THE FIGHTER COLLECTION

EAGLE DYNAMICS

DCS: MiG-29 Fulcrum

Flight manual

DCS: MiG-29 for DCS World

The MiG-29 (NATO codename Fulcrum) – is a soviet multirole 4th generation fighter, created in Mikoyan and Gurevich Design Bureau to counter the American F-15 "Eagle". It's is a twin-engine, supersonic, highly maneuverable air superiority fighter, which is capable of engaging targets well beyond visual range as it is in a dogfight given its amazing slow speed and high angle of attack maneuverability. The MiG-29 is a dangerous opponent for almost any modern fighter, because it uses its radar and stealthy infrared search and track system. An important trump card in MiG-29´s arsenal is the helmet-mounted sight that allows you to simply look at a target to lock it up! In addition to its powerful air-to-air capabilities, the Flanker can also be armed with bombs and unguided rockets to fulfil a secondary ground attack role.

Mig-29 in DCS World is represented as two modifications – MiG-29A (9-12) and MiG-29S (9-13), which focus on ease of use without complicated cockpit interaction. The aircraft can be controlled by joystick or keyboard, which reduces the number of required operations and reduces the time required for training.

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

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INTRODUCTION

The MiG-29, NATO codename Fulcrum, is one of the pillars of modern-day Russian combat aviation, created to counter American 4th generation aircrafts. It's a twin-engine, supersonic, highly maneuverable air superiority fighter, which is capable of engaging targets well beyond visual range as it is in a dogfight. Using its radar and stealthy infrared search and track system, the Fulcrum can engage target with wide array of radar and infrared guided missiles.

MiG-29 also includes helmet-mounted sight that allows you to simply look at a target to lock it up! In "Track Wile Search 2" mode MiG-29S can engage two targets at the same time using R-77 missiles.

In addition to its powerful air-to-air capabilities, the Fulcrum can also be armed with bombs and unguided rockets to fulfil a secondary, ground attack role.

MiG-29A and MiG-29S models for DCS World are focused on ease of use, without cockpit interaction, significantly reducing the learning curve.

Figure 1: MiG-29

MiG-29 HISTORY

MIG-29 HISTORY

The first developments in designing a light-weight frontline new generation fighter were started in 1960s. In 1969, the USSR learned about USAF F-X program (result of the program was a McDonnel Douglas F-15 "Eagle"). Soon the leadership of USSR made a conclusion that new American fighter considerably exceeds any of the existing Soviet fighters. The MiG-21 was quite modern, but inferior in-flight range, armament and possibility of improving. The MiG-23 was quite fast and had more fuel, but it was not enough maneuverable in close air combat.

The Soviet air force needed a high-tech, well balanced fighter with good maneuverability. In 1969 they announced a tender for the creation of such an aircraft, which received designation AFF ("Advanced Frontline Fighter"). The tactical and technical requirements for such aircraft were very ambitious: long range, possibility to use short airfields (including usage of poorly prepared runways), excellent maneuverability, with speed above 2 Mach and heavy weapons. The aerodynamic design of the new aircraft was carried out by CIoA (Central Institute of Aerodynamics) in cooperation with Sukhoi DB. The contest was attended by such design bureaus as Sukhoi, Yakovlev and Mikoyan & Gurevich (MiG shortly). The winner was the "MiG" bureau.

Light-weight frontline fighter program

In 1971, it became clear that the Advanced Frontline Fighter aircraft were too expensive to realize the needs of USSR Air Force regarding jet fighters, that's why the project was separated into Heavy Advanced Frontline Fighter and Light-weight Advanced Frontline Fighter. Sukhoi DB started working on HAFF, LAFF project was given to Mikoyan DB. MiG-29 became a result of the LwAFF program.

Work on LwAFF began in 1974. The result of this program was "Product 9" (as per DB classification), which received the designation "MiG-29A". The first flight of the prototype was performed on October 6, 1977. First time the pre-production aircraft has been seen by US reconnaissance satellites in November, 1977 and received designation "RAM-L" (Ramenskoe — it is the place, where plane has been spotted for the first time).

The task of LwAFF development was to create a machine with flight characteristics that weren't inferior to such aircrafts like the F-15, F-16 and YF-17 (later F/A-18). The main task of the aircraft was air superiority over the combat area, second task – striking ground targets with unguided weapons in daytime (simple weather conditions).

Figure 2: MiG-29 mock-up

Due to delays associated with the loss of two prototypes in flight accidents, serial production was started only in 1982 on the Moscow plant №30 aka "Znamia Truda". First serial MiG-29's began to arrive to the Kubinka airbase in August, 1983. The aircraft successfully passed all state admission tests in 1984, after which its deliveries began to the frontline airbases. 234 Fighter Avia Regiment (Kubinka) and 145 FAR were first regiments which got the MiG-29. In early 1985, they reached operational readiness. Separation into two different projects was clear after first aircraft were delivered to the first regiments. The heavy Su-27, having bigger action range, had tasks at greater depth behind the front line - intercepting and destroying NATO aircraft and vehicles, a smaller MiG-29 replaced the old MiG-23 in frontline aviation.

According to the idea if military theorists, MiG-29´s should be deployed near the frontline and must ensure local air superiority for the advancing ground units of the Soviet motorized army. At that time, Soviet military commanders put on advance of mechanized units, which implied the usage of frontline aviation on damaged or poorly prepared runways. That's why the MiG-29 was equipped with rugged chassis and protective frills on the air intakes. The MiG-29 also had to carry out the task of assault aircraft escort, protecting vulnerable aircrafts from enemy fighter attacks. Frontline MiG's were made to provide a moving "Air Umbrella" for ground forces.

The new fighter was "Fulcrum-A" designation according to NATO classification. Based on MiG-29 9-12, export MiG-29A and MiG-29B modification were developed with reduced avionics, without the ability of delivering nuclear bombs. The Mig-29 was first seen during the visit to Finland in July, 1986. In September 1988, MiG-29 was introduced for the first time at the international airshow in Farnborough. Western viewers were impressed by the capabilities of the new machine and its outstanding maneuverability, but noted a serious drawback – increased smokiness of RD-33 engine.

On January 21, 1989, the converted mass-produced MiG-29 No. 0405 took-off. It was the first time when the R-77 air-to-air missile was launched to engage two targets simultaneously from this plane. Tests shown, that such an attack is possible under strict restrictions. In the same year, another MiG-29S, re-equipped from serial aircraft No. 404 started ty fly. Four flights took place in Joint State tests, and in 1991 the serial production of the plane has begun. Air Force bought only 16 of 50 built airplanes for CoCTaPR (Center of Combat Training and Personnel Retraining) and the 73th FAR. The fighter has proved itself positively, however it wasn't possible to sell other planes.

By the end of 1991, the workshops of MAPO produced nearly 1200 one-seat MiG-29's. Near 200 two-seat training MiG-29UB were produced in Nizhny Novgorod. In accordance with the plans for the development of the aircraft industry of the USSR, by this time it was planned to transfer MiG-29M production to the MAPO. Even before 1990 it was supposed to build the first 60 planes of the M modification. In the next decade, it was necessary to increase their number to 300 or 400 units (simultaneously in 1986-1995 it was expected to build also 27 ship-based MiG-29K fighters). However, the development of the MiG-29M was delayed. By the early 90's only flight-design tests were completed.

Fulcrum testing

Preliminary design and full-size mock-up of the MiG-29 9-12 were introduced in 1976. The newest K-27 ("A" and "B" modifications with a conventional power unit) missile became the main armament of the fighter, despite the fact that plans existed to use the SLAR "Safir" and other 3rd generation equipment. Preference was given to the K-27 project, made by ICB "Vympel". The construction of the first prototype MiG-29 started in the same year.

First plane for stat-tests was built in summer 1977, by the factory "Zenith". Assembling was based on accelerated program, later it got a permission to start flight tests. And finally, the first experimental MiG-29 was ready.

On October 10, senior test pilot Alexandr Fedotov raised the "nine" into the first flight. Later, Moscow Aviation Production Association released two more test aircrafts.

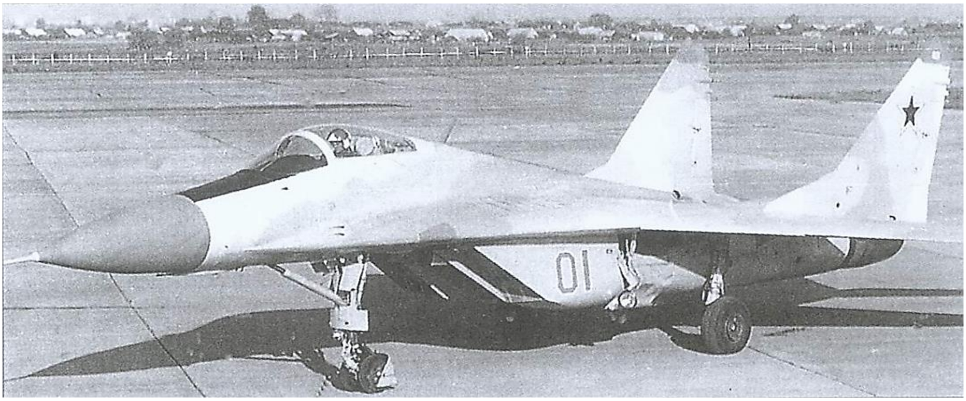

Figure 3: The first MiG-29 prototype

A new critical stage of the aircraft development began in 1982 – the spin tests. The plane "conquered" all kinds if this dangerous flight modes.

9-01 had engines from the so called "zero" party. Bench tests of the RD-33 were very intense. Power plant tests were planned to make it on the second prototype of the aircraft – 9-03. Its first flight took place on April 20, 1978. But an accident happened in the ninth flight on June 15. Due to pressure drop in the oil system of the right engine, the compressor collapsed. Broken blades caused a fire, damaged the traction control system, the plane went into pitch-up and fell into a tailspin. Test pilot V. Menitsky damaged his spine in the ejection process.

When you lose the experimental aircraft it's a hard hammer blow. But there were also two positive moments. The new ejection system K36, which in a few years will gain a worldwide fame, successfully ejected and in fact, that second engine continued to work in the condition of the first engine compressor failure and severe damage of the airframe.

In the meantime, preliminary testing of the aiming equipment and guided weapons was completed in 1978. The flying laboratory LL-124 (based on Tu-124) was used for those purposes. It had a Radar Targeting System "Rubin" and Fire Control System FCS-29 installed on board, also, with the K-27, K-62 and K-14 target seeking devices. Tests of the missiles were made on the "RV" plane, re-equipped from the MiG-23ML. The fighter-bomber MiG-23BK was used for Inertial Navigation System INS-29 testing.

The first MiG-29 with a full set of avionics became an experimental "9-02". Due to equipment delivery delays, it was flown only on December 28, 1978. The radar set (RLPK-29) wasn't installed. Instead, a test of IR missiles (K-62M, K-27T) and Electro Optical Sighting/Navigational System EOSNS-29 were conducted. It included the electro-optical targeting system OEPS-29, the inertial navigation system SN-29, the fire control system FCS-29(20P), the helmet-mounted target designator "Shchel-3UM", the mission computer C100, the single indication system SEI-31 and the multifunctional control panels. All this equipment was also used in the Su-27.

A lot of tests of delivering bombs and gun fire was also made with this aircraft. 9-02 had a light single-barreled gun 9A4071 (GSh-301), which was designed by the Tula KBP for the cartridge of AO-18 munition.

9-02 has got another important improvement. The tests of its predecessors showed that garbage, flying out from the nose wheel falls exactly in the scoops of the air intakes. As a result, the nose wheel was pushed back on one and half meter and shortened half meter. But because of that, it was necessary to shorten the first fuel tank. Fuels tanks also were placed into the wings to compensate the reduction of the fuel.

In service

First combat planes were received by the 4th Center of Combat Training and Pilots Retraining in 1983. Two regiment army units (CTaPR), 455th instructor-test mixed squadron in Lipetsk and 760th mixed squadron in Voronezh got 37 new fighters. Pilots retraining on the MiG-29 became the most important task of the center for a long time. The aircraft was highly appreciated during different military tests, despite a number of accidents. The head of the training center S. Oskanov, also flying on Su-27, played a special role in the MiG-29 training. He approved that a light-weight MiG-29 can fight with more powerful enemy aircrafts, such as the F-15, and became a winner. Oskanov died in flight on a MiG-29 in February 1992.

In order to speed-up the MiG-29 training process, 1080th combat training center in Borysoglebsk has got 79 new fighters.

The first combat unit which got the new MiG-29 was the 234th Guards Proskurovsky Fighter Squadron. In 1983, 20 MiG-29 9-12 arrived at the Kubinka airbase. In addition to the MiG-29, Kubinka airbase had a few MiG-23UM.

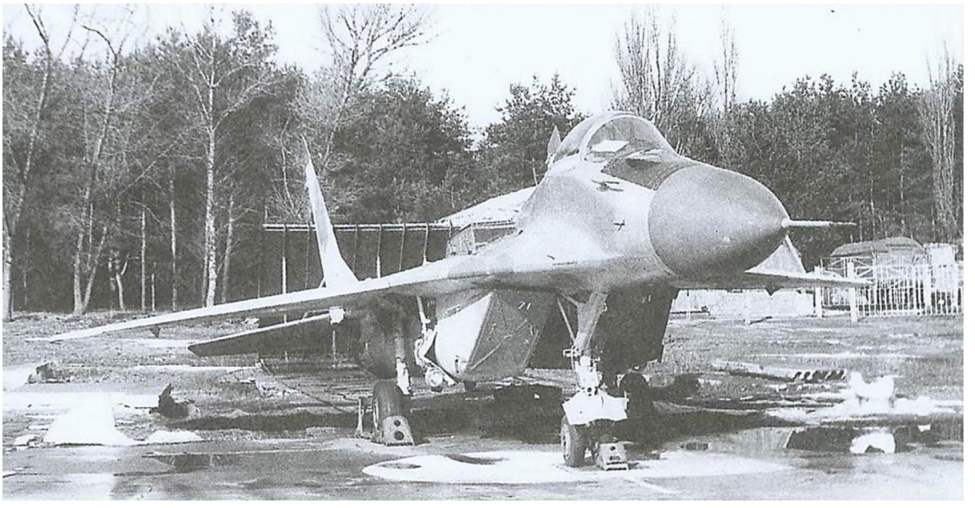

Figure 4: One of the first MiG-29 9-12 on the ramp

Priority for the arrival of the MiG-29 was given to the districts that faced NATO forces in Europe. After 234th Guard Squadron, 968th Fighter Squadron of the 95th fighter division got the new "Fulcrums" (Ross' airbase). In the Carpathian Military District, 145th Fighter Squadron of the 14th Air Army (based in the city of Ivano-Frankivsk) got new the MiG-29 9-12. 92th Fighter squadron, which was a part of the same army in Mukachevo, got the newly modified MiG-29 - 9-13. Later, near 1990's, 168th Fighter Squadron from Starokonstantinov got 36 MiG-29.

The largest number of such airplanes (about 250 aircrafts, at the beginning of 1990s), had 16th Air Army, located in German Democratic Republic (Western Army). Rearmament on the MiG-29 began, starting from 16th Guardian Fighter Squadron. In 1986, 33th squadron, located in Wittstock (GDR), returned it's MiG-23M´s and received the new 4th generation fighter (the first, outside the USSR).

In 1987, in connection with the transition to the MiG-29, the 35th Fighter-Bomber Aviation Regiment became a fighter regiment. It was located at the Zerbst (GDR) airfield and was a member of the 16th Air Army.

Figure 5: MiG-29 on the runway of the Zerbst airfield

In 1988, 85th Guard Fighter Squadron, located in Merseburg, got new planes. 31th Guard Fighter Regiment of the Suvorow, located on Falkenberg airbase got also the new MiG-29, 968th Fighter Regiment from Noblitz also got the MiG-29. Thus, 8 Soviet regiments of three divisions in Eastern Germany received the Mig-29.

Despite the fact, that the Mig-29 was not suitable for the role of an assault aircraft, a lot of fighter-bomber squadrons received it. In the mid-1980s, 642th Regiment changed their MiG-27 to Mig-29 9-13. 927th Königsberg Regiment, located at Bereza-Karpusska in Belarus, also got their MiG-29's.

In total, 25 combat aviation regiments of the USSR Air Force got new planes. Air Defense forces also would use this light and maneuverable fighter. Preparation of pilots for a new aircraft was started in the 116th Astrakhan Aviation Training Center. First air defense squadron of this center, which received the MiG-29, was located in Volga Federal District. In 1989, the 119th Division from the OdVO was reassigned to the Black Sea Fleet and renamed into 119th Sea Fighter Air Division, its regiments were renamed into 86th Fighter Air Regiment and 161th Fighter Air Regiment. They became the only regiments of the Soviet Navy, which operated and maintained the MiG-29.

Experience of the MiG-29 usage showed, that correctly chosen tactic allowed a light-weight fighter to resist more powerful aircrafts. At the main probable enemy – the USAF – such machine was the F-15. When joining with it into close air combat, MiG-29 should have superiority, which although somewhat inferior to the F-15 in turn characteristics, but with a clever tactic at low altitudes, it successfully matched the enemy.

Mikoyan's fighter was equipped with more modern weapons for close air combat – the R-73 missile, which, thanks to a large angle of track and gas-dynamic control were surpassing the AIM-9 missile in a number of parameters.

MiG-29 GENERAL DESIGN

GENERAL DESIGN

Aircraft construction

The aircraft is a monoplane, based on integral aerodynamic scheme. Integral scheme provides a creation of the one lifting surface area, smoothly joined through the zone of highly developed extension with the wing. MiG's structural system uses aluminum, titanium alloys, steel, composite materials and others.

