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DCS: Su-33 Flanker D

Flight Manual

DCS: Su-33 for DCS World

The Su-33 Flanker-D aircraft has been developed on the Su-27 base.

The Su-33 is a single-seat ship-based STOBAR fighter, with upward folding wings and horizontal tail surfaces and has aerial refuelling capability. The Su-33 is designed for defence of naval ships from aerial threats. It is manufactured in Komsomolsk-on-Amur.

The Su-33 as famous Su-27 his is equally capable of engaging targets well beyond visual range as it is in a dogfight given its amazing slow speed and high angle attack manoeuvrability. Using its radar and stealthy infrared search and track system, the Flanker can employ a wide array of radar and infrared guided missiles. In addition to its powerful air-to-air capabilities, the Flanker-D can also be armed with bombs and unguided rockets to fulfil a secondary ground attack role.

Su-33 for DCS World focuses on ease of use without complicated cockpit interaction, significantly reducing the learning curve. As such, Su-33 for DCS World features keyboard and joystick cockpit commands with a focus on the most mission critical of cockpit systems.

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

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INTRODUCTION

The Sukhoi Su-33 (Russian: Сухой Су-33; NATO reporting name: Flanker-D) is an all-weather carrier-based twin-engine air superiority fighter designed by Sukhoi and manufactured by Komsomolsk-on-Amur Aircraft Production Association, derived from the Su-27 and initially known as the Su-27K. Compared with the Su-27, the Su-33 has a strengthened undercarriage and structure, folding wings and stabilators, all for carrier operations. The Su-33 has canards and its wings are larger than the Su-27 for increased lift. The Su-33 has upgraded engines and a twin nose wheel, and is air refuelable.

First used in operations in 1995 aboard the carrier Admiral Kuznetsov, the fighter officially entered service in August 1998, by which time the designation "Su-33" was used. Following the break-up of the Soviet Union and the subsequent downsizing of the Russian Navy, only 24 aircraft were produced.

Figure 1: Su-33 on the deck

HISTORY

SU-33 HISTORY

The preliminary design of the Su-27K carrier-based fighter was prepared by the P.O. Sukhoi Machine-Building Plant in 1978. The design was based on the Su-27 fighter, which was at that time still in its initial prototype configuration (T-10) and was undergoing flight trials the year prior. The Su-27K carrier-based fighter, equipped with two AL-31F engines with a thrust of 12,500 kgf, was required to have a normal take-off weight (without armament) of 22,800 kg, and a maximum take-off weight (with air-to-air missiles) of 26,600 kg. The maximum combat loadout of the aircraft included two R-73 short-range missiles, six R-27E medium-range missiles, as well as 150 rounds for the internal cannon system. With a full fuel load of 7680 kg, the Su-27K's combat radius could reach 1200 km, and its patrol endurance at a distance of 250 km from the carrier could reach at least 2 hours. Compared with the land-based version of the prototype, the Su-27K was equipped with a folding wing, a reinforced chassis, an arrestor hook, as well as special navigation equipment. During the process of its construction, a number of measures were envisaged for additional protection against corrosion for the chassis, power plant and equipment.

The Su-27K surpassed the MiG-29K in its loaded and maximum takeoff weight by almost 1.5 times; in addition, the Su-27K had almost twice the fuel reserve which provided it with 1.5 times greater range. Achieving the same tactical radius and patrol endurance from the MiG-29K was possible only with the use of external fuel tanks - one under the fuselage and two under the wing, which greatly reduced the MiG-29's already paltry combat loadout of air-to-air missiles. The firepower of the Su-27K greatly exceeded that of the MiG-29K: along with the same 30-mm cannon with 150 rounds of ammunition and the same R-73 short-range missiles, the Flanker could carry an additional six R-27 medium-range missiles, compared to a maximum of four on the Fulcrum (and a minimum of only two, if external fuel pods were required.) Moreover, unlike the latter, the Flanker could utilize the so-called "extended" versions of these missiles, the R-27E, which provided increased launch range. The downside of all these advantages was the larger size and increased production cost of the Su-27K, which limited the number of these fighters in the carrier's air wing.

The T10-3's flight testing began on July 24 1982 at the NITKA complex, where test pilot N.F. Sadovnikov performed its very first takeoff from the detents. In August 28, the T10-3, also piloted by Sadovnikov, took off from the ramp. The takeoff weight of the aircraft in this test session was 18,200 kg, with a takeoff distance of 230 m and a liftoff speed of 232 km / h.

All in all, the first stage of testing at the NITKA complex, which lasted until September 17 1982, saw 27 take-offs performed on the T10-3 prototype. With a take-off weight of 18 000 kg, the take-off distance of the aircraft was established to be 142 m, and the liftoff speed reduced to 178 km/h. The maximum take-off weight of the T10-3 for a ramp take-off was 22 000 kg.

Based on the results of the first stage of flight testing at the NITKA complex, a decision was made to change the profile of the take-off ramp. Based on the calculations of specialists from the Gromov Flight Research Institute, the Central Aero-Hydrodynamic Institute, and from the Sukhoi Experimental Design Bureau showed that the best results could be achieved if the surface of the ramp was formed not by an arc of a cylinder, as on the T-1, but by a cubic curve. As a result, the angle of exit of the aircraft from the ski-ramp would increase from 8.5° to 14.3°. While a new ski-ramp, designated T-2, was under construction, Summer of 1983, saw the beginning of the second stage of the aircraft's flight testing in NITKA - with arresting gear-assisted landings.

In the summer of 1983, the T10-3 was outfitted with an arrestor hook. As the flight life of the T10-3 had already been exhausted, it was decided that the aircraft, while grounded, was to be used to test the operation of the arrestor cables. Using its engines, the aircraft accelerated along the runway to a speed of 180-240 km/h until reaching the arrestor cables. These "touchdowns" were carried out both with the aircraft on its three points, as well as with the front gears held elevated.

The longitudinal deceleration load of the aircraft reached 4.5. The deceleration of the aircraft during asymmetrical contact was also tested - with lateral displacement of the aircraft from the axis of the runway up until 5m and with an angle relative to the axis of the runway up until 5°. The length of the aircraft's landing runout was reduced to 90 m.

Thus, the first stage of testing of the experimental aircraft at the NITKA complex in 1982-1983 confirmed the principal possibility of, firstly, implementing shortened fighter aircraft take-off runs from a ski-ramp with a take-off roll distance within the limits allocated by the flight deck of the Admiral Kuznetsov (TAKP 1143.5), and secondly, landing operations with the implementation of arrestor cables. Further testing, as well as the operation of the first Soviet ship-based fighters onboard the Admiral Kuznetsov, revealed a number of significant advantages of ski-ramp take-off over the traditional catapult-assisted take-off employed by Western aircraft carriers.

The Su-27K long-range fighter-interceptor was created on the basis of the Su-27 front-line fighter, preserving the existing weapons system at the first stage. Further down the road, designers inteded to provide the Su-27K the capability of employing a newer fire control system, as well as guided air-to-surface missiles that were intended for use on the modernized Su-27M fighter.

On the Path to the SU-33

The Decree of the Central Committee of the CPSU and the Council of Ministers of the USSR on April 18, 1984 was the official recognition of the many years of work by the staff of the P. O. Sukhoi Machine-Building Plant devoted to the project of developing a naval version of the SU-27 fighter. As a result, massive efforts went underway on developing the blueprints and then the engineering development of the Su-27K naval fighter (given the factory code of T-10K).

All the work on the ship-based fighter was overseen by the General Designer of the Sukhoi Machine-Building Plant: Mikhail Petrovich Simonov. In 1984, Konstantin Khristoforovich Marbashev was appointed head of the Su-27K project in the Sukhoi Experimental Design Bureau.

The SU-27K, a single-seat supersonic carrier-based fighter, was created as a modification of the Su-27 fighter, the mass production of which by that time had already been underway at the Komsomolsk-on-Amur Aviation Plant (named after Yuri Gagarin). While retaining the basic design and layout solutions of the basic model and having a high degree of continuity with it in terms of the power plant, equipment and armament system, the Su-27K also had to implement in its design a number of significant changes determined by the intricacies and demands of the aircraft's future carrier-based operations and naval combat assignments. Thus, designers managed to determine the necessary changes that were to be implemented for the "navalization" of the Su-27. Chiefly, these are:

- Improving the bearing properties of the wing on takeoff and landing modes by increasing its area and employing more efficient mechanization;

- ncrease the thrust of the aircraft to ensure takeoff from the carrier with a short takeoff run, and safe missed approaches in case of contact failure with the arrestor cables.
- reinforcement and modification of the undercarriage, and installation of an arrestor hook to ensure the safe touchdown of the aircraft with large descent rates and G-Forces (without flaring or floating) directly onto the carrier's arrestor system;
- introduction of an in-flight refueling system and the possibility of using a fuel transfer system to another aircraft to increase the range and duration of patrols over the sea;
- application of specialized flight-navigation equipment to guide the aircraft onto the carrier and for deck approach;
- modification of the target sighting system to ensure smooth operation of the aircraft over the sea in tandem with shipborne radio-electronic systems;
- an increase in the total capacity of air-to-air missiles on the aircraft to increase its combat potential in one sortie;
- introduction of folding wingtips to reduce the dimensions of the aircraft, ensuring an increase in the maximum number of fighters stored in the hangars of the ship and at the technical positions on the upper deck;
- introduction of special anti-corrosion protection of the aircraft's chassis and systems to ensure its long-term operation under maritime conditions.

September to October of 1984 in the experimental design bureau saw the consideration of the preliminary design of the Su-27K carrier-based fighter, which embodied these improvements, by the client's commission, headed by the commander of the Navy's Air Wing Colonel-General G. A. Kuznetsov.

Although the commission approved the draft design, there were nevertheless a number of comments. Among the main concerns raised was the need to improve the combat capabilities of the Su-27K in carrying out its combat missions over the sea. Operational requirements for the Su-27K formulated by the 30th branch of the Central Research Institute allowed for the aircraft's deployment not only as air cover for the aircraft carrier, but also for combatting hostile surface ships. However, the experimental design bureau defended its position, according to which the first stage of development (in the interest of speeding up the development process) required the creation of a "clean" fighter aircraft, with significant weapons system harmonization with the land-based version of the Su-27. According to the leaders of the P.O. Sukhoi Machine Building Plant, by the end of the 80s, such an approach would have allowed to press into service the first serial-production supersonic carrier-based fighters, while the development of new weapons systems would require considerably more time. They were supposed to be introduced at the second stage of the creation of the Su-27K. Nevertheless, the commission managed to insist that, at the first stage, unguided means of defeating surface (ground) targets - air bombs and unguided rockets - at the very least must be included in the Su-27K armament.

This and the other comments made by the client's commission were taken into account by the developers during the finalization of the draft design. As a result, in February 1985, the draft of the Su-27K project was approved by the commanders of the Air Force and the Navy of the Soviet Union. The S. O. Sukhoi Machine Building Plant then began to work on the full-scale development of the carrier-based fighter. Over the course of its construction, the aircraft underwent a number of further changes.

One of the most significant changes was the modification of the aerodynamic layout of the Su-27K due to the installation of forward canards on the aircraft. The idea to equip Su-27 type aircraft with forward canards came up way back in 1977, when it became necessary to restore the longitudinal static instability of the fighter caused by the excess weight of the radar sighting system. The weight of the radar system, reaching almost 200 kg, in comparison with the figures laid down in the preliminary weight calculation, meant that the center-of-gravity on this new version of the Su-27 could be displaced substantially forwards, altering the focus point. The aircraft became statically stable along the longitudinal axis and as a consequence it became necessary to balance it by deflecting the stabilizers downwards. The common lift characteristics of the all-body/canards system thus decreased, which, as a consequence, resulted in reduced range and deterioration of the aircraft's manoeuvrability.

The front canards could become one of the means of reducing static stability, which was achieved by shifting the application point of the resultant lift of the allbody/canards system forward. As of then, however, practical tests on the application of front canards on fighter aircraft had yet to begin, and the first serial Su-27s practically lost the inherent advantages of the unstable configuration - depending on the center-of-gravity, they had either a neutral or positive longitudinal static stability, albeit with a very small margin.

The idea of using front canards on Su-27 type aircraft returned in 1982, when developement began on the a modification (Su-27M) of the fighter with a more powerful and, consequently, heavier radar. Naturally, the center-of-gravity on the aircraft moved even further, and the coveted longitudinal static instability would become almost impossible to realize. At the same time, deflection of the front canards was decided to be used for more effective control of the aircraft at large angles of attack.

As is widely known, Su-27 fighters can successfully fly in a wide range of angles of attack, but there is a certain critical value of the angle of attack at which the horizontal tail is caught in a low-energy wake generated by the wing; its efficiency drops, and the deflection of the stabilizers, even nosed up at the maximum designed angle, would not be enough to create the necessary diving force to return the aircraft to normal flight. In such cases, the front canards installed in front of the wing and connected to the fly-by-wire system resolve the problem. Even later, other important advantages of the application of forward canards were discovered.

General Designer M. P. Simonov became the initiator of the forward canard flight tests on experimental aircraft. For the purposes of assessing assessing the influence of forward canards on the stability and maneouverability characteristics of a fighter aircraft in real flight conditions, one of the first serial Su-27s, the T10-24, was chosen to serve as the testers' "flying laboratory." Testing began in May 1985, with the aircraft flown by V. G. Pugachev. Mounted on T10-24 at the end of the wing influx, the canards deflected automatically and proportionally to the angle of attack of the aircraft. The canards increased the "instability" of the aircraft, which made it possible to reduce the balancing losses during maneuvering and ensured a safe descent from large angles of attack when the main horizontal tailplanes were obscured.

An unexpected result of the tests conducted on the T10-24 with forward canards was also the discovery of a significant increase in the maximum lift of the aircraft due to the favorable interference of the canards and the all-body with the chosen layout scheme. Thanks to all these advantages, it was decided that the front canards were to be used as an integral element of the aerodynamic layout of the new Su-27 variants - the first of which was to be the Su-27K naval fighter.

The installation of the front canards required changing the contours of the influx of the fighter's wing and finalizing the fly-by-wire system, as well as the hydraulics system of the aircraft, into which the canard control units were incorporated. It was decided that the Su-27's fly-by-wire system was to be realized by means of a three-channel implementation of the principles of fly-by-wire control of the control surfaces not only in the longitudinal (as it is in the Su-27) channel, but also in the lateral and lateral channels, which allowed for a transition from the traditional methods using rigid wiring with power amplifiers and loading mechanisms in the roll and yaw channels. The modified aerodynamic scheme and the fly-by-wire system made it possible to realize the degree of longitudinal static instability of 5-7% on the Su-27K, due to which a significant gain in aerodynamic quality at subsonic modes was achieved as a result of the reduction in trim loss.

Another major change in the design of the carrier fighter was a change in the scheme of the folding wings and the introduction of folding canards. This was due to the fact that, in the original version of the layout, the overall width of the Su-27K with the folded wing consoles was about 10 m, while the other carrier fighter design, the MiG-29K, had only 7.8 m. Taking into account a fuselage that was longer by 4m (21.2m compared to 17.3m) led to the conclusion that the MiG-29K held the advantage over the Su-27K by the number of aircraft that can be stored in the hangars and on the flight deck of the Kuznetsov. As a result, the board of the Ministry of Aviation Industry in the mid-80's even raised the issue of the termination of the Su-27K development program and the transfer of the Admiral Kuznetsov air group exclusively to the lighter MiG-29K naval fighters.

After conducting research on several new variants of folding wings in the Sukhoi Design Bureau, (over the course of which saw considerations on the possibility of double-folding wing layouts, in which each console was to consist of three parts: one fixed and two rotary parts, one relative to the other), the decision was made to implement a simpler and more technological scheme. Now the wing was to fold approximately at the middle of the general span (the distance between the folding axes being 7.0 m, with the wingspan ratio of the fixed and rotary parts of the wing being 1: 3), while preserving the fuel tank-compartments in both the fixed and rotary parts.

The overall width of the fighter with the wing folded down under the new scheme was reduced to 7.4 m and became even smaller than that of the MiG-29K. Due to the fact that the sweep of the canards on the Su-27K was 9.9 m, its panel was also decided to be folded about halfway along their span (the distance between the folding axes and the wing being 7.0 m). And, to reduce the overall length of the aircraft in the hangar of the ship, designers also considered the possibility of folding the fuselage's central tail boom upwards, as well as raising the nose cone that housed the radar system. The latter idea, however, was later abandoned, due to the limits imposed by having to fold the bar of the air pressure receiver.

These measures made it possible to increase the number of Su-27K fighters on the ship, thereby "rebutting" the first wave of arguments against the project from its opponents in the ministry. The development of the aircraft continued.

Additionally: in the interests of creating the Su-27K, the Sukhoi Design Bureau in the mid-80's finalized several models of the Su-27 and Su-27UB aircraft. In 1984-1987 up until the appearance of the first prototypes of the Su-27K, a large amount of tests was carried out on these machines at the NITKA complex in order to develop and improve the technique of performing shortened take-offs from the ski-ramp as well as landings on the arrestor system.

In 1986, the experimental production section of the P. O. Sukhoi Machine Building Plant began assembling the first, and then the second, prototypes of the Su-27K, which received the designations T10K-1 and T10K-2.

One of the significant differences between the Su-27K ship fighter and the Su-27 base model was the design of the wing. With the preservation of the previous wingspan (14.7 m), the wing area of the Su-27K increased by almost 10% in comparison with the Su-27's, reaching 67.84m^2. This was achieved mainly due to the change and increase in the mechanization area, which was dictated by the requirements to reduce the landing speed of the aircraft and increase the bearing properties of the wing to facilitate short takeoffs from the flight deck. The single-section flaperon gave way to two separate control elements - firstly, to a two-section single-slot flap with a deflection angle increased to 45° (one section on the fixed part of the wing, the second on the folding section) and secondly, to the hanging ailerons (flaperons). The total area of mechanization of the trailing edge of the wing increased by 84% in comparison with the base model Su-27. The now three-piece leading edges saw an increase to their area by 17%. The underside of the fixed part of each panel saw the installation of one additional pylon for the suspension of air-to-air missiles.

The next group of changes concerned the take-off and landing devices of the aircraft. The main and front support of the aircraft's undercarriage was reinforced, while the front support was equipped with a telescopic rack and two gears. All of the undercarriage's struts were outfitted with ship-based mooring and towing units; additional landing lights and a three-color signaling device were installed on the forward strut, the lights of which informed the Landing Signal Officer about the position of the aircraft on the glide path.

A drop-down landing hook was installed under the central tail boom (stinger) fixed to the fuselage. The hook is equipped with a deployment, lifting and damping system. The parachute braking system in the central tail boom was removed, and the passive countermeasure blocks were moved from the stern "flipper" (its configuration was also heavily modified) to the tail section of the fuselage in the vicinity of the engine compressors. The configuration of the central stinger and its end also saw changes: the beam was shortened, raised, and the lower surface was made flat.

In order to increase the initial thrust of the aircraft to ensure a short takeoff from the flight deck and a safe missed approach in case of an unsuccessful attempt to land on the arrestor system, plans were made to outfit the aircraft with modified AL-31F series 3 engines, which, in comparison with the serial AL-31F, were equipped with an additional special mode of operation, at which the thrust rose for a short time to 12800 kgf. The modified engine also differed from the standard model in terms of its structural material and coating that provided a high degree of corrosion resistance. An automatic throttle system was also proposed for the engine control system in order to simplify the control of the aircraft during approach to the steep carrier glide path without the pre-touchdown flare.

While preserving almost the same fuel reserve as on the base Su-27 model, the design of the Su-27K saw changes to the configuration of the fuselage fuel tanks, and new tank compartments were installed in the folding sections of the wing panel. The total fuel reserve on the aircraft was 9500 kg (compared to 9400 kg on the Su-27). An emergency fuel drain was installed on the aircraft for the purposes of ensuring an emergency landing on the ship, affording the pilot a few minutes to reduce the flight weight of the aircraft to allow for safe landing on the deck.

