Su-25
FROGFOOT

THE FIGHTER COLLECTION

Eagle Dynamics

Su-25: DCS Flaming Cliffs

Flight Manual

INTRODUCTION

Thank you for your purchase of Su-25: DCS Flaming Cliffs. This simulation is an outgrowth of our Flaming Cliffs series that provides great graphics and flight models, yet has a more shallow learning curve than some of our other DCS titles like the A-10C, Ka-50 and P-51D. While this Su-25 retains the cockpits functionality of the Su-25 from the Flaming Cliffs series, it adds a very advanced flight model.

Key features of the Su-25: DCS Flaming Cliffs include:

- Detailed and accurate 3D model and animations
- Six Degrees of Freedom (6DOF) capable cockpit
- Advanced Flight Model (AFM)
- Campaign and missions
- Su-25 skins from a wide array of squadrons
- "Game" modes for more relaxed gameplay

Perhaps most important, as part of DCS World, the Su-25: DCS Flaming Cliffs operates in the regularly updated DCS World and is fully compatible with other DCS titles online.

TABLE OF CONTENTS

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.

Figure 1. The 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.

Figure 2. Su-25 on the Caucasus

GAME AVIONICS MODE

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

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

Figure 3. Easy 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

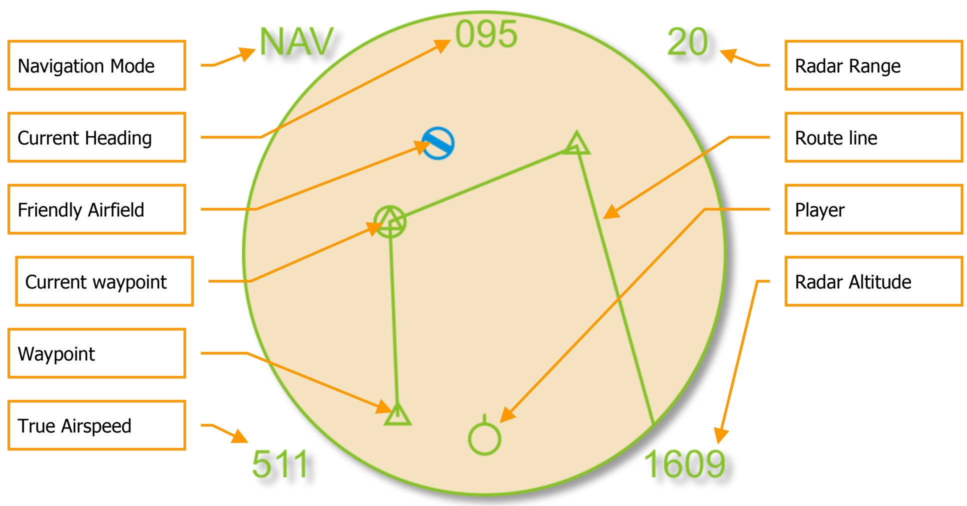

Figure 4. Easy Radar, Navigation Mode

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