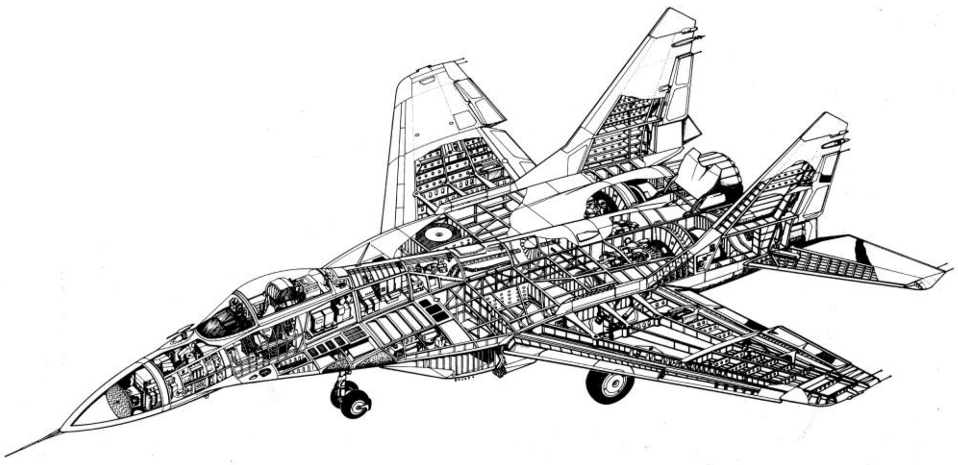

Figure 6: MiG-29 9-12 Composite design

The fuselage (semi-monocoque structure) consists of 10 power frames, normal frames, diaphragms, stringers, beams and panels. Nose section is formed by the radio-transparent cone of the Radar Targeting System antenna. Airtight cab compartment is located behind the nose section (different avionics equipment is also pressurized). Next is airtight cockpit. The nose is tilted down relatively to the aircraft's horizontal reference line in order to improve front-to-bottom view.

A transparent spherical radome of the electronic-optical station OEPS-29 is placed in front and right of the frontal part of the canopy. The hardware compartment is located behind the cockpit, nosewheel compartment is located under the hardware compartment. Further – two compartments of the tanks #1 and #2, behind which is the integral fuel tank #3, which is the main fuel source of the aircraft. Engine compartments are located behind the fuel tank #3 as well as two fuel tanks #3a.

The final section of the aircraft is the tail section. Tail fins, afterburners and airbrakes are attached to the tail section. Break chute container is located behind the engine nozzles. The area of the top airbrake is 0.75 m^2, deviation angle - +56°, bottom airbrake - 0.55 m^2 and -60°, respectively.

Leading edge extensions are monolithic with the fuselage. Sweep at leading edge is 73°30', LEX area - 4.71 m^2. Upper air intakes are installed in the LEX. The wing has a 42° sweep along the leading edge, near 9° at the trailing edge, angle of the transverse "V": -3°. The wing console consists of 3 spars, 3 walls, 16 ribs and monolith faying surfaces. Thee-section leading edge flaps (2.35 m^2) are installed on wing leading edge. Their deviation angle equals 20°. LEF are extended automatically, when Angle of Attack is more than 8.7° and retraction respectively or synchronously with the extended flaps. Flaps square (single-slotted) equals 2.84 m^2, deviation angle - 25°. Ailerons square - 1.45 m^2, upward deviation - 25°, downward deviation - 15°. Their neutral position corresponds to the upward deflection angle by 5°.

The horizontal stabilizer is fully rotary, differential. During takeoff deviation angles are close to 15° upward and 35° downward, while in flight - 5°45' and 17°45', respectively. Stabilizer are - 7,05 m^2, Sweep angle at leading edge - 50°, transversal "V" angle - 3°30'. Horizontal stabilizer consoles are mounted to the bearing units, which are built into the tail section of the fuselage. The front section of the console is made of duralumin. The caisson of the console is formed by a wall, a longeron, a root rib, 16 normal, 2 auxiliary ribs and monolithic fiberglass panels.

The tail part of the console is a light-weight three-layer construction, made of composite materials. Rudder fins square - 1.25 m^2 (first series aircraft had 20% less ruder fins). Rudder fin console consists of 2 spars and 10 ribs. Rudder fin construction includes monolithic panels made of fiberglass. Fin extensions are also a part of the fuselage. First series aircrafts had ventral tail fins.

The tricycle geared aircraft is intended for operations from concrete, asphalt-concrete, metal, ground and snow runways. Wheel base - 3.645m, wheel tread - 3.09 m. There are 2 brake wheels KT-100 (570x140 mm) equipped with a mud guard and installed on the nose pillar stand. Angles of rotation while taxi - 30°, while takeoff - 8°.

Figure 7: MiG-29 Nose Wheel

Main gear - single KT-150 wheels (840x290 mm), which retract into recesses above the air intake channels forward with a 90° turn.

The main air intakes of soviet type, supersonic, external compression, adjustable, with a horizontal arrangement of the braking wedge, have a boundary layer drain system. When the aircraft is moving on the ground, the upper air intakes are used, which operates at speeds up to 200 km/h.

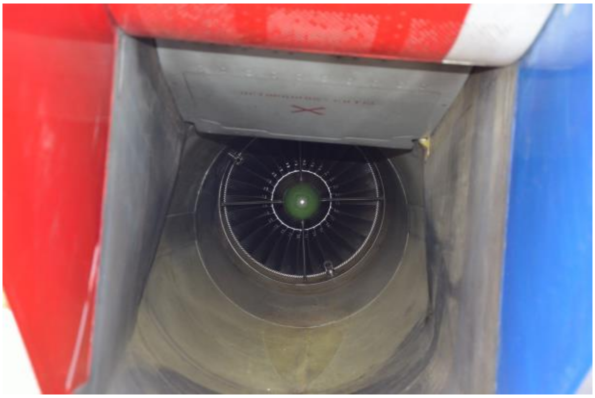

Figure 8: Air intake of the aircraft No.08 (aerobatic team “Strizhy”)

Airborne avionics

The weapon control system SUV-29 is designed to handle the aircraft and control its weapons. It consists of Radar Sighting System RLPK-29, Opto-Electronic Sighting/Navigation System OEPrNK-29 and the firing control system SUO-29. Target detection range of the side-looking airborne radar N019 "Rubin" in front hemisphere is 70 km, in the rear hemisphere - 35 km. It can track up to 10 targets simultaneously. Radar antenna is movable in two dimensions (azimuth deviation - 67°, elevation deviation angles - 60° upwards and 38° downwards). In close air combat, the radar antenna rotates only in the vertical axis.

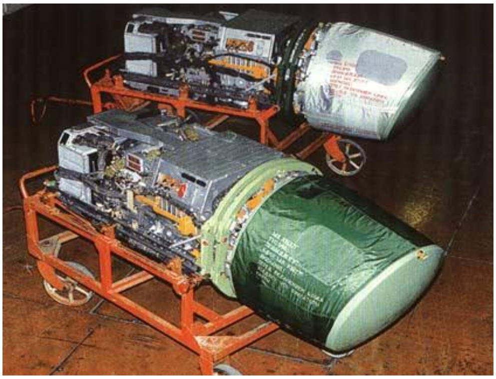

Figure 9: Airborne radar N019 "Rubin"

In addition to the weapons control system, the equipment was planned to include an interrogator of the state recognition system, onboard part of the radio link "Birjuza", automatic flight control system SAU-29, aircraft transponder SO-69, radar warning receiver "Bereza-L", radio altimeter "Reper-M", automatic direction finder "Olenek", marker radio MRP-56P, radio station "Juravl-30" and other devices.

OEPrNK-29 consists of the electro-optical sighting system OEPS-29, navigation system CH-29, digital mission computer C100 series, indication system SEI-31, photo controller and multifunctional panels. OEPS-29 system includes combined optical-laser station KOLS and helmet-mounted sighting system "Shchel-3UM". The SN-29 navigation system includes: attitude/heading reference system IK-VK-80, air data system SVS-M-72-3-2I, short-range radio navigation system RSBN A-323 "PION" and switching-block BK-55. The connecting link of this system is the computer that is part of the A-323 system.

Figure 10: Helmet-mounted sighting system "Shchel-3UM"

The firing control system SUO-29 includes: central logic unit BCL-10P-20P, two missiles control units BUR-20PR-1 and -2, gun automation unit BAP-20, four automation units (for unguided weapons), special suspension control system.

Flight and navigation equipment, in addition to the subsystems, includes the SN-29 navigation system, the automatic direction finder ARK-19, the radio altimeter A037 and other devices.

The radar warning receiving system L006LM "Berjoza" detects the radiation of the enemy radar and determines the relative direction and type of radiation source.

Countermeasures dispense system 20SP includes 2 BVP-30-26 blocks. Each block has 30 PPI-26 flares or chaffs (26 mm. caliber).

The aircraft is equipped with an SPU-9 intercom system. The pilot can receive commands from ATC by guard communication channel through ARC-19 radio compass in an emergency situation.

Tactical and technical characteristics MiG-29		
Parameter	**MiG-29 9-12**	**MiG-29 9-13**
Power plant		
Engines	RD-33	RD-33
Static thrust, full afterburner, kgf	8300	8300
Static thrust, maximum military, kgf	5040	5040
Weight data		
Empty weight, kg	10900	11200
Takeoff weight (normal), kg	15300	15300
Takeoff weight (maximum), kg	18100	18480
Flight characteristics		
Maximum ground speed (without loadouts), km/h	1500	1500
Max speed at high altitude, km/h	2450	2450
Maximum climb rate, m/s	330	330
Flight range (without external wing tanks), km	1430	1500
Ferry range, km	2100	2900
Operating ceiling, m	18000	18000
Maximum operational G-force, units	9	9
Geometric data		
Wing span, m	11,36	11,36
Wing area, sq. m	38,056	38,056
Wing sweep, degree	42	42
Full length, m	17,32	17,32
Wheel base, m	3,645	3,645
Wheel tread, m	3,09	3,09

GAME AVIONICS MODE

GAME AVIONICS MODE

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

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

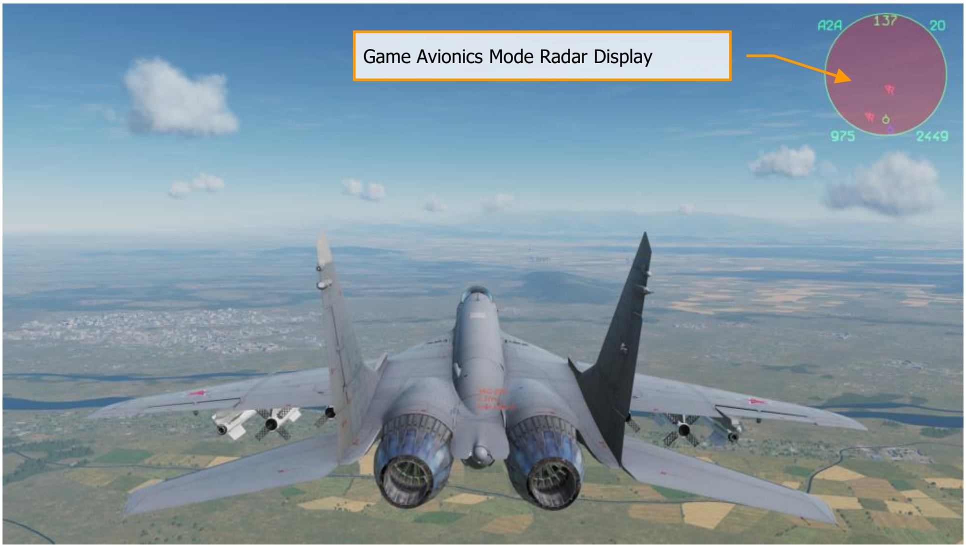

Figure 11: Game Avionics Mode Radar Display

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

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

- However, each mode will have the following data in common:
- **Mode**. Indicated outside of the top left corner of the display. This can show NAV (navigation), A2A (air to air) or A2G (air to ground).

  Mode keys:

  - Navigational mode: **[1]**
  - Air-to-Air: **[2]**, **[3]**, **[4] or [6]**
  - Air-to-Ground mode: **[7]**

- **Radar range**. Outside of 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

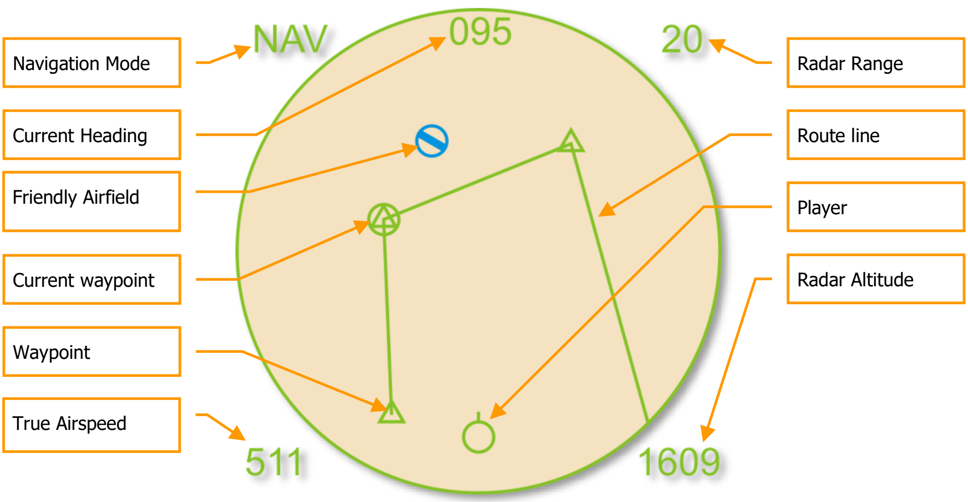

Figure 12: Navigation mode

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

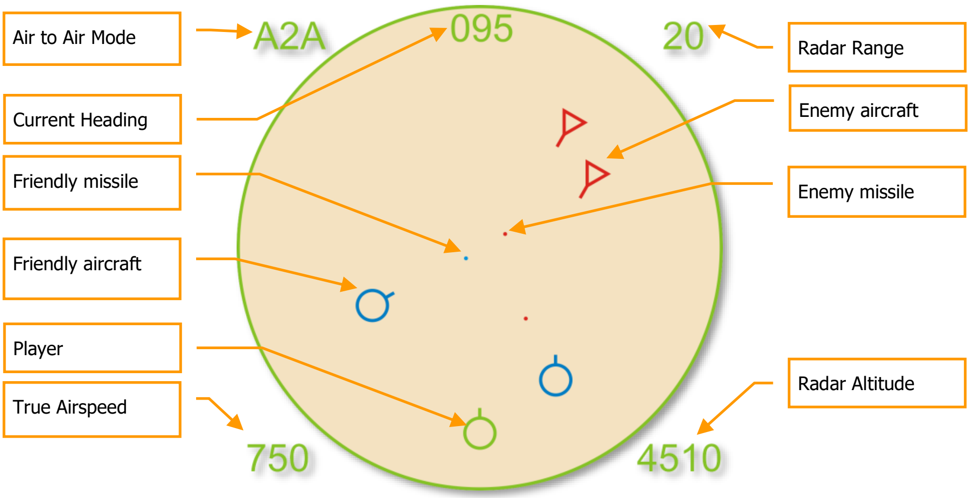

Figure 13: Air to Air Mode

Unique symbols of the Air to Air mode include:

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

Useful key commands when in Air to Air mode include:

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

Air to Ground Mode

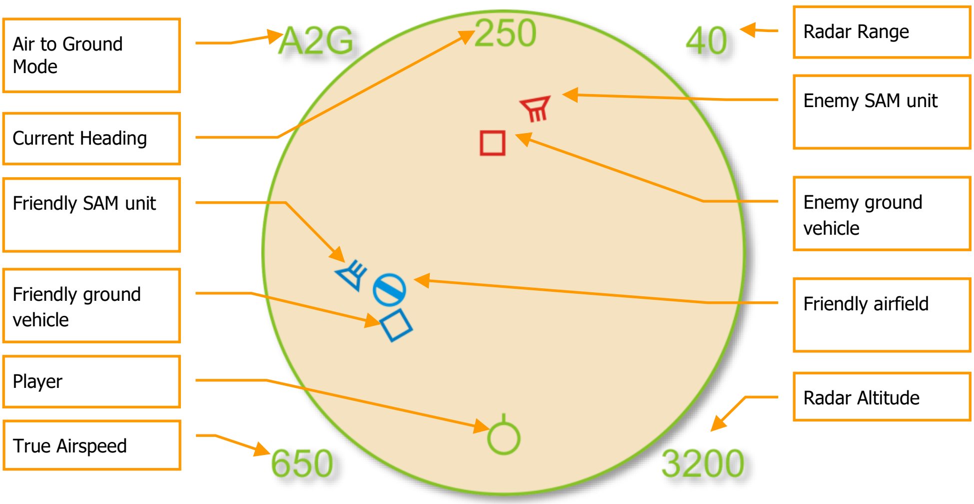

Figure 14: Air to Ground Mode

Unique symbols of the Air to Ground mode include:

- **(Player symbol)**. Your aircraft is indicated as a green circle at the bottom of the display.
- **(Friendly ground vehicle)**. All friendly ground units are indicated as blue square.
- **(Enemy ground vehicle)**. All enemy ground units are indicated as red square.
- **(Friendly SAM units)**. All friendly air defense units are indicated as blue trapezoid with three strokes.
- **(Enemy SAM units)**. All enemy air defense units are indicated as red trapezoid with three strokes.

