by pressing the **[Enter]** key. For positive target identification you can increase the sensor's magnification level by pressing the **[+]** and **[-]** keys.

Step 2

To lock a target, you need to manually set a specified size (also known as "target base") of the target correctly. By default, the target specified size is 10 m. It is recommended to use the following target base values:

- Personnel and minor structures – 5 m.
- Cars and armored vehicles – 10 m.
- Tactical aircraft and helicopters – 20 m.
- Transport and strategic aircraft – 30–60 m.
- Buildings – 20–60 m.
- Ships – 60 m.

The "Shkval" targeting system will lock on to the nearest object within the acquisition frame that has dimensions comparable with the set target size. If the incorrect object is locked, move the acquisition frame to the correct target with the **[;], [,], [.], [/]** keys.

When a target is locked, an "AC" message will appear on the TV monitor – auto-tracking.

Step 3

Range to target is indicated by the range scale displayed on the HUD. When the maximum launch range is reached and the "LA" message appears, release the weapon by pressing the weapon release button on your joystick or by pressing the **[Space]** key on your keyboard.

After release/launch, you can immediately begin another task.

Note that it is impossible to deliver TV-guided weapons in poor visibility conditions and at night; they only work in the visible light spectrum and are influenced by all the limitations associated with daytime TV-devices. To lock a target, the target must be illuminated by a natural or artificial light source.

Laser Designation Missiles

The Su-25T can use the Kh-29L and Kh-25ML laser designation homing missiles. The Kh-29L and Kh-25ML were designed to destroy buried command centers, control centers, reinforced concrete shelters and structures, antiaircraft artillery positions, artillery, and other protected targets.

The delivery procedure for such weapons is as follows:

Step 1

Select air-to-ground mode by pressing the **[7]** key. Select the desired weapon by pressing the **[D]** key. Confirm the selected weapon type on the HUD. To detect and identify targets, you must turn on the "Shkval" TV targeting system by pressing the **[O]** key, or the "Mercury" system by pressing the **[RCtrl-O]** key. Search for your target by moving the scan zone center with the **[;], [,], [.], [/]** keys. Upon target acquisition, ground-stabilize the sensor by pressing the **[Enter]** key. For positive target identification you can increase the sensor's magnification level by pressing the **[+]** and **[-]** keys.

Step 2

To lock a target, you need to manually set a specified size (also known as "target base") of the target correctly. By default, the target specified size is 10 m. It is recommended to use the following target base values:

- Personnel and minor structures – 5 m.
- Cars and armored vehicles – 10 m.
- Tactical aircraft and helicopters – 20 m.
- Transport and strategic aircraft – 30–60 m.
- Buildings – 20–60 m.
- Ships – 60 m.

The "Shkval" targeting system will lock on to the nearest object within the acquisition frame that has dimensions comparable with the set target size. If the incorrect object is locked, move the acquisition frame to the correct target with the **[;], [,], [.], [/]** keys.

When a target is locked, an "AC" message will appear on the TV monitor – auto-tracking.

Step 3

Turn on laser range-finder by **[RShift-O]** key. Range to target is indicated by the range scale displayed on the HUD.

When the maximum launch range is reached and the "LA" message appears, release the weapon by pressing the weapon release button on your joystick or by pressing the **[Space]** key on your keyboard.

Step 4

Take note if the target was destroyed by the missile. If not and range to target still permits, launch another missile. Remember that you must lock the target the entire time the missile is in flight. If the lock is broken prior to the missile reaching its target, the missile will most likely miss. When locked to target, restrict your maneuvering as this could bring the target outside the gimbal limits of the "Shkval" targeting system.

Step 5

Turn off the laser range-finder by pressing the **[RShift-O]** key. Remember that the range-finder/target designator has a limited, continuous duration time, which is about one minute. After that, the device needs time to cool down or risk damage. During this cool-down time indicated by **"Л"**, a green lamp will flash at 2 Hz; when the device has sufficiently cooled, the lamp will extinguish. The cooling time is nearly equal to the work time, and it depends on environment temperature conditions.