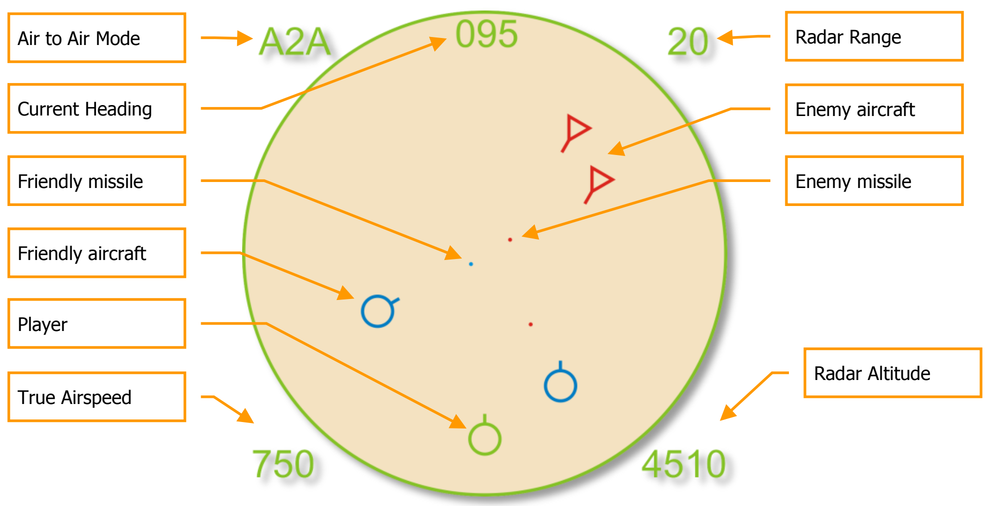

Figure 5. Easy Radar Air Mode

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

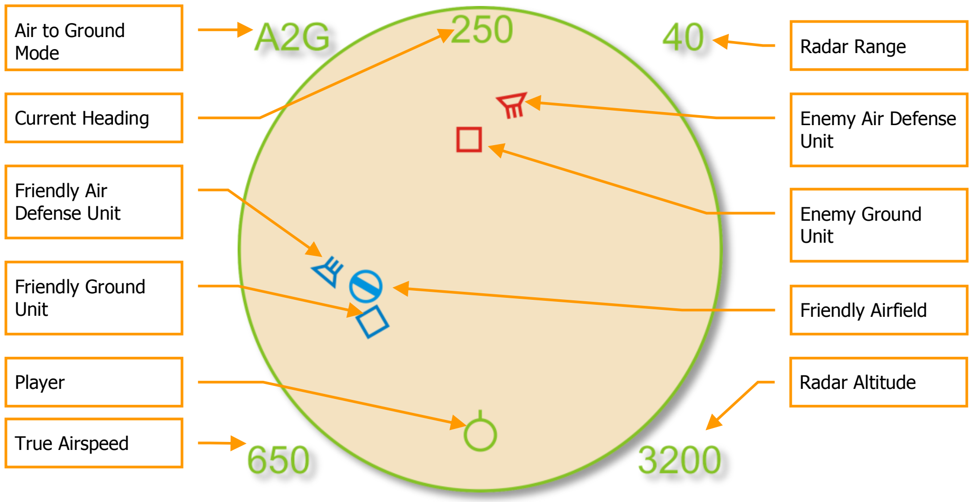

Figure 6. Easy Radar Ground Mode

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]**

Su-25 COCKPIT INSTRUMENTS

Figure 7. Cockpit Controls

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.

Figure 8. 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.

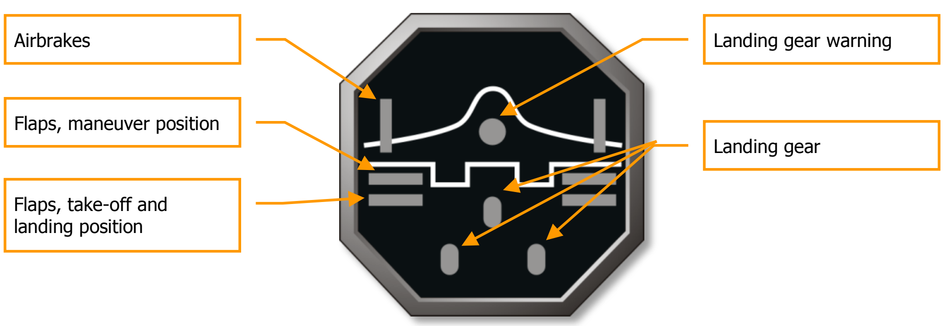

Figure 9. Configuration Indicator

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.

Figure 10. AoA and Accelerometer Indicator

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.

Figure 11. 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.

Figure 12. 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.

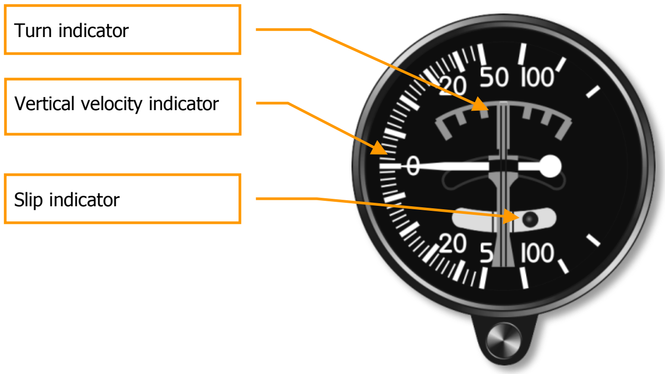

Figure 13. VVI

Radar Altimeter

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

Figure 14. Radar Altimeter

Tachometer

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

Figure 15. 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.

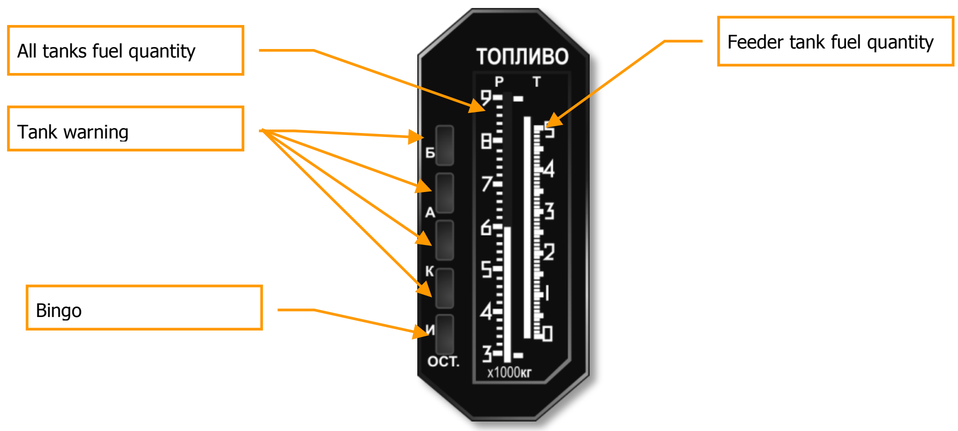

Figure 16. Fuel Quantity Indicator

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.

Figure 17. Jet Engine Temperature Indicators

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.

Figure 18. Weapon 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:
  К 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.

Figure 19. 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.