Useful key commands when in Air to Ground mode include:

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

COCKPIT INSTRUMENTS

COCKPIT INSTRUMENTS

This chapter will instruct you about the MiG-29 cockpit instrumentation. For successful piloting, you must understand the function and position of all cockpit instruments.

Instrument equipment of the MiG-29 cockpit mainly consists of electromechanial devices. Cockpit instruments of the MiG-29A and MiG-29C are identical. Most of the instruments are also very similar or identical to those, installed in the Su-27 cockpit.

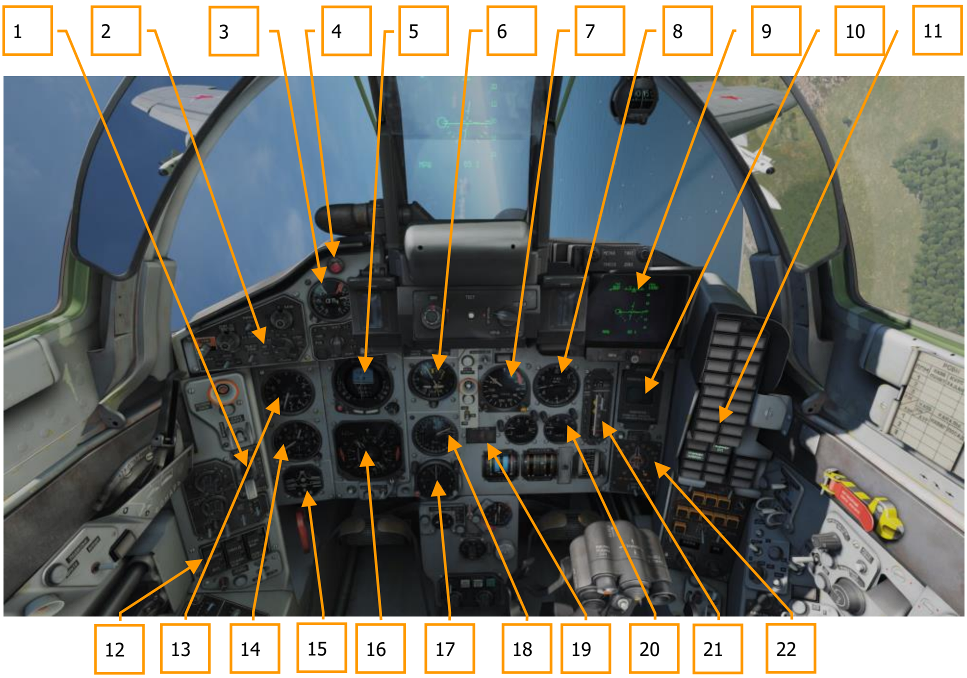

Figure 15: Central panel of the MiG-29

1. Gear Handle.
2. Weapons control system panel.
3. Combined AOA indicator and Accelerometer.
4. Master Caution lamp.
5. Attitude Direction Indicator (ADI).
6. Vertical Velocity Indicator (VVI).
7. Radio altimeter.

8. Tachometer.
9. Head Down Display (HDD).
10. "Ecran" integrated information system panel.
11. Signal lights panel.
12. AFCS Panel.
13. Airspeed indicator.
14. Barometric altimeter.
15. Mechanical devices indicator.
16. Horizontal situation indicator (HSI).
17. Clock.
18. Airspeed and Mach indicator.
19. Flares counter.
20. Interstage turbine temperature indicators.
21. Fuel quantity indicator.
22. SPO-15 "Beryoza" radar warning system.

Airspeed indicator

Airspeed indicator is used to show indicated aircraft airspeed. Scale is graduated from 1 to 9 x 100 km/hour.

Figure 16: Airspeed indicator

Pressure Altimeter

The barometric air pressure altimeter indicates the aircraft's altitude above sea level. The Inner altimeter ring scale is graduated from zero to 30000 meters in 1,000 meter increments. The outer altimeter ring scale is graduated from zero to 1,000 meters in increments of 10 meters. The aircraft's altitude is the sum of the readings of both scales.

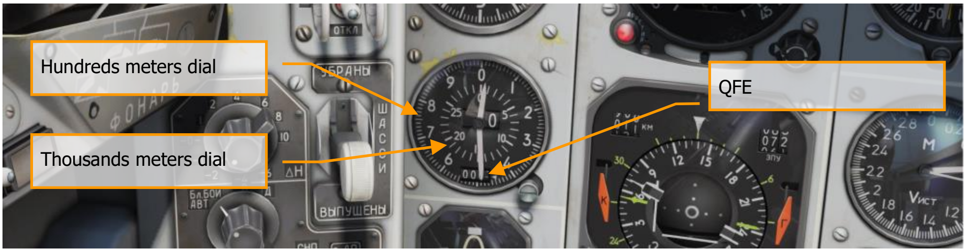

Figure 17: Pressure altimeter

Radar Altimeter

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

Figure 18: Radar altimeter

Mechanical Devices Indicator

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

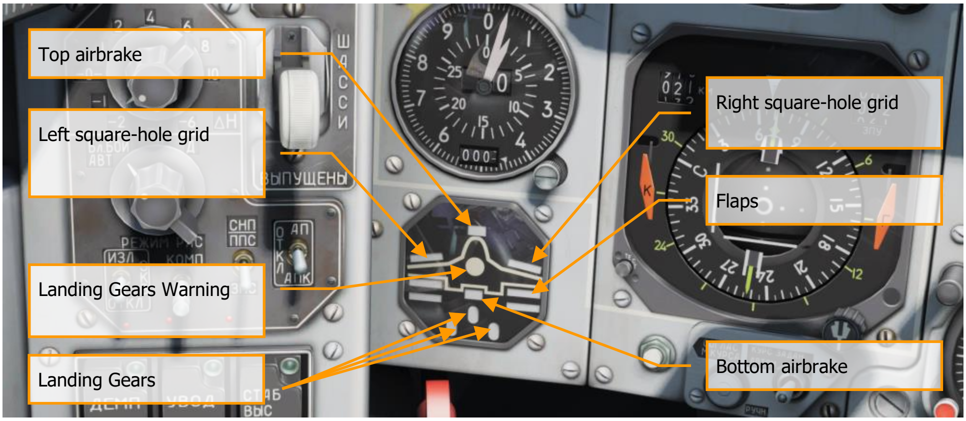

Figure 19: Mechanical Devices Indicator

AoA Indicator and Accelerometer

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

Figure 20: AoA Indicator and Accelerometer

Attitude Direction Indicator

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

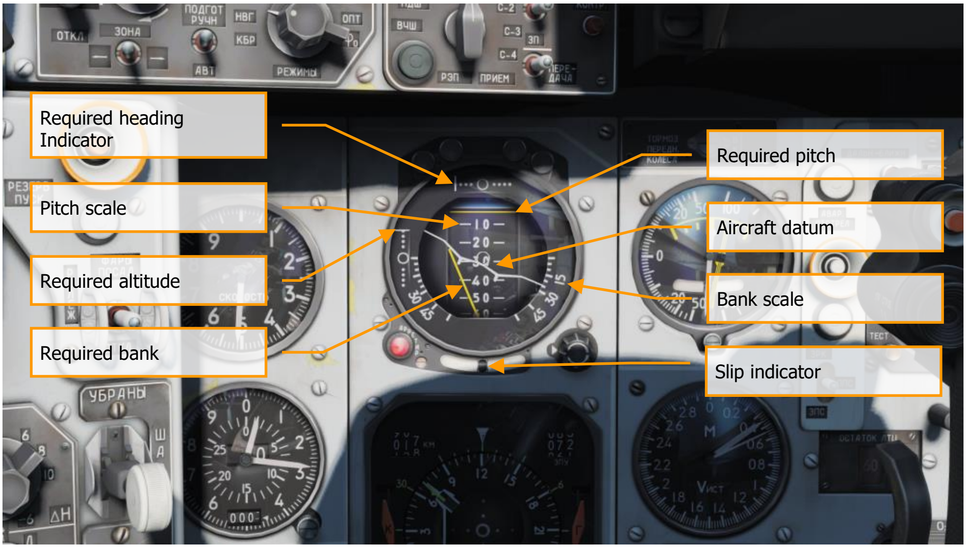

Figure 21: ADI

Horizontal Situation Indicator

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

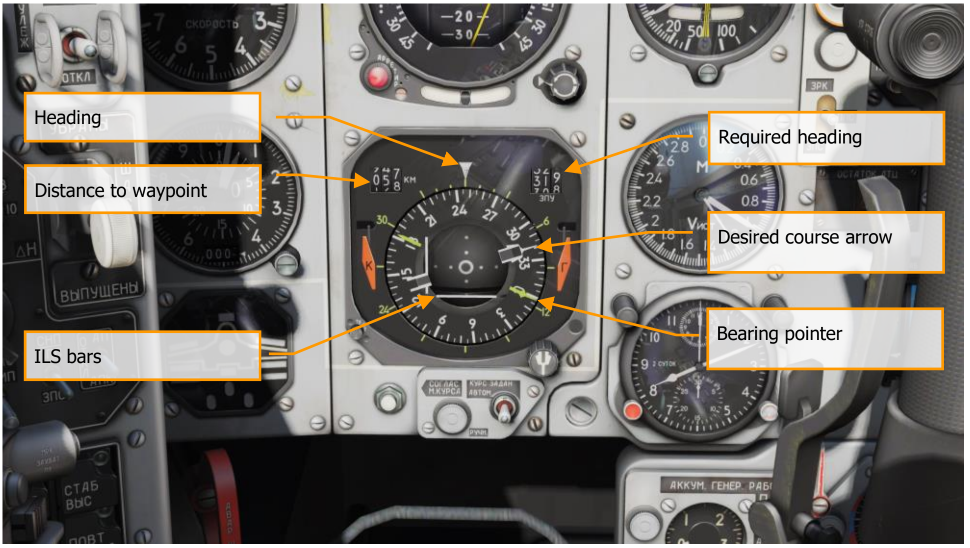

Figure 22: HSI

Vertical Velocity Indicator

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

Figure 23: Vertical Velocity Indicator

Aircraft Clock

The aircraft clock shows the current time (as set in Mission Editor) in hours and minutes, as well as for measuring and counting time intervals, using a stopwatch. By consecutively pressing key command "Timer, start / stop / reset" you can start, stop or reset the timer.

Figure 24: Aircraft clock

Tachometer

The Tachometer measures the RPM of both engines and is shown as a percent of maximum RPM. Full afterburner power (reheat) is shown as 100%. When full afterburner is on, red lights "**ФОРСАЖ**" are lit on the Signal Lights Panel.

Figure 25: Tachometer

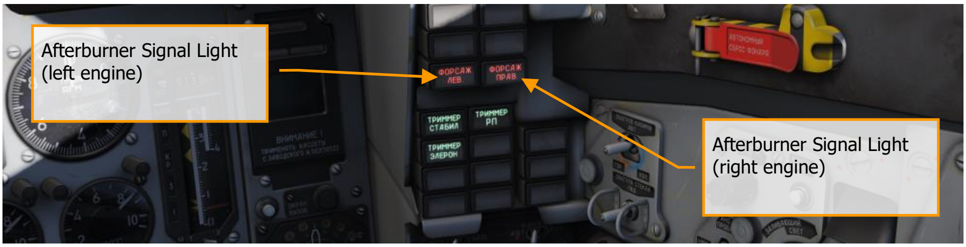

Figure 26: "Форсаж" (Afterburner) signal lights

Fuel Quantity Indicator

The fuel indicator consists of a tape-type scale which indicates fuel quantity, forecasted flight range indicator and zero-quantity indicators in various fuel tanks.

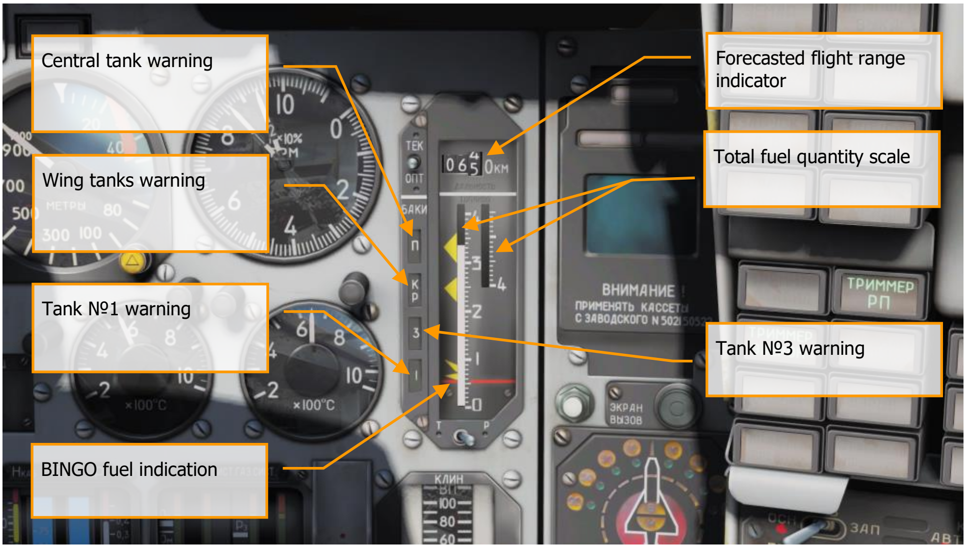

Figure 27: Fuel Quantity Indicator

Interstage Turbine Temperature Indicators

There are two identical indicators on the instrument panel. Turbine temperature indicators shows exhaust gas temperature of the left and right engine turbines from 200° до 1100°C.

Figure 28: Interstage Turbine Temperature Indicators

Head Down Display (HDD)

The Head Down Display (HDD) is positioned in the right upper corner of the instrument panel. The indicator duplicates aircraft HUD data.

Duplication of the information from the Head-Up Display is required for cases of full illumination of the HUD by sun or other bright sources.

Figure 29: HDD

Radar Warning System

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.

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 PROVIDE THE DISTANCE TO THE EMITTER

SPO-15 Radar Warning System

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

The SPO-15 model implemented in game is very close to the actual system installed in the MiG-29.

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

The maximum number of threats on screen: Unlimited.

The threat history display duration time: 8 seconds.

Function modes: All (acquisition) or Lock (the "ОБЗОР/ОТКЛ" switch).

Threats types:

П – airborne radar

З - long-range radar

X - medium-range radar

H - short-range radar

F - early warning radar

C - 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).

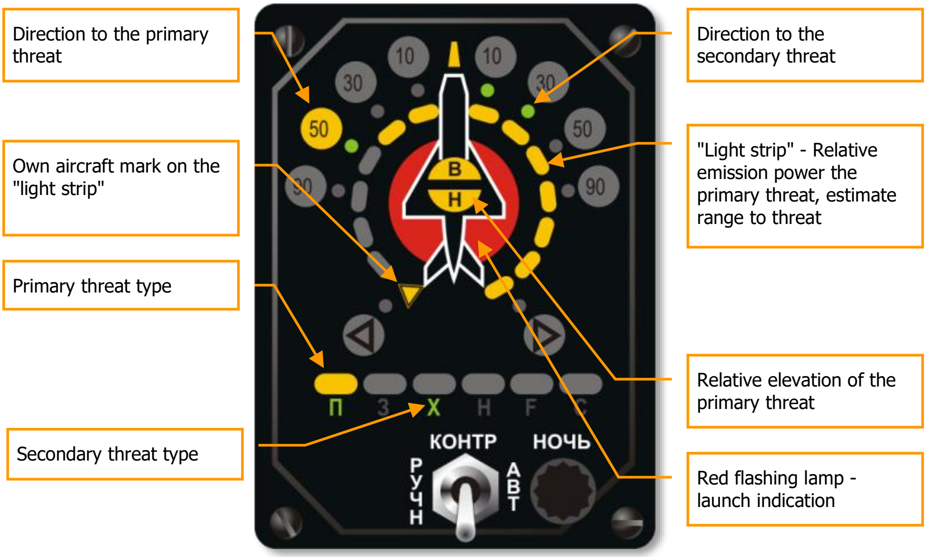

Figure 30: "Beryoza" SPO-15LM indicator

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 you're 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 its direction. In this case, it is recommended to use the RWS mode filter **[RShift-R]** that removes all emitters operating in acquisition mode.

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

Trim Mechanism

Trimming of the aircraft control stick is performed by pressing the **[RCtrl + .]** and **[RCtrl + ;]** keys in pitch and **[RCtrl + ,]** and **[RCtrl + /]** in roll.

To trim the rudder pedals, the **[RCtrl + Z]** and **[RCtrl + X]** keys are pressed.

Trim ranges are as follows:

- Pitch: 38% of backward stick travel and 50% of forward stick travel
- Roll: 50% on both sides
- Rudder pedals: 50% on both sides

The neutral position of the trim mechanism is controlled by three annunciators: "ТРИММЕР СТАБИЛ." (neutral stabilizer trim), "ТРИММЕР ЭЛЕРОН" (neutral aileron trim) and "ТРИММЕР РП" (neutral rudder trim) in the lower part of the main cockpit panel.