An in-flight refueling system was implemented in order to increase the aircraft's maximum flight range and patrol duration over the sea. At the same time it was intended that all Su-27K aircraft would be equipped with a retractable fuel rod. With a buddy refueling pod (quipped with a deployable hose) mounted on the centerline pylon, an Su-27K could by itself serve as a refueling aircraft for others.

For mid-air refueling of the aircraft, the pilot must release the receiver rod and make with the cone of the tanker's refueling hose. Once reliable contact is established between the rod and the cone, the refueling process begins, and pressurized fuel begins to pass through the refueling hose.

By this time, the system of mid-air refueling using the "cone-rod" scheme in tandem with the buddy refueling pods was already mastered by pilots of the Sukhoi Design Bureau, and adopted into service with the Su-24M. Thus its introduction to the Su-27 fleet did not cause any special problems.

The retractable fuel rod is located on the Su-27K, front and to the left of the pilot's cockpit, while the Infra-red Search and Track (IRST) sensor was moved to the right of the axis of symmetry of the aircraft. During night conditions, the bar and the refueling cone were illuminated by special headlights, which were released from the left and right sides of the head of the fuselage.

The modifications made to the aircraft structure also caused significant changes to the hydraulic system, which received additional functions: controlling the canards and the mechanizations of the wings; folding the wingtips and stabilizers; deploying and retracting the landing hook, refueling rods, etc. The pneumatic system was also modified to allow for the emergency release of the landing hook and refueling rod.

The navigation equipment of the naval fighter also included systems that provided assitance during flights over the sea and for landing approaches to the carrier. The landing main instrument was the on-board A-380 automatic radio facility for short-range navigation, flight control, approach and landing of shipborne aircraft, the Resistor-K42 landing aid. To ensure efficient operation and avoid electrical interference, all airborne radio electronic equipment of the aircraft was brought into compliance with the requirements of ensuring electromagnetic compatibility with the radio-electronic equipment of the ship.

The weapons control system of the Su-27K was mostly analogous to that of the Su-27: it used the same N001 radar developed by the Tikhomirov Scientific Research Institute of Instrument Design. However, instead of the OLS-27 IRST present on the Su-27, a new OLS-27K IRST was used - the main difference being the operating software. The improved weapons control system for the shipborne fighter Su-27K (SU-33) allowed for the successful interception of air targets in the expected combat conditions.

The array of air-to-air weaponry employed by the new fighter also corresponded to the armaments employed by the base Su-27 model, but the Su-27K model saw the total number of missile hardpoints increased to 12 - resulting in a larger combat loadout. The Su-27K could load up to six R-27ER, two R-27ET, and four R-73 missiles simultaneously. The Su-27K also had the possibility of using unguided air-to-ground/surface munitions, with a total mass of up to 6,500 kg: 100 to 500 kg iron bombs, cluster munitions, incendiary bombs, the S-8, C-13 and C-25 unguided rockets, and other such munitions.

Future plans were made for the modernization of the Su-27K for a new weapons control system, developed mainly for the Su-27M fighter.

Taking into account all the modifications of the design, the installation of new equipment, as well as the reinforcement of the chassis, fuselage and wing structure (due to the rigorous demands of no-flare carrier landings, vertical G's and descent speeds far greater than those experienced when landing on conventional airfields), the empty weight of the aircraft greatly increased by more than 3000 kg compared to the base Su-27 model, reaching 19 600 kg (while the Su-27 weighed 16 400 kg). As a consequence, there were some deteriorations in the flight characteristics of the fighter. Its maximum flight range decreased by 30-40%, while its maximum flight speeds and service ceiling decreased by 7-9%.

At the same time, the Su-27K could take off from the deck with a weight of up to 33,000 kg (the maximum take-off weight of the Su-27 was 28,000 kg), having up to 6,500 kg of its combat load on board (while the Su-27 could hold up to 2,500 kg). The normal take-off weight of the Su-27K with less than full fuel load, depending on the number of missiles it carried, ranged from 25 to 28 tons; all the while, it had a starting thrust of 0.9 to 1.0 and could take off from the first or second take-off positions on the deck of the ship (with a take-off roll distance of 105m). With a full fuel load and the maximum load of air-to-air missiles, the takeoff weight of the aircraft increased to 32 tons, and its thrust-to-weight ratio decreased to 0.8. In this case, the takeoff of the aircraft would begin from the third take-off position (with a distance of 195 m). From here, the plane could take-off even with a maximum combat load of unguided bombs and rockets.

Despite a significant increase in the aircraft's landing weight compared to the Su-27, the introduction of new wing mechanisms and forward canards allowed for a reduction of its approach speed to 240 km/h (whereas the Su-27 usually performs landing approaches at a speed of about 270 km/h, lowering it to 225-240 km/h during the flare, depending on its landing weight. At the same time, the length of the Su-27K's landing roll along the deck, with arrestor cable assistance, was to be only 90 m.

Such flight characteristics provided the Su-27K parity with modern fighter aircraft employed by the potential adversary, and, in terms of handling characteristics -

maneouverability, turn and ascension rates - was outright superior to them. A significant internal fuel supply and the possibility of mid-air refueling provided the Su-27K with the endurance for extended patrols over the sea in the vicinity of of its battlegroup, lead by the aircraft carrier. The maximum patrol time of the fighter, with a loadout of two medium-range R-27E missiles and two R-73 close-combat missiles, at an altitude of 11 km and a distance of 250 km from the carrier, even without mid-air refueling, could reach 2 hours.

In the summer of 1984, the installation of the new T-2 ski-ramp (with a height of 5.6 m, a length of 53.5 m, a width of 17.5 m, and an angle of descent of 14.3°) was completed at the NITKA complex: replicating the design of the ski-ramp on the Admiral Kuznetsov aircraft carrier that was being built at the same time. The new profile of the ski-ramp, formed by a third-order curve, was designed to allow for smooth increase in Gs on take-off.

The NITKA complex saw not only testing of the ski-ramp take-off and arrestor system landing processes, but also testing of the landing aid equipment designed for the ship: the "Luna-3" and "Glissada-N" optical landing systems - the radar landing system, and the instrument landing system. The "Luna-3" optical system was intended to allow for visual landings in the daytime, while the "Glissada-N" ILS was designed for visual landings at night. The "Resistor" radio-technical system was intended to ensure the approach of the aircraft for landing in semi-automatic and directorial modes day and night in simple and difficult weather conditions.

August to October of 1984 saw a total of 160 approaches made by the T10-25 aircraft with a touchdown and second approach, including 44 automatic approaches, 9 landings on the arrestor system, and 16 take-offs from the T-2 ski-ramp. Unfortunately, the flight career of T10-25 was to reach an abrupt end: on November 23 of 1984, during flight at the testing grounds of the State Scientific Test Red Banner Institute of the Air Force in Akhtubinsk, due to destruction of the hydraulic system's pipelines leading to the rudders, the pilot, N. F. Sadovnikov, had to eject; The plane crashed and was destoyed. The pilot ejected at an altitude of 1000 m and from an inverted position, but managed to reach the ground safely, and, thankfully, was able to continue flying. Here is how N. F. Sadovnikov described the incident: "During that test flight, I had an emergency, which, unfortunately, resulted in the loss of the aircraft. At an altitude of 2000 m and a speed of 1270 km/h, a signal suddenly appeared on the dashboard notifying me about a pressure drop: first in one hydraulic system, and, after a few moments, in the other. The plane became uncontrollable. I had to abandon it... Following the conclusions made by the accident board, improvements were made to the hydraulic system, and that was the last of such incidents."

In the summer of 1986, a T10-24 test aircraft, equipped with front canards, was brought for testing at the NITKA complex. As the canards were planned for usage on the serial ship-borne Su-27K fighters, research began on the T10-24 concerning the effect of front canards on the aerodynamics of the aircraft's ski-ramp takeoff. However, only 6 flights were performed according to this program: on the 20th of January, 1987, the T10-24 was involved in another accident, with the test pilot, A. Puchkov, managing to eject. The role of the T10-24 in NITKA was filled by yet another test aircraft, the T10U-2, equipped with the mid-air refueling system and an arrestor hook. Within two months, the test pilots carried out 12 flights on the T10-U2, having perfected the approach procedure for night landings assisted by the Glissada-N system. Fate, however, would decree that this prototype was also to be lost several years later in an accident.

In the summer of 1987, the experimental production section of the P. O. Sukhoi Machine Building Plant finally saw the completion of the assembly of the first Su-27K prototype - the T10K-1 aircraft, receiving the tail number of 37. The tail number was determined by the fact that the T10K-1, according to the end-to-end numbering of the experimental bureau, was the 37th aircraft of the Su-27 family that was passed on to the design bureau for testing (and therefore, its factory code was T10-37). Initially, the T10K-1 had a non-folding wing and canards, borrowed from the base Su-27.

Six months later, the second copy of the Su-27K-T10K-2 (with a tail number of 39 and a second designation of T10-39), also assembled from the Komsomol units, was deployed for testing: the principal difference being the presence of the folding wings intended for the carrier fighter, an enlarged wing area, and new wing mechanisms. Intensive work was performed on both prototypes to determine the basic flight characteristics of the modified aircraft, to assess its stability characteristics and maneouverability, to check a number of the design improvements implemented, in particular the new fly-by-wire system, the front canards, and the mid-air refueling system (for which the buddy refueling pod was used, with the T10-U2 carrying it.)

Summer of 1988 saw the T10K-1 equipped with a set of folding wings. Its first flight with this modification was performed on August 25, but after only a month, on September 27, 1988, the plane crashed. The test flight required the pilot of the T10K-1, N. F. Sadovnikov to perform several tasks at once: the determination of the strength of the aircraft's design in supersonic flight, and the study of the stability and maneouverability of the aircraft at large angles of attack, and the imitation of engine failure due to defects in the hydraulic system. There was a failure in the control system of the horizontal canards, due to which the aircraft entered a stall, and the pilot was, as a consequence, forced to eject and leave the first-ever Su-27K to its demise.

The second Su-27K, piloted by V. G. Pugachev, was then left to perform the bulk of the factory flight tests after the T10K-1's accident. In the year after the loss of the first prototype and until the beginning of flight tests based on the carrier, about 300 flights were carried out on the T10K-2. A significant part of them was executed at the NITKA complex.

The first flights implementing no-flare landing approaches and with the employment of the Luna optical landing system were performed by military testers on a Su-27 fighter in late 1988. On the basis of these studies and for the purpose of further testing and training, landings on "ship" glide paths with angles of up to 3° were authorized on Su-27 aircraft, using the Luna system, and with a landing weight of less than 18,500 kg and a speed of 240 km/h.

Flight development tests of the Su-27K aircraft, launched on July 17 1987, were officially completed on December 28 1990. Two experimental and two production aircraft took part.

State tests of the Su-33 aircraft began in March 1991. They were held at the airfields of the Crimean branch of the Suky and Kirovskoye Air Defense Research Institute and directly onboard the aircraft carrier in the Black Sea. Seven Su-33 production fighters participated in the testing - from the T10K-3 to the T10K-9. Simultaneously, training of combat pilots for the 100th ship fighter regiment, which was formed in 1986 in Saki with the purposes of flying the Su-33, began at the Saki aerodrome and in the NITKA complex.

The state tests of the Su-33 aircraft, as well as several stages of special flight tests, were completed. The first ocean campaign of the aircraft carrier had also passed, yet the aircraft could work from the aircraft carrier only during the day and at dusk. It became necessary to solve the problem of conducting flights from the ship in night conditions. Thus another stage of testing began in September 8 1997 in the NITKA complex in Crimea, with the goal of improving the nighttime take-off and landing procedures.

After completion of the assessments on the possibility of landing the Su-33 and Su-25UTG in nighttime conditions on the NITKA complex, the decision was made to conduct similar tests on the Admiral Kuznetsov. The tests were conducted only in September to October of 1999. After several flights on the Su-25UTG, the decision was made to fly the Su-33 and allow combat pilots to fly at night on the Su-25UTG. On October 28, 1999, the Su-33's nighttime carrier flight tests were successfully completed.

The night flights on the Admiral Kuznetsov were to become the final tests of the Su-33 conducted in the past century. The year prior, on August 31 1998, the President of the Russian Federation signed a decree on the introduction of the Su-33 into military service. This event summed up the many years of hard work done by the engineers, designers, scientists, workers and other specialists of the Sukhoi Design Bureau, the production plant in Komsomolsk-on-Amur, a large number of related enterprises, plants, institutes and military organizations, all to create the first Russian carrier-based fighter.

279th Separate Shipborne Fighter Aviation Regiment

The first four Su-33 fighters arrived at the Northern Fleet, to the home port of the Admiral Kuznetsov aircraft carrier, on April 5, 1993. With their arrival began the practical stage of creating the first Russian naval air group, with supersonic fixed-wing fighter aircraft. In February 1992 it was decided to organize the air wing of Kuznetsov in the form of a compound air division: the 57th Smolensk Red Banner Mixed Airborne Division, consisting of the 279th Naval Fighter Aviation Regiment, equipped with the new Su-33 fighters, and the 830th shipborne antisubmarine helicopter regiment, equipped with the Ka-27, Ka-27PS and Ka-29 helicopters.

The ship-borne Su-33 fighters were slated to join two squadrons of the 279th Naval Fighter Aviation Regiment of the Northern Fleet Air Force.

GENERAL DESIGN

GENERAL DESIGN

Design

The Su-33 is built according to a normal aerodynamic scheme with additional front pylons and has an integrated configuration.

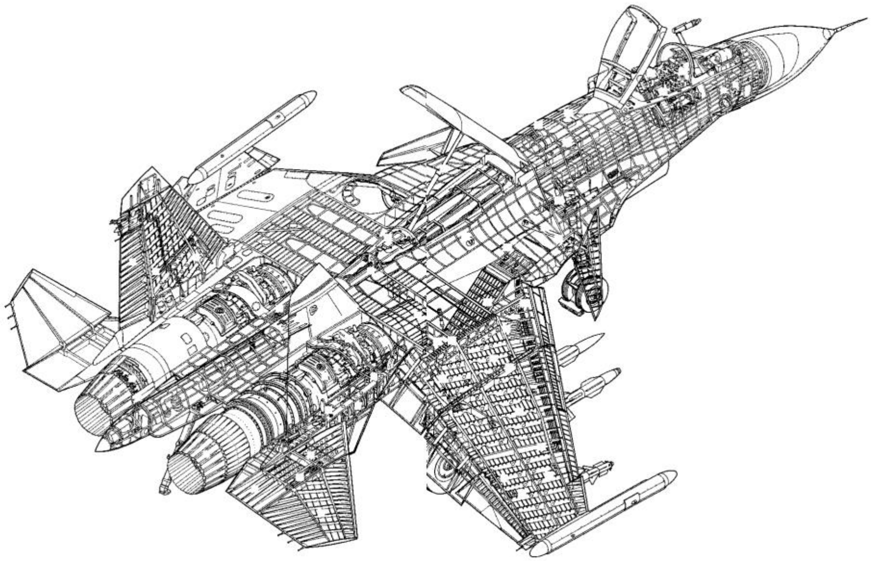


Figure 2: Su-33 cutaway

The central trapezoidal wing with a small elongation, equipped with leading-edge extensions, smoothly joins with the fuselage, forming a single load-bearing body. Two AL-31F 3rd series two-circuit turbojet engines with afterburners are placed in separate nacelles placed under the aircraft's chassis separately from each other such that it eliminates their aerodynamic interference and allows for the placement of the aircraft's weapons, as well as the buddy refueling system, in the space between. The variable supersonic air intakes are located under the center wing and are equipped with a protective device that prevents foreign object debris from entering the engines during the aircraft's take-off and landing modes.

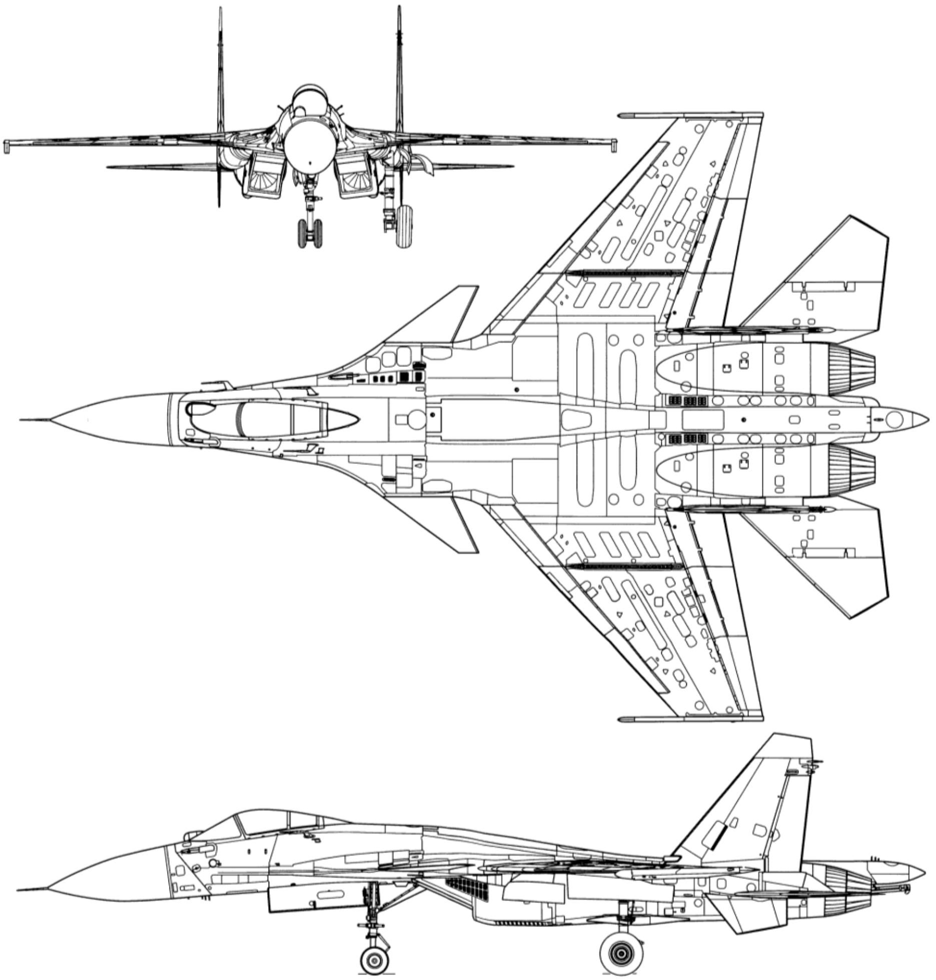


Figure 3: Su-33 drawings

The fairings of the chassis smoothly transition into the tail beams, serving as platforms for the installation of: all-moving stabilizer panels with a straight axis of rotation, two-kilo tail fins spaced apart from the outer edges of the tail stinger, and underside fins. The panels of the all-moving front canards, installed on the leading edge root extension of the wing, serve to increase the load-bearing properties of the airframe and improve the flight characteristics of the aircraft at large angles of attack. To reduce the size of the aircraft during storage in the ship hangar and parking at the technical positions of the upper deck, the wing and horizontal tail units can be folded. The aircraft is equipped with a retractable three-point undercarriage with telescopic struts on the main and front supports, with one brake wheel on each main support and a controllable two-wheel front support. To ensure landing on the ship's arrestor system, the aircraft is equipped with an arrestor hook.

The aircraft is designed according to the concept of "electronic stability" and does not have a traditional mechanical control system - instead, it uses an electrical remote control system, also known as the "Fly-by-Wire" system. The basic control surfaces of the aircraft are: an all-moving tailplane with the possibility of differential deflection of the panels for roll control, all-moving front canards, rudders and flaperons. Two-section single-slot flaps, flaperons and three-section deflectable wing leading edges make up the adaptive wing mechanization, the automatic deflection of which increases the bearing properties of the wing during all modes of flight.