The "Vikhr" has limited capabilities against low-speed air targets such as helicopters and low-speed aircraft. Engagement of air targets is the same as described above. However, the launch range against air targets, especially in a pursuit courses, significantly drops. Use the "Vikhr" against air targets less than 3 – 5 km away, depending on the target speed and aspect angle.

Laser Beam-Riding Missiles

The Su-25T can use the "Vikhr" laser beam-riding missile. The "Vikhr" is a specialized antitank missile (ATGM) designed to destroy mobile armored units.

The delivery procedure for such weapons is as follows:

Step 1

Select air-to-ground mode by pressing the **[7]** key. Select the ATGMs by pressing the **[D]** key. Confirm the selected weapon type on the HUD. To detect and identify targets, you must turn on the "Shkval" TV targeting system by pressing the **[O]** key, or the "Mercury" system by pressing the **[RCtrl-O]** key. Search for your target by moving the scan zone center with the **[;], [,], [.], [/]** keys. Upon target acquisition, ground-stabilize the sensor by pressing the **[Enter]** key. For positive target identification you can increase the sensor's magnification level by pressing the **[+]** and **[-]** keys.

Step 2

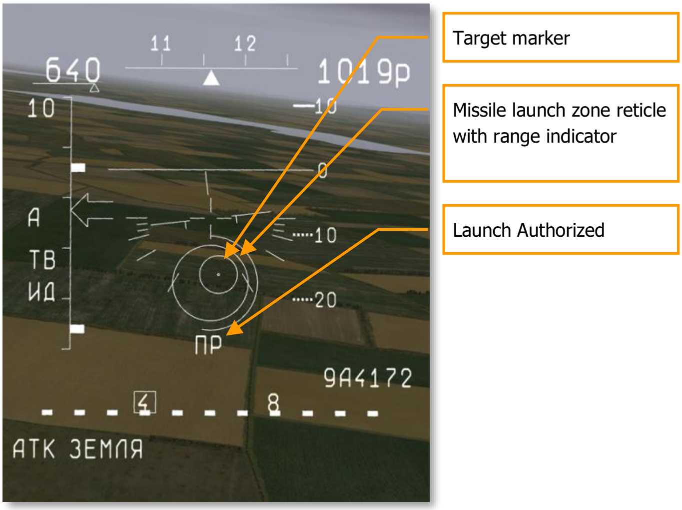
To lock a target, you need to manually set a specified size (also known as "target base") of the target correctly. By default, the target specified size is 10 m for armored targets.

The "Shkval" targeting system will lock on to the nearest object within the acquisition frame that has dimensions comparable with the set target size. If the incorrect object is locked, move the acquisition frame to the correct target with the **[;], [,], [.], [/]** keys.

When a target is locked, an "AC" message will appear on the TV monitor – auto-tracking.

Step 3

Turn on laser range-finder by **[RShift-O]** key. Range to target is indicated by the range scale displayed on the HUD.



13-1: ATGM delivery

Upon reaching maximum launch range, maneuver the aircraft to position the target marker within the missile launch zone reticle. Once aiming is complete, the target line-of-sight symbol will be within the missile launch zone reticle.

When the "LA" message appears, release the weapon by pressing the weapon release button on your joystick or by pressing the **[Space]** key on your keyboard.

Step 4

Take note if the target was destroyed by the missile. If not and range to target still permits, launch another missile. Remember that you must lock the target the entire time the missile is in flight. If the lock is broken prior to the missile reaching its target, the missile will most likely miss.

While the missile is in flight, maintain the aircraft's current heading such that it does not exceed the Shkval's angular gimbal limits. Try to avoid high angular velocity that can cause the missile to lose the laser-guidance beam.

Step 5

Turn off the laser range-finder by pressing the **[RShift-O]** key. Remember that the range-finder/target designator has a limited, continuous duration time, which is about one minute. After that, the device needs time to cool down or risk damage. During this cool-down time indicated by **"Л"**, a green lamp will flash at 2 Hz; when the device has sufficiently cooled, the lamp will extinguish. The cooling time is nearly equal to the work time, and it depends on environment temperature conditions.