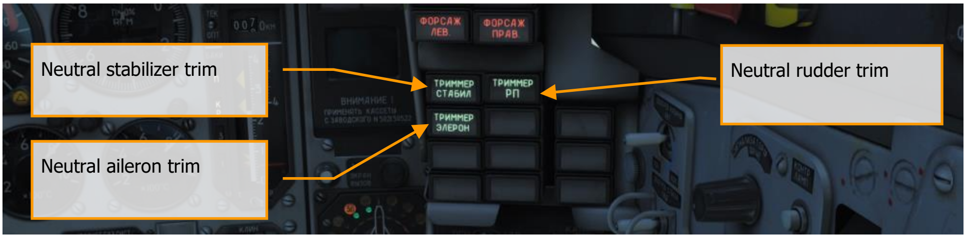

Figure 31: Trim annunciators

Setting of the trim mechanism in the neutral position is activated by pressing **[LCtrl + T]**. This is justified because there is no feeling of true loads of the controls, according to which real aircraft are trimmed.

If a joystick has force feedback, trimming shifts the joystick neutral position, which is similar to how the real MiG-29 is trimmed.

Automatic Flight Control System (AFCS)

The automatic flight control system SAU-451-02 is designed for automatic and director control at the most important stages of flight, and improved stability and controllability of the aircraft with manual control over the entire operational altitude range, airspeed and angle of attacks.

The AFCS SAU-451 is a three-channel automatic control system and offers the following functions:

- Damping of short-time aircraft oscillations in manual, automatic and director control, aircraft's stability improvement and controllability characteristics;
- Bank, pitch and course stabilization as set by the pilot;
- Plane recovery into horizontal flight from any spatial position with subsequent stabilization of altitude and course;
- Barometric altitude stabilization;
- Automatic aircraft recovery from dangerous altitude by the radio altimeter signal, while automatic modes are enabled and Weight-Off-Wheels;
- Automatic and director control of the aircraft.

SAU-451 has next operating modes:

- **Damper mode**. This mode is designed to attenuate oscillations along all axes of the aircraft. The activation of this mode occurs automatically when you select any AFCS mode.
- **Attitude hold mode**. This mode is used to maintain the given roll and pitch angles, and also, the course. The course is no stabilized, if bank angle is in range from 7^0 to 80^0. If the pitch angle is less than 40°, the roll is zeroed and the course is held. Adjustment of the aircraft's direction can be performed by trimming of ailerons and stabilizers.
- **Barometric altitude stabilization mode**. This mode is used to stabilize the barometric altitude. Vertical velocity should be close to zero (path angle should be less than 5^0) in order to enable this mode. When enabling barometric altitude hold, course stabilization and roll angle zeroing can occur, if roll angle is less than 7^0. If roll angle is from 7° to 50°, roll stabilization occurs. This mode can be disabled by pressing **[Alt -9]** or enabling Level Up To The Horizon mode.
- **Ground Collision Avoidance mode**. This mode takes the aircraft from a predetermined dangerous altitude and then transitions the aircraft into level flight. Current mode can be enabled, when roll angle is not more than 30°, flight path angle is not more than 8°, altitude between 300 meters and 500 meters, Weight-off-Wheels. When altitude is less than the set minimal warning altitude, radio altimeter caution is triggered, the system performs an automatic climbing with +8° flight path angle and zero bank angle. When altitude is more than the dangerous preset, transition to level flight is performed automatically. When roll angle is less than 7 degrees and pitch angle is less than 5 degrees, after 4-5 seconds, AFCS enables Barometric Altitude Hold mode. If the pilot intervenes in the withdrawal process, the mode is turned off, after the intervention is stopped, the transition to level flight occurs.
- **Level Up To The Horizon mode**. This mode is designed to recovery aircraft into a level flight. After enabling this mode, when roll angle is more than 80 degree, the AFCS reduces roll angle to 80 degree, and after, increases pitch angle. When aircraft reaches 7 degree angle of roll and 5 degree angle of pitch, barometric altitude and course hold is enabled. The angular velocity while transition to level flight is 40-45 degree per second with acceleration, starting from -1 until +4,5G. Flight correction can be done via trimmer.

Before turning on the AFCS, the aircraft should trim (except for the "Level up to the Horizon" mode).

During cold startup operations AFCS initiates bit-test for 3 monutes, if power supply and hydraulic pressure is present. During bit-test DAMPER DISABLED (“**ДЕМПФЕР ВЫКЛ**”) warning light is lit. In the second part of the test DAMPER (“**ДЕМП”**) push-light switch, which is located on the AFCS panel, starts flashing. After the test is completed, DAMPER DISABLED (“**ДЕМПФЕР ВЫКЛ**”) warning light goes out and DAMPER (“**ДЕМП**”) mode is activated.

INCLUSION OF ANY OF THE AFCS MODES DURING BIT-TEST IS NOT POSSIBLE.

Before turning on the AFCS, the aircraft should trim (except for the “Level up to the Horizon” - “Приведение к горизонту” mode).
The AFCS reset can be done by the “**СБРОС**” (**RESET**) push button **[Alt -9]**. When RESET button is held for more than 3 seconds, the **DAMPER** and **Ground Collision Avoidance** modes are disabled.
The AFCS modes are controlled by push-light switches on the left console.

Figure 32 – AFCS push-light switches

To control the AFCS, the following commands are used:

[A] – Switches on **DAMPER** (**“ДЕМП”)** mode. In case if any AFCS mode was active, button RESET will be pushed and currently active mode will be disabled (even “**Ground Collision Avoidance**”).

[H] – Switches on the attitude hold mode (bank, pitch and heading hold). “**Level Up To The Horizon**” mode is disabled automatically.

[LAlt - 1] – Switches on “**DAMPER**” mode.

[LAlt - 2] – Switches on “Ground Collision Avoidance mode” mode.

[LAlt - 3] – Switches on barometric altitude stabilization mode (requires “**Attitude Hold**” mode enabled).

[LAlt - 4] – Switches on attitude hold mode.

[LAlt - 5] – Switches on “**Path control**” mode (not implemented).

[LAlt - 6] – Switches on “**Reapproach**” mode (not implemented).

[LAlt - 7] – Switches on “Level Up To The Horizon” mode.

[LAlt - 9] – Pushing the **“СБРОС”** (RESET) button switching off any current mode. If button is held for more than 3 seconds, the “**DAMPER”** and “**Ground Collision Avoidance”** modes are disabled. It also resets an AFCS failure.

[LCtrl - ,] – Increases minimum altitude value on radar altimeter.

[LCtrl - .] – Decreases minimum altitude value on radar altimeter.

Figure 33: Radar altimeter and warning lamp

Sighting systems

Modern technologies make it possible to detect air and ground targets from a distance tens or even hundreds of kilometers. Radars, opto-electronic sighting systems, laser range/target designators - all this is included into modern combat aircraft equipment. The radars of the 4th generation aircrafts are Pulsed-Doppler radars, which are subject to the basic principles of operation and typical limitations inherent in this generation.

Radar sighting system RLPK-29

The radar sighting system is the main weapon control system of the MiG-29 fighter and is designed for:

- Radar detection at short and medium ranges, including small-sized, low-flying high-speed maneuvering targets.
- Tracking a selected target and providing target designations to the homing heads of guided missiles.
- Calculation of the possible firing ranges of the missiles and displaying this information on different indicators.
- Radar target illumination after missile launch (for semi-active homing head missiles).

RLPK-29 consists of:

- Antenna wave-guide block
- Transmitter
- Receiver
- Synchronization and control channels
- Computing system
- Communication unit (with a fire control system)

Radar emits electromagnetic waves into the surrounding space. The signals, reflected from the air or ground objects are returned and processed in the radar receiver. Computing system process and filter the signals. It determines elapsed time of the emission of pulses to their return, spatial attitude, phase shift and frequency of the pulses reflected from the target. Based on this data, the system calculates target range, altitude, speed, relative direction and closure velocity. However, when signals pass through the atmosphere and reflect from the target, inevitable energy losses occurs. There is a concept (parameter), called Radar Cross-Section (to assess objects visibility), which is measured in square meters.

THE BIGGER THE OBJECT’S RCS. THE HIGHER THE DETECTION RANGE.

The radar uses Doppler effect to determine the frequencies shift between the emitted and received pulses. Due to the Doppler shift, the radar can determine the target against the earth background or the radio-contrast cloud and the true target in electronic countermeasures (interference) conditions. With the target angles close to 90 degree, their detection becomes difficult, because of small value of the radial closure velocity and small Doppler shift value. Such “blind” angles are present in all radars that use the Doppler effect. That's why such flight is an effective maneuver to break the radar lock. For example, when target makes a simple turn and enters "blind" zone, inertial tracking can be applied (on up to 6 seconds) by the radar, which allows target tracking on "blind" angles. The essence of this method is simple: on-board computer tracks target's trajectory and, based on the maneuvering parameters, prolongs trajectory in blind zones, directing radar mirror to the target exit point from the blind zone. But this method is working well only if a target makes a predictable maneuver without an aggressive changes of the flight parameters. If the target, while entering blind zone, will make an aggressive turn, the radar will lose contact with a high probability. Note that fact, when in BVR combat.

FLIGHT, PERPENDICULAR TO THE DIRECTION OF THE RADIATION FROM THE TARGET WITH DOPPLER RADAR, WHICH MAKES AN AGGRESSIVE TRAJECTORY CHANGE, IS AN EFFECTIVE MANEUVER, THAT MAKES AIRCRAFT TRACKING EXTREMELY COMPLEX

Radars scan the space in a certain zone. The field of view is formed by Beam-Sweep with a certain azimuth and elevation angle. The larger the field of view, the longer it takes to view this part of the space.

High speed and maneuverable targets can pass unnoticed through the radar viewing area, if a view time is too long. However, like any other device emitting energy in the surrounding space, the operating radar can be detected by electronic reconnaissance systems. Many modern combat aircrafts are equipped with radar warning systems. RWS determines a direction and type of the radar threats.

After detection of the radar, as a rule, the type (or class) of its carrier can be determined. Modern radars operate in different modes with different pulse repetition rates (PRI) and viewing zones. PRI – is number of pulses emitted per second. Changes in pulse repetition frequency are used to increase the sensitivity of the radar, when searching for targets flying at different angles. A high PRF is used to detect targets flying towards, medium PRF – for searching targets at dogging courses. In normal mode, the radar constantly switches between high and medium PRF to ensure all-track target detection. Usually, the radar operates in a wide view angle mode. In target tracking mode – a narrow beam angle is used. After target lock is acquired, radar goes into tracking mode.

Many modern radars have TWS (Track While Scan) mode implemented. In this mode, the radar can simultaneously track several targets, maintaining the search mode. The positive side of this mode is that the radar shows detailed information about a wide area of space. On the other hand, while moving scanning beam in space, information about targets outside scanning zone is missing. Target's parameters of the movement are extrapolated using previous values. The scanning period is relatively long, that's why fast and maneuvering target can make an aggressive maneuver and go beyond the scan area. The predicted trajectory of the target's movement will be displayed all the time on the radar indicator. Next coordinates refinement occurs only after some time.

TRACK WHILE SCAN MODE PROVIDES DETAILED INFORMATION ABOUT TARGETS; HOWEVER, THIS MODE IS USED FOR THE FORECAST OF THE TARGET POSITION. WHILE THE RADAR SCANS ANOTHER TARGET, FIRST TARGET MAY EXIT SCAN AREA BY MAKING AN AGGRESSIVE MANEUVER.

Opto-electronic sighting-navigational system OEPrNK-29

Opto-electronic sighting-navigational system OEPrNK-29 includes opto-electronic sighting system OEPS-29, which, in turn, consists of a quantum optic-locational station KOLS (IR sensor, collimated with it laser tracker designator/ranging) and autonomous helmet-mounted sighting system "Shchel-3UM", which provides information about the sighting angles to the targeting systems, IR-missiles and provides information about the system states and missiles readiness to launch to the pilot. Information of the helmet-mounted sighting system is displayed on a special helmet reflector.

Aircraft engines emit head, than can be detected. This fact was used by the developers of infrared (IR) aiming systems. Early IR systems were detecting jet aircraft only from the rear hemisphere, where the engine nozzles are located. Modern high-sensitivity systems detects IR contrast targets from any angle. Now, many aircrafts are equipped with opto-electronic sighting systems. Unlike radar systems, OESS systems are passive, i.e. not radiating energy. The enemy doesn't know that OESS is tracking his aircraft. This significantly increases the attack stealthiness.

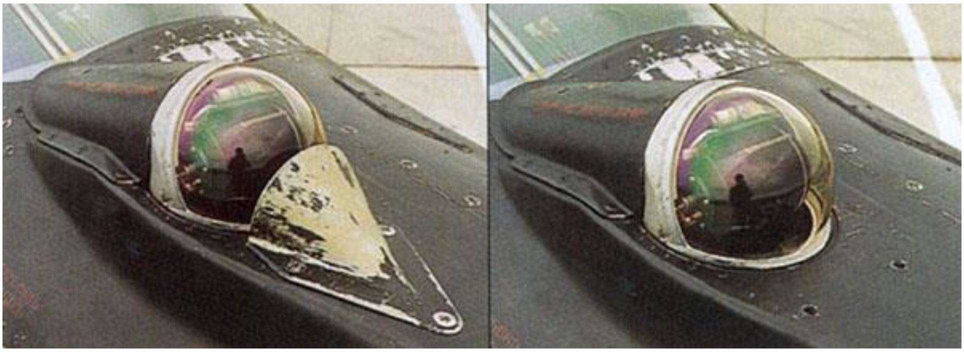

Figure 34: Quantum Infrared Search and Track system OEPS-29-23S

The opto-electronic sighting systems were especially widely used in attack aircrafts and bombers. Various sighting systems, including television, low-level television and infrared sensors, allows to make strikes on ground targets at any time of day. But, like all optical devices, they lose efficiency in difficult weather conditions, fog, smoke and dustiness of the battlefield.

MiG-29 HUD Operational Modes

Basic HUD symbols

Regardless of the avionics mode, some HUD symbology is unchanged between modes. We will take a look at the HUD in ROUTE ("**МАРШРУТ**") mode.

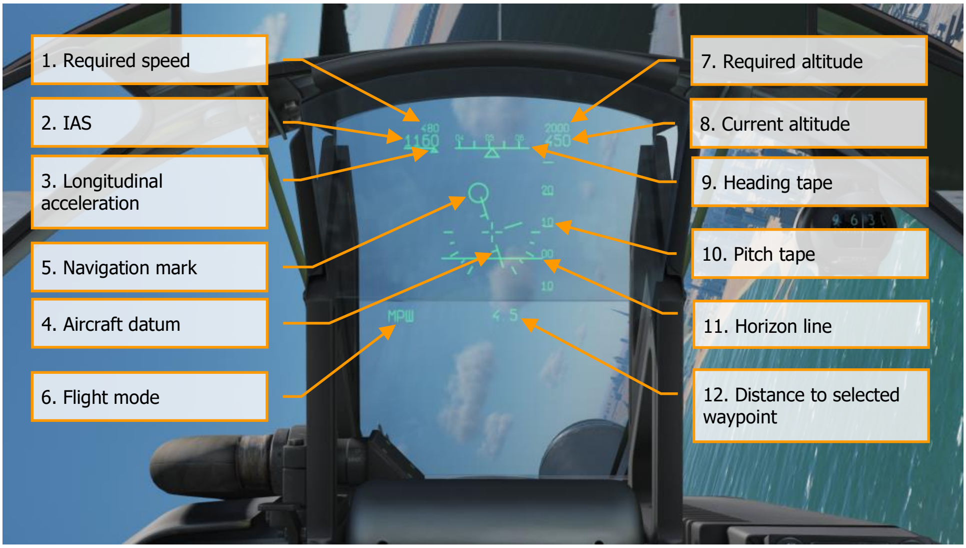

Figure 35: HUD basic symbols

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

8. To the right of the heading scale, the current altitude is indicated. For altitude less than 1,000 meters above ground level, the radio altitude is indicated to within 1 m. At an altitude over 1,000 meters barometric, the height is shown to within 10 meters. Above the scale the required altitude is shown. This will depend on the flight mode and in the case of route flight mode, it shows the preplanned route altitude.
9. The current heading is positioned in the upper portion of the HUD. It shows the aircraft's current heading. (example: 11 corresponds to the value of 110 degrees).
10. The pitch ladder, situated in the right of the HUD, displays current pitch angle .
11. The artificial horizon line indicates a virtual horizon that corresponds to 0 degrees of pitch and is intended to assist the pilot when flying in poor visibility conditions.
12. In the lower center part of the HUD, the distance to the selected waypoint is indicated in Km.

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

To switch between waypoints, you can use the **[LCtrl+~]** key.

In LANDING mode, airfield selection can be chosen by cycling the **[LCtrl+~]** key.