Figure 20. ASP-17 Gunsight Indication

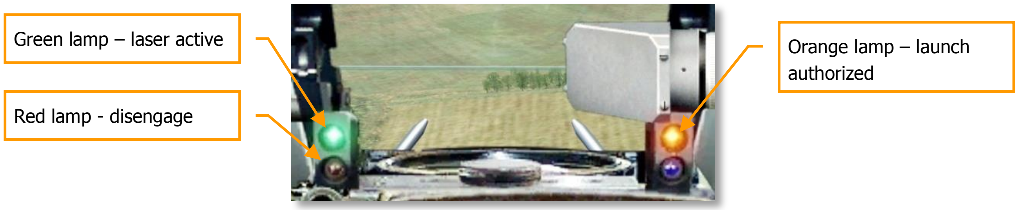

Figure 21. ASP-17 Gunsight Lamps

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.

TARGETING SYSTEMS

Close air support (CAS) aircraft, do not commonly have radars. This is because it is not sensible to install expensive radars on a rather simple aircraft that operate over the battle field at low altitudes. Such aircraft primarily rely on visual acquisition of targets. 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.

Figure 22. Nose of Su-25 with laser range finder "Klen"

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.

Figure 23. Laser Rangefinder/Target Designator "Klen-PS"

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

AIR-TO-AIR MISSILE

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".

Figure 24. 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.

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.

Air-to-Surface Missiles

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. 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.

Kh-25ML (AS-10 "Karen")

The Kh-25ML 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-25ML 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. Kh-25ML missiles are carried on APU-68U/UM/UM2/UM3 pylons.

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.

.

Figure 25. The Kh-25ML (AS-10 "Karen") Tactical Missile

Missile	TSD type	Warhead, kg	Launch effective range, km
Kh-25ML	Semi-active laser	90	2-10

Kh-29L (AS-14 "Kedge")

The Kh-29L (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.

Figure 26. The Kh-29L (AS-14 "Kedge") Tactical Missile

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

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.

Figure 27. 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.

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 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 - 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.

Figure 28. The FAB-500 High-Explosive Bomb

Figure 29. The FAB-250 High-Explosive Bomb

Figure 30. 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.

Figure 31. The BetAB-500ShP Concrete Piercing Bomb

SAB-100 Illumination Bomb

Figure 32. 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.

Figure 33. 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.

Figure 34. 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.

Figure 35. 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.

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.

Figure 36. 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.

Figure 37. 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.

Figure 38. 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.

Figure 39. 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.

Figure 40. 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

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.

Figure 41. 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.

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

SPO-15 Radar Warning Receiver

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").

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).

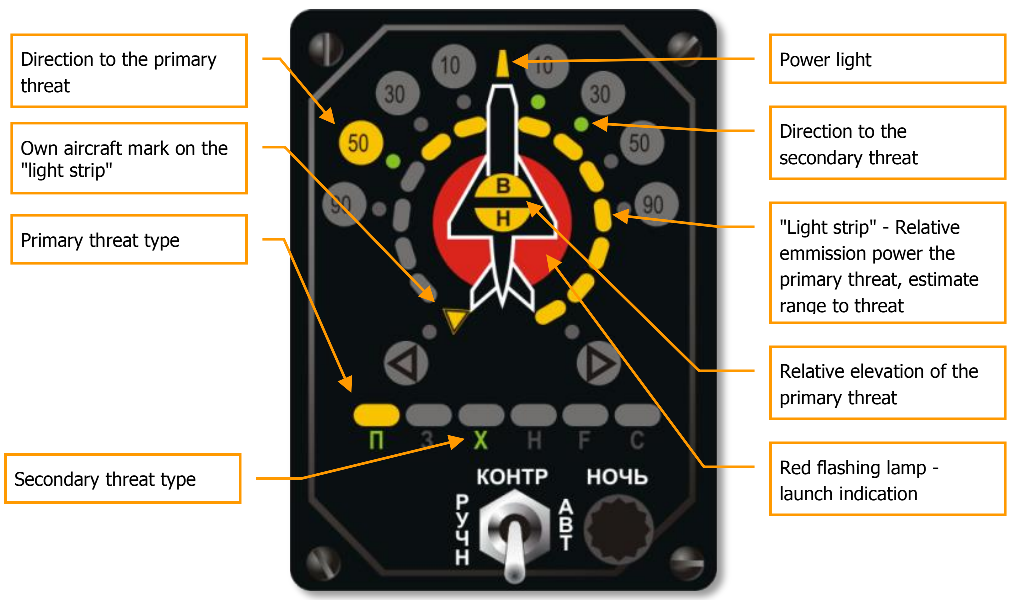

Figure 42. "Beryoza" SPO-15LM indicator

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 "**B**" and "**H**" 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 "**X**" 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.

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 approach point and has been handed over to Tower control. However, an aircraft is already in the pattern.	**"(x), Tower, orbit for spacing,"** where (x) is the callsign of the aircraft. Example: "Falcon one one, Tower, orbit for spacing."
	Player is above glide path while landing	**"(x), Tower, you are above glide path,"** where (x) is the callsign of the aircraft. Example "Eagle one one, Tower, you are above glide path."
	Player is below glide path while landing	**"(x), Tower, you are below glide path,"** where (x) is the callsign of the aircraft. Example "Eagle one one, Tower, you are below glide path."
	Player is on glide path while landing	**"(x), Tower, you are on glide path,"** where (x) is the callsign of the aircraft. Example "Eagle one one, Tower, you are on glide path."