The "Vikhr" has limited capabilities against low-speed air targets such as helicopters and low-speed aircraft. Engagement of air targets is the same as described above. However, the launch range against air targets, especially in a pursuit courses, significantly drops. Use the "Vikhr" against air targets less than 3 – 5 km away, depending on the target speed and aspect angle.

Antiradar Missiles Delivery

The Su-25T can employ the Kh-25MPU and Kh-58 anti-radiation missiles against surface radars. To target these weapons, the "Fantasmagoria" L-081 emitter targeting system pod is suspended from the belly of the aircraft. This pod detects the radar emissions of an air defense radar and cues the missile to the designated target.

The acquisition and lock process is as follows:

Step 1

Select air-to-ground mode by pressing the **[7]** key. To select the desired missile, cycle the **[D]** key. Confirm the selected weapon identification on the HUD.

Step 2

After detecting a threat on the RWS, maneuver your aircraft such that you are flying towards the threat emitter and activate the emitter targeting system (ETS) pod by pressing the **[I]** key. The ETS will detect the radar emitter and the threat marker and index will be displayed on the HUD.

Threats type and their associated indexes are listed in the table below.

Step 3

Place the TDC over the target mark on the HUD with the **[;], [,], [.], [/]** keys and then press the **[Enter]** key to lock the target. Note the distance to target scale on the HUD. When the maximum launch range has been achieved and the "LA" message appears on the HUD, you can launch the missile.

Anti-radiation missiles (ARM) are a "fire-and-forget" class of weapon and do not require launch aircraft support after they have been fired. After the missile has been launched, you can move on to your next task.

To survive over the modern battlefield, you must be familiar with different SAM systems, the degree of danger they each pose, and strike the most dangerous first. For example: the SA-10C (C-300) or Patriot SAM systems are the most dangerous in comparison with other SAM systems and they should be destroyed at long range with the Kh-58 ARM.

SAM or Ship	Radar designation	HUD designation
Patriot	AN/MPQ-53	P
Improved Hawk	AN/MPQ-50	H50
Improved Hawk	AN/MPQ-46	H46
Roland	Roland search radar	G

Roland	Roland	R
SA-10 S-300PS SR 64N6E	Big Bird	BB
SA-10 S-300PS SR 5N66M	Clam Shell	CS
SA-10 S-300PS TR 30N6	Flap Lid	FL
SA-11 Buk SR 9S18M1	9S18M1	S11
SA-6 Kub STR 9S91	1S91	SA6
SA-8 Osa 9A33	9A33	SA8
SA-15 Tor 9A331	9A331	S15
SA-19 Tunguska 2S6	2S6	S19
SA-3 SR P-19	Flat Face	FLF
SA-3 TR SNR-125	SNR-125	SA3
USS "Carl Vinson"	Sea Sparrow	SS
CG "Ticonderoga"	SM2	SM2
FFG "Oliver H. Perry"	SM2	SM2
"Admiral Kuznetsov" cruiser	SA-N-9 Gauntlet	SN9
"Neustrashimy" frigate	SA-N-9 Gauntlet	SN9
"Moskva" missile complex	SA-N-6 Grumble	SN6
"Albatros" boat	SA-N-4	SA8
"Rezky" cruiser	SA-N-4	SA8

F-15C

The F-15C is a "pure" fighter and is optimized for air superiority. Despite the fact that it has limited capabilities to employ some air-to-ground weapons, today's F-15C squadrons do not train with such weapons nor would they be used in combat.

Air-to-Air Weapons

AIM-120 AMRAAM

Step 1

Acquire the target with radar **[I]** in either LRS **[2]** or the TWS **[RCtrl-I]** sub-mode.

Step 2

Place the TDC on the radar contact with the **[;], [,], [.], [/]** keys and press the **[Enter]** key to lock the target. Once locked, the radar will automatically transition to an STT lock.

When in TWS mode it is possible to lock up to 4 targets simultaneously. The first target will be the PDT and all subsequent targets will be SDTs.

When within visual range, the VISUAL **[6]** mode can be used.