Navigation Modes

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

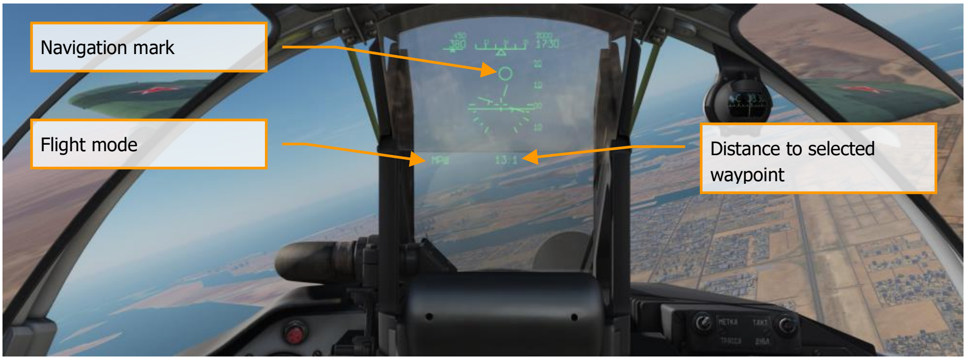

Figure 36: HUD "МРШ" (ROUTE) mode

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

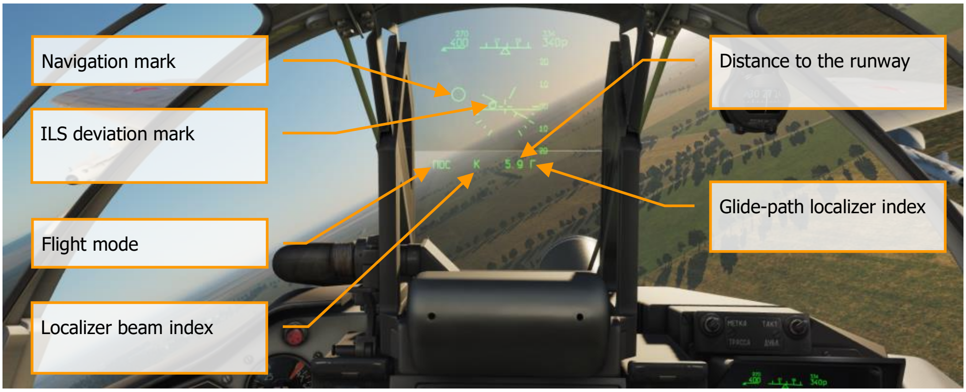

Figure 37: ILS Landing

In the LANDING sub-mode, the HUD director circle points to the landing airfield. Different airfields can be cycled with the **[LCtrl-~]** key. When approaching an airfield, Tower will begin to control your landing. In this mode, glide-slope deviation indicators of the ILS system appears on ADI.

Beyond Visual Range Combat Modes

There are several beyond visual combat (BVR) combat modes: **ОБЗ** (SCAN) – scan, **СНП** (TWS) – track-while-scan, **СНП2** (TWS2)– track-while scan with the ability to attack two targets simultaneously/sequentially (MiG-29S) and **РНП** (STT)– single target track.

"ОБЗ" (SCAN) MODE

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

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

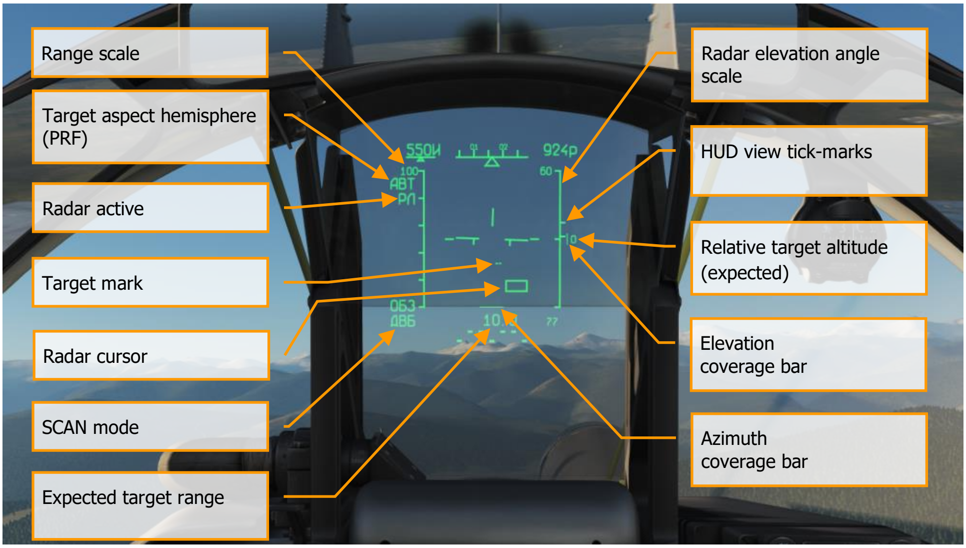

Figure 38: "ОБЗ" (SCAN) mode - BVR

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

- Range scale is changed by the **[+]** and **[-]** keys.

- The expected target aspect hemisphere is controlled with the **[RShift-I]** key. ABT (ILV) mode can be used if the target aspect is unknown. The expected target aspect determines the pulse repetition frequency (PRF) to be used by the fighter radar in search mode. High PRF (HPRF), which provides the longest detection range against approaching forward-hemisphere targets, is indicated by ППС (HI), whereas medium PRF (MPRF) for receding rear-hemisphere targets is indicated by ЗПС (MED). In ABT (ILV) mode, high and medium PRFs are interleaved on alternate bars of the radar scan pattern. This provides all-aspect target detection at the expense of a 25% reduction in maximum range.

- An air target is indicated on the HUD as a horizontal row of dots.

  The number of dots corresponds to the approximate size of the target as measured by its radar cross-section (RCS). One dot indicates a target RCS of 2 sq. m or less, two dots – from 2 up to 30 sq. m, 3 dots – from 30 up to 60 sq. m, and four dots - 60 sq. m or more. Tactical fighters typically have RCS values between 3 and 30 sq. m, dependent upon the type, external payload, and aspect angle. Most fighters are thus usually displayed on the HUD as a row of 2 dots. Friendly aircraft have an identification marking in the form of a second row of dots positioned above the main one.

- The "РЛ" symbol on the left side of the HUD indicates that the radar is turned on and actively transmitting .

- The radar cursor for target designation is moved by using the **[;], [,], [.], [/]** keys .

- The expected (manual) range to target (often derived from AWACS and GCI data), as set by **[RCtrl-+]** and **[RCtrl--]** keys and is indicated at the bottom of the HUD under the azimuth coverage bar. The elevation coverage of the radar scan pattern is calculated from this parameter.

- The expected relative altitude of the target with respect to your aircraft, as set by the **[RShift-;]** and **[RShift-.]** keys is indicated on the right side of the HUD, next the elevation coverage bar. This parameter is also used to calculate the scan pattern elevation coverage.

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

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

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

"СНП" (TWS) MODE

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

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

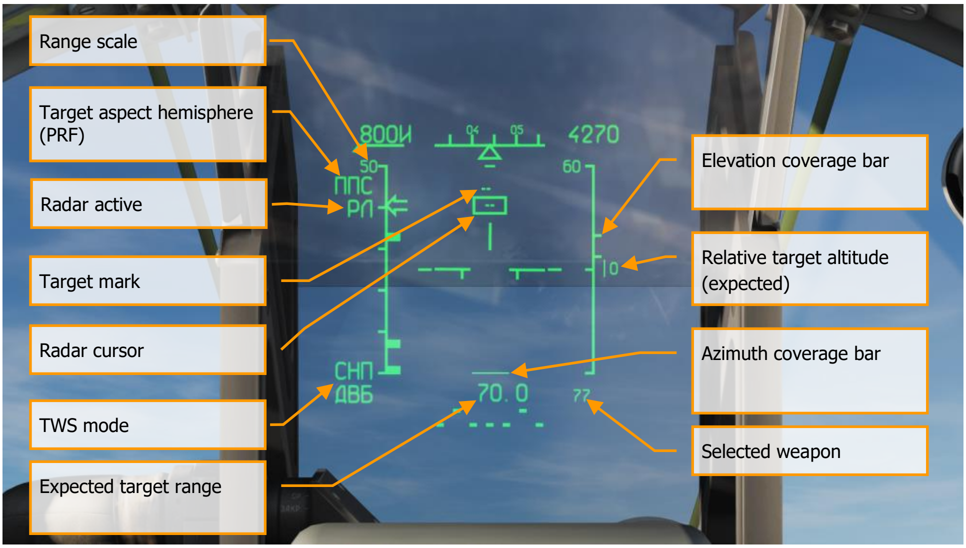

Figure 39: "СНП" (TWS) MODE

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

- "СНП ДВБ" (TWS BVR) in the lower left corner of the HUD indicates the current mode.
- The chosen weapon is indicated in the lower right corner of the HUD, beneath the elevation angle scale. The **77** above indicates R-77 missiles.
- The range scale at the left side of the HUD features three thick inwards facing tick marks. Going from the top downwards, these are: Rmax - maximum permitted launch range vs. non-maneuvering target, Rtr - maximum permitted launch range vs. maneuvering target ("no-escape zone"), and Rmin - minimum permitted launch range.

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

"Атака – РНП" (ATTACK – STT) MODE

After locking up the target in either mode, SCAN or TWS/TWS2, the radar automatically switches to Single Target Track (STT) mode. It stops tracking all other targets and additional information is indicated at the HUD in the following form:

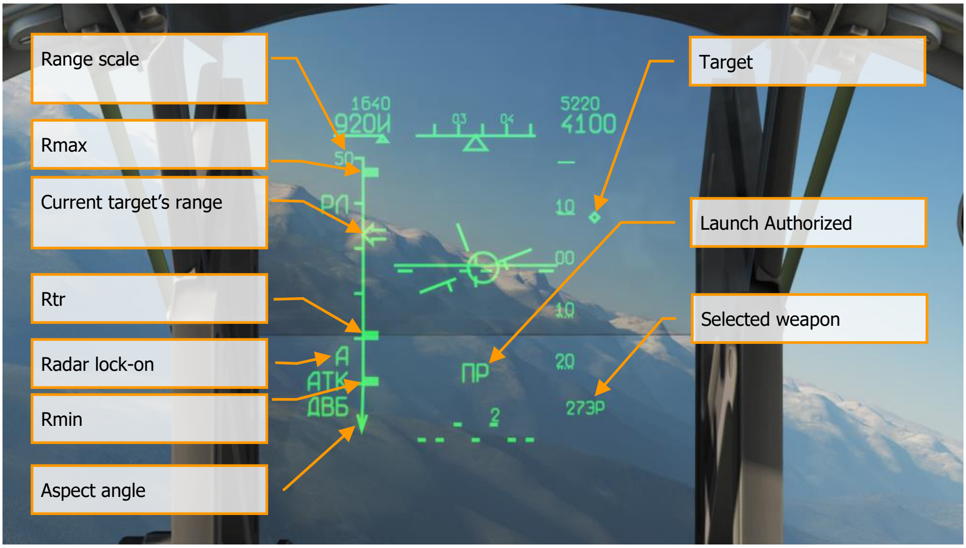

Figure 40: "АТК ДВБ" (STT BVR) MODE

- Rmax – maximum permitted launch range vs. non-maneuvering target.
- Rtr - maximum permitted launch range vs. maneuvering target .
- Rmin – minimum permitted launch range .
- The attack symbol indicates an active radar lock. After missile launch, the attack symbol flashes at a frequency of 2 Hz .
- Aspect angle shows target velocity vector in the plane turned in the HUD vertical plane.
- "АТК ДВБ" (STT BVR) mode is displayed in the HUD left lower corner .
- The arrow indicating current range to target moves along the range scale .
- The target diamond is superposed over the target in the HUD .

- The “ПР” (LA) Launch Authorized symbol appears when the target enters the permitted range limits and any other launch conditions are satisfied .

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

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

In the STT mode, the radar can lock one target and track it in 120 degree of azimuth.

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

When semi active radar homing (SARH) missiles like the R-27R and R-27ER are used, it’s necessary to illuminate the target until the missile hits.

"СНП2" (TWS2) on MiG-29S

Third BVR mode is the "СНП" (Track-While-Scan 2 or TWS2) mode, which is available only on MiG-29 using R-77 missiles. It is activated from the "ОБЗ" (SCAN) mode by double pressing **[RAlt-I]**. The radar can correlate tracks for up to 10 targets simultaneously in "СНП2" (TWS2) mode. The main distinction from TWS mode is that TWS2 has a possibility to attack 2 targets at the same time and make a simultaneous or sequential launch of the R-77 missiles.

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

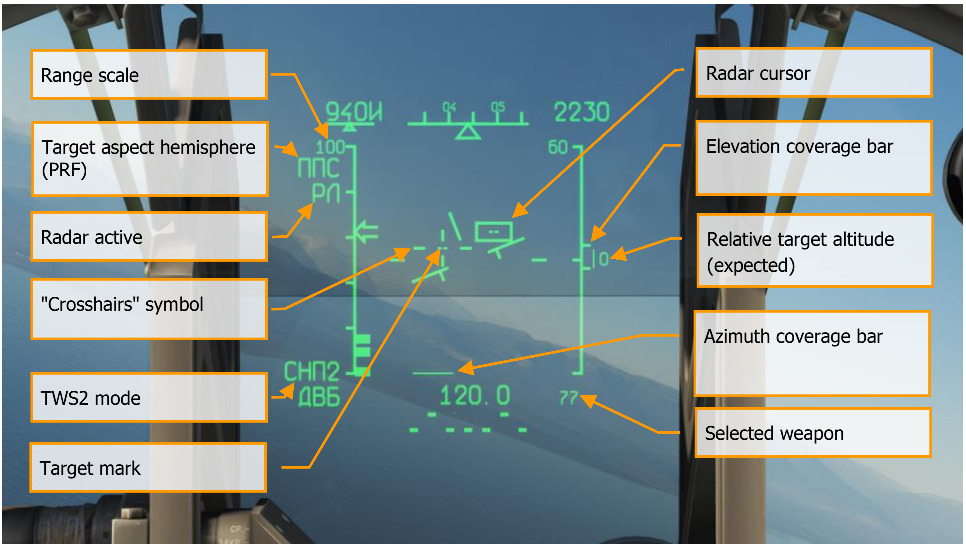

Figure 41: "СНП2" (TWS2) MODE - BVR

The "**Ц1**" (and "**Ц2**") symbols appears in the bottom center of the HUD after the target was locked. Primary (first) target is displayed as "diamond" symbol on the HUD. Secondary target is displayed as a "crosshairs" symbol on the HUD.

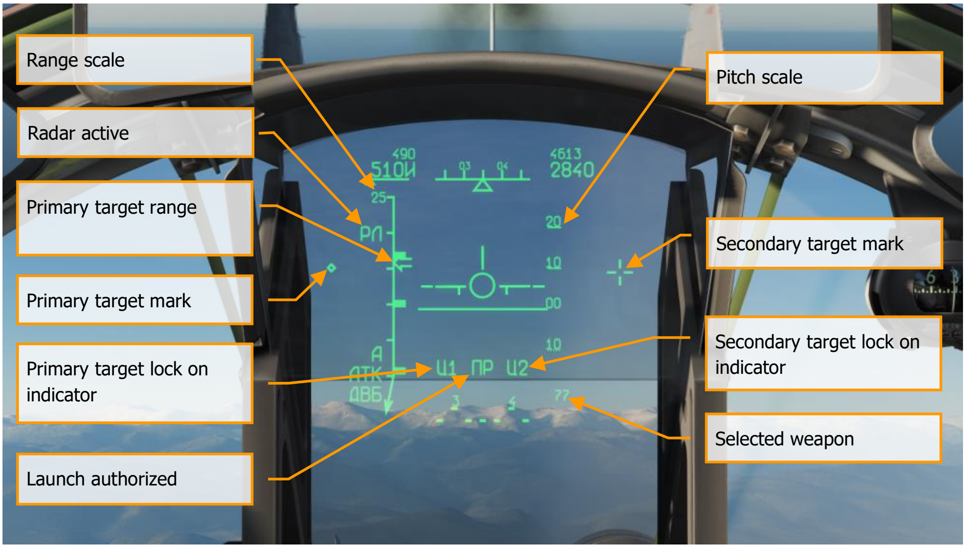

Figure 42: "СНП2" (TWS2) MODE - STT

When all launch parameters are met, the "ПР" Launch Authorized symbol appears on the HUD. Press and hold the trigger until the two missiles are launched.

SCAN – IRST MODE

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

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

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

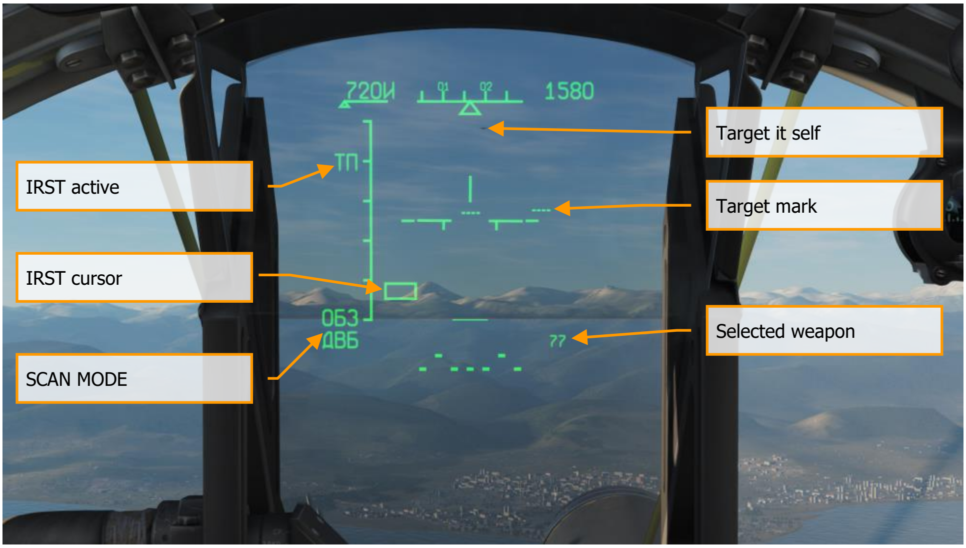

Figure 43: "ОБЗ ДВБ" (SCAN BVR) Mode with IRST as chosen sensor

- The "**ТП**" symbol at the left side of the HUD indicates IRST operation.
- The name of the chosen mode is displayed in the left lower corner.
- Target mark is displayed in the azimuth-elevation angle format .