Figure 4: Su-33 in the Severomorsk airbase

The flaperons act as the aircraft's flaps and ailerons. In flight mode, the differential deflection of the flaperons, determined by the deviation of the aircraft's control stick, provides control of the fighter along the roll axis (together with the differential deflection of the stabilizer halves), and their in-phase deviation from the signals of the automatic control system, depending on the angle of attack, increases the bearing properties of the wing. In the takeoff and landing modes, the flaperons are deflected synchronously at a fixed angle, as flaps, and their differential deflection, determined by the position of the control stick, controls the aircraft along the roll axis.

For effective braking of the aircraft during combat maneuvering and landing, a large airbrake panel is installed on the upper surface of the fuselage behind the cockpit.

The aircraft's fuselage is integrated into the wings and is technologically divided into the following main parts:

- The head/frontal part of the fuselage;
- The central section of the fuselage;
- The tail section of the fuselage;
- The air intakes.

The frontal part of the fuselage is of an all-metal semi-monocoque design, beginning with the radio-transparent axisymmetric fairing of the antenna of the on-board radar, includes the nose compartment that houses the radar system as well as the Infra-red Search and Track system and the mid-air refueling boom. Located in this section of the fuselage are also the cockpit, the electrical systems underneath and behind the cockpit, as well as the housing of the undercarriage's frontal strut. The Pitot tube is installed in the nose section of the radar housing, angled downwards from the construction of the fuselage by an angle of 7.5˚. For maintenance access to the antenna and radar, the attachment frame (#1) located between the nose compartment and the radar-transparent housing is built inclined, and the radio-transparent housing with the metallic nouse is inclined upwards. The monoblock frame of the radar system, together with the antenna with the raised radar-transparent cone, can be extended to provide access to the radar and IRST units. To reduce the size of the aircraft during storage in the aircraft carrier's hangar bays, the Pitot tube system may be folded.

Figure 5: Cockpit and canopy

The pilot cockpit is hermetically sealed and has a two-section canopy consisting of the fixed frontal section (the windshield), and a separate deployable rear section that may be jettisoned in emergency situations (either during ejection or manually by the pilot.) This separate rear section also has three rear-view mirrors mounted on it. The canopy protects the pilot from the harsh flight environment, and, thanks to the large cockpit glass area and the presence of rear-view mirrors, provides an almost circular view. The cockpit provides a forward viewing angle of 14˚ downward.

The front part of the canopy, glazed with plexiglass, can withstand bird impacts of a weight of 1.8 kg at speeds of 450 km/h without causing damage to the windshield. To prevent windshield icing, an alcohol-based de-icing system is used.

The pilot's seating is equipped with a K-36DM 2-second ejection seat installed with a backrest angle of 17° towards the back of cockpit. The IRST station is installed just in front and a little to the right side of the cockpit's windshield. Emergency (duplicate) Pitot tubes are also located along the sides of the fuselage, to the rear of the cockpit.

Figure 6: Su-33 starboard

The cockpit canopy consists of a fixed front part with a central framing, and two rear sections (left and right). The latter may be removed during operation for maintenance and dismantling of the ejection seats, for the purposes of emergency ejection, or during flight without having to engage the ejection process.

Two blocks of radio electronic equipment are housed in the compartments located under the cockpit (one central and two lateral). The frontal section of the fuselage is completed by a cramped compartment, in which the main bulk of radio electronic equipment, as well as the ammunition compartment for the built-in gun, is located. The undercarriage housing for the frontal undercarriage strut is also located in the rear-cockpit compartment of the frontal fuselage section.

The walls of the rear-cockpit compartment connect to the port and starboard leading edge root extensions. The starboard side houses the GSh-301 30mm built-in rapid-fire cannon with a system for ammunition loading, spent cartridge ejection and clip collection; A cartridge box housing the gun ammunition is installed across the cramped compartment and occupies part of LERX and the rear-cockpit compartment. The starboard side also contains special slits and gills for gun cooling and for shielding the chassis from the incandescent gases produced when firing the gun in the area of the gun barrel slit. A panel made of heat-resistant steel is installed just in front of the gun barrel. The port side LERX houses the aircraft systems and electronic equipment units. The forward canard panels (with a straight angle of rotation) are installed on the front edges of the LERX.

The frontal section of the fuselage in the design is an all-metal semi-monocoque with an integrated surface.

The central part of the fuselage is divided into the following technological compartments:

- The frontal fuel tank (compartment No.1), located along the axis of symmetry of the aircraft between the head of the fuselage and the center wing;
- the center wing (the main load bearing surface of the aircraft), shaped in the form of a fuel tank (compartment No. 2) with transverse walls and a row of ribs. The upper and lower surfaces of the central wing are made in the form of panels (the top panel is milled and constructed from aluminum alloys; the bottom is welded and is made of sheets of titanium alloy);
- The central fuselage fairing, which is a compartment designed to accommodate the communications and equipment installation;
- the frontal compartment of the central wing (right and left) is located on the outer sides of the frontal fuel tank / compartment No. 1 and consists of the central wing leading edges and the and main landing gear housing.

Figure 7: Su-33 takeoff

On the upper surface of the central fuselage, a membrane-free airbrake panel (with an area of 2.6 m^2) is deployed by means of the hydraulic drive. The angle of deflection of the shield is 60° upwards. The release of the brake panel is used to reduce airspeeds during landing approach and during combat maneuvering at instrument speeds of up to 1000 km/h.

The rear section of the fuselage is divided into the following technological compartments:

- Two engine power pods, each of which is divided into two parts;

- tail beams adjacent to the outer sides of the engine nacelles: these beams are a continuation of the housing compartment of the main landing gear and serve as a platform for installing the tailfins of the aircraft;
- The central fuselage beam, which includes the central equipment compartment, the rear fuel tank (compartment No. 4), the end of the central stinger and the side fins.

Figure 8: Su-33 Engines

The engine air intakes of the Su-33 are located in the central parts of the engine nacelles located under the central wing; On the main frame of each middle section is a lock that engages when the main undercarriage struts are deployed; on the lower surface are the weapon suspension hardpoints; in the upper outer corners are the aggregates and communication lines of the aircraft systems.

The engine compartments are equipped with AL-31F ser. 3 engines with a top arrangement of the remote accessory gearbox. A turbo starter, an alternator, a hydraulic pump and a fuel pump.

The engine installed in the motor compartment is removed from the aircraft back-down by means of a special trolley; The tail cone is made detachable in order to facilitate the replacement of the engine. When the engines are dismantled, the remote accessory gearboxes remain on the aircraft. This reduces the engine replacement time. Operational hatches to provide access to the remote accessory gearbox and the main engine assemblies are located in the upper part of the motorized sections. The engine nacelles have a semi-monocoque scheme with a load-bearing skin, reinforced with a transverse set (by means of frames) and a longitudinal set (by means of stringers).

The rear part of the tail beams (on both sides) is load-bearing; on its upper surface are nodes for supporting the vertical and horizontal tailfins, as well as the stabilizer servos. Compartments for aircraft equipment are located in the tail beams, just in front of their load-bearing sections.

Aircraft systems equipment and propulsion systems are housed in the central compartment of the central tail stinger. On the lower surface of the central stinger are weapon hardpoints and the attachment point for the arrestor hook that is released when landing on the carrier's arrestor system. To minimize the size of the aircraft during storage in the hangars of the aircraft carrier, the tip of the stinger is made to fold upwards.

Engine Air Intakes

The engine air intakes are variable intakes of rectangular section, placed under the wing LERX and equipped with protective devices to prevent foreign object debris from entering the engines during take-off and landing modes. The placement of the air intake braking surfaces is horizontal: the braking wedge moves away from the surface of the load-bearing chassis, and a gap is formed between the wing and the wedge for draining the boundary layer.

Figure 9: Air Intakes

The suction relief doors are located on the bottom surface of the air intakes in the area where the protective device is located. The valves are "floating", i.e. they open and close in response to drops in pressure.

To bypass the boundary layers of air, a special perforation is provided on the outer and inner side walls of each air intake, which is closed from the outside by panels with profiled slots. Optimal supersonic diffusion in the diffuser of the air intake is provided by the installation of its adjustable elements in positions calculated by the automatic control system of the air intake. The position of the adjustable air intake panels, as well as that of the safety devices, is indicated in the pilot's cabin on special signs and placards.

The protective device of each air intake is a perforated titanium panel with a large number of holes, 2.5 x 2.5 mm in size. Release of the air intake safety devices for landing and their removal on take-off occurs automatically, tied to the signal from the undercarriage strut compression. In the released position, the panels of the protective device covers the whole cross section of the air intake and thereby prevents foreign objects from entering the engine from the surface of the runway (or, in the case of the Su-33, the carrier flight deck) during landing and takeoff runs, and during taxiing. In flight, the panels of the protective devices in the retracted position are pressed against the bottom surface of the air intake duct. The mesh is deployed along the current by means of hydraulic cylinders; The axis of rotation is located behind the inlet throat in the diffuser part of the channel.

The aircraft's wings are free-bearing. The detachable parts (panels) of the wings have a sweep angle along the leading edge of 42.5° and are made from a P44M type structural stock with a relative thickness of 4.9% (in the root) and 4.0% (at the end). The wing aspect ratio is 3.48, while the constriction is 3.76. The base area of the wing is 67.84 m^2, whereas the wingspan is 14.7 m (with the suspension of missiles on the wingtip hardpoints - 14.948 m).

The wing mechanization consists of the flaperons (hovering ailerons) with an area of 2.4 m^2 acting as flaps and ailerons, along with two-piece single-flaps of 6.6 m^2 and a three-section leading edge of 5.4 m^2.

The flaperons have in-flight deflection angles of +15 to -20°. In the take-off configuration: + 15 ... -25° (with a hang angle of -14°). The flap release angle at take-off is 15/25°, where the leading edge angle is 0 - 30 °. The release of flaperons (in flap mode) and the deflection of the leading edge in flight is performed to increase the bearing properties of the wing when maneuvering at instrument speeds of up to 860 km / h.

To reduce the dimensions of the aircraft when parked on the deck or stored in the hangar of the aircraft carrier, the wings are folded. The overall width of the aircraft with folded wingtips is reduced to 7.4 m, from the 14.7m with wingtips deployed. Folding the wingtips is done by means of the hydraulic system. The hydraulic control cylinders that are responsible for folding the wingtips is located in the fixed parts of the panels.

Structurally, each wing panel consists of power cells of the fixed and rotary (folding) parts, bow and tail sections, mechanization and ends. The cells of the fixed part of the wing and the part of the cells of the turning part of the wing are hermetically sealed and form fuel tank-compartments.

An additional hardpoint is installed on each wingtip for mounting either one short-range air-to-air missile or one active jamming pod per hardpoint. The weight of each jamming pod is 205 kg, with a length of 4200 mm and a diameter of 300 mm.

Wings

The wings of the aircraft consist of two panels of an all-moving differentially deflecting stabilizer with a straight axis of rotation and bearing arrangement in the panels of the wings. The strutted beams of the stabilizer are fixed in place in the tail beams of the fuselage.

Figure 10: Su-33 with folded wings

The horizontal wing panels have a trapezoidal shape (with a sweep angle along the leading edge of 45 °). The stabilizer wingspan is 9.9 m, with an area of 12.3 m^2. The angle of the dihedral of the wings is 0°. The deflection angles of the stabilizer are +15 to -20˚. For roll control, a differential deviation of the halves of the wings of ± 10° is possible. The deflection of the stabilizers is powered by the hydraulic drive.

To reduce the dimensions of the aircraft when it is stored in the ship hangars, the wings are foldable to half their span.

Horizontal Canard

Figure 11: Canards

The canard of the aircraft are installed at the end of the leading edge root extensions of the wing and consist of two all-moving panels with a span of 6.43 m and an area of 2.99 m^2. The sweep angle along the leading edge of the panels is 53.5°. The angle of the dihedral of the panels is 4.7°. The canards' deflection angles are +3.5 to -51.5°. The canards' hydraulic drives are placed in the LERX of the wing.

Vertical Fins

The vertical tailfins of the aircraft are composed of two arrow-shaped fins with a sweep angle of 40° along the leading edge and an area of 15.1 m2. The fins are installed with a camber angle of 0°. Each fin is equipped with a rudder (the area of the two rudders is 3.49 m2, with deflection angles of ± 25° in each direction). In the upper part of the fins, equipped with fiberglass tips, and along their leading edge under the radio-transparent fairings are antennas of various radio engineering devices.

The movement of the rudders is powered by blocks of hydraulic cylinders installed inside the fins. Each rudder is controlled by one cylinder block.

To improve the aircraft's anti-stall characteristics and to increase its directional stability, two sub-beam ridges with an area of 2.47 m^2 with a sweep angle of 38 ° along the leading edge are installed under the tail beams.

The aircraft has a retractable three-way undercarriage, with a controllable frontal strut. The main struts equipped with telescopic racks each have one brake wheel with dimensions of 1030 x 350 mm.

The frontal strut is telescopic and has two non-braking wheels with dimensions of 620 x 180 mm. The control of the front strut is powered by the hydraulic steering-damping mechanism installed on it: this allows the aircraft to make maneuvers with a very small turning radius during taxiing. The turn angles of the frontal strut in control mode is ± 45°, while in aerotowing (self-orientation) mode it is ± 70°.

Figure 12: Su-33 Tail

All chassis supports are retracted forwards during the flight: the main struts fold into the niches of the central wing, while the frontal strut enters the compartment located under the frontal section of the fuselage, under the cockpit. Hydromechanical locks keep the undercarriage in place while in flight.

The undercarriage deployment/retraction system is hydraulically-powered. In case of failure, an emergency pneumatic system is used to deploy the undercarriage by means of compressed nitrogen. The braking of the wheels of the main undercarriage strut during taxiing and the landing roll, as well as the automatic braking of the wheels during retraction, are all powered by the hydraulic system.

The undercarriage shock absorption system is pneumohydraulic. Two landing lights and one taxiing light are attached to the front landing gear of the undercarriage, as well as a three-color signaling device used for landing on the ship.

The Su-33 aircraft's take-off and landing equipment also includes an arrestor hook used to forcefully stop the aircraft upon touchdown on the deck and successful contact with the arrestor system. Deployment and retraction of the hook is powered by the hydraulic system by means of a damper-hoist installed between the hook frame and the fuselage. In the retracted position, the hook is held by a hydromechanical lock. For stable engagement with the cables of the arrestor system and prevention of the "bouncing" of the hook when it strikes against the deck during landing, a damping device of the damper-hoist is used. If the hydraulic deployment system fails, the hook can be released during landing by means of the backup pneumatic system.

The undercarriage and arrestor hook deployment status is shown by the corresponding status indicator located in the pilot cabin.

Power Plant and General Aircraft Equipment

The power plant of the aircraft consists of two AL-31F ser. 3 two-circuit turbojet engines with afterburners, air intakes with adjustable panels, suction relief doors, air ducts and a control system; an engine cooling system; remote accessory gearboxes containing the gas turbine starters; a fuel system; engine protection from foreign object debris; fire fighting system; de-icing system and engine monitoring system.

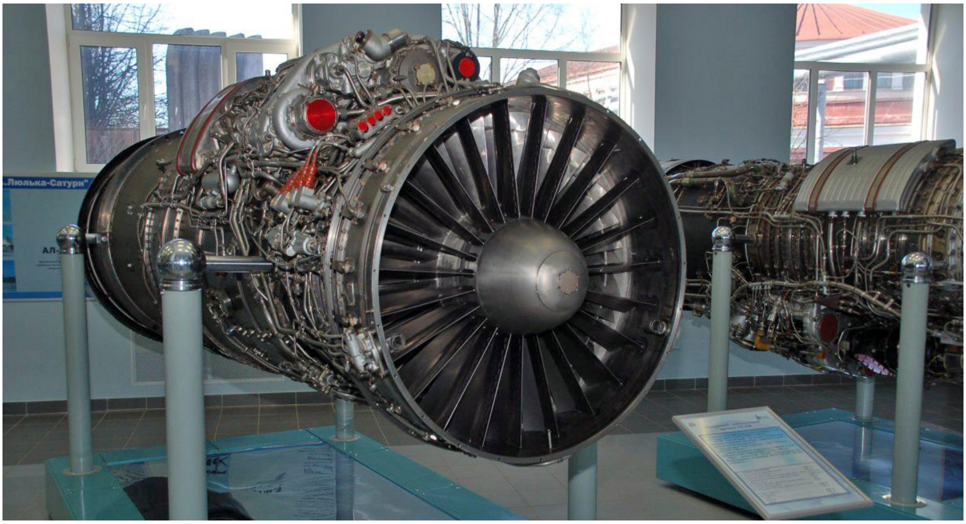


Figure 13: AL-31F Engine

The general aircraft equipment includes:

- Hydraulic system;
- Pneumatic system;
- Power supply system;

- Aircraft control system;
- Lighting equipment;
- Power supply system for aneroid-membrane devices;
- Life-support systems and cooling equipment;
- Emergency ejection system;
- Cockpit instrumentation systems.

The AL-31F ser. 3 engine has a modular design and consists of a 4-stage low-pressure (fan) compressor with variable inlet guide vanes, an intermediate housing with a central drive box, a 9-stage high-pressure compressor, an external circuit, an annular combustion chamber, an air-to-air heat exchanger in the turbine cooling system, single-stage cooled high-pressure turbine, single-stage low-pressure cooled turbine, an afterburner, supersonic jet nozzles, plus the gearbox and its components located on the top of the engine.

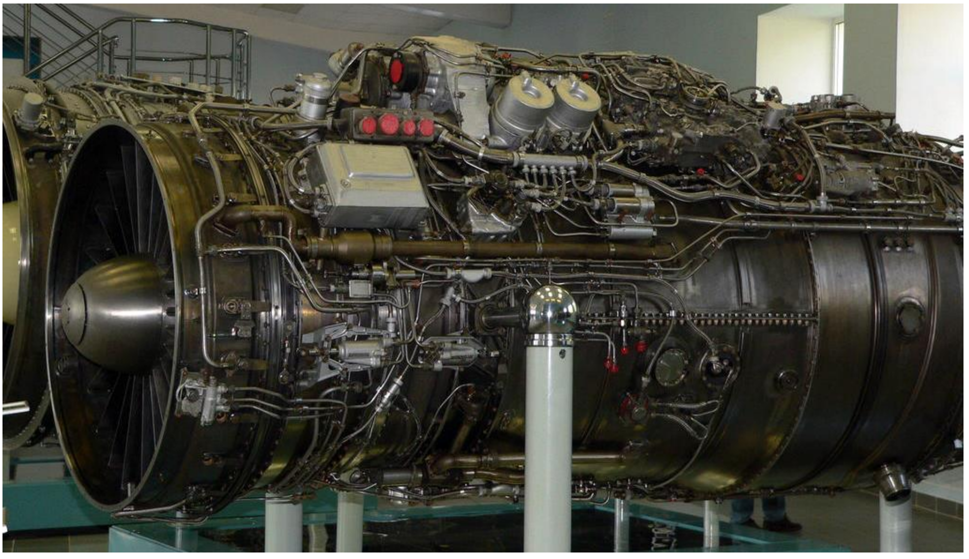


Figure 14: AL-31F Engine

The engine produces a booster thrust of 12,500 kgf in the full afterburner mode and 7670 kgf at maximum rating. One of the main differences between the AL-31F series 3 engine and the AL-31F engines (series 1 and 2) used on other SU-27 aircraft is the introduction of an additional special emergency mode, in which engine thrust rises to 12,800 kgf . This mode can be used for a short time to ensure successful take-off of the naval fighter with full combat load from the flight deck of the carrier, or for emergency missed approaches during landing. The increase in thrust during emergency mode is achieved by increasing the temperature of the gases in front of the turbine.

The thrust of the engine during minimum afterburner operation is 8450 kgf; during minimum fuel consumption mode it is 3500-4400 kgf, while it is 250 kgf during idle mode.

The specific fuel consumption of the AL-31F ser. 3 engine at its maximum operating mode is 0.75 kg / (kgf*h); in the full afterburner mode, the fuel consumption is 1.92 kg /(kgf*h). The minimum cruising specific fuel consumption is 0.685 kg / (kgf-h). The acceleration time of the engine under standard atmospheric conditions does not exceed: 3-5 seconds from idle to maximum, 7 seconds from idle to full afterburner, and 60-80 seconds from the beginning of the engine startup process to full afterburner.