Voice Messages and Warnings

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

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

Voice Message System Messages

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

An enemy missile that is targeting the player's aircraft is within 15 km of player, is in front of the player, and is at a lower altitude than the player.	"Missile, 12 o'clock low"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is in front of the player, and is at a higher altitude than the player.	"Missile, 12 o'clock high"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is behind of the player, and is at a lower altitude than the player.	"Missile, 6 o'clock low"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is behind of the player, and is at a higher altitude than the player.	"Missile, 6 o'clock high"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is to the right of the player, and is at a lower altitude than the player.	"Missile, 3 o'clock low"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is to the right of the player, and is at a higher altitude than the player.	"Missile, 3 o'clock high"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is to the left of the player, and is at a lower altitude than the player.	"Missile, 9 o'clock low"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is to the left of the player, and is at a higher altitude than the player.	"Missile, 9 o'clock high"

THEORETICAL TRAINING

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

Indicated Air Speed and True Airspeed

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

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

THE AIRSPEED INDICATOR SHOW THE AIRCRAFT'S INDICATED AIR SPEED

Velocity Vector

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

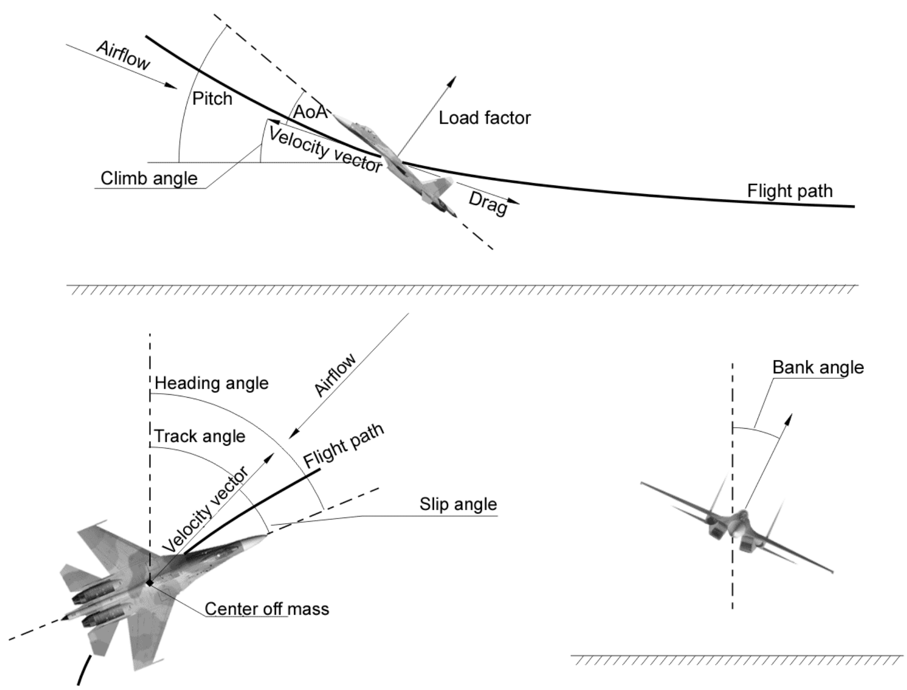

Figure 43. Aircraft aerodynamic forces