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

Work in Complicated Countermeasures Conditions

In complicated countermeasures conditions, when the enemy uses passive and/or active radar jamming, the **TWS**/**TWS2** mode cannot be used. SCAN mode should be used instead. In the conditions of strong radio-electronic countermeasures the radar cannot determine the range to the target – instead, a vertical jamming strobe of randomly flashing target marks appears in the HUD along the jammer's bearing. Detection of ECM in the radar scan pattern also causes the "**АП**" (ECM detected) symbol to appear at the right side of the HUD. Nevertheless, it is possible to obtain a bearing-only "angle-of-jam" (AOJ) lock on the countermeasures strobe and to launch semi-active radar homing (SARH) missiles, which in this case will guide in the passive "home-on-jam" (HOJ) mode.

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

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

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

The moment when the fighter radar can recognize the reflection of its own signal above the jamming noise and receive the information on the target movement is called "burn-through". When the radar starts to provide full data on the target despite the presence of ECM, the radar has "burned-through" the interference.

Figure 44: SCAN Mode with jammer strobe

- Blinking vertical countermeasures strobe is located at the jammer azimuth. Upon locking it, the information on the HUD is similar to the STT mode with fixed mark of the current range to the target.

- The “АП” active jamming indicator is displayed when electronic countermeasures are detected in the fighter radar scan zone.

Vertical Scanning - Close Combat Mode

This Vertical Scanning sub-mode **[3]** is the most frequently used mode in close maneuvering air combat. In this sub-mode, the radar or IRST scan pattern is a vertical bar that is -10+50 degrees wide in elevation. The HUD displays two vertical lines denoting the boundaries of the scan zone. Lock-on is possible when a target is inside the scan zone, which starts at the lower edge of the HUD and extends above it by about two more HUD lengths. To lock-on a maneuvering fighter, fly to place the target in the scan zone and press the lock-on **[Enter]** key. If the **[Enter]** key is not pressed, the lock-on will not take place.

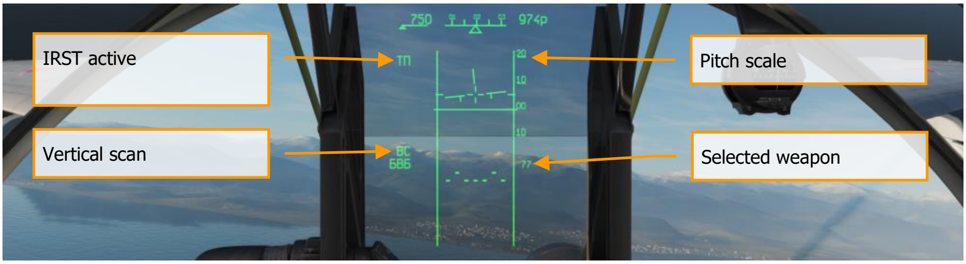

Figure 45: VS MODE

Lock-on occurs within 1 – 3 seconds of the target entering the scan zone with **[Enter]** pressed. After the target is locked, the display on the HUD changes to the Attack (**STT**) mode.

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

BORE - Close Combat Mode

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

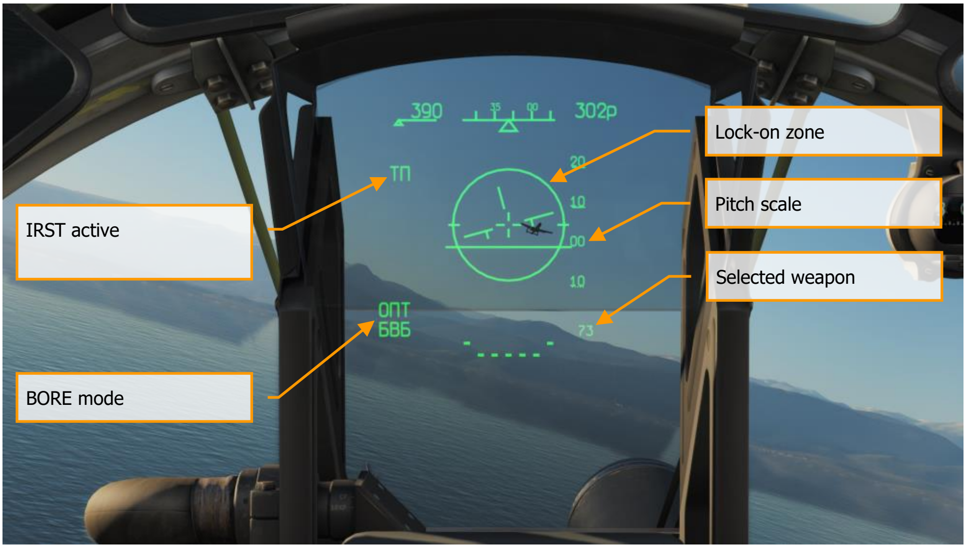

Figure 46: BORE Mode

BORE mode selects the IRST sensor by default. The default weapon is the IR missile. In order to launch missiles with radar instead, the radar is first activated with the **[I]** key, then the desired missile is selected with the **[D]** key.

HELMET - Close Combat Mode

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

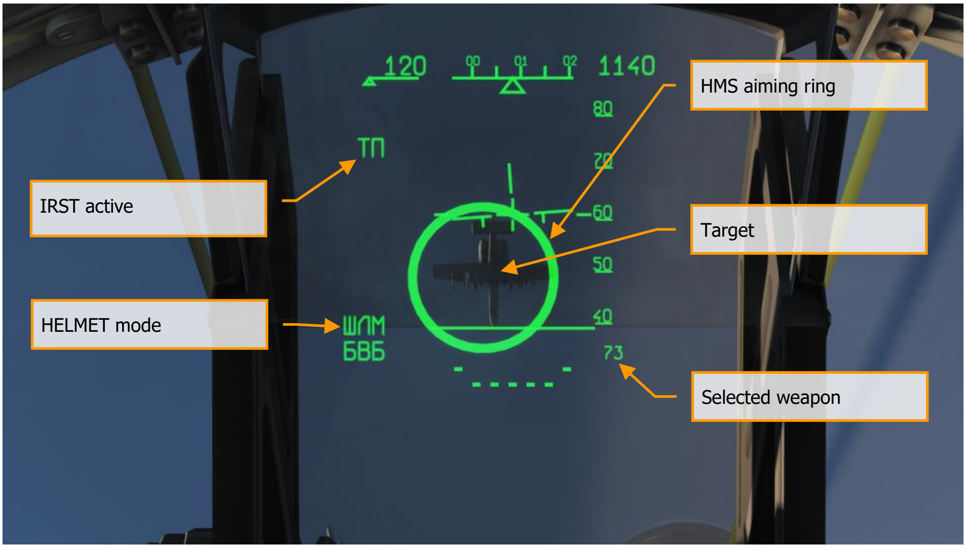

Figure 47: HELMET mode

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

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

Fi0 – Longitudinal Aiming Close Combat Mode

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

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

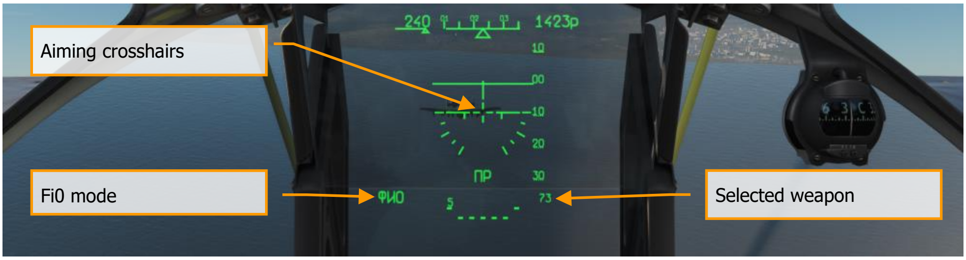

Figure 48: Fi0 (Longitudinal) MODE

Gun Employment

The aircraft cannon can be used in air-to-air combat mode. To do so, first select the cannon by pressing the **[C]** key. Press the **[Enter]** key to lock the target with the active sensor when target is visible in the HUD. If a sensor lock is present, the WCS will automatically enter the Lead Computed Optical Sight (LCOS) mode.

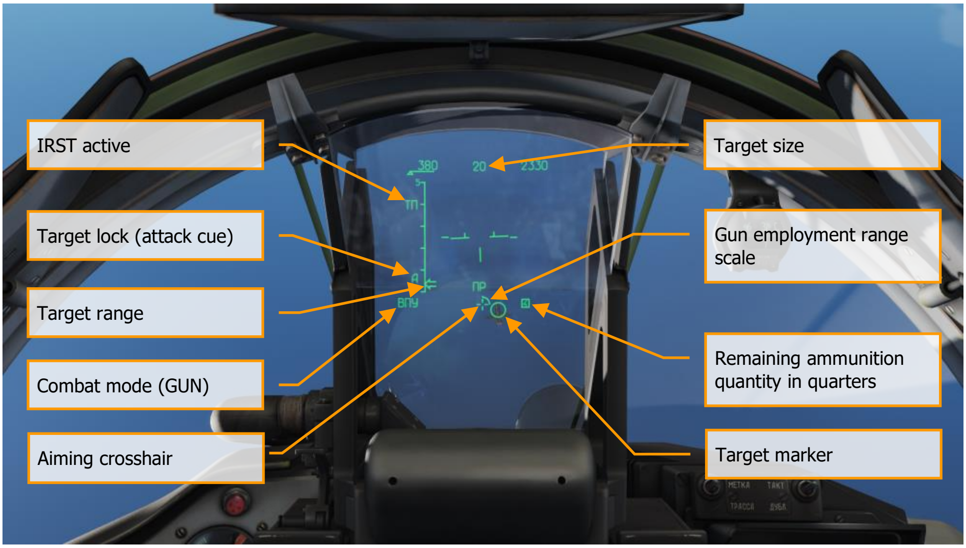

Figure 49: Lead Computed Optical Sight (LCOS) mode

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

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

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

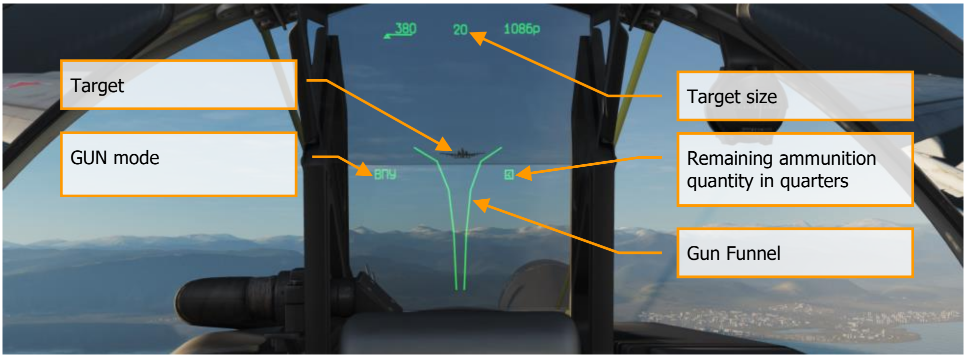

Figure 50: Gun Funnel mode

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

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

Air-to-Ground Mode

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

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

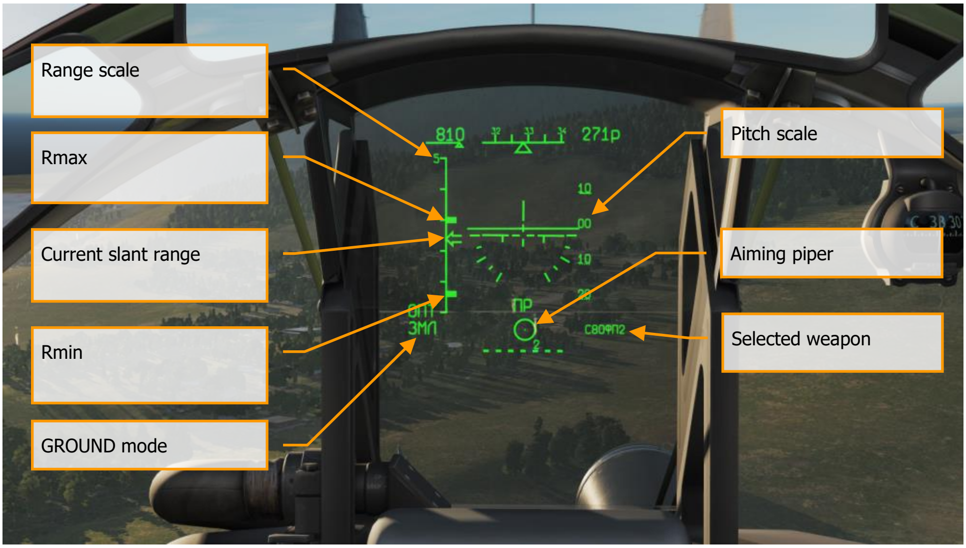

Figure 51: VISUAL GROUND mode

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

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

Reticle

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

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

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

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

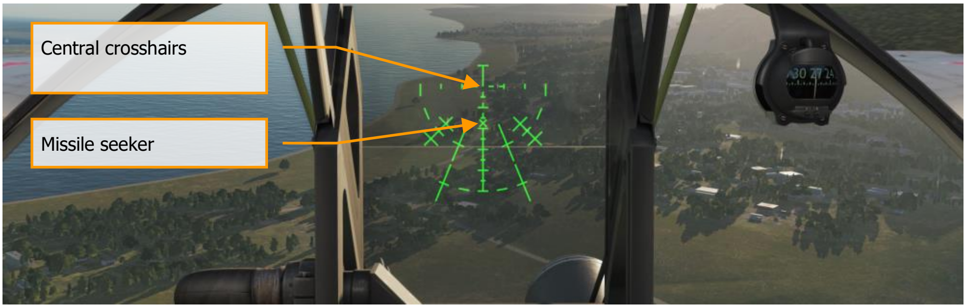

Figure 52: Reticle

Electronic countermeasures stations

Electronic warfare (EW) is a deep and complex topic that covers a long history of opposing and rapidly evolving sensors, tactics, weapons and other equipment from numerous countries. In this section, we consider only a MiG-29S active radar jamming electronic countermeasures (ECM) - or as it has been more recently called, "electronic attack" (EA) system that is designed to protect the aircraft.

Electronic Countermeasures (ECM) Station "Gardeniya"

The Fulcrum-S active ECM station "Gardeniya" (codename "Product L203") is designed for individual protection against air-to-air or ground-to-air radio-guided weapons. It provides active electronic jamming against ground, ship or aircraft radar systems guidance and missiles control systems, as well as the homing missiles in order to reduce a probability of aircraft engagement.

The in-game modelled station operates only in the noise-speck mode with distance stealing. This means, that the station creates interferences that does not allow the enemy to determine the range of your aircraft and, accordingly does not allow the effective deployment of missiles against you. The jamming is effective only at a relatively long range. While in close range (dogfight), the ECM station is not effective and is not used.

ECM station works in the following sectors:

- ± 60° in azimuth
- ± 30° in elevation
- In front and rear hemisphere.

MiG-29 WEAPONS

MIG-29 WEAPONS

The armament of the MiG-29 includes missiles, unguided bombs and rockets, canon. Cannon armament consists of one single-barreled 30 mm gun GSh-30-1 Gryazev-Shipunov, which is installed in the hull compartment on the left side of the aircraft's nose section. The ammunition of the canon – 150 rounds, fire rate – 1500 rounds per minute. Missile armament consists of guided missiles, mounted on aircraft catapults and launchers, which can be loaded onto 6 different external stations. Standard loadout consists 2 R-27R and 4 R-73 missiles. MiG-29 can be armed with a wide range of conventional bombs and unguided rockets in order to engage different ground targets. However, note that these tasks are secondary for the MiG-29.

Air-To-Air Missiles

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

AAMs are a collection of integrated components that consist of the seeker, the warhead, and the motor. Motor burn can only last for a limited amount of time. This usually ranges from 2 to 15 seconds, depending on the missile type.

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

The missile launch range, or missile employment zone (MEZ), is greatly influenced by the aircraft's altitude at the moment of missile launch. This is due to the much denser air at lower altitude. If the flight altitude is increased by 20,000 feet, the maximum launch range is about doubled.

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

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

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

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

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

- Short range missiles. Less than 15 km. (R-73, R-60, AIM-9 and others)

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

These missiles use a variety of guidance systems:

- Passive infrared. Infrared target seeker (R-60, R-73, R-27T, AIM-9, R550)
- Passive radar. Radar emitter targeting, is usually combined with semi-active or active targeting. It is a targeting mode, modern missiles such as AIM-7M, AIM-120, and R-27R can use. This is sometimes referred to as Home-On-Jam (HOJ) mode.
- Semi-Active Radar Homing (SARH). Such seekers home in on the reflected radar energy from the launch aircraft's continuous wave radar. (R-27R/ER, AIM-7, R-33)
- Active Radar Homing (ARH). Active systems have their own radar seekers built into the missile. (R-77, AIM-120, AIM-54)

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

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

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

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

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

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

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

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

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

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

MiG-29 Missiles

R-77 (AA-12) Medium Range Missiles

R-77 is designed to engage air targets - aircrafts, helicopters, ground-to-air and air-to-air missiles at any daytime in simple and difficult weather conditions. This missile can be launched from a MiG-29S 9-13 and J-11 in DCS World.

Figure 53: Air-to-Air Missile R-77

Aerodynamic scheme is typical for air-to-air missiles. Cylindrical body and wings are the main elements that creates a lift. The wings of small elongation have a simple shape and thin profile. The nose of the rocket has a parabolic shape, which increases overall lift of the rocket. Grating fins with a very small hinge moment makes possible to use a small-sized electric drive of low power. This structure of the missile rudders makes a continuous airflow and saves efficiency up to 40° AoA.

The R-77 missile is equipped with a solid-propellant engine, which provides an energetic initial departure from the carrier for the maximum flight range with 4M maximum speed.