Figure 15: AL-31F Nozzle

The AL-31F high-pressure two-stage compressor engine provides a degree of compression of incoming air of 23.8 at its flow rate of 112 kg/s and a bypass rate of about 0.57. The temperature of the gases in front of the turbine at its maximum rating and full afterburner modes reaches 1665 K. The dry weight of the engine is 1520 kg (in its 'delivery state', with the remote accessory gearbox, the turbo starter and the electronic engine control unit this weight is not more than 1920 kg), with a specific gravity of 0.122.

The overall length of the engine is 4950 mm with a maximum diameter of 1180 mm. The diameter of its intake is 905 mm. The service life of the AL-31F ser. 3 engine before the first repair is 500 h, while its assigned service life is 1000 h.

The jet engine has a convergent-divergent nozzle. To ensure that the trust vector of the engine remains near the center of gravity of the aircraft, the axis of the jet nozzle in the vertical plane is inclined relative to the motor axis by 5 °.

The oil system of the closed-type engine is unified with the oil system of the remote accessory gearbox. The AL-31F ser. 3 engine consumes the following types of jet fuel: RT, TS-1, (or their mixtures).

The engine control system is hydroelectronic with analog electronic limiter. It ensures: the maintenance of the set parameters of engine operation in the steady and transitional modes in all operating conditions of the aircraft, automatic surge protection of the engine (e.g. during the usage of aircraft weaponry), the transmission of necessary information to the pilot and the emergency recorder, as well as to the built-in ground and in-flight self-control system.

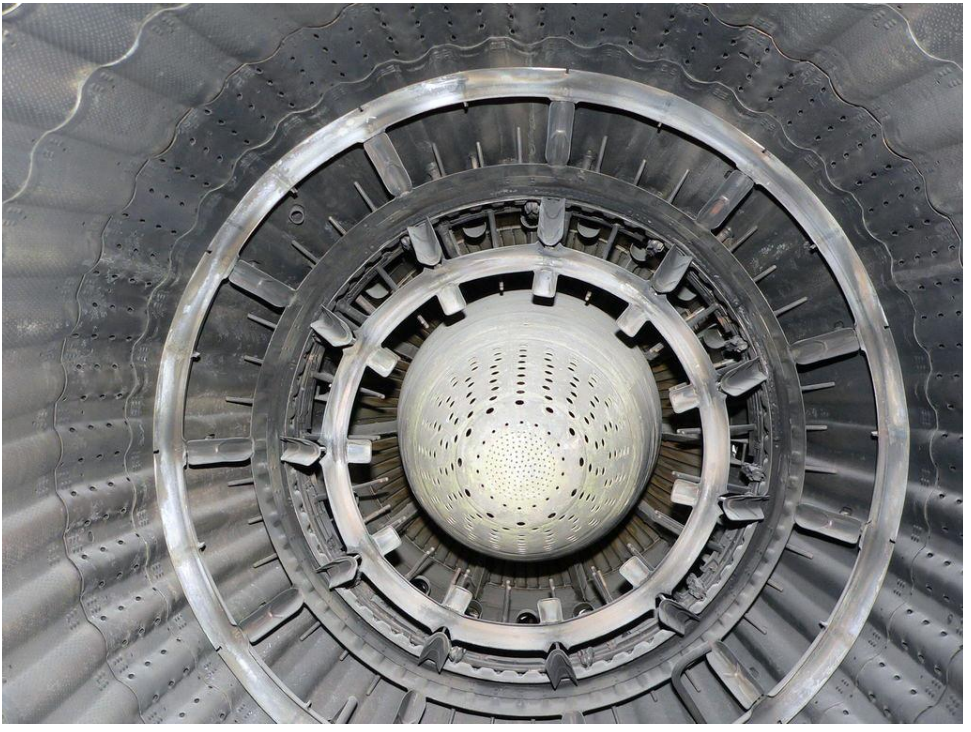


Figure 16: AL-31F Afterburner Duct

Control over the operating modes of the powerplant is provided by the skid-type throttle lever located on the left side of the pilot cabin and connected to the levers of the pump-regulators of the engines by means of mechanical cable wiring.

The start of the two engines can be carried out either sequentially or simultaneously. The spin-up of the engine rotors, when started up on the ground, is provided by gas turbine starters, which in turn are started by electric starters, the voltage to which is supplied either from ground-based power sources or from storage batteries. Airborne engine-startup occurs when their rotors rotate under the influence of the oncoming air flow in the autorotation mode, and reliable start-up is possible practically throughout the entire range of the aircraft's flight speeds. It may occur automatically (if the engine switches off spontaneously), semi-automatically (after pulling the throttle to "Stop" and then back to "Idle" during rundown or windmilling) or forced (with the help of the duplicate start switches in the cockpit). There is also a system for engine relighting in the event of a drop in their speed below a certain level during the usage of aircraft weapons (i.e. during missile launch.) The engines are started in the air with an oxygen boost.

The aircraft's fuel system is designed to house the aircraft's fuel load, to provide uninterrupted power to the engines in all modes of operation both in the air and on the ground, to ensure that the aircraft's center of gravity remains within design parameters, and to provide cooling of the air, oil and other special fluids in the heat exchangers. It includes four tanks: are sealed compartments of the frame construction: tank No. 1 is located in the front of the central wing; tank no. 2 is located in main part of the center wing with two side compartments in the left and right fixed parts of the wing; tank no. 3 is comprised of two compartments in the left and right folding sections of the wing; and finally, tank no. 4 is located in the tail section of the fuselage, between the left and right engine compartments. In addition, the fuel system includes a refuelling subsystem, a propellant feed subsystem, and subsystems for the hydraulic pump drives and for feeding active fuel to the jet pumps, for pumping fuel through the radiators, for draining fuel, boosting and draining the fuel tanks, mid-air refueling, and finally, instruments and devices for monitoring and control. The total fuel reserve in the internal tanks of the Su-33 is 9500 kg (about 12 100 liters at a fuel density of 0.785 kg / dm^3).

Fuel is supplied to the engines from the fuel reservoir of tank number 2. The feed to the motor pumps carried out by two hydraulic turbines through the flow collector along two flow lines. There are fuel flow sensors in each flow line, and fuel emergency shutoff cocks in front of the engine compartments. During engine startup on the ground, the fuel is fed to the flow lines by a DC electric pump installed in the fuel reservoir of tank No. 2. Under the influence of negative and near-zero G-forces, fuel is supplied to the flow line from the storage tank and from the reservoir of tank No. 2, which, due to the installation of a booster pump raised from the bottom serves as a fuel compartment for use in flight under negative G-forces. Reliable operation of the engines is nevertheless ensured during all combat flight maneouvers performed by the aircraft, including those with negative G-loads of 0 to -3.

To obtain the necessary characteristics of stability and maneouverability of the aircraft, the consumption of fuel from the tanks is carried out in a certain sequence, ensuring that the aircraft maintains its designed center of gravity. First to be consumed would be 2/3 of the capacity of tank No. 1 and the entirety of tank No. 4, after which the remaining fuel in tank No. 1 is consumed completely. Following this, part of the fuel is drained from the front compartment of tank No. 2 and tank No. 3 is drained completely. Tank number 2 will be the last tank to be drained, with the exception of its fuel reservoir, which is then drained after tank number 2 is empty. The fill status of the fuel tanks and the current fuel balance are indicated on the fuel gauge located in the pilot cockpit.

The main way of fueling the fuel tanks of the Su-33 is by means of a centralized pressurized fueling system through a unified pressure fueling coupling. At the same time, the fuel supply to the aircraft tanks from the tanker stops ceases after the tanks reach maximum capacity. Also possible are refuelling modes ending with the incomplete filling of the fuel tanks, but without automatic termination of the fuel transfer process. The backup version of refuelling by an open refuelling process performed through the filler necks of the 1st, 2nd and 4th tanks, and the right and left compartments of tank No. 3. At the same time, the fuel level is determined visually the filler necks of the tanks and according to the flowmeter of the tanker.

To increase the range and duration of continuous flight, the Su-33 is equipped with a mid-air refueling system with the "hose-cone" scheme. Refuelling can be carried out from Il-78 tankers and from the same type of Su-33 fighters equipped with the UAPAZ-1 type buddy refuelling pod with a fuel transfer rate of up to 2000 L / min. Refuelling can be performed at altitudes of 2000-6000 m and at a flight speed of 450-550 km / h, at any time of the day.

To facilitate the aircraft's approach and contact with the tanker, the automatic control system of the Su-33 has a special "Refuelling" control mode. In the case of the use of the Su-33 fighter as a tanker aircraft, it is equipped with the UPAZ-1 buddy refuelling pod suspended on the 1st hardpoint under the central wing.

To facilitate the Su-33's emergency landings on the deck of the carrier, the aircraft has the option of draining its fuel while in flight, carried out from the afterburner pumps of the engines through the aggregates and emergency discharge collectors installed on the engines.

To create conditions for the cavitation-free operation of the fuel pumps, and to ensure the operation of the storage tank and the consumption of the contents of tank No. 3, excess pressure is maintained in the fuel tanks of the aircraft during all flight modes.

Fuel on the Su-33 is also used to cool the air in the air-conditioning system, the oil of the generator cooling systems, and the hydraulic fluid by pumping through the fuel-air and fuel-oil radiators (heat exchangers).

Information about the supply and consumption of fuel is provided by the fuel content gauging system with a display panel on the dashboard of the pilot. The system calculates and displays the remaining amount of fuel (in the flowmeter mode), signals the exhaustion of fuel in individual tanks, measures and provides information about the fuel supply in the tank No. 2 reservoir, generates control signals for refueling on the ground, refueling in the air, fuel pumping to the engines and between tanks. The pilot receives information about the remaining fuel load on the indicator; fuel tank exhaustion and the emergency fuel load are shown by indicator lights and signals. The reserve fuel status signal is also duplicated by the "Almaz" voice warning system.

The aircraft's hydraulic system consists of two independent closed-type hydraulic systems (first and second) with a working pressure of 280 kgf/cm^2 and a drive connection each from its own engine (the first from the left engine, the second from the right engine). The energy sources in each hydraulic system are piston-type pumps of variable capacity, installed on the remote accessory gearboxes of the corresponding engines. The operating fluid of the hydraulic system is the AMG-10 hydraulic fluid.

The first and second hydraulic systems provide a parallel operation of the steering drives of the stabilizers, front canards, rudders, flaperons, flaps and droppable leading edges.

In addition, the first hydraulic system facilitates and/or provides: the deployment and retraction of the undercarriage, the opening and closing of the doors of the undercarriage hatches; automatic braking of the wheels of the main undercarriage struts during their retraction; startup and emergency braking of the wheels on the main landing gear; control of the frontal undercarriage strut; control of the air-intake wedge and its protective device; the folding of the wing and horizontal tailfins, as well as the tail stinger; it also powers the pedal limiters. For parking and towing brake functions, the energy of the hydraulic accumulator of the first hydraulic system is used, which is charged on the ground by means of the hand pump in the niche of the left main landing gear.

The second hydraulic system provides and/or facilitates: the main brakes on the wheels of the main landing gear; control of the wedge and protective device of the right air intake; deployment and retraction of the airbrake, landing hook and refueling boom.

The pneumatic system of the aircraft is a backup system and provides operation to several consumers of the hydraulic system in case of its failure. Autonomous emergency pneumatic systems provide the emergency release of the undercarriage, landing hook and refuelling boom. In addition, the pneumatic system on the aircraft is used to open and close the cockpit's canopy. The operational fluid of the pneumatic system is high-pressure technical nitrogen. The nominal pressure in the pneumatic system is 210 kgf/cm^2.

The aircraft power supply system consists of a three-phase alternating current system with a voltage of 115/200 V and a frequency of 400 Hz, and a direct current system with a voltage of 27 V. The AC supply system consists of two independent channels operating separately. The main sources of electricity in each of them are one AC drive generator with a nominal power of 30 kVA installed on the remote accessory gearboxes of the left and right engine assemblies. The generator drives supply separate busbars and are able to operate in overload mode (up to 150%) for 2 hours, which, in the case of failure of either is sufficient for the aircraft's power needs almost without restrictions on the load of the electrical system. The AC power sources' backups are the static DC converters from the storage batteries to a three-phase current of 115/200 V, 400 Hz, with power values of 800 VA (per channel). They are automatically connected to the emergency buses of their channel in the event of generator drive failure and ensure the operation of the minimum amount of equipment necessary for successful completion of the flight.

The DC power system also has two independent channels. The main sources of electric power in each of them are rectifiers of 6 kW each, transforming the alternating current generated by the generator drives into a constant voltage of 27 V. The backup direct current power sources are two nickel-cadmium batteries with a nominal voltage of 24 V and a capacity of 25 Ampere hours each. These are also used to start the turbo-starters in the absence of external airfield power.

During normal operation of the power supply system, the generators and rectifiers provide power to all the aircraft equipment (with a maximum load of 60 kVA in the AC circuit, and 12 kW in the DC circuit). If one of the generators fails, the second one can be set to output in overload mode (with an output power of up to 45 kVA), and the remaining rectifier, after the failure of the first one, can output 7.2 kW in the overload mode. If both drive generators and rectifiers fail, the batteries and converters provide power to the consumers connected to the direct and alternating current emergency buses respectively (in such cases the maximum load in the AC circuit is 1.6 kVA). Such a construction of the power supply system ensures the successful completion of the flight even with several failures of individual subsystems and electrical equipment assemblies.

Connection of the aircraft's power system to external AC power sources located on either the airfield or on the aircraft carrier is provided by an airfield power connector that meets international standards.

The aircraft control system includes an electrical Fly-by-Wire system, an automatic control system (ACS), which is part of the PNK-10K flight control and navigation complex, and a mechanical part of the control system. The structure of the Fly-by-Wire system includes redundant calculators, redundant position and flight sensors, leading edge servos, a limiter for marginal conditions and of the front canards, electrohydraulic actuators of the stabilizer, flaperon and rudder panels, as well as control and monitoring panels. The structure of the automatic control system includes calculators, sensors and the autothrottle actuator. The mechanical part of the control system includes the control surfaces (control stick and rudder pedals) equipped with loading and trimming mechanisms, as well as the mechanical wiring of the wings and canards in the wing control channels.

The aircraft may be controlled in the manual and automatic modes. Manual control of the aircraft is performed using the control stick (for elevator and aileron control) and pedals (for yaw control). Trim settings for in the longitudinal and lateral axes may be adjusted by means of a four-axis button located on the handle; trim settings for the directional axis are likewise adjusted by means of a separate pressure switch.

The movement of the control stick and the yaw pedals is measured by sensors whose electrical signals are fed to the computers of their respective channels.

In automatic mode, aircraft control is carried out by the signals of the SAU-10K automatic control system. Automatic control mode is activated by means of the push-light-switch on the flight-navigation complex.

The SDU-10K Fly-By-Wire system with four-fold redundancy provides manual control over the aircraft while the system's calculators convert according to the specified algorithms the electrical signals, received from the control levers' movement sensors and the flight parameters sensors, to signals controlling the control surface actuators. The Fly-by-Wire system provides the following:

- management of a statically unstable aircraft in the longitudinal, lateral, and directional axes;
- the required stability and controllability in all axes;
- automatic deflection of the wing and flaperon leading edges depending on the aircraft's angle of attack and flight mode;
- automatic deflection of the front canards depending on the aircraft's angle of attack, flight speed and deviation of the flight stick;
- the formation of restriction signals on the aircraft's control stick when the G-force and angle of attack values exceed those that are permissible for the current configuration and the flight weight of the aircraft;
- reduction of aerodynamic loads on the design of the airframe;
- special control mode of the aircraft when performing mid-air refueling;
- flight control by the ACS signals.

The CDS remains operational even after two consecutive failures. Flight conditions are ensured at large angles of attack after a single failure in the leading edge control channel. In the takeoff and landing modes, the control algorithms for the fly-by-wire system differ from those for regular flight. The switch of algorithms is performed automatically by the undercarriage deployment and retraction signals. The activation of the system's refuelling mode is manually carried out by the pilot.

Longitudinal control of the aircraft is facilitated by the fly-by-wire system according to the commands received during longitudinal deflection of the control stick, and according to the parameters of the longitudinal movement of the aircraft - angle of attack, angular pitch velocity, normal acceleration, etc., all of which are corrected according to the flight modes depending on the impact air pressure and static pressure.

The generated signals produce in-phase deviation of the stabilizer, flaperon, canard and leading edge panels.

Limitations for the angle of attack and normal G-force in any of the flight modes is achieved by limiting the longitudinal deflection of the control knob when the angle of attack or G-forces for this mode are exceeded. Overpowering the spring stop makes it possible to exceed the limits for the angle of attack and G-load.

Lateral control of the aircraft is carried out according to the commands received during lateral deflection of the control stick and according to the signals of the sensors for roll angular velocity, which are corrected depending on the impact air pressure and static pressure. The stabilizer and flaperons panels deflect differentially according to the signals generated in the fly-by-wire system calculators.

Yaw control is carried out by deflection of the rudders according to the pedal deflection signals, yaw rate sensors and lateral load sensors. The sensor signals are corrected in terms of the impact air pressure, static pressure and angle of attack.

To ensure coordinated control of the roll of the aircraft, the fly-by-wire system employs a crossfeed between the lateral displacement of the control stick and the displacement of the rudders. The crossfeed is adjustable depending on the angle of attack.

The steering surface actuators are heavy-duty hydraulic drives, each of which is connected to two independent aircraft hydraulic systems. Control of the stabilizer, flaperon and rudder panels is carried out by means of redundant electrohydraulic two-circuit drives, the inputs of which receive the electrical signals from the fly-by-wire system. The control parts of the stabilizer and flaperon drives are four times redundant.

The rudders are controlled by duplicated drives, which set the control surface in its neutral position with a maximum of two failures. Following two failures, yaw control is maintained by operating the rudders.

A three-channel servo drive is connected to the power drives of the front canards, and a servo drive is attached to the power drives of the wing leading edges.

Four-channel drives of the stabilizer and flaperon panels, as well as the three-channel servo drive of the canards remain operational even after two consecutive failures. The rudder drives remain functional after one failure. In the event of failure of the wing leading edge servo control, the leading edges are set to maximum deflection to facilitate successful flight at large angles of attack.

The SAU-10K automatic control system, which interacts with the navigation instrumentation, the weapons control system and command guidance equipment, provides automatic control of the aircraft through the Fly-By-Wire system, the drives of which deflect the control surfaces according to the signals given by the automatic control system and the signals used for increasing the stability of the aircraft. The ACS provides:

- stabilization of the angular positions of the aircraft and its flight altitude;
- stabilization of the instrument speed (with the help of the autothrottle system);
- bringing the aircraft on pilot command to horizontal flight from any flight position;
- guidance and attack of air targets according to commands issued by ground, ship and air guidance points, as well as signals from the on-board weapons control system;

- flight along the determined flight path, base approach vector, and landing approaches according to the signals sent by ILS lighthouses in automatic mode up to a height of 50 m;
- flight along the determined flightpath, carrier approach vector, and landing approaches according to the signals sent by shipborne radio equipment before entering the ship's light-based landing systems' zone of effect.

The aircraft's lighting equipment provides illumination of the runway, external signalling lights, lighting of the aircraft's mid-air refueling system boom and the cone of the refuelling hose, as well as in-cockpit lighting.

For illumination of the runway (deck of the ship) during takeoff, landing and taxiing of the aircraft in night conditions or with insufficient visibility in the daytime, one taxi headlight and two landing lights are installed on the landing gear of the undercarriage's frontal strut.

Proper illumination and communication of the dimensions of the fighter and the direction of its flight (during taxiing) to prevent its collisions with other aircraft in the air and on the ground (or on the ship) is provided by the aeronautical lights installed on the tips of the wing panels and on the left vertical tailfin (the left side aerial navigation light is red, the right side light is green, and the tail light is white).