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

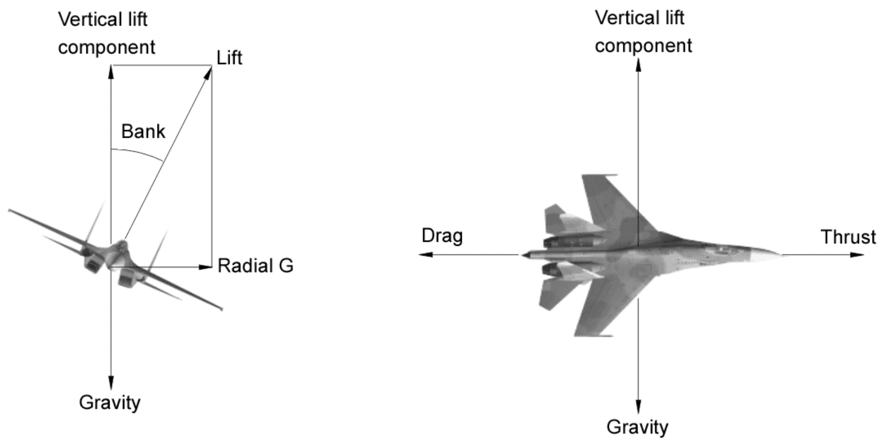

Figure 44. The forces acting at the aircraft maneuver

Turn Rate

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

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

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

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

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

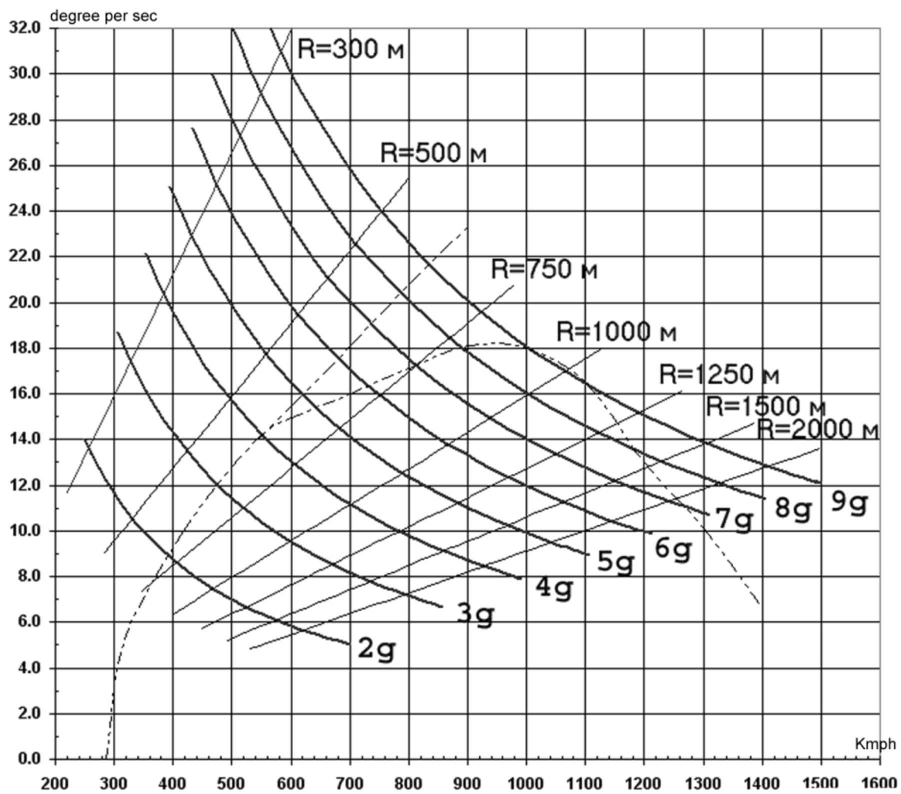

Figure 45. Typical turn rate vs KIAS "dog house" plot of a modern fighter

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

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

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.

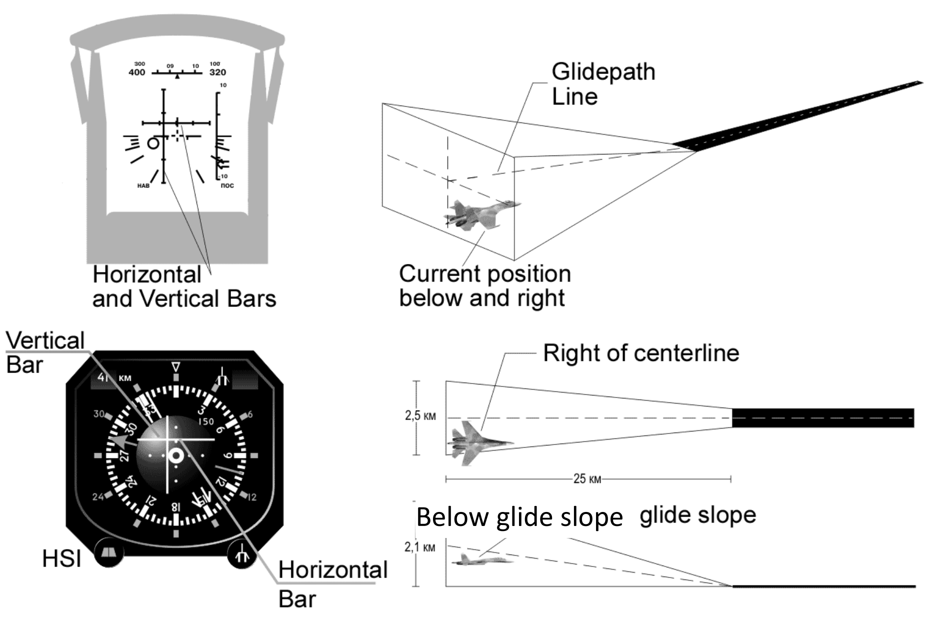

Figure 46. Instrument landing system

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 ADVANCED FLIGHT DYNAMICS DESCRIPTION

Advanced flight dynamics model was created for the Su-25. 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

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.

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.

Maneuvers

If both you 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.

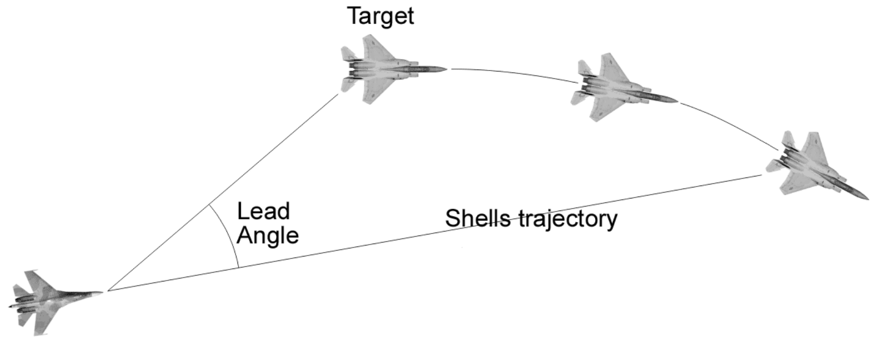

Figure 47. Gun use during air combat

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

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

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

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

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

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

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

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

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

Air-to-Air Missile Tactics

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

Air Defense

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

Antiaircraft Artillery (AAA)