Guidance of the rocket is combined: command-inertial on the initial and active on the final section of flight. The transition to active guidance is made by an on-board computer that calculates the range of the target, locked on by the homing head. After switching to active (homing) mode, the correction line of the missile continues to form a mathematical model of the target. In case the lock is lost, the missile tries to restarts search, using this model. Lock on range of the target with RCS 5m² is near 16 km.

The homing head includes a monopulse direction finder and a computer. In order to increase jamming resistance and ensure high guidance accuracy, the missile computer makes space-time signal processing, Kalman filtering, continuous solution of kinematic equations with the ability to maintain the guidance process during temporary auto-tracking breaks.

The missile is equipped with a laser fuse. While illuminating the target and calculating the distance from reflected signal to it, the device detonates the warhead at the optimal distance. The parameters of the fuse are adapted to the size of the target. It has also a contact fuse (for cases of falling to the ground or into water and a direct missile hit).

Warhead – a rod with microcumulative elements. Weight of the warhead — 22 kg. The rods are connected with each other. They form a continuously expanding ring that "cuts" target when the missile warhead detonates.

R-77 is uses from the AKU-170 launcher.

R-27 (AA-10) Medium Range Missiles

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

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

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

The same rail and ejector launchers are used for both size variants of the R-27, the standard and extended range.

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

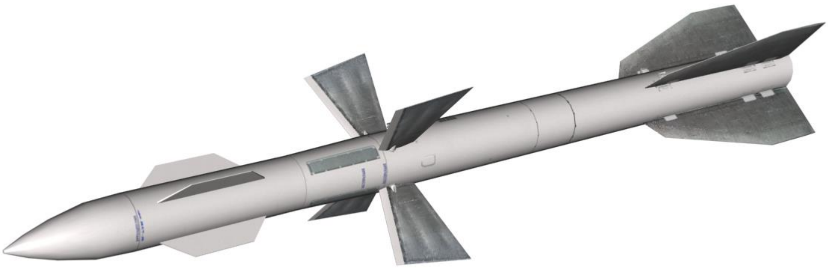

Figure 54: Air-to-Air Missile P-27P

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

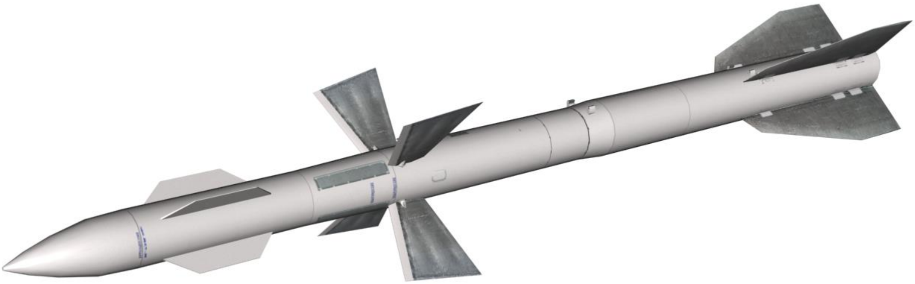

Figure 55: Air-to-Air Missile P-27ЭР

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

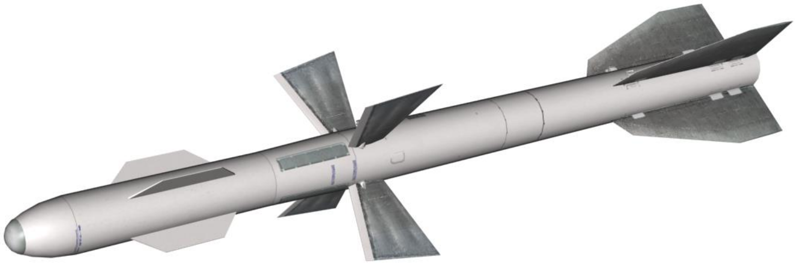

Figure 56: Air-to-Air Missile P-27T

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

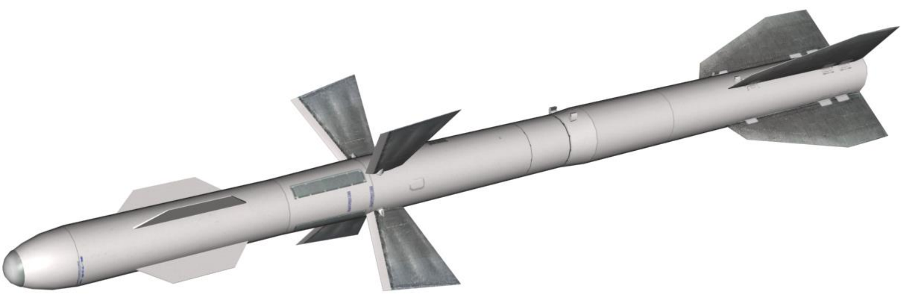

Figure 57: Air-to-Air Missile P-27ЭT

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

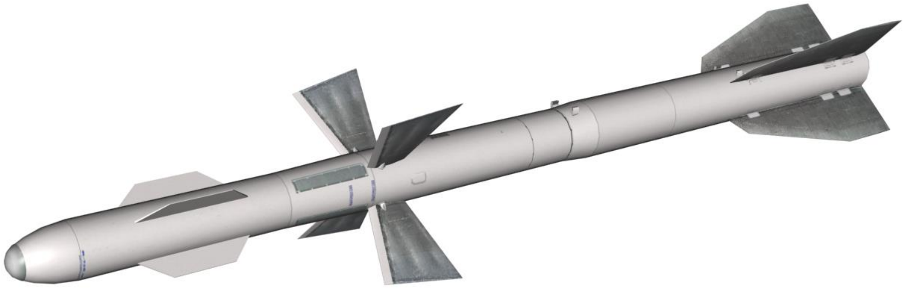

Figure 58: R-27ET missile

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

R-73 (AA-11) Short Range Missile

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

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

At first, these requirements were distributed between two different design bureaus. Reviewing the results and preliminary developmental work performed in the framework of the project, a resolution dated July 26, 1974 defined the requirements of the future Su-27 and MiG-29, entrusted "Molniya" design bureau with development of a highly-maneuverable, small, close air combat missile - the K-73. The missile was first envisioned as an enhanced P-60, but taking into account the high maneuverability requirements, it was allowed to increase its weight to be between the R-60 and R-13.

Figure 59: Air-to-Air Missile P-73

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

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

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

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

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

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

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

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

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

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

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

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

R-60M (AA-8) Short Range Missile

This is an air-to-air guided missile. Missile development started in 1967 in the PKPK (OKB-4) Minaviaprom under direction of Matus Bisnovat.

Missile design is based on "duck" aerodynamic schema. It uses small stabilizers, mounted on the forward section of the body (near the homing head), in order to increase the efficiency of the rudders at large angles of attack and for straightening of the oncoming airflow. The pairwise kinematically connected aerodynamic control surfaces are installed on the third compartment of the front section of the missile.

The P-60M is equipped with a more sensitive IR homing head "Komar-M" (OGS-75 or TGS-75). It has a large designation angles and able to track a highly maneuverable target. Warhead weight is 3,5 kg (warhead compartment is extended to 42 mm). Development started almost in parallel with the entry into the service of the basic version (R-60). The missile was also exported to different countries. The operational range of the optical fuse is around 5 meters.

Figure 60: Air-to-Air Missile P-60M

Trapezoidal wings of a large sweep are mounted on the engine outline (5th compartment). Their small elongation ensures compactness of the rocket's placement on the carrier. Rollers are placed along the rear edges of the wings.

The solid-propellant engine is located in the aft (fifth compartment beginning at the front of the missile) compartment and has a time-varying thrust diagram with a more powerful starting pulse. Engine operating time is 3-5 seconds.

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" or "iron") bombs and unguided aerial rockets.

Originally, MiG-29A и MiG-29C can use only unguided bombs and 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.

Free-fall Bombs

MiG-29 has some limited ground attack capability, being able to carry free-fall bombs and unguided rockets in place of air-to-air missiles.

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

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

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

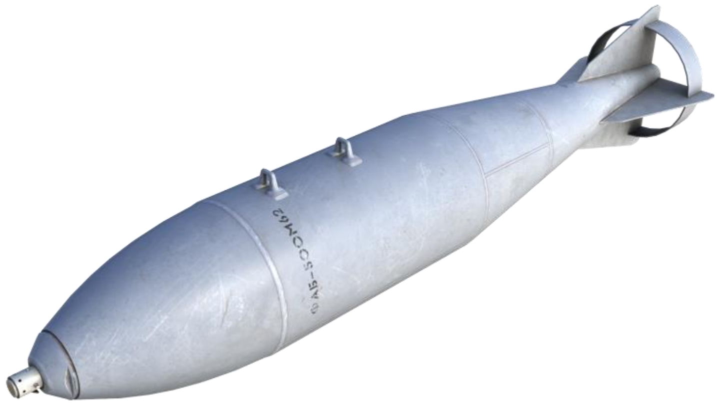

Figure 61: FAB-500 High-Explosive Bomb

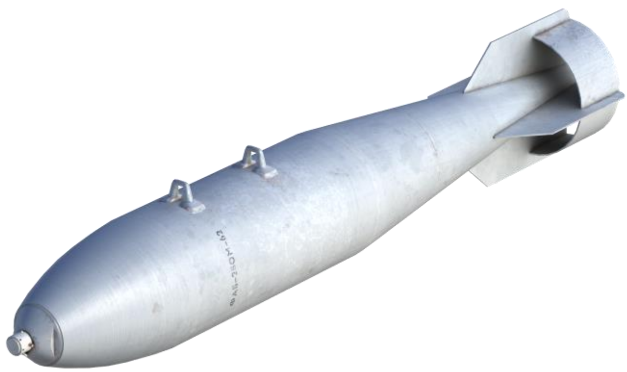

Figure 62: FAB-250 High-Explosive Bomb

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 63: BetAB-500ShP Concrete Piercing Bomb

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 64: 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 65: 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 66: 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 piper 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 67: 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.

MiG-29

PROCEDURES

MIG-29 PROCEDURES

The powerplant of the MiG-29 consists of two RD-33 engines, each has its own turbine starter, the BK-100. Because both engines have a separate starter, both, individual and simultaneous start of both engines is possible.

Engine Ground Start

In order to start the engines on the ground:

- Turn on electric power **[RShift + L]**
- Set the engine throttle to IDLE
- Press **[RAlt + Home]** to start the left engine and **[RCtrl + Home]** to start the right engine

After this, signal lamp "**ЗАПУСК**" will lit up.

Figure 68: "Engine Start Left" signal lamp ("ЗАПУСК ЛЕВ")

After the engine start, if power supply and hydraulic pressure is present, AFCS starts a bit-test for 3 minutes. DAMPER DISABLED ("**ДЕМПФЕР ВЫКЛ**") warning light will lit during the bit-test.

In the second part of the bit-test DAMPER ("ДЕМП") push-light switch on AFCS panel starts flashing. After the bit-test is completed, DAMPER DISABLED ("**ДЕМПФЕР ВЫКЛ**") light goes out and DAMPER ("ДЕМП") mode is activated.

Engine Shutdown

Engine shutdown is performed by placing the engine throttle to IDLE stop and then pressing the keys **[RAlt + End]** (for the left engine) and **[RCtrl + End]** (for the right engine).

In Flight Engine Restart

Thus, to start the engine in flight it is necessary to place the engine throttle to IDLE and then to the **"СТОП"** (STOP) position by pressing the keys **[RAlt + End]** (for the left engine) and **[RCtrl + End]** (for the right engine). Then move the throttle from the **"СТОП"** (STOP) position, press the keys **[RAlt + Home]** (for the left engine) and **[RCtrl + Home]** (for the right engine).

Weapons Delivery

This section provides instruction on the steps needed to successfully deliver many types of weapons.

To employ a weapon, the pilot needs to execute the following steps:

- Detect the target
- Lock or designate the target
- Deploy weapon

Below are descriptions of the procedures needed to employ air-to-air weapons. This begins with long-range weapons and concludes with short-ranged systems.

Beyond Visual Range Combat

Missile Engagement with Radar as the Active Sensor

Depending on the mission, target type, and jamming environment, you can use three primary radar acquisition modes **SCAN**, **TWS** for long-range missile employment and **TWS2** (MiG-29S 9-13). The **TWS & TWS2** modes provides more detailed target information and can lock targets in an automated mode. However, these modes cannot be used to detect targets in a heavy ECM environment or simultaneously detect high and low targets aspect. In such a situation, it's best to use **SCAN** mode. To search for both high and low targets aspect, use the **"АВТ"** (AUTO) sub-mode. Using AUTO however incurs about a 25% reduction in detection range compared to the **"ППС"** (Hi PRF) and **"ЗПС"** (Med PRF) sub-modes. If you already know the target aspect, it is recommended to that you enter the appropriate sub-mode with the **[RShift-I]** key.

Target acquisition, locking and launching a missile consists of the following steps:

Step 1

To search for targets at long range, select the long range **"ОБЗ"** (SCAN) **[2]** mode, activate the radar with the **[I]** key and to set the appropriate range scale on the HUD in km with the **[+]** and **[-]** keys. If the situation permits, you may choose to enter **"СНП"** (TWS) or **"СНП2"** (TWS2) mode by pressing the **[RAlt-I]** key. Select the best missile for the range and target by cycling the **[D]** key and confirm the selection on the HUD.

Step 2

Orient the radar azimuth scan zone in the direction of the target. The azimuth scan zone moves discretely and has three positions: central ±30 degrees, left –60 - 0 degrees and right 0 - +60 degrees. If the target is out of the central ±30 degrees zone, then it is required to move the scan zone to the left or right with the **[RShift-,]** or **[RShift-/]** keys.

Step 3

Orient the radar elevation scan zone in the direction of the target. There are two ways to do this.

The first method is to set the zone elevation by the data coordinates: range and elevation. To do this you first need to know the range to target (coming from the AWACS or GCI) in kilometers, which can be entered on the HUD with the **[RCtrl-+]**, **[Ctrl--]** keys. To set the target elevation in relation to your own, use the **[RShift-;]** and **[RShift-.]** keys. Doing this will center the scan zone on the target.

The second method is to use scan zone axis. Control of this setting can be assigned to a game controller axis. The elevation scan zone setting will correspond to the reading on the HUD.

Step 4

After you have oriented the scan zone in the direction of the target, you may have to wait up to six seconds before the target is detected. This is only accomplished after the radar has completed several scanning cycles. After the radar has detected a target, a contact mark is displayed on the HUD. Aircraft that return a friendly identify friend or foe (IFF) return are double-marked. Hostile aircraft return only a single mark. On the HDD, friendly contacts have a circular mark. The number of dashes in the contact on HUD represents the RCS size of the target. Generally, the larger the contact mark is, the larger the contact is.

Шаг 5

Upon target detection, the next step is to lock it up.

To do so in SCAN mode, place the Target Designation Cursor (TDC) over the contact and press the **[Enter]** key. If range, target RCS, and jamming permit, the target will be locked and framed with a circular target marker. The radar will now be in STT mode.

When in **"СНП" (**TWS) mode, place the TDC near the contact with the **[;], [,], [.], [/]**, keys and the TDC will automatically "snap to" the target mark. This indicates that the radar is now tracking this particular contact and receiving additional data about the contact. To enter a full STT lock, press the **[Enter]** key. If an STT lock is initiated over 85% of the selected missile's maximum range, the STT lock will not take place. However, once at or under 85%, then an STT lock will be initiated automatically.

TWS/TWS2 MODES CAN'T BE USED IN HARD ECM CONDITIONS.

Step 6

Once in STT mode and the distance to target is 85% or less than that of the maximum range of the selected missile, the **"ПР"** (LA – launch authorized) message will appear on the HUD. With this authorization you may launch the missile by pressing the launch weapon button on your joystick or by pressing the **[Space]** key. You should press and hold the weapon launch button for at least 1 sec until the missile launches.

It should be mentioned that launching from maximum range on a maneuvering targets is not very effective because the target can avoid the missile by performing a simple missile avoidance maneuver. If the situation permits, wait until Rtr range is reached; this will greatly increase your probability of kill. However, launching at, or over maximum range with launch override, can be used to put the enemy on the defensive early.

In regards to SARH missile (R-27R, R-27ER) employment, it is required to maintain an STT lock on the target during the missile's entire time of flight. If the target breaks lock, and you are able to quickly re-acquire lock, the missile will continue homing in on the target.

> TO USE SARH MISSILES, YOU MUST LOCK THE TARGET IN STT MODE THE ENTIRE TIME OF MISSILE FLIGHT. IN CASE OF ARH MISSILES, WHEN TARGET RANGE IS 15KM AND LESS, YOU CAN SWITCH TO ANOTHER TARGET.

Engaging two targets in СНП2(TWS2) mode on MiG-29S

The "СНП2" (TWS2) mode is designed for simultaneous or sequential engagement of two targets using R-77 missiles.

Lock on limitations:

- Targets shouldn't be separated by angle of more than 8° (width of the strobe/radar cursor) on the azimuth.
- Maximum G-Force of the maneuvering targets should be not more than 3G.
- Absence of organized ECM jamming.

The HUD indication of the primary target tracking in "**СНП2" (TWS2)** mode is represented by a moving cursor and the secondary target tracking is represented by a crosshair. After performing manual or automatic target lock on, radar transitions into "РНП" (STT) mode. Primary (the most dangerous) target is represented by a diamond mark on the HUD, secondary target is represented by a crosshair mark on the HUD.