Illumination of the refuelling system hose' cone and the aircraft's refuelling boom during night refueling is provided by two headlights equipped with lamps of 250 W output from both sides of the nose of the fuselage.

Illumination of the instrument dashboard in the cabin is provided by lamps installed above the instruments; the inscriptions on the panels are illuminated by incandescent lamps through the light conductors.

The aircraft's life support systems and cooling equipment are designed to maintain normal atmospheric conditions for pilot survival in the airtight cabin, and the operation of equipment during all flight modes.

The air conditioning system is designed to cool the air coming in for cockpit ventilation, and to cool the electronic equipment of the aircraft. The air for the air conditioning system is taken from the seventh stage of the compressor of each engine. It is subsequently cooled in the air-to-air heat sink, the fuel-air cooler and the turbo-cooling unit.

The cabin pressure control system provides for a gradual build-up of differential pressure in the cabin from 0 to 258 mm Hg during ascents to an altitude of 4700 m, and for maintaining a differential pressure of 258 mm Hg at altitudes of more than 4700 m. The differential pressure in the hermetically sealed cockpit is maintained automatically by adjusting the volume of the exhaust air. The rate of change in pressure in the cabin does not exceed: 10 mm Hg/s during a decrease atmospheric pressure, and 5 mm Hg/s during an increase in atmospheric pressure.

The automatic cabin temperature control system ensures the maintenance of the preset air temperature in the cabin within the limits of 15-25°C and the required air temperature for cooling the electronic equipment units, with temperatures of 5°C at altitudes up to 8000 m, and up to -50°C at altitudes of more than 8000 m.

The electronic equipment liquid cooling system of the aircraft is designed to cool the most heat-stressed elements in electronic units. The necessary temperature profile for the operation of these electronic units is maintained by the system pumping the cooling liquid. The liquid, which is hot while it passes through the cooling blocks, is cooled by fuel in the fuel-liquid heat exchanger. Circulation of the liquid is carried out by means of the pump.

The pilot and aircraft's oxygen dispensing equipment ensure the oxygen supply of the pilot and his G-tolerance to maintain his efficiency in all modes of flight, i.e., when performing high-altitude flights, flights with large G-loads, and during ejection. The oxygen supply system dispenses an oxygen-air mixture in the mask at flight altitudes of up to 8000 m, and pure oxygen at high altitudes. The oxygen supply of the pilot operates for a long time during flights in a sealed cockpit at altitudes up to the operational ceiling of the aircraft; in a depressurized cockpit at altitudes of up to 12,000 m; as well as briefly during depressurization of the cabin at altitudes of more than 12,000 m (for 3 min, and up to 1 min at altitudes of 20,000 m).

The emergency oxygen supply system is located in the ejection seat. It is activated automatically during pilot ejection or manually and can supply the pilot with oxygen during the ejection, parachute dropping, splashdown and floating in the water for a maximum of 3 minutes.

The oxygen supply on board the aircraft is placed in oxygen tanks.

The pilot's protective equipment includes an anti-G suit or or a high-pressure suit with a protective helmet equipped with an oxygen mask. Flights over the sea provide for the use of a high-altitude marine rescue kit instead of the G-suit or high-pressure suit. The pilot's suit provides the pilot with G-force tolerance during all flight modes of the aircraft.

The emergency escape system of the aircraft includes a K-36DM series 2 ejection seat, as well as a pyromechanical control system for jettisoning the canopy and ejecting the pilot. The ejection seat allows for pilot evacuation in all operational ranges of altitude and flight speeds, including during aircraft movement on the tarmac and on the ship deck. Safe ejection is guaranteed during a horizontal flight with instrument speeds from 0 to 1300 km/h (Mach numbers from 0 to 2.5) and at altitudes from 0 to 20 km, maneuvering with G-forces from -2 to +4, at angles of attack of up to ± 30˚, sideslip angles to ± 20˚ and roll angles to ± 180˚, as well as on run-on and roll-off modes at speeds of at least 75 km/h. The minimum altitude for a safe (injury-free) ejection during aircraft dives with an angle of 30˚ is 85 m; with a roll of 90˚ this minimum altitude is 150 m, and from an inverted flight position this altitude is 200 m. The minimum altitude for a safe ejection when the aircraft the aircraft is descending is defined as five vertical descent rates (in m/s). The maximum G-load in case of ejection from the aircraft is 18 units.

The K-36DM ejection seat is equipped with a two-stage combined firing mechanism, a parachute deployment mechanism, a suspended rescue system with a 28-line parachute, having a dome area of 60 m^2, and a stabilization system with two stabilizing parachutes. The power burst of the propellant rocket engine is 630 kgf*s. To save the life of the pilot and to facilitate his search and rescue after ejection, an oxygen system, a NAZ-7M personal survival kit and a "Komar-2M" (R-855UM) automatic radio beacon are installed on the ejection seat. The weight of the K-36DM ejection seat, together with the oxygen equipment and survival kit, is 123 kg.

Aviation Electronic

On-board radio electronic equipment of the aircraft includes:

- the weapons control system;
- the navigation instrumentation;
- the communications equipment;
- the aircraft defense and countermeasures equipment;
- the aircraft's flight data recording, signalization, and control devices.

The Su-27K's weapons control system, in tandem with its array of air-to-air and air-to-surface armaments, facilitates the detection, tracking and destruction of air, land and sea targets, in any weather conditions during the day and night. In the air-to-air mode, the Su-27K's weapons control system provides the use of R-27 type guided missiles in long-range missile combat, and R-73 missiles and the GSh-301 airborne gun for short-range combat. The weapons system also facilitates target locking and tracking by means of the surveillance modes of the radar and IRST systems in long-range missile combat, capturing and tracking a targets in visual range during close combat, as well as determining the identity of detected targets. In the "air-to-surface" mode, the weapons system ensures the use of unguided bomb and rocket armaments for a wide range of ground (sea) targets.

Figure 17: N-001 Radar

The Su-33 fighter's weapons control system includes two main channels for detecting and tracking targets: the RLPK-27K radar targeting complex and the OEPS-27K electro-optical sighting system. The latter, in turn, includes an OLS-27K infra-red search and track system and a "Shchel-3UM-1" helmet-based target designation system. The weapons control system also includes a weapons management system, an IFF interrogator, a single indication system and a live monitoring and recording system.

- The weapons control system interfaces with the other radio electronic equipment of the aircraft:
- aerobatic and navigation complex;
- the onboard part of the equipment of the ground automatic control system;
- the IFF interrogator system;
- the inter-aircraft telecommunications equipment, and air-to-ground data transmission equipment;
- the aircraft's defense and countermeasures system.

The RLPK-27K radar sighting system is designed for all-weather, round-the-clock, all-aspect detection, tracking, and destruction of air and radio-contrast surface (sea) targets by means of guided and unguided weapons. The basis of the RLPK-27K is the H001K pulse-Doppler radar with an antenna diameter of 1075 mm. The radar is capable of mechanical azimuth and elevation scans. The N001K radar of the Su-33 is a variant of the Su-27's N001 radar, with modifications taking into account the specifics of flight over the water surface. The operation of the RLPK-27K is controlled by the on-board C100 digital computer.

The Su-33's RLPK-27K facilitates the following:

- speed-based detection of air targets, with distance measurement;
- tracking of up to 10 of the biggest airborne threats while maintaining an overview of the airspace and providing an overview of present targets according to their threat level;
- offensive action against high-priority targets of targets selected by the pilot by means of the aircraft's short and medium-range missiles with various guidance systems;
- search, capture and tracking of targets within visual range during short-range aerial combat;
- IFF interrogation of detected targets;
- All-weather detection of radio-contrast surface targets.

The RLPK-27K of the Su-33 has the following characteristics:

Detection range of fighter-type aerial targets with a radar cross-section of 3 m^2. No less than (values in km):

Head-on aspect	100
Pursuit (rear) aspect	40
Field of view, in degrees. - azimuth - elevation	 ± 60 ± 55

Maximum number of simultaneously-tracked targets	10
Altitude range of target detection in a solid angle of 120°, in meters	50-27 000

The optical-electronic sighting system OEPS-27K of the Su-33 is designed for searching, detecting and tracking air targets by means of their infrared radiation; determining the coordinates of the line-of-sight during pilot operation against visually-acquired targets; calculating the range and solving for a firing solution for air and ground targets. The OEPS-27K includes the OLS-27K IRST station which is a combination of a search-and-track thermal direction finder and a laser rangefinder, a "Shchel-3UM-1" helmet-mounted targeting system and a C100 digital calculator. The OEPS-27K performs the same functions as the RLPK-27K, but only in simple weather conditions. The OEPS-27K, however, provides more accurate data and generates less noise.

The OLS-27K system is placed in a spherical fairing in front of the cockpit windshield. The OLS-27K is used to track airborne targets from the front and rear hemispheres by means of its thermal radiation, and to measure the range to air and ground targets by means of a laser beam.

Figure 18: OLS-27

The OLS-27K of the Su-33 has the following characteristics:

Detection and tracking area, in degrees: - azimuth - elevation angle	 ± 60 15 ... +60
Search field, in degrees:	120 x 75

Field of view, in degrees:	60 x 10; 20 x 5; 3 x 3
Range of tracking for heat-contrasting airborne targets, in km: - from the frontal hemisphere - from the rear hemisphere	 40 100
Range of measured distances to aerial targets, in km:	6
Accuracy of measured coordinates: - angularly, angular min. - by range, in m	 5 10
The angular velocity of the system's target auto-tracking, in degrees s	25

Figure 19: "Shchel-3UM-1" Helmet-mounted Target acquisition System

The "Shchel-3UM-1" helmet-mounted target acquisition system makes it possible to direct the aircraft's homing missiles and the OLS-27K scanner simply by turning the pilot's head. The helmet-mounted target designation system includes a sighting device fixed to the pilot's helmet, and an optical locating unit with a scanning device that is used to detect the movement of the pilot's head. The opto-electronic sighting system, in tandem with the helmet-mounted targeting system, gives the pilot the ability to visually search for targets in the azimuth zone of ± 60° and elevation zone of -

15˚+ 60˚. The system also provides the measurement of the line of sight coordinates when tracking the target, with sight line speeds of up to 20.

The SEI-31-10 integrated indication system of the Su-33 displays all the necessary navigational and sighting information on the pilot display unit on the background of the ILS-31 windscreen. This system also outputs the information received from the radar and the optical seeker system to the head-down display (MFI). The SEI also includes an electronics unit and a power supply unit.

Figure 20: ILS-31 HUD

The ILS-31 is an electronic-optical indicator that displays information first in alphanumeric and graphic forms on the screen of the cathode-ray tube. This image of this information is then transferred to the semitransparent reflector sight by means of a collimator system. This indicator is built on a projection tube with high brightness and operates in two modes:

- output of sighting and flight information in alphanumeric and graphical form with a total of 120 characters;
- output of sighting and flight information with a total of 60 characters, shown together with background information on a 60-line bitmap.

The multi-functional HDD (head down display) is an electronic indicator that displays tactical situation together with the information received from the radar and optical sighting systems in alphanumeric and graphical form with the required number of symbols.

The HUD and HDD can mutually duplicate each other. The Head-down display system provides the pilot with a clear view of the image on screens without having to use the light filter in conditions of direct sunlight.

The weapons control system includes a communications and control unit which ensure the issuance of all necessary signals and commands for the preparation of weapons for combat operations in accordance with the time schedules given. The links of this block with the missile seeker heads are organized on the basis of unification of signals for all equipped missiles. The target indication used by missiles is provided by a single onboard target designation system using all available on-board sources of information. The preparation of missiles for launch, as well as the launch process itself, is carried out by the weapons control system.

- The weapons control system provides the following in order to minimize pilot load during weapons use in combat:
- transition from the use of one type of weapon to another without disrupting the pilot's control of the aircraft;
- semi-automatic and manual modes of weapons use and preparation;
- programmed consumption of missile ammunition;
- issuance of signals regarding the missile being chosen for use, its current condition, the consumption and the balance of the aircraft's ammunition load.

For ease of weapons use and to ensure that the pilot remains in control of the aircraft at all times during combat, the control stick of the aircraft has switches used for weapons selection, and a trigger used for fire control. A selector button for selecting aircraft hardpoints (and the corresponding weapons equipped on them) is present on the aircraft's throttle handle.

With a heterogeneous load, the pilot can choose one of four symmetrically loaded pairs of hardpoints: wing, fuselage and nacelle.

The onboard equipment of the command and control radio link is designed for:

- receiving and decoding the interrogation signals of ground stations and shipborne active addressing and reporting system;
- receiving target information and flight and intercept vectors transmitted by ground and ship-based automated control systems;
- decoding and converting the received information for transmission to the aircraft's onboard processing and display systems.

The above data is received though radio communication circuits by the onboard equipment. This data comes in the form of sets of instructions containing guidance vectors, targeting information, one-time commands, as well as target coordinate support for semi-autonomous operations. Information from the ground control systems is received by the aircraft's automatic control systems and weapons control system for processing and is displayed on the aircraft's flight reference display.

The Su-33's navigation instrumentation is designed to solve the problems encountered during navigation and piloting of the aircraft at all stages of the flight in both simple and difficult weather conditions, at any time of the year and day, over the sea and over land in any geographical conditions.

The aircraft's navigation instrumentation facilitates the following:

- autonomous calculation of the coordinates of the aircraft in the airspace using information received from the inertial navigation system;

- automatic correction of the system's calculated coordinates using information received from the short-range radiotechnical navigation system;
- flight along the pre-planned route and return vectors to the ship (airfield) using the shortest path;
- calculation of the location of the aircraft carrier;
- calculating distance by fuel consumption and available fuel;
- pre-landing maneuvers: approach and landing;
- rendezvous with and approach to tanker aircraft.

The PNK-10K subsystem includes an information complex of speed and altitude parameters, an air-signal system, a radio altimeter, and a SAU-10L automatic aircraft control system and other such equipment.

The PNK-10K navigation equipment includes: an information complex for calculating the course and vertical position, a short-ranger radiotechnical navigation system, a system for calculating landing approach and carrier touchdown, a Doppler velocity and drift angle gauge, an automatic radio compass, a radio navigation system and a marker beacon receiver.

The K-DLA communications complex is designed to conduct stable two-way radiotelephone communication between the crew and the command and control tower, and between the crew and other aircraft in the area. The plane is equipped with a R-800L VHF radio station, a R-864L radio station and P-515 intercom equipment. The antennas of the radio stations are placed inside the radio-transparent fiberglass tailfin ends.

For exchanging tactical information between aircraft during the course of group operations, the equipment of the Su-33 includes data communications equipment. It provides for a two-level exchange of tactical information within the fighter wing. At the upper level, the data communications equipment also provides for information exchange between the commander of the fighter group with other group commanders. In total, the united group can have up to 4 groups of 4 Su-33 aircraft each.

The Su-33's onboard defense and countermeasures system is designed to detect the aircraft's illumination by enemy radar stations, to alert the crew of this fact, and to emply passive and active countermeasures in both radar and infrared ranges. The aircraft is equipped with an SPO-15LM / L006 "Beryoza" (Birch) airborne warning system, as well as an APP-50 device (with 48 50mm cartridges) for the deployment of passive countermeasures - false thermal targets (flare) and dipole reflectors (chaff).

The passive countermeasure devices are located on the upper surface of the tail section of the fuselage between the nacelles near the trailing edge of the wing (8 triple blocks on both sides of the central tail stinger). There are several modes of deploying passive countermeasures: by volleys, with the number of cartridges in one volley ranging from 1 to 8; in seriels, with the number of volleys in the series from 0.01 to 0.8 s for the chaff and from 1 to 8 s for flares; and continuously.

The aircraft may also be equipped with an L005 ("Sorbtsiya") active radar jamming station located in two containers on the aircraft's wingtip hardpoints in place of the air-to-air missiles launcher racks. These active countermeasure pods are designed for individual and mutual protection of aircraft from attacks by weapons with radio-electronic seekerheads with pulsed, continuous and quasi-continuous radiation by creating deliberate interference that disrupt the normal functioning of radar systems.

The main types of jamming used are the following: speed-leading and noise-free in the range of Doppler frequencies, impact noise, masking high-frequency noise, and so on.

The flight data recording, signalization, and control devices of the Su-33 include an in-cockpit system of emergency, warning and signal lights, the "Ekran" system – a general system designed to display aircraft events and failure indications, a live monitoring and recording system, "ALMAZ" voice alarm equipment, and the "Tester" on-board flight data recording device.

Armament

The armament of the Su-33 is divided into several categories: the onboard automatic cannon, its array of guided air-to-air missiles and unguided air-to-surface rockets and bombs.

Its cannon armament is represented by a built-in GSh-301 automatic 30mm single-barrel gun installed in the leading edge extension of the right wing, with an ammunition capacity of 150 rounds. Missile/rocket and bomb-type weapons are suspended under the wing on the aircraft's weapon hardpoints, with a total of 12 such hardpoints.

The aircraft may carry up to six medium-range guided R-27R (R-27ER) air-to-air missiles with semi-active radar seeker heads, two R-27T (R-27ET) medium-range missiles with thermal seeker heads, and four to six R-73 short-range missiles with thermal seeker heads.

The maximum weight of unguided air-to-surface armament used by the Su-33 is 6500 kg. It can include up to 8 500kg high-explosive bombs (single-use bomb dispensers, incendiary tanks), up to 28 250 kg high-explosive or high-explosive fragmentation air bombs (on single or multiple ejector racks), up to 32 100 kg high-explosive bombs on multiple ejector racks), or 50kg P-50T training air bombs. Its array of unguided rocket armament is composed of 80 S-8 unguided rockets (housed in 4 B-8M1 units), 20 S-13 rockets (in 4 B-13L units), and 4 S-25-OFM rockets (in the O-25 launch pods).

Aircraft Gun Armament

The GSh-301 cannon is designed to fire the AO-18 30mm cartridge. The maximum rate of fire the gun can output is 1500-1800 rounds per minute, with an initial project velocity of 860 m/s and a recoil force of 6000-7500 kgf. The gun has a linked two-way ammunition belt-feed system. AO-18 cartridges can be of several types: fragmentation-explosive-incendiary, and armor-piercing tracer. These are designed to defeat unarmoured and lightly armored ground, surface and air targets. The weight of the cartridge with the HEI and tracer shells is 836g and 860g respectively: the mass of the HEI shell is 384g, where the tracer shell weighs 394g. The maximum armor penetration of these shells is 40mm.

Figure 21: GSh-301 Gun

Fire control is electric and remote. Weapons fire can be carried out continuously, until the entire ammunition supply is exhausted (with a total ammunition time of 6s) and in short bursts. The length of the burst is determined by setting the firing mode on the control panel. The effective range of fire from the gun against airborne targets is 800-200 m; for ground targets, the distance is greater:

1800-1200 m. The gun's automaticity operates according to the principle of using recoil energy when the barrel is retracted. The internal water cooling system of the gun and the external blow-off ensure its high service life. The operational life of the gun is 3000 shots. The gun weighs 50kg, with a length is 1978 mm, a width of 156 mm, and a height of 185 mm.

Air-To-Air Missiles

The R-27R (ER) and R-27T (ET) missiles are designed for intercepting and destroying all types of aircraft and helicopters, unmanned aerial vehicles and cruise missiles in medium-range air combat, day and night, in simple and difficult weather conditions, from any direction, against the background of the terrain and sea, with active information, fire and maneuver countermeasures undertaken by the enemy. The missiles are made according to the "duck" scheme with large-area rudders and destabilizers. The missile control system includes an inertial navigation system with radio correction and a homing warhead of several types: semi-active radar-guided for the R-27R (ER) missiles and heat-seeking missile warheads for the R-27T (ET) missiles. These missiles can track and destroy a target flying in a range of altitudes from 20 m to 27 km at a speed of up to 3,500 km/h at any initial position in the target designation field ± 50° (for missiles with semi-active radar-guided warheads) and ± 55° (for missiles with heat-seeking warheads). The G-forces of the carrier aircraft at the time of launch may reach up to 5 units. The maximum altitude separation of the target relative to the carrier can be up to 10 km.