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

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

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

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

Surface-to-Air Missile (SAM) systems

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

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

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

Command Guidance

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

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

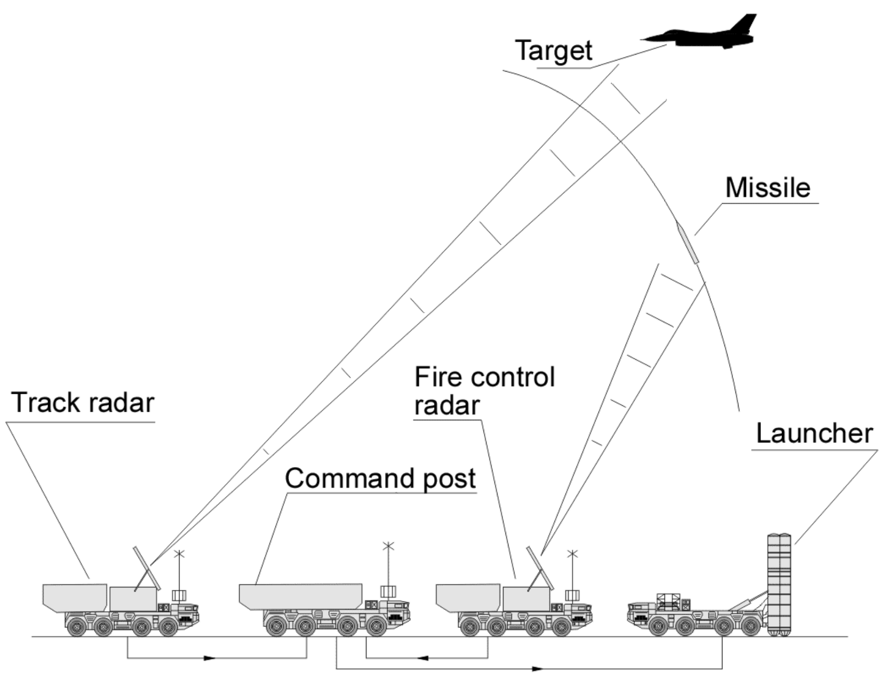

Figure 48. Command guidance

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

Semi-Active Guidance

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

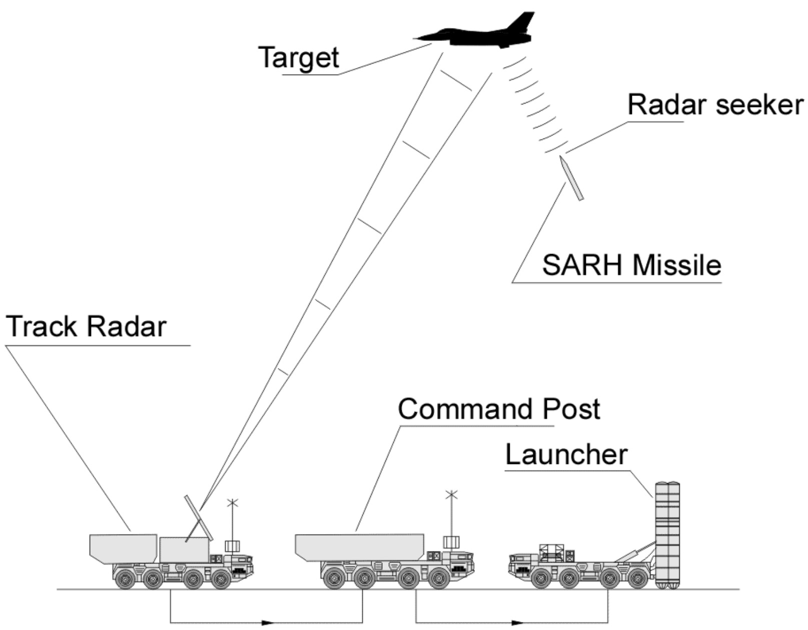

Figure 49. Semi-active guidance

Active Guidance

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

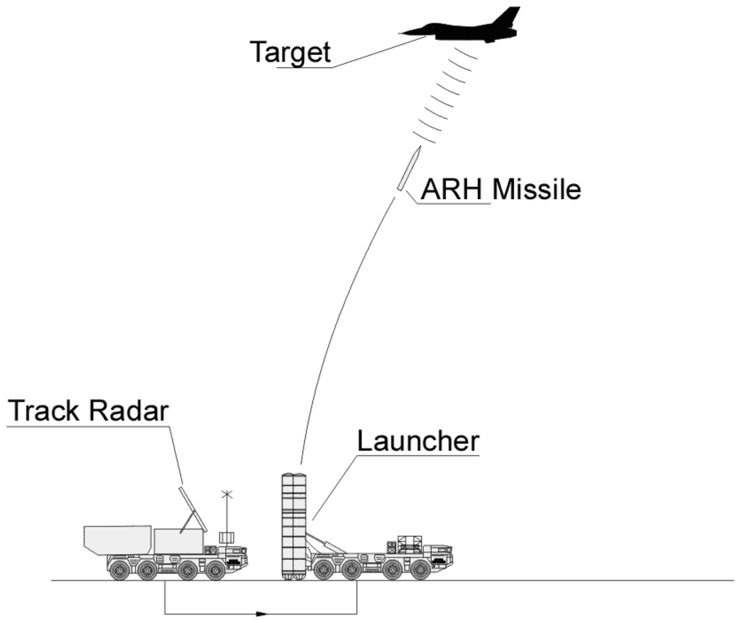

Figure 50. Active guidance

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

Passive Guidance

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

Combined Guidance

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

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

SAM Engagement Zone

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

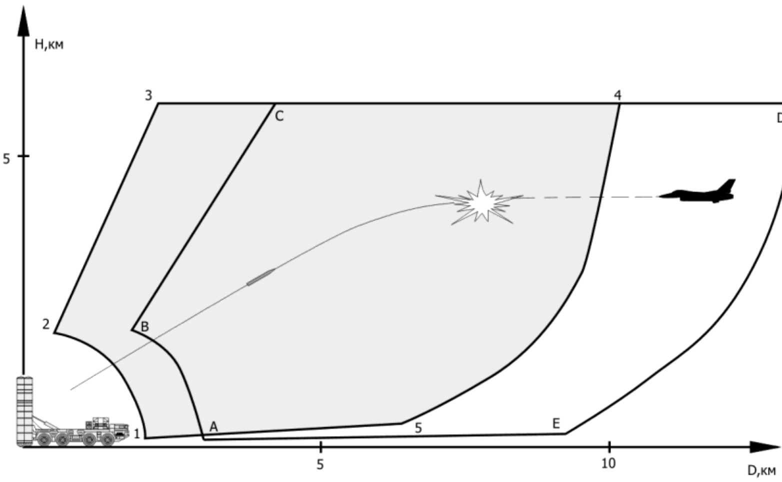

Figure 51. SAM typical engagement zone

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

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

SAMs are usually classified by range:

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

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

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

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