Step 3

Use the dynamic launch zone (DLZ) on HUD and vertical situation display (VSD) to determine when the target is within range (in VISUAL mode there are no cues on VSD).

When the target is within Rtr range and the shoot cue is provided, press the weapon release button on your joystick or the **[RAlt-Space]** key on your keyboard.

> THE AIM-120 CAN BE USED IN BOTH STT AND TWS MODES. TWS MODE ALLOWS YOU TO ENGAGE MULTIPLE TARGETS SIMULTANEOUSLY.

AIM-7 Sparrow

Step 1

Acquire the target with radar **[I]** in either LRS **[2]** or the TWS **[RCtrl-I]** sub-mode.

Step 2

Place the TDC on the radar contact with the **[;], [,], [.], [/]** keys and press the **[Enter]** key once when in LRS mode and twice when in TWS mode to lock the target. The radar will then enter STT mode.

When within visual range, the FLOOD **[6]** mode can be used and does not require a radar lock..

Step 3

Use the dynamic launch zone (DLZ) on HUD and vertical situation display (VSD) to determine when the target is within range (in FLOOD mode there are no cues on VSD).

When the target is within Rtr range and the shoot cue is provided, press the weapon release button on your joystick or the **[RAlt-Space]** key on your keyboard.

TO USE THE AIM-7, THE RADAR MUST BE IN STT MODE. WHEN IN CLOSE COMBAT IN FLOOD MODE, THE TARGET SHOULD BE KEPT IN THE FLOOD RETICULE ON THE HUD DURING THE ENTIRE TIME OF MISSILE FLIGHT

AIM-9 Sidewinder

Step 1

Acquire the target with radar **[I]** in either LRS **[2]** or the TWS **[RCtrl-I]** sub-mode. When in close combat, use the VS **[3]** or BORE **[4]** scan modes.

Step 2

Place the TDC on the radar contact with the **[;], [,], [.], [/]** keys and press the **[Enter]** key to lock the target. Once locked, the radar will automatically transition to an STT lock.

If in VS mode, maneuver the aircraft to place the target within or above the vertical lines on the HUD.

If in BORE mode, maneuver the aircraft to place the target within the reticule on the HUD.

In weapon bore sight mode, place the target within the weapon seeker's field of view as represented by the reticule on the HUD.**[6]**.

Step 3

Use the dynamic launch zone on the HUD and VSD to monitor range to target. Note the weapon bore sight will not provide any ranging information about the target. A high-pitched done will sound when the seeker has locked onto the target.

When the target is within Rtr range and the shoot cue is provided, press the weapon release button on your joystick or the **[RAlt-Space]** key on your keyboard.

BOTH THE RADAR AND THE MISSILE BORE SIGHT MODE CAN BE USED TO DESIGNATE A TARGET FOR THE AIM-9; HOWEVER, A VALID SEEKER LOCK MUST TAKE PLACE FOR A THE MISSILE TO TRACK THE TARGET. WAIT FOR THE HIGH-PITCHED TONE BEFORE LAUNCHING.

M-61 Gun

Step 1

Acquire the target with radar **[I]** in either LRS **[2]** or the TWS **[RCtrl-I]** sub-mode. When in close combat, use the VS **[3]** or BORE **[4]** scan modes. Alternatively, you can select auto guns mode.

Step 2

If in VS mode, maneuver the aircraft to place the target within or above the vertical lines on the HUD.

If in BORE mode, maneuver the aircraft to place the target within the reticule on the HUD.

In weapon bore sight mode, place the target within the weapon seeker's field of view as represented by the reticule on the HUD.**[6]**.

In auto guns mode, place the static gun reticule over the target.

Step 3

If not already in auto guns mode, select the gun by pressing the **[C]** key; this will activate the GDS gun sight and place the radar in STT mode.

When the target is under the GDS pipper, fire by pressing the trigger on your joystick, or press the **[Space]** key on your keyboard.

The gun can be used without a radar lock but is much less accurate.

A-10A

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.

15

SUPPLEMENTS

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

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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

Matthias "Groove" Techmanski

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Nikolay "Agm" Borisov

Norm "SiThSpAwN" Loewen

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