Figure 22: Su-33 on the Kuznetsov deck with two R-27ERs under the inlets and two R-73 under wings

The R-27ER and R-27ET rockets are modifications of the R-27R and R-27T missiles, which are distinguished by the use of a propulsion system with increased power-to-weight ratio, ensuring a greater maximum launch range. The presence of R-27 missiles with varying seeker heads in the combat loadout of the fighter increases the its effectiveness in combatting enemy countermeasures and increases the efficiency of the aircraft's weapons systems. R-27R (ER) missiles are suspended from AKU-470-type ejector racks, while R-27T (ET) missiles are suspended from APU-470-type ejector racks.

The R-73 missile is equipped with a heat-seeking homing head and is designed for close air combat to intercept and destroy high-manoeuvrability manned and unmanned means of air attack by the enemy in day and night conditions, from any aspect, into the front and back hemispheres of the target, against the background of terrain and with active electronic countermeasures employed by the enemy. The missile is constructed according to the "duck" scheme with destabilizers in the head part of the hull and aerodynamic control. A distinctive feature of the construction is the presence of an aerodynamic device that allows for control over the thrust vector of the propulsion system. This gives the missile a high degree of maneouverability, ensuring its ability to reach and destroy targets maneuvering with G-forces of up to 12 units.

Due to the presence of a highly sensitive cooled thermal homing head, the R-73 is one of the first all-aspect short-range missiles capable of tracking and reaching targets not only on pursuit, but also on head-on courses. The missile can attack a target flying in a range of altitudes from 20 m to 20 km at speeds of up to 2500 km/h from any initial position, in target acquisition angles of a range of ± 45˚ at line-of-sight rates of up to 60˚/s. Target acquisition for the R-73 missile's seeker head can be performed by using the targeting system built in to the pilot's helmet. R-73 missiles are suspended from APU-73 type hardpoints mounted on the outer underwing pods.

Unguided Bombs

FAB-500, FAB-250 high-explosive aerial bombs are designed to destroy ground targets with explosion forces, fragmentation, shock waves, as well as its own kinetic energy.

The air bombs are suspended on the aircraft on the BDZ-USK-B universal bomb racks (one bomb up to 500 kg in each rack) or MBD3-U6-68 multi-bomb bomb racks (with up to 6 bombs of 250 kg on each rack)

Figure 23: MBD3 multi-bomb racks under inlets and B8 rocket launchers on double racks under wings

RBK-500 type single-use cluster bomb canisters are designed for combat use of fragmentation, incendiary and anti-tank bomblets of a small caliber (0.5-2.5 kg). Su-33 aircraft can use these 500 kg caliber bomblet dispensers equipped with AO-2.5PT 2.5 kg caliber fragmentation bombs and SHOAB-0.5M 0.5 kg caliber sphere bomb fragments. The single-use RBK-500 bomb dispensers are suspended one by one on the BDZ-U series universal bomb racks.

Unguided Rockets

Unguided air-launched rockets are designed to defeat single small-sized strong, armored or lightly-armored targets, enemy infantry, as well as air targets. The purpose of the unguided rockets in question is determined by the explosive effect of their respective warheads.

The unguided 80-mm caliber S-8 air-launched rockets are equipped with warheads of the following types: high-explosive dual-purpose (S-8KOM), high explosive anti-armor (S-8B), high-explosive fragmentation (S-8-OF), fuel-air explosive (C-8D), as well as flechette (C-8AC.) 122-mm caliber C-13 rockets – have high explosive anti-armor(C-13T), high-explosive (C-13Д) or high-explosive fragmentation (C-13-ОФ) warheads.

Figure 24: Heavy rockets S-25 on the double rack under wing

Heavy unguided 266 mm caliber C-25 rockets have over-caliber fragmentation (C-25-O) or high-explosive fragmentation (C-25-OF) warheads with a diameter of 420 and 340 mm, respectively.

Unguided S-8 air-launched rockets are used from B-8M1 20-barrel units. S-13 rockets are launched from 5-barrel B-13L canisters, and S-25 rockets are launched from the PU-O-25 single-shot launchers. The canisters and other launching devices of these unguided rockets are suspended on standard weapon racks mounted on the underwing hardpoints of the aircraft.

Aircraft performance	
Takeoff weight: **- normal (including 2xR-27R + 2xR-73, 5270 kg fuel), kg** **- maximum, kg**	 23,430 33,000
Maximum landing weight, kg	24,500
Landing weight limit, kg	26,000
Maximum internal fuel, kg	9,500
Maximum ordnance, kg **Air-To-Air** **Air-To-Ground**	 3,200 6,500
Service ceiling (without external ordnance and stores), m	17,000
Maximum flight speed at sea level (without external ordnance and stores), km/h	1,300
Max Mach (without external ordnance and stores)	2.17
G-limit (operational)	8.5
Maximum flight range (with missiles 2xR-27R, 2xR-73 launched at half distance): **- at sea level, km** **- at height, km**	 1,000 3,000
Aircraft dimensions: **- length, m** **- wingspan, m** **- height, m**	 21.185 14.7 5.72
Crew	1
Powerplant	
Number and type of engines	2 x AL-31F mod 3
Thrust: **- in special afterburner mode, kgf** **- in afterburner, kgf** **- at full power, kgf**	 12,800 12,500 7,670

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.

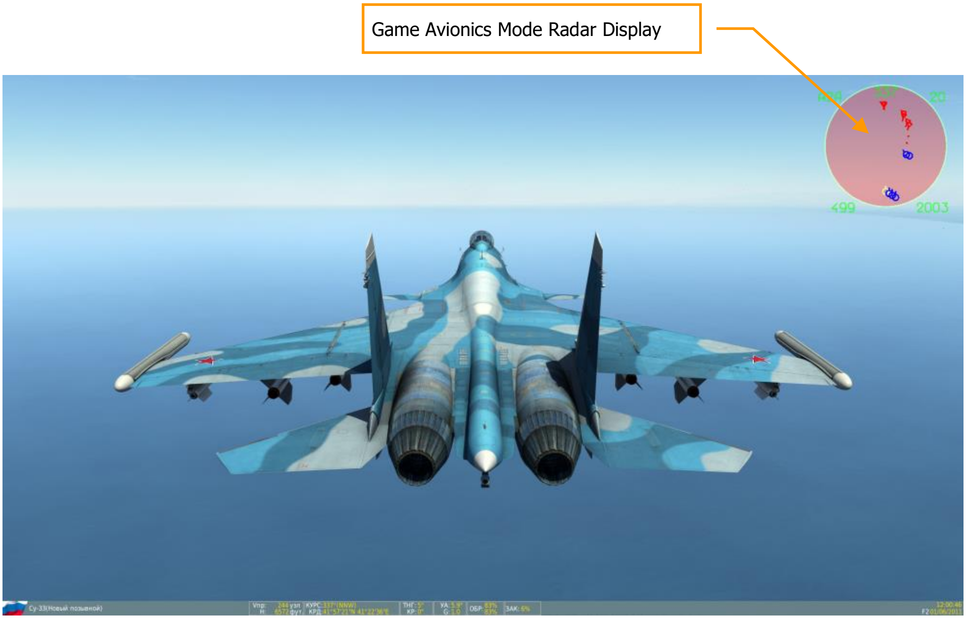


Figure 25: Game Avionics Mode Radar Display

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

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

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

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

Mode keys:

  - Navigation: **[1]**

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

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

Radar range keys:

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

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

Navigation Mode

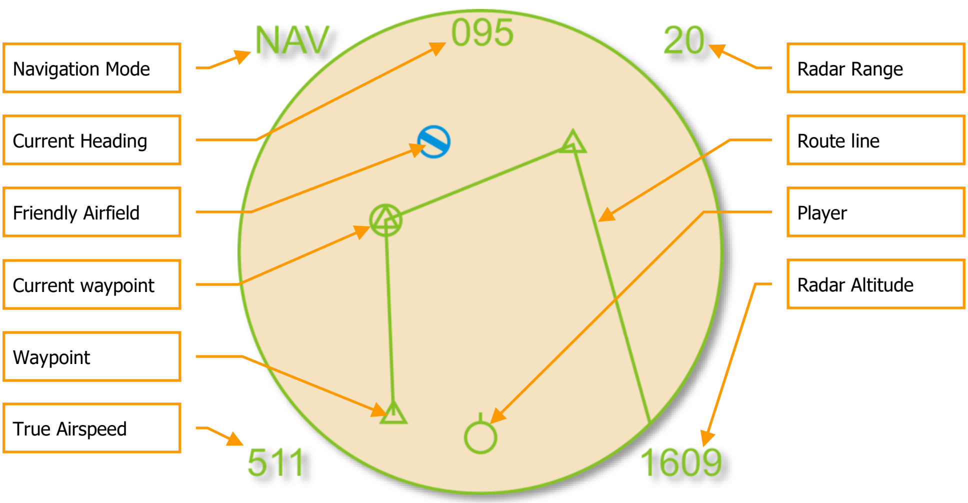


Figure 26: Navigation Mode

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

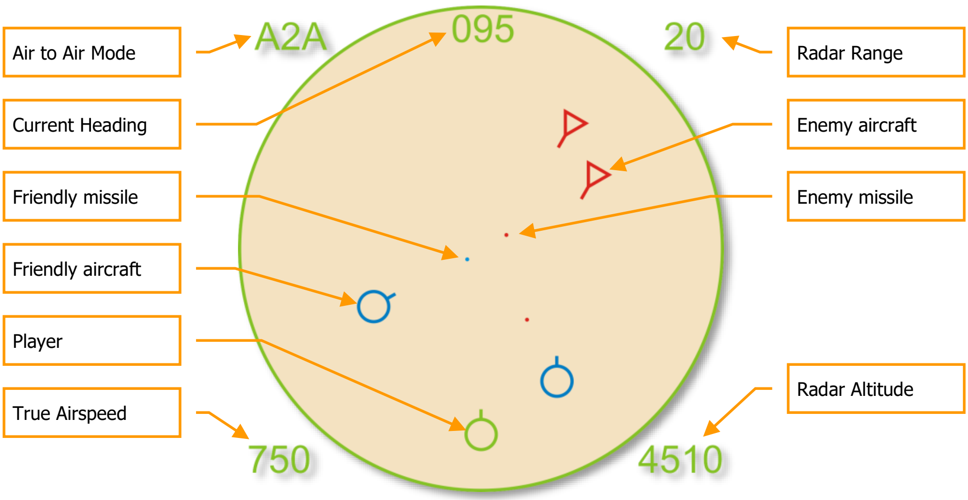


Figure 27: Air to Air Mode

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]**

COCKPIT INSTRUMENTS

COCKPIT INSTRUMENTS

This chapter will instruct you about the Su-33 cockpit instrumentation. For successful piloting, you must understand the function and position of all cockpit instruments.

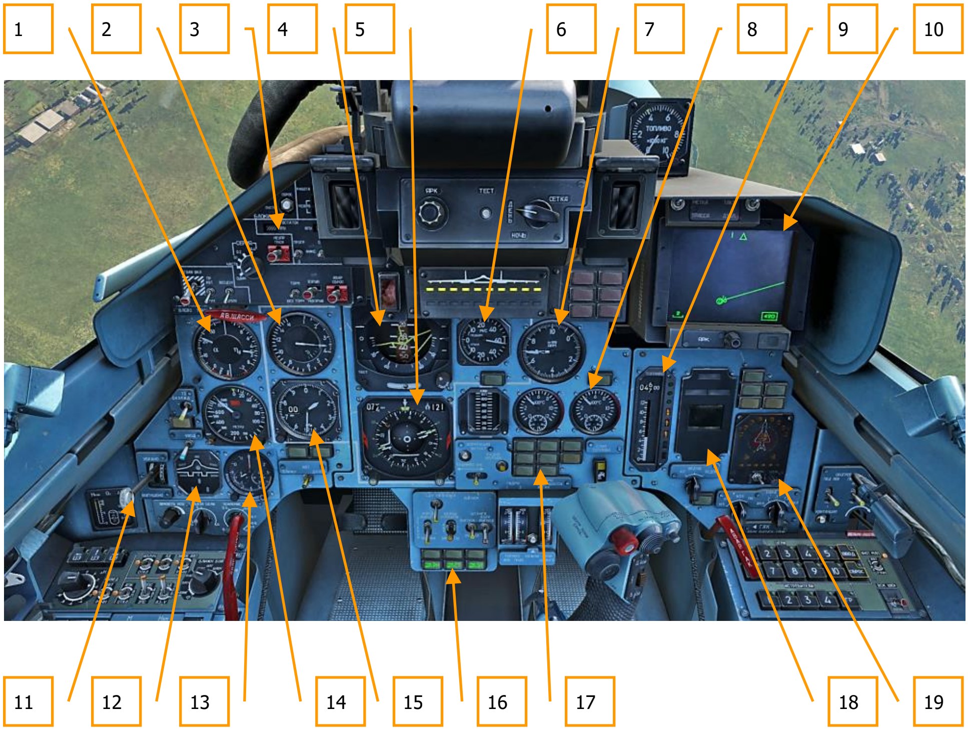


Figure 28: Su-33 instrument panel

1. AOA indicator and Accelerometer
2. Airspeed and Mach indicator
3. Weapons control panel
4. Attitude Direction Indicator (ADI)
5. Horizontal situation indicator (HSI)
6. Vertical Velocity Indicator (VVI)
7. Tachometer

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

Airspeed and Mach Indicator

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

Figure 29: Airspeed and Mach indicator

Pressure Altimeter

The barometric air pressure altimeter indicates the aircraft's altitude above sea level.

The short pointer shows the altutude in thousends of meters, the long pointer in hundreds of meters. The value of the flight altitude is obtained by summing the readings of the short and long pointers.

In the illustration, the flight altitude is 5150 meters.

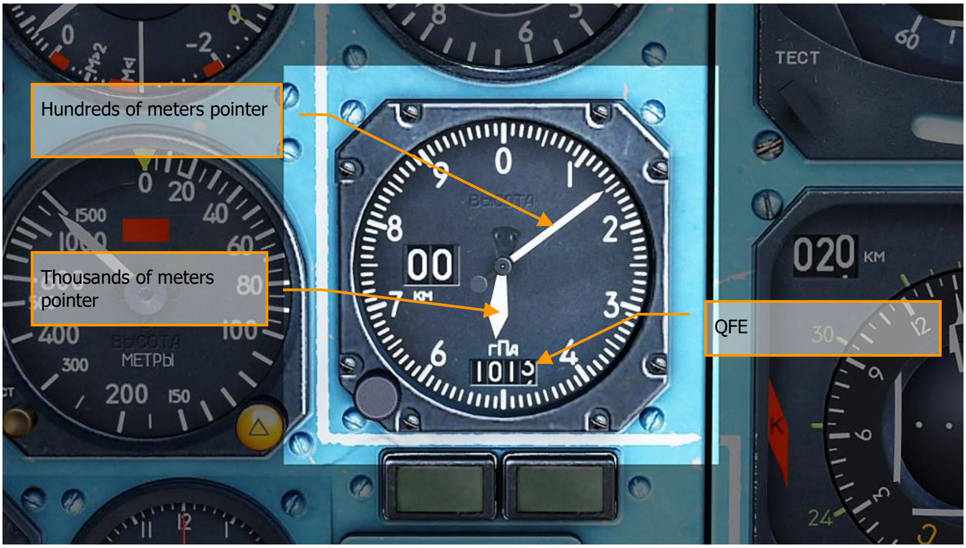


Figure 30: Pressure altimeter

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 31: Radar altimeter

Mechanical Devices Indicator

The mechanical devices indicator shows the position of the landing gear, flaps, intake FOD shields, airbrake, hook, wings.

If the landing gear is not extended or retracted, a red lamp lights in the center of the indicator.

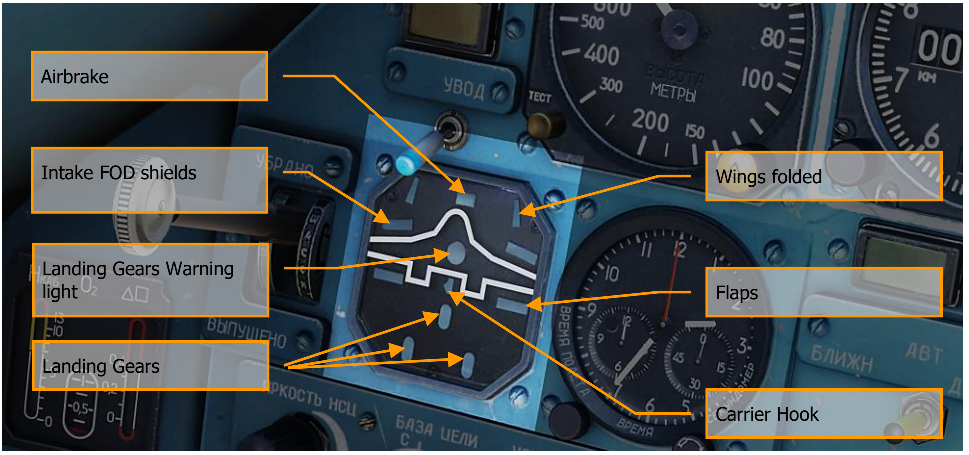


Figure 32: Mechanical Devices Indicator

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. An index mark shows the maximum G recorded during a flight.

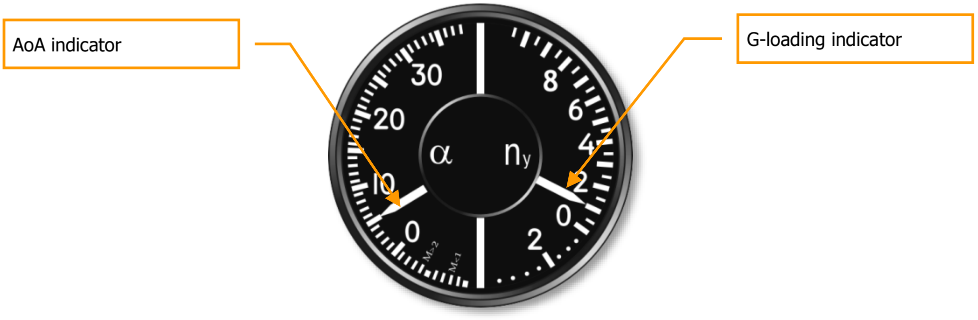


Figure 33: AoA indicator and Accelerometer

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.

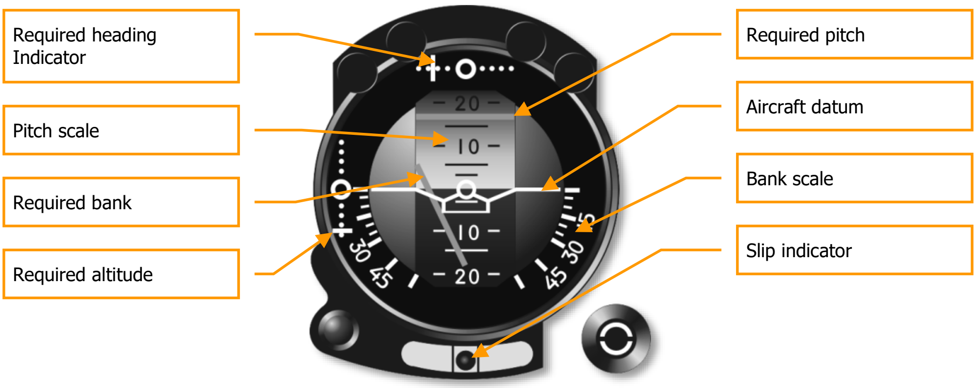


Figure 34: ADI

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.