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

Ground Control Intercept

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

Enemy Air Defense Penetration

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

Don't Get Shot At…

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

Suppression of Enemy Air Defenses (SEAD)

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

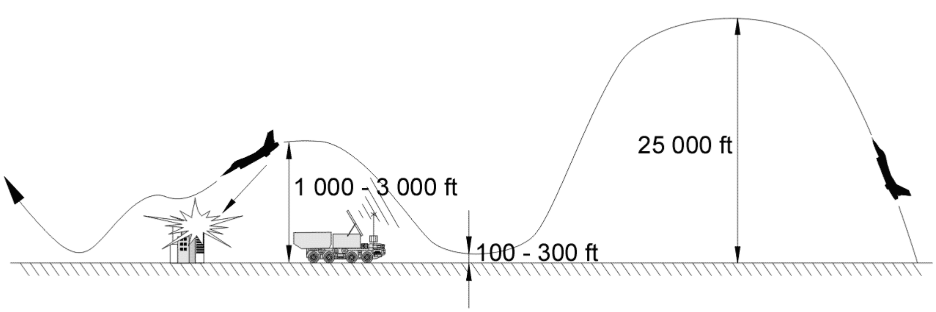

Figure 52. SEAD flight profile

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

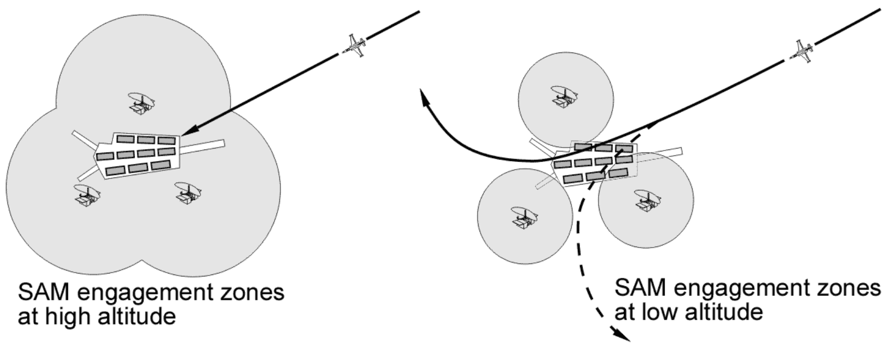

Figure 53. SAM engagement zones at high and low altitudes

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.

Missile Evasion Maneuver

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

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

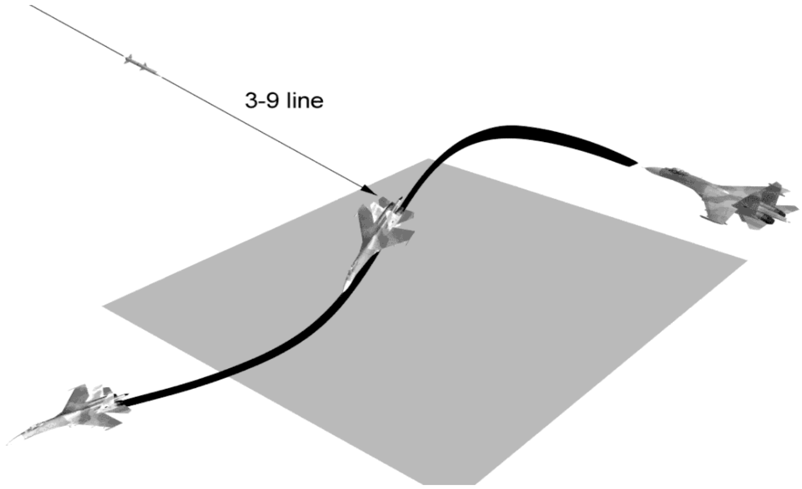

Figure 54. Missile evasion maneuver

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

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

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

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

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

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

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

There are some additional items to keep in mind. The lower the altitude is; the greater the air density will be. Accordingly, the missile will lose speed and range much quicker when flying at lower altitudes. When a missile is inbound, fly a perpendicular course in relation to the missile's flight path and dispense the chaff and flares. During this maneuver, try to stay near your aircraft's instantaneous corner velocity.