When entering the zone of the permitted missile launch, **Ц1**/**Ц2** (in case the secondary target lock on is established) symbols appears on the HUD. Missiles launch is authorized when **Ц1**/**Ц2** and **ПР (LA – Launch Authorized)** are present in the HUD. When the secondary target **Ц2** (marked by a cross) leaves radar coverage area, simultaneous reset of the tracking or transition to a single target track mode can happen.

When the "**ПР**" (LA – launch authorized) message appears on the HUD, you may launch the missile(s) by pressing and holding the launch weapon button on your joystick or by pressing the **[Space]** key.

> СНП2(TWS2) CANNOT BE USED DURING PRESENCE OF HARD ECM JAMMING IN RADAR COVERAGE AREA.

Missile Engagement with IRST as the Active Sensor

Using the "OEPS-29" - infrared search and track (IRST) system for long-range missile combat allows stealth attacks. The IRST is immune to active jamming, but it has much less target detection range than radar. The R-27ET, R-27T, R-73 and R-60M can all be used with the IRST system.

IRST works the in the infrared spectrum and detects targets by their thermal contrast. The "hottest" aircraft section is the jet engines that expel hot gases and heat up the surrounding metal fuselage. This is why infrared detection is more effective from the rear of the aircraft than the front.

Target information on the HUD is presented in the form of azimuth in the horizontal and target elevation in the vertical. The IFF interrogator does not operate with the IRST, so be absolutely sure that the target is an enemy aircraft before attacking.

Target acquisition, locking, and launching a missile consists of the following steps:

Step 1

To search for targets at long range, select the long range **[2]** mode, activate the IRST with the **[O]** key and set the appropriate range scale on the HUD and HDD in km **[+]** and **[-]**. Select the best missile for the range and target with the **[D]** key and confirm the selection on the HUD.

Step 2

Orient the radar azimuth scan zone in the direction of the target. On the MiG-29 the azimuth scan zone moves discretely and has three positions: central ±30 degrees, left –60 - 0 degrees and right 0 - +60 degrees. If the target is out of the central ±30 degrees zone, than it is required to move the scan zone to the left or right by the **[RShift-,]** and **[RShift-/]** keys.

Step 3

Orient the IRST elevation scan zone in the direction of the target.

To do so, move the scan zone up or down depending on the possible target elevation with the **[RShift-;]** and **[RShift-.]** keys. The optimal way to search for targets is to scan along the vertical axis in small increments.

Step 4

After you oriented the scan zone in the direction of the target, you should allow the IRST to search each increment for four to six seconds; this allows the IRST to properly search that portion of sky. The number of dashes that comprise a target marker on the HUD corresponds to the size of the infrared signature. Generally, large aircraft have larger infrared signatures. The exception would be an aircraft in afterburner.

Step 5

Once the target has been detected, you next need to lock it up.

To do so, place the TDC over the contact and press the **[Enter]** key. If the target distance and infrared signature permit, the IRST will initiate an STT lock. The target will then be framed by a circle on the HUD.

Step 6

Once in STT mode and the distance to target is 85% or less than that of the maximum range of the selected missile, the **"ПР"** (LA – "launch authorized") message will appear on the HUD. With this authorization, you may launch the missile by pressing the launch weapon button on your joystick or by pressing the **[Space]** key. You should press and hold the weapon launch button for at least 1 sec until the missile launches.

Note that launching from the maximum range on a maneuvering targets is not very effective because the target can avoid the missile by performing a simple missile avoidance maneuver. If the situation permits, wait until Rpi range is reached; this will greatly increase your probability of kill.

Missiles with IR seekers are "fire-and-forget" and do not require any additional support from the launch aircraft. Once launched, the pilot can immediately begin engaging in other tasks.

> THE R-27T/ET MEDIUM RANGE MISSILES MUST HAVE AN INFRARED SEEKER LOCK ON A TARGET BEFORE FIRING. THESE SYSTEMS ARE IR-HOMING ALL THE WAY AND DO NOT USE A DATA LINK SYSTEM.

Close Air Combat

Close air combat (CAC) is combat with the enemy at visual distances. This leads to fast, hard turning fights with each side looking for an advantage that will enable them to get the first shot.

CAC ranges are usually limited by the targeting and weapon system's maximum detection and engagement ranges in CAC modes; this equates to about 10 km.

In CAC, highly-maneuverable missiles are often used, such as R-73 and R-60M. These have wide-angle IR seekers that are optimized to attack maneuverable targets performing high G tactics. These missiles are often used in conjunction with guns.

Several targeting modes used in CAC are described below:

Close Air Combat – Vertical Scan Mode

The vertical scan mode is perhaps the most convenient and useful mode when performing high-G combat maneuvers. In this sub-mode, the radar and IRST are scanning a zone three degrees wide and form–10 to +50 degrees in the vertical. Two vertical lines are displayed on the HUD that illustrates the scan zone azimuth limits. When you are trailing a maneuvering target, but it is still above your HUD on the same lift-line, the VS mode allows you to lock the target without "over-pulling" to place the target in the HUD.

The lock and launch steps are as follows:

Step 1

When an air target is visually detected, activate **VS** mode by pressing the **[3]** key. The IRST sensor will become active automatically; this allows an attack without active sensors. If you then select a SARH-type missile, you will need to manually activate the radar by pressing the **[I]** key. Select the desired missile by cycling the **[D]** key or select the internal gun by pressing the **[C]** key. Your active weapon will be displayed on the HUD.

Step 2

Maneuver your aircraft to place the target between the two vertical lines on the HUD. Note that the actual scan zone extends two HUD lengths above the top HUD frame. As such, it is possible to lock on to targets far above your HUD.

With the target in the scan zone and either sensor active, you must manually initiate a lock by pressing the **[Enter]** key. Once locked, the IRST or radar will automatically transition to an STT lock.

Step 3

Once in STT mode and the distance to target is less than that of the maximum range of the selected missile, the **"ПР"** (LA – launch authorized) message will appear on the HUD. With this authorization, you may launch the missile by pressing the launch weapon button on your joystick or by pressing the **[Space]** key. You should press and hold the weapon launch button for at least 1 sec until the missile launches.

If in the LCOS gun mode, you must place the gun piper on the target and press the weapon release button on your joystick or the **[Space]** key on your keyboard.

To increase the probability of kill, try to minimize your aiming error by flying a collision course with the target prior to missile launch. This will reduce the amount of G the missile must pull at launch.

Close Air Combat – STROB (BORE) Mode

BORE mode is similar to VS mode, the only differences being that the sensors scan along the longitudinal axis (a 2.5-degree cone) of the aircraft and not along the lift vector as VS does and that you must manually lock the target. The scan zone is shown on the HUD as a 2.5-degree reticule and it can be moved with the **[;], [,], [.], [/]** keys.

The lock and launch steps are as follows:

Step 1

When an air target is visually detected, activate **BORE** mode by pressing the **[4]** key. The IRST sensor will become active automatically; this allows an attack without active sensors. If you then select a SARH-type missile, you will need to manually activate the radar by pressing the **[I]** key. Select the desired missile by cycling the **[D]** key or select the internal gun by pressing the **[C]** key. Your active weapon will be displayed on the HUD.

Step 2

By either maneuvering your aircraft or using the **[;], [,], [.], [/]** keys, place the BORE reticule over the target. When the target is in the reticule, you must manually initiate a lock by pressing the **[Enter]** key. Once locked, STT mode will be automatically selected.

Step 3

Once in STT mode and the distance to target is less than that of the maximum range of the selected missile, the **"ПР"** (LA – launch authorized) message will appear on the HUD. With this authorization, you may launch the missile by pressing the launch weapon button on your joystick or by pressing the **[Space]** key. You should press and hold the weapon launch button for at least 1 sec until the missile launches.

If in the LCOS gun mode, you must place the gun piper on the target and press the weapon release button on your joystick or the **[Space]** key on your keyboard.

To increase the probability of kill, try to minimize your aiming error by flying a collision course with the target prior to missile launch. This will reduce the amount of G the missile must pull at launch.

Close Air Combat – Shlem (Helmet) Mode

This is a unique close air combat mode. With the Schel-3UM helmet-mounted cueing system (HMCS), a pilot turning his head can control the aircraft targeting systems and direct weapons to the target placed in his monocle reticule. By turning his head and placing the reticule over a target, the pilot can lock sensors and weapons on the designated target. The reticule is not like a symbol reflected on the HUD, but instead is always shown in the center of the screen. This mode is used in close air combat to lock and engage targets at high off-bore sight angles.

The lock and launch steps are as follows:

Step 1

When an air target is visually detected, activate **SHLEM** mode by pressing the **[5]** key. The IRST sensor will become active automatically; this allows an attack without active sensors. If you then select a SARH-type missile, you will need to manually activate the radar by pressing the **[I]** key. Select the desired missile by cycling the **[D]** key. Your active weapon will be displayed on the HUD.

Step 2

Panning your in-cockpit view using the number pad keys, you can place the HMCS reticule over a target and press the **[Enter]** key. Alternatively, you can first padlock the target with the **[NumPadDel]** key and then activate SHLEM mode and press the **[Enter]** key. After locking the target, STT mode will automatically be initiated.

Step 3

Depending on the form of the reticule, you can determine three conditions:

The reticule is attached to the target – you have a good target lock but not ready to launch a weapon.

The reticule is attached to the target and it blinks with the frequency of 2 Hz – launch is authorized. This means that conditions for the missile launch have been met. The **"ПР"** (LA) message will be displayed on the HUD and you can launch a missile by pressing the weapon release button on your joystick or by pressing the **[Space]** key on your keyboard. You should press and hold the weapon launch button for at least 1 sec until the missile launches.

If the reticule has an "X" through it, it indicates that launch is not permitted, and a lock on is not possible. This will be seen when the HMCS reticule is beyond the permitted designation angles.

To increase the probability of kill, try to minimize your aiming error by flying a collision course with the target prior to missile launch. This will reduce the amount of G the missile must pull at launch.

Fi0 (Longitudinal) Mode

Longitudinal mode is a reserve mode in case the WCS fails. This mode is used for the infrared-guided (R-27T, R-27ET, R-73) missiles, which able to lock on the target without help of the aircraft's WCS. In this mode, target lock is aided only by the missile's onboard seeker, which has the scan zone of about two degrees in the longitudinal axis. For the seeker to lock a target, the target must enter the scan zone of the seeker, which is in the center of the aircraft symbol on the HUD.

The lock and launch steps are as follows:

Step 1

When you detect an air target visually, activate longitudinal mode by pressing the **[6]** key. If the WCS system is damaged and there is no indication on the HUD, switch to the SETKA (Reticle) mode. Select the desired missile by cycling the **[D]** key or select the internal gun by pressing the **[C]** key.

Step 2

Maneuver the aircraft to position the center of the HUD aircraft symbol over the chosen target. When the target is in the missile seeker's field of view, the "launch authorized" sound tone will be given.

Step 3

You will need to visually determine the distance to the target and if it is less than the missile's maximum launch range. Launch the missile by pressing the weapon release button on your joystick or press the **[Space]** key on your keyboard. You should press and hold the weapon launch button for at least 1 sec until the missile launches.

Note that a launch authorized notification does not factor range to target. There is a strong probability that the missile will not have enough energy to reach the target. As such, you will need to gauge range by eye and factor in aspect angle.

Air-to-Ground Weapons

The MiG-29 can carry limited types of air-to-surface weapons. This arsenal includes free-fall bombs and unguided rockets.

General Purpose, Low-Drag Bombs

This category of bombs includes the FAB-100, FAB-250 and FAB-500 freefall bombs. They have low drag indexes and have flat trajectories. This often allows you to release a bomb at a target while it is still visible.

Step 1

Visually identify the target.

Step 2

Select the air-to-surface mode by pressing the **[7]** key.

Step 3

When the CCIP aiming piper starts moving from the HUD lower portion of the HUD, place the piper on the target and press the weapon release button on the joystick or the **[Space]** key on the keyboard when the **"ПР"** (LA) appears on the HUD.

> THE BOMBS CAN BE RELEASED AFTER THE LA SYMBOL APPEARS ON THE HUD. BEFORE RELEASE A STEADY DIVE TOWARDS THE TARGET ASSURES A GOOD RELEASE. TRY TO AVOID CHANGES IN BANK, PITCH AND YAW AND SIGNIFICANT AIRSPEED CHANGES DURING THE BOMBING PASS. SUCH CONTROL INPUTS MAY LEAD TO REDUCED ACCURACY.

General Purpose, High-Drag Bombs

This bomb category includes bombs with aerodynamically high drag such as PB-250, ODAB-500, various RBK types, KMGU-2 containers, and BetAB concrete-piercing bombs. They have high drag values and have a curved trajectory that significantly complicates that targeting of visible targets.

It is recommended to use the continuously calculated release point (CCRP) delivery mode when using this type of bomb. To drop a high-drag bomb, follow these steps:

Step 1

Identify the target visually.

Step 2

Select air-to-surface mode by pressing the **[7]** key.

Step 3

Place the CCRP piper on the intended target and press and hold the weapon release button on your joystick or the **[Space]** key on your keyboard. The WCS will initiate the release point calculation, and on the HUD will appear a diamond symbol that represents the designation point. In the upper portion of the HUD, a steering ring will be displayed. Fly the aircraft such that the aircraft symbol "tail" is placed in the center of this ring. The range scale on the right side of the HUD turns into a time-to-release scale that is graduated in seconds. The arrow indicating time-to-release will appear on the scale only 10 seconds before the bombs release. For accurate bombing it is best to minimize changes in bank and yaw. When the timer reaches zero, the bomb(s) will automatically be released and you can release the trigger.

Unguided Rockets and Internal Gun

Unguided rockets include all the rockets and missiles that are not equipped with guidance system. These include the S-8 in the B-8 rocket launcher, the S-13 in the UB-13 rocket launcher, and the S-25. The internal gun is the GSh-301 30-mm gun with 150 rounds.

Step 1

Identify the target visually.

Step 2

Select air-to-surface mode by pressing the **[7]** key and cycle the **[D]** key until the rocket of choice is selected. Or, select the **[C]** to make the gun the active weapon. Confirm that the correct weapon is selected on the HUD. Maneuver into a shallow dive towards the target.

Step 3

When the aiming piper is over the target and launch conditions are satisfied, the **"ПР"** (LA) message will appear on the HUD. Fire the rocket(s) or guns by pressing the weapon release button on your joystick or by pressing the **[Space]** key on your keyboard.

UNGUIDED ROCKETS CAN BE LAUNCHED ONCE THE "LA" MESSAGE APPEARS ON THE HUD. BEFORE FIRING THOUGH, ASSUME A SHALLOW BANK WITH MINIMAL BANK, PITCH, AND YAW DEVIATIONS. SUCH DEVIATIONS CAN LEAD TO AN INACCURATE ROCKET PASS

RADIO COMMUNICATIONS

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 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.
		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 an 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 indication 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"

SUPPLEMENTS

SUPPLEMENTS

Acronym List

AAA	Anti-Aircraft Artillery
A2A	Air-to-Air
A2G	Air-to-Ground
AAM	Air-to-Air Missile
ACS	Automated Control System
ADI	Attitude Direction Indicator
AFCS	Automatic Flight Control System
AFF	Advanced Frontline Fighter
AGM	Air-to-Ground Missile
AIM	Airborne Intercept Missile
AOA	Angle of Attack
AOJ	Angle of Jam
ARH	Active Radar homing head/missile
ASM	Air-to-Surface Missile
AWACS	Airborne Warning and Control System
BIT	Built-in Test
BVR	Beyond Visual Range
CAC	Close Air Combat
CCIP	Continuously Computing Impact Point
CCRP	Continuously Computing Release Point
CEP	Circular Error Probable
CIoA	Central Institute of Aerodynamics
CoCTaPR	Center of Combat Training and Personnel Retraining
DB	Design Bureau
ECM	Electronic Countermeasures
EGT	Exhaust Gas Temperature
EOS	Electro-optical system

EW	Early Warning
FCS	Fire Control System
FCS	Flight Control System
GCI	Ground-controlled Intercept
HAFF	Heavy Advanced Frontline Fighter
HDD	Head Down Display
HI	High
HIS	Horizontal Situation Indicator
HMS	Helmet Mounted Sight
HOJ	Home on Jam
HUD	Head-up Display
IAS	Indicated Air Speed
IFF	Identification Friend or Foe
ILS	Instrumental Landing System
IR	Infra Red
IRH	Infra-Red Homing Head/Missile
IRST	Infra Red Seek and Track System
KOLS	Quantum Optical-Laser Station
LA	Launch Authorized
LAFF	Light-weight Anvanced Frontline Fighter
LCOS	Lead Computed Optical Sight
LEF	Leading Edge Flaps
LEX	Leading Edge Extension
LTRD	Laser Track/Ranging Designator
MED	Medium
MEZ	Missile Employment Zone
MLWS	Missile Launch Warning System
NAV	Navigation
OEPS	Opto-electronic targeting system
OESNS	Opto-electronic Sighting/Navigation Station
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Rates

QFE	Q-code Field Elevation
RCS	Radar cross-section
RKT	Rockets
RPM	Rounds per minute
RWR	Radar Warning Receiver
RWS	Radar Warning System
SAM	Surface-to-Air Missile
SARH	Semi-active Radar Homing head/missile
SLAR	Side-Looking Airborne Radar
STT	Single Target Track
TAS	True Air Speed
TDC	Target Designation Controller
TWS	Track While Search
VS	Vertical Scaning
VSD	Vertical Situation Display
VVI	Vertical Velocity Indicator
WCS	Weapon Control System
WoffW	Weight-off-Wheels
WonW	Weight-on-Wheels

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