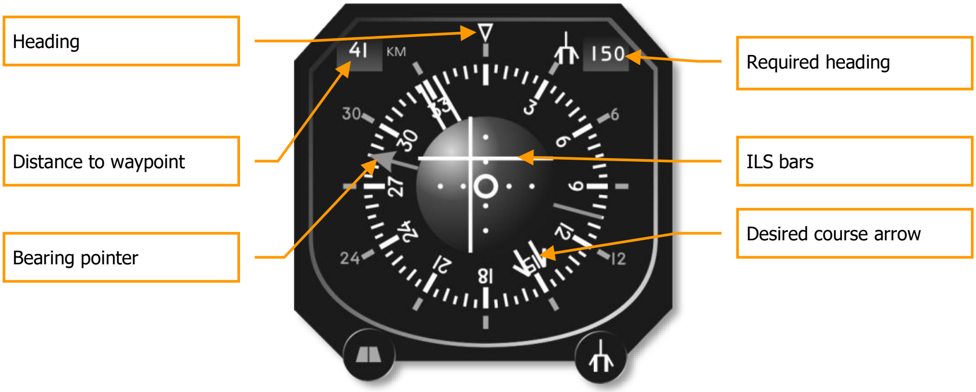


Figure 35: HSI

Vertical Velocity Indicator

The Vertical Velocity Indicator measures the aircraft's vertical speed, i.e. rate of climb or sink in m/s.

1 meter/second = 197 foot/minute

Figure 36: Vertical velocity indicator

Aircraft Clock

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

Figure 37: Aircraft clock

Tachometer

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

Figure 38: Tachometer

Fuel Quantity Indicator

Fuel quantity indicator and scale show the fuel remaining in all tanks.

Lights in the right side show the empty of corresponding fuel tanks.

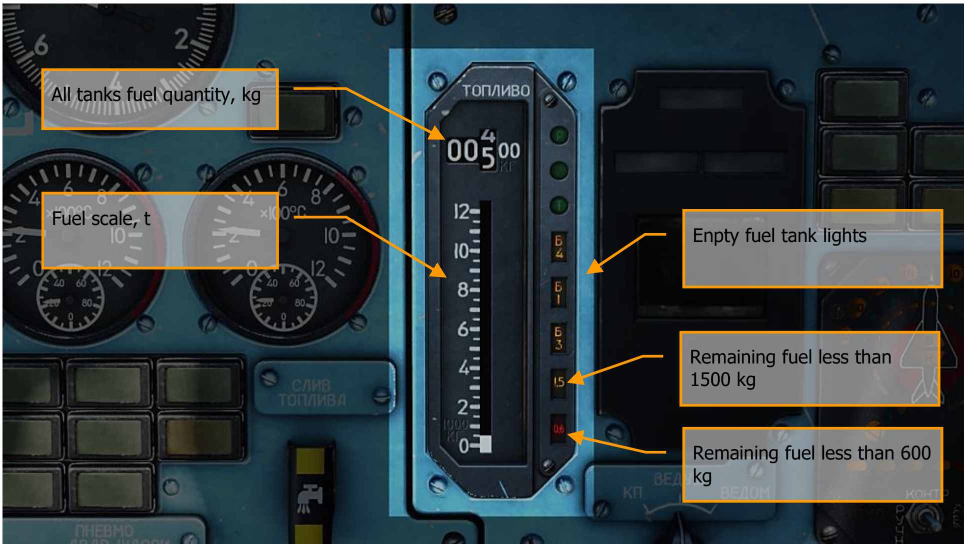


Figure 39: Fuel quantity indicator

Interstage Turbine Temperature Indicators

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

Figure 40: Interstage turbine temperature indicators

Head Down Display (HDD)

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

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

Figure 41: 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 DEFINE 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 close to the actual system installed in the Su-27/33.

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

Н - short-range radar

F - early warning radar

С - AWACS

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

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

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

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

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

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

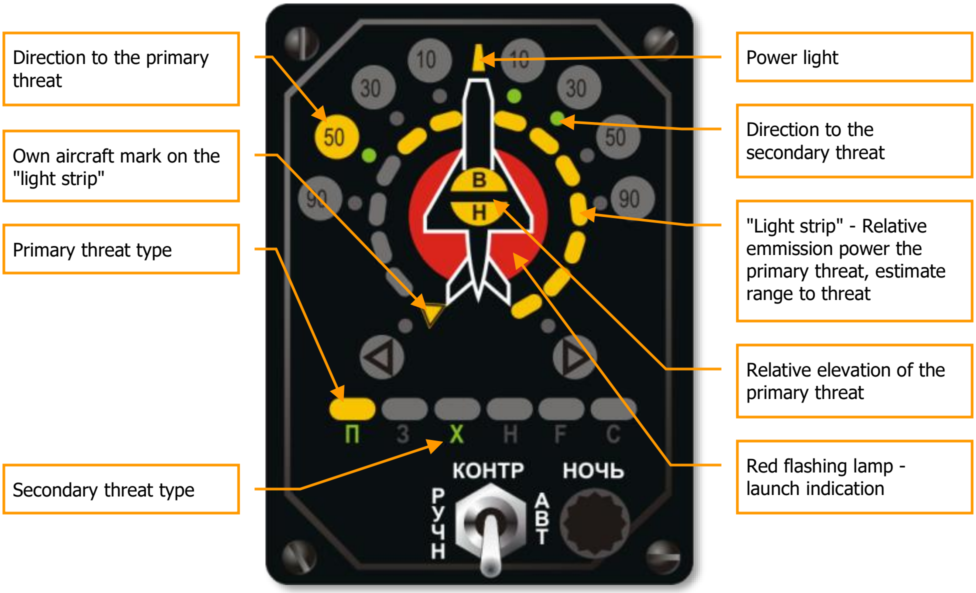


Figure 42: "Beryoza" SPO-15LM indicator

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

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

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

1. The primary threat at 50 degrees left (10 o'clock) is indicated in the form of a large yellow lamp. The lamp above "**П**" symbol, which means "interceptor", is lit. This type of threat includes all fighters. The circular scale of signal power ("light strip") consists of yellow segments that show the relative emission power of the primary threat's radar. The large red circle under the aircraft symbol indicates that your aircraft has been locked by the primary threat radar. The lit, yellow hemispheres marked as "**B**" and "**H**" in the center of the aircraft silhouette, indicates the threat's relative altitude to yours. In this situation, the primary threat is at the same altitude as your own, within 15 degrees in elevation. Consequently, the display can be interpreted in the following way: your primary threat is a fighter approaching from 10 o'clock; it is near co-altitude with you; and judging by the signal strength and lock light, it is ready to launch a missile.
2. The secondary threat is positioned at 10-30 degrees azimuth (1-2 o'clock right), and this is indicated by the two green lamps. The green "**X**" symbol in the threat types line indicates

that your being targeted by a medium-range radar. There is no additional data on secondary threats.

In a complex threat environment, it is often difficult to define the threat type and 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.

PPD-SP Panel

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

Figure 43: PPD-SP panel

Direct Control Switch

The DIRECT CONTROL mode is switched on by pressing the **[S]** key in the event that the fly-by-wire system fails. Piloting in this mode requires special care; the flight is characterized by:

- Insufficient pitching stability
- Low aerodynamic damping
- Increased longitudinal stick sensitivity

It is in this mode that the "Pougachev's cobra" aerobatic maneuver can be performed. The mode is switched off by pressing the **[S]** key again. The on/off control can be checked by the switch on the left panel in the cockpit.

Figure 44: Direct control switch

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: "ТРИММ. СТ. НЕЙТР." (neutral stabilizer trim), "ТРИММ. ЭЛ. НЕЙТР." (neutral aileron trim), and"ТРИММ. Р.Н. НЕЙТР." (neutral rudder trim) in the lower part of the main cockpit panel.

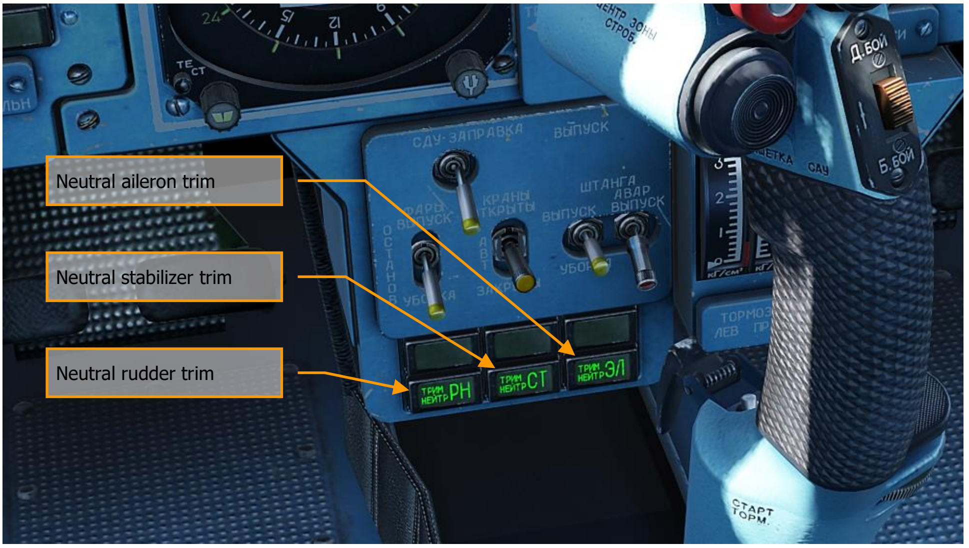


Figure 45: Trim annunciators

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.

Holding the third joystick button **[Joybutton3]** is an alternate means to trim the aircraft. Joystick operation is switched from virtual control stick deflection to trimming. In this mode, the joystick deflections activate the control stick trimmer in the respective channel.

If a joystick has force feedback, trimming shifts the joystick neutral position, which is similar to how the real Su-27 is trimmed.

Automatic Control System (ACS)

ACS provides:

- Auto-stabilization of pitch/bank and barometric altitude
- Automatic leveling of the aircraft in roll and pitch
- Stabilization of absolute altitude in accordance to the radar altimeter at altitudes between 100-1000 m, with automatic ground collision avoidance
- Automatic control of during climbing and descending
- Automatic control of the flight control surfaces in accordance with data from the navigation system during enroute navigation mode

- Automatic return to the programmed airfield and landing approach down to 50-60 m in accordance with input from the navigation system
- Ground collision avoidance mode
- Autothrust mode that is compatible with other modes

Actuators of the fly-by-wire system and trim mechanisms are used as actuators of the automatic control system (there are no separate ACS actuators).

Before turning on the ACS, the aircraft should trim (except for the "Level up to the Horizon" - **"Приведение к горизонту"** and "Ground collision avoidance" - **"Увод"** modes). Deflection of the controls of more than 20% during the ACS operation (or excess of pitch/bank angles of 80 degrees) disables ACS and places it in Manual Control mode (except for the Level up to the Horizon) as the annunciator on the left part of the main cockpit panel indicates. In this case, one should reset ACS by the **"СБРОС"** (RESET) pushbutton **[Alt -9]**.

Figure 46: Manual Control annunciator

The ACS modes are controlled by push-light switches on the left console.

Figure 47: ACS push-lights and switches

The push-light switch "АВТОМ" (AUTO) will activate when any of the ACS modes (combined with other push-light switches) is enabled. If this push-light switch is off, it means that the ACS is inactive. If this push-light switch is the only one on, it means the attitude hold mode of the aircraft is active.

To control the ACS, the following commands are used:

[A] – Switches on the route following and barometric altitude stabilization modes. When the ACS is active, this command pushes the **"СБРОС"** (RESET) button switching off any current mode including the **"УПРАВЛЯЙ ВРУЧНУЮ"** (MANUAL CONTROL) mode and **"УВОД НА ВЫСОТУ"** (GROUND COLLISION AVOIDANCE MODE).

[H] – Switches on barometric altitude stabilization mode. This is only possible when the bank angle is less than 8 degrees and the heading is stabilized.

[LAlt-1] – Switches on the attitude hold mode (push-light switch **"АВТОМ"** is on) if the bank angle is less than 8 degrees and the heading is stabilized.

[LAlt -2] – An alternative command to enable barometric altitude stabilization.

[LAlt -3] – Level to the horizon. In this mode, the ACS is not switched off by control stick overriding and it has no pitch and bank angle limits. If this mode is on, the push-light switch **"ПРИВЕД К ГОРИЗ"** (Level up to the horizon) is on in the lower right portion of the front cockpit panel.

Figure 48: "ПРИВЕД К ГОРИЗ" (Level to the horizon) annunciator

[LAlt -4] – An alternative command to enable barometric altitude stabilization. Same as **[H]**.

[LAlt -5] – Switches on the radar altitude stabilization mode at altitudes between 300 to 1000m. At a radar altitude of less than 50 meters or vertical velocity of more than -15 m/s, the **"УВОД НА ВЫСОТУ"** (GROUND COLLISION AVOIDANCE MODE) mode is engaged automatically the bank angle is zeroized and attain positive pitch using a g-load of up to 4 units.

[LAlt -6] – Switches on the route following modes. Simultaneously, the pitch is stabilized based the value at mode initiation is used.

[LAlt -6] – Ground collision avoidance mode.

The Override button (press and hold) **[LShift-A]** disables the autopilot and allows you to adjust the aircraft attitude. After releasing the button, the autopilot accepts the new control input values.

Figure 49: Ground collision avoidance mode annunciator and switch

[J] – Autothrust. This can be combined with other modes and can be adjusted with a special switch: **[LShif – J]** increase speed, **[LAlt – J]** – decrease speed.

[LAlt -9] – Pushing the **"СБРОС"** (RESET) button switching off any current mode, including the **"УПРАВЛЯЙ ВРУЧНУЮ"** (MANUAL CONTROL) mode and **"УВОД НА ВЫСОТУ"** (GROUND COLLISION AVOIDANCE MODE). It also resets an ACS failure.

[LAlt -A] – Autopilote override button.

Combined Aircraft Control

In order to shift the aircraft's position while automatic stabilization is enabled (indicated by a lit-up "AUTO" light **[LAlt-1]** as well as the relevant signal lamps when stabilized according to the barometric **[LAlt -4]** or radio altimeter **[LAlt -5]**), the pilot must:

- Press the Autopilot override button **[LAlt -A]** on the aircraft control stick. Upon doing so, control signals from the autopilot system are not transmitted to the aircraft's fly-by-wire system, but the control signals transmitted by either the barometric or radioaltimeter stabilization modes cease transmission (the signal lamp goes off);
- Upon recieving manual control of the aircraft, set the desired altitude and attitude.
- Release the Autopilot override button **[LAlt -A]**. The automatic stabilization mode will resume, accounting for the new parameters, and the signal lamps of the previously active mode will once again light up.

At roll and pitch angles of more than 80 °, after releasing the combined control trigger, the automatic control system will switch off, and an indicator displaying "MANUAL CONTROL" will light up on the aircraft instrument panel.

Disengaging the ACS while holding down the Autopilot override button can be done by pushing the RESET button **[LAlt -9]** or the ACS OFF button.

Refueling Mode

When performing refueling, it is recommended turn on a special REFUELING mode control system **[RCTRL-R]**, in which the aircraft is controlled by position-based control profile.

This profile facilitates precise piloting around the tanker. Responsibility zone is 5 degrees in pitch and 10 degrees on the roll. Outside the zone the aircraft is operated according to the standard law.

Figure 50: REFUELING mode control system switch

Angle of Attack Indexer

The AoA indexer "ISM-1" is attached to the left side of the HUD, intended for indicating angle of attack ranges when landing.

The indicator has three lamps placed in a vertical block:

- Yellow lamp - the angle of attack is low; the speed is high.
- Green lamp - angle of attack and speed are optimal.
- Red lamp - the angle of attack is high; the speed is low.

By speed control of the aircraft you should strive for a steady lit of the green lamp.

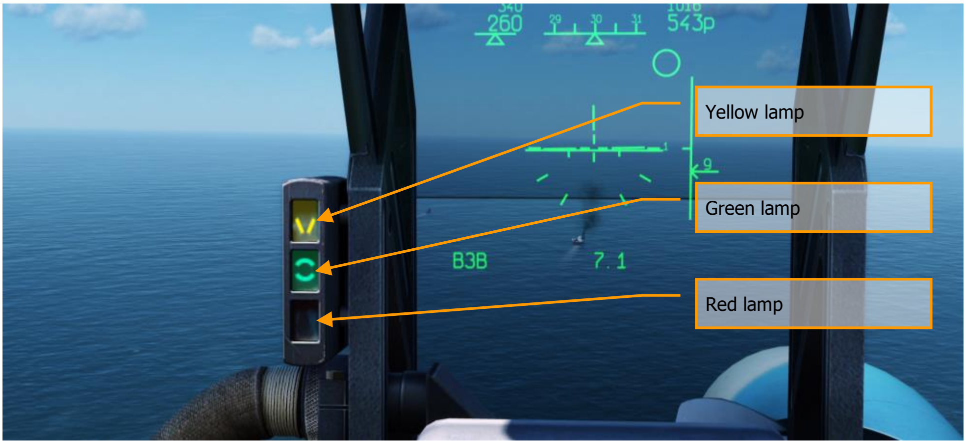


Figure 51: AoA Indexer

Below is a diagram of indicator lamps, depending on the angle of attack of the aircraft.

- The angle of attack is below 10.5 degrees - the yellow lamp is flashing.
- The angle of attack is from 10.5 to 11 degrees - the yellow lamp is on.
- Angle of attack from 11 to 11.5 degrees - both yellow and green lamps are on.
- Angle of attack from 11.5 to 12.5 degrees - the green lamp is on (optimum AoA).
- Angle of attack from 12.5 to 13 degrees - both green and red lamps are on.
- Angle of attack from 13 to 13.5 degrees - the red lamp is on.
- The angle of attack is more than 13.5 degrees - the red lamp flashes.

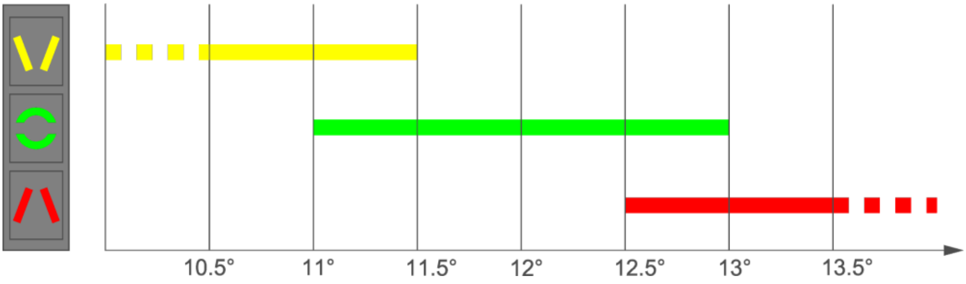


Figure 52: Diagram of indicator lamps

Su-33 HUD and HDD Operational Modes

The Su-33 HUD and HDD indication are the same as the Su-27, so this description applies to both.

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 mode.

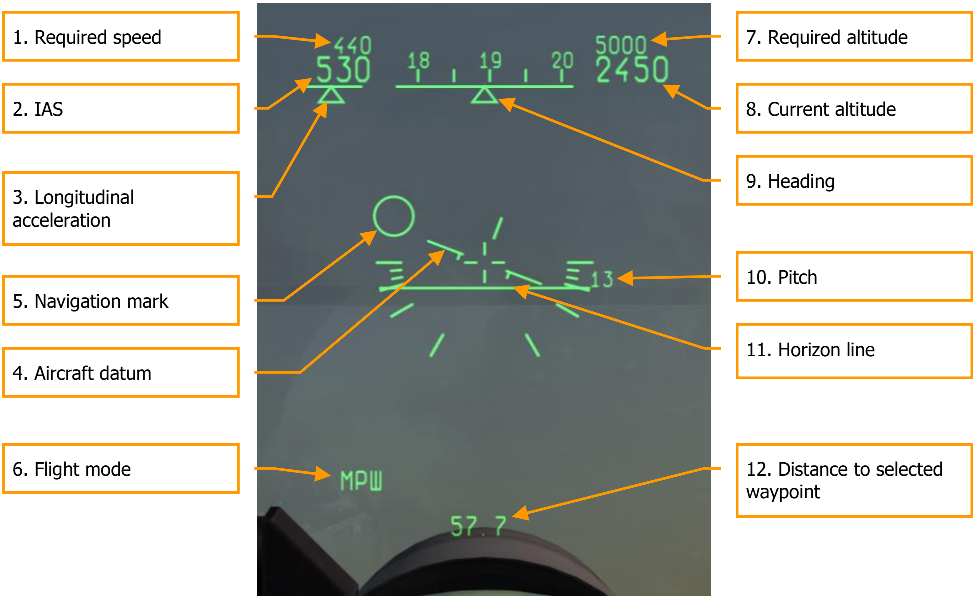


Figure 53: HUD basic symbols

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 1,500 meters above ground level, the radio altitude is indicated to within 1 m. At an altitude over 1,500 meters barometric, the height is shown to within 10 meters. Above the scale the required altitude is shown. This will depend on the flight mode and in the case of route flight mode, it shows the preplanned route altitude.
9. The 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.