If the missile continues to track, you will need to perform a "last ditch" maneuver. When the missile is approximately 1 – 2 km from you (depending on missile speed), perform a nose-low maximum-G break turn into the flight path of the missile. For this to work, a couple factors have to be in your favor. First – the missile should be low on energy and unable to generate a high-G maneuver. Second – the missile seeker, as any mechanical device, has a limited speed at which is can gimbal and finite a angle at which it can track targets. If you provide a radical enough change in course, the seeker may be unable to track your aircraft.

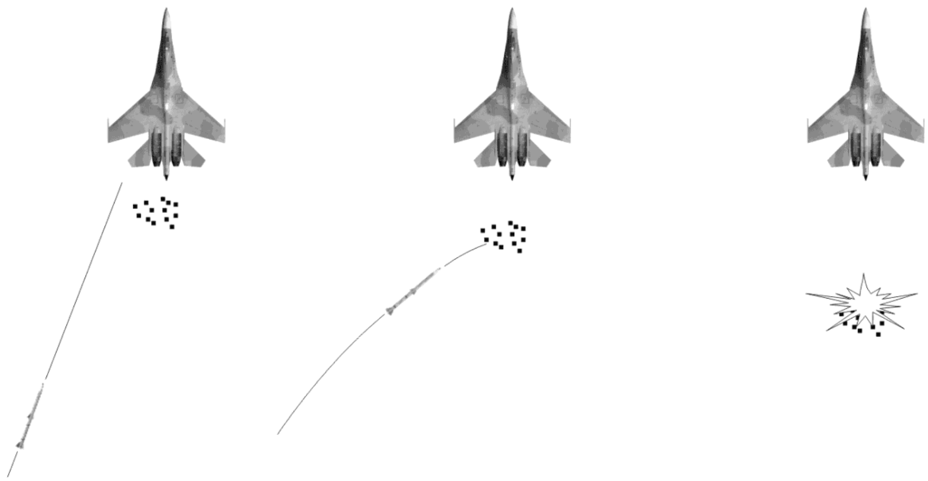

Figure 55. Decoying missiles with chaff and flares

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.

SU-25 WEAPONS USE CHECK LISTS

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 4

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

SUPPLEMENTS

Acronym List

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

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

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

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

DEVELOPERS

Eagle Dynamics Team

Management

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

Programmers

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

Artists and Sound

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

Quality Assurance

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

Localisation

Andrey "Andrey Andreevich" Kryuchenko	Lead localization
Elena Pryanichnikova	Localization

Science Support

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

IT and Customer Support

Konstantin "Const" Borovik	System and network administrator, WEB, forum
Ekaterina Perederko	WEB
Andrey Filin	System and network administrator
Andrey Ustinovich	Customer support
Alena Yurykovskaya	Customer support

Testers Staff

Alexander "asd1234" Amelin

Alexander "BillyCrusher" Bilievsky

Alexander "vatel" Tyshkevich

Andrea "FCS_Heater" Papaleo

Anthony "Blaze" Echavarria

Carlos "Design" Pastor Mendez

Chris "Ells228" Ellis

Christopher "Mustang" Wood

Daniel "EtherealN" Agorander

Danny "Stuka" Vanvelthoven

Darrell "AlphaOneSix" Swoap

David "USAFMTL" Slavens

Dmitry "Laivynas" Koshelev

Dmity "Simfreak" Stupnikov

Ed "Manawar" Green

Edin "kuky" Kulelija

Erich "ViperVJG73" Schwarz

Evan "Headspace" Hanau

Gareth "Maverick" Moore

Gavin "159th_Viper" Torr

George "GGTharos" Lianeris

Grayson "graywo1fg" Frohberg

Guillaume "Dimebug" Leleve

James "Dusty_Rhodes" Rhodes

James "Eddie" Knight

Jeff "Grimes" Szorc

Jens "=STP=Dragon" Giesser

John "Speed" Tatarchuk

Jon Espen "Panzertard" Carlsen

Kiko "Mistral" Becerra

Matthew "44th_Rooster" Sartin

Matthias "Groove" Techmanski

Nick "BlueRidgeDX" Landolfi

Nikolay "Agm" Borisov

Norm "SiThSpAwN" Loewen

Paul "paulrkii" Kempton

Paul "PoleCat" Johnston

Pavel "Shadowowweosa" Kuzin

Peter "Weta43" McAllister

Phil "Druid_" Phillips

Raul "Furia" Ortiz de Urbina

Roberto "Vibora" Seoane Penas

Scott "HuggyBear" Matthew

Stephen "Nate--IRL--" Barrett

Steve "joyride" Tuttle

Steve Davies

Timothy "WarriorX" Westmore

Tyler "krebs20" Krebs

Vadim "zetetic" Vyveritsa

Valery "=FV=BlackDragon" Manasyan

Vladimir "lester" Ivanov

Werner "derelor" Siedenburg

Zachary "Luckybob9" Sesar