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

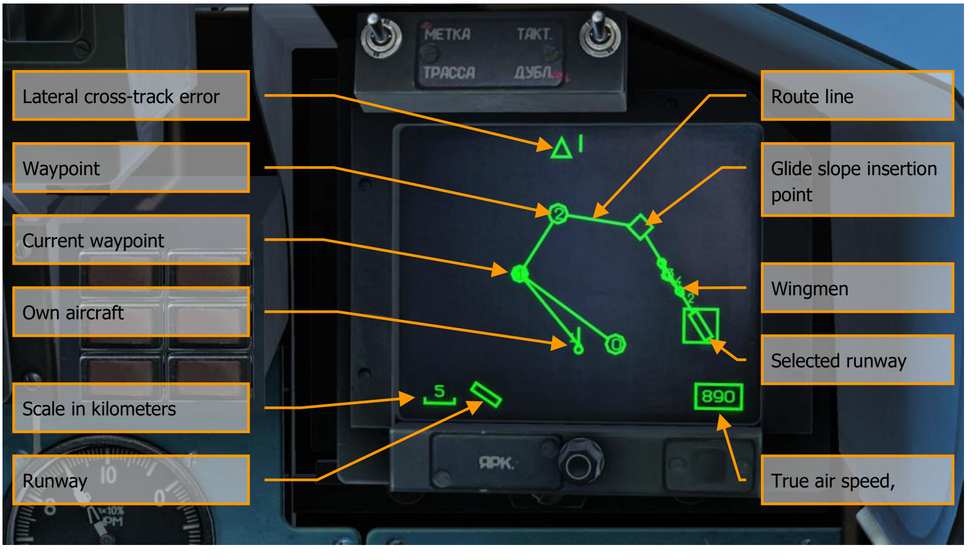


Figure 54: HDD in navigation mode

- Waypoints are indicated by circular marks
- Waypoint number is indicated into waypoint mark
- Initial point for glide slope interception is indicated by a diamond
- Runways are indicated by a solid rectangle
- Current waypoint has inverted color
- All waypoints are connected by a route line

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

The next route and waypoint will be displayed on HDD.

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

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

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

Navigation 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. Planned route and waypoints are displayed on HDD.

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

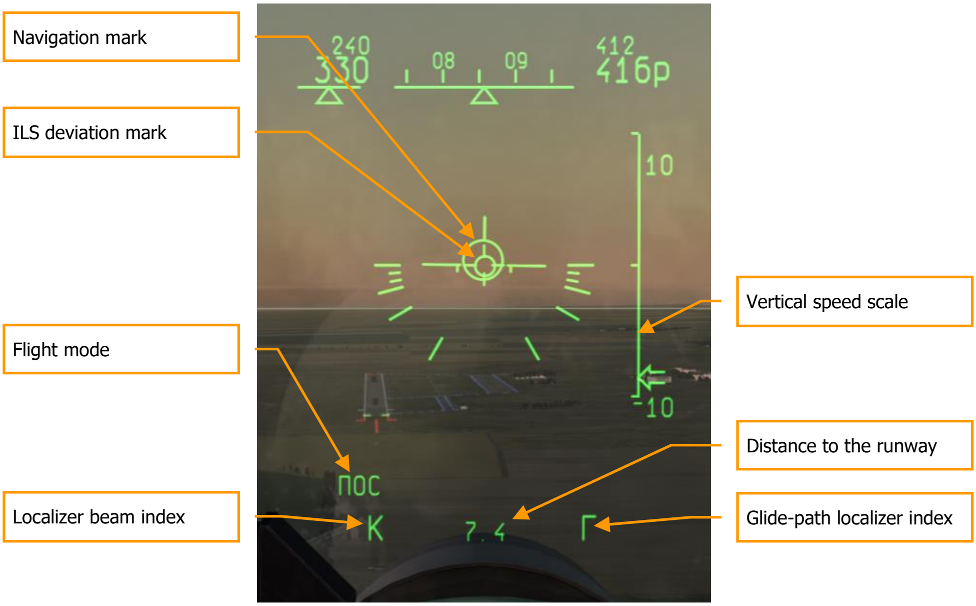


Figure 55: ILS landing

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

Beyond Visual Range Combat Modes

There are several beyond visual combat (BVR) combat modes: "ОБЗ" (SCAN) – scan, "СНП" (TWS) – track-while-scan, 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 or IRST) before targets can be detected and engaged. In BVR mode, the fighter's radar is normally used. The radar enables target detection at longer ranges, and also the use of semi-active radar homing (SARH) missiles.

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

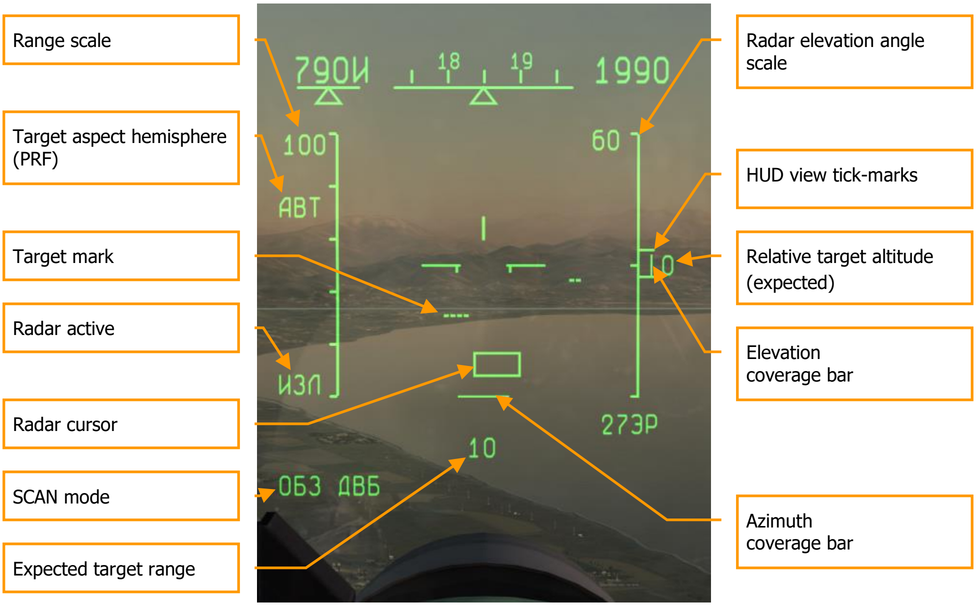


Figure 56: "ОБЗ" (SCAN) mode - BVR

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 "**ИЗЛ**" 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.

The following information is displayed on the HDD in BVR modes:

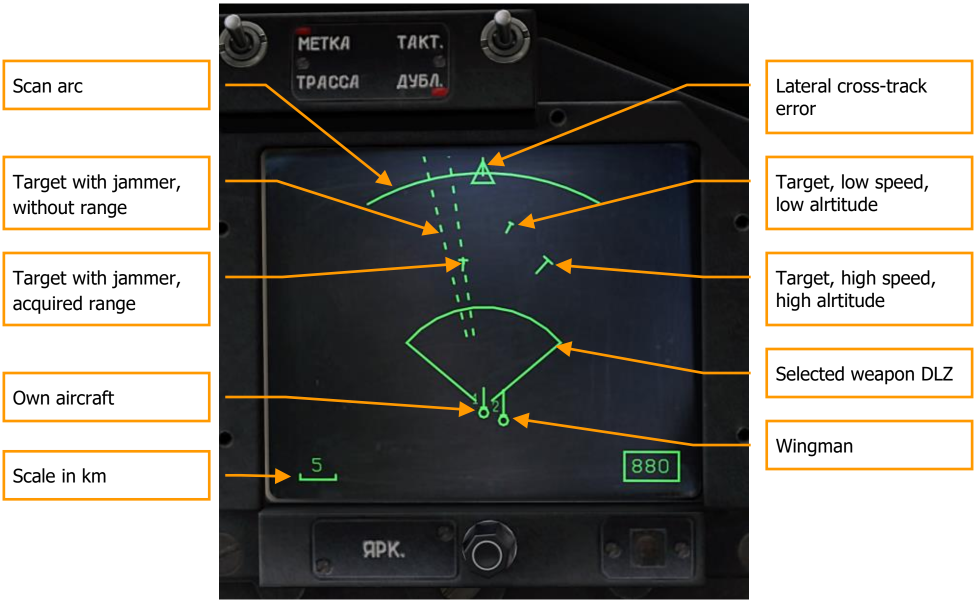


Figure 57: HDD in BVR modes

- Scan arc (60 degrees) has 3 positions: center, left and right. The scan arc position is corresponding with the azimuth coverage bar on the HUD.
- A target with jammer and unknown range is displayed with dash line
- Target using jamming but acquired range is displayed with mark and within a dashed line
- A target has a velocity vector and cross stroke. The length of velocity vector depends on target's speed. Length of cross stroke depends on target's altitude.
- Circles denote friendly aircraft
- Your own symbol is fixed near the bottom, center of the HDD
- The display scale is indicated in the lower left corner

"СНП" (TWS) MODE

Another 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.

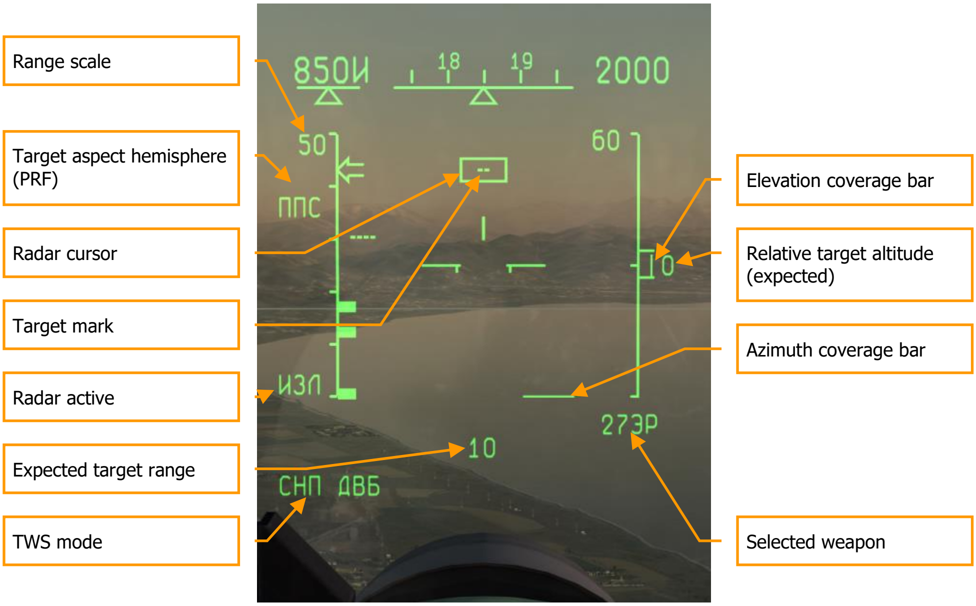


Figure 58: "СНП" (TWS) MODE

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 **27ЭР** above indicates R-27ER missiles.
- The range scale at the left side of the HUD features three thick inwards facing tick marks. Going from the top downwards, these are: Rmax - maximum permitted launch range vs. non-maneuvering target, Rtr - maximum permitted launch range vs. maneuvering target ("no-escape zone"), and Rmin - minimum permitted launch range.

"СНП" (TWS) mode is only available together with "ППС" (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, 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:

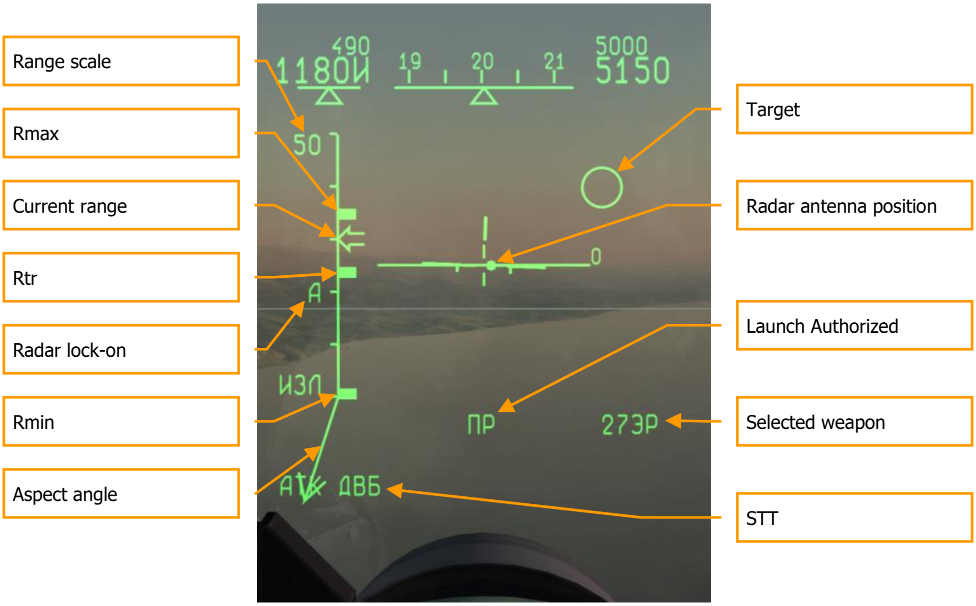


Figure 59: "АТК ДВБ" (STT BVR) MODE

- 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.
- A round dot indicates the radar antenna position relative to the fighter boresight.
- The target circle is superposed over the target in the HUD.

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

In STT mode, all radar energy is concentrated on 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.

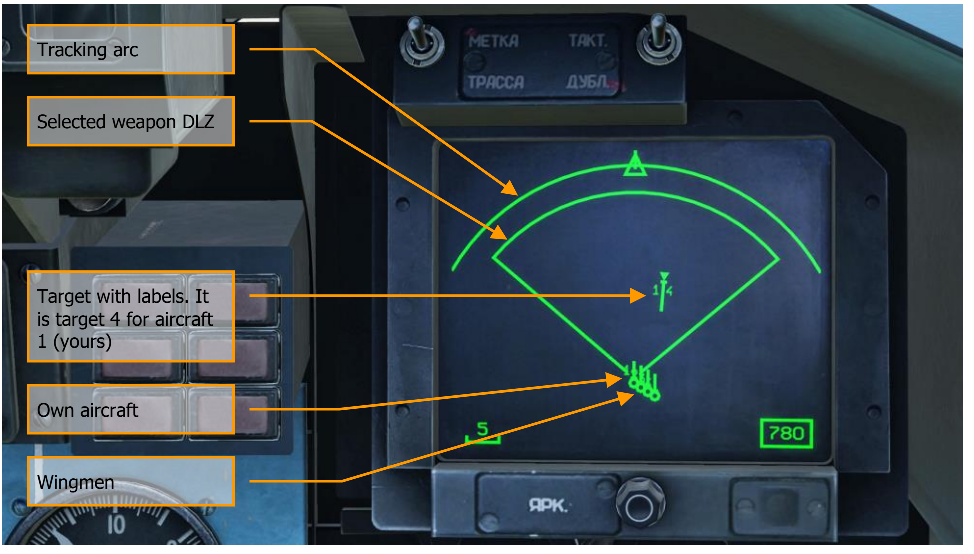


Figure 60: HDD "АТАКА – РНП" (ATTACK – STT)

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

The STT target mark has a solid triangle above it.

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

SCAN – IRST MODE

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

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

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

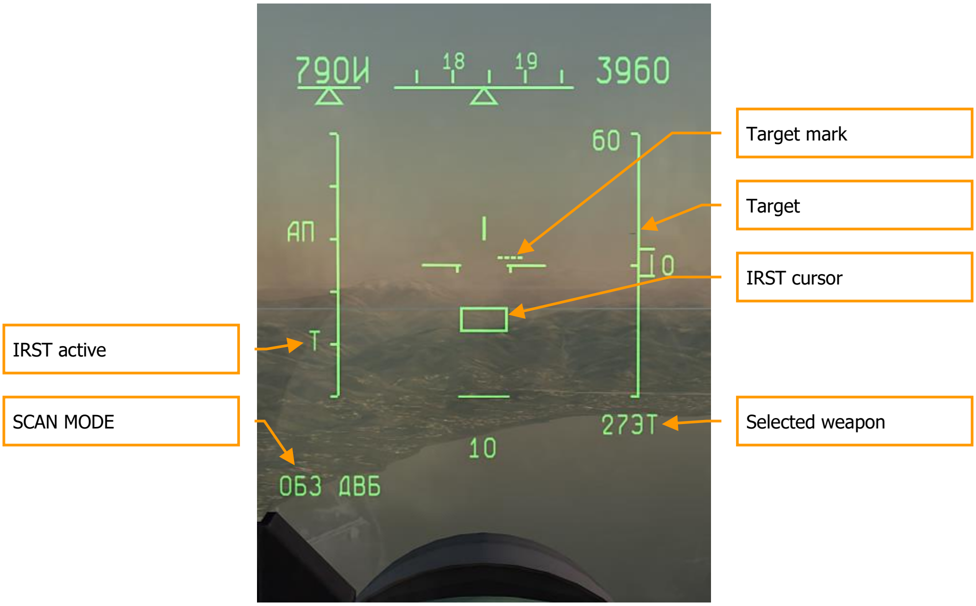


Figure 61: "ОБЗ ДВБ" (SCAN BVR) Mode with IRST as chosen sensor

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

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

Digital Datalink

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

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

HDD Datalink Symbology

Below are shown and described the HDD symbols with datalik engaged.

Figure 62: HDD target symbology

Target label description.

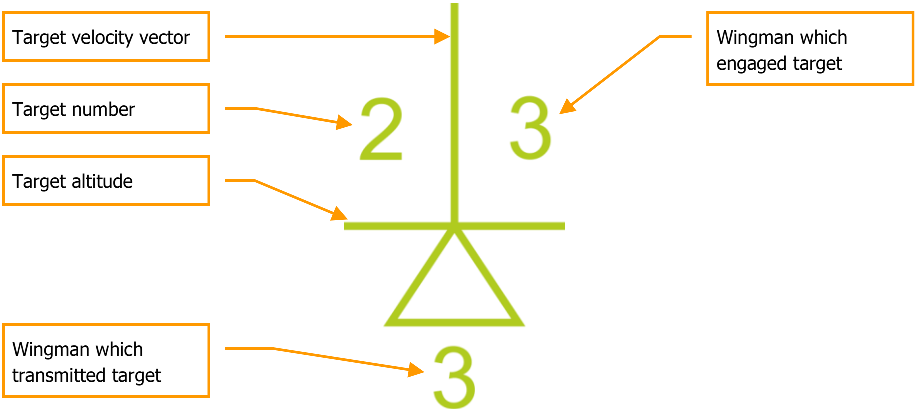


Figure 63: Target label

- Target velocity vector represents of target velocity vector. The length of the vector depends of the target's speed.
- Target altitude is indicated as the target altitude indicator leg. The length of the leg depends of target's altitude.
- The digit at left side of velocity vector is the target number.
- The digit at right side of velocity vector is the number of the wingman engaged with the target.
- The digit behind the tail of target represents the reporting source. In this case, wingman 3 is providing trackfile information on the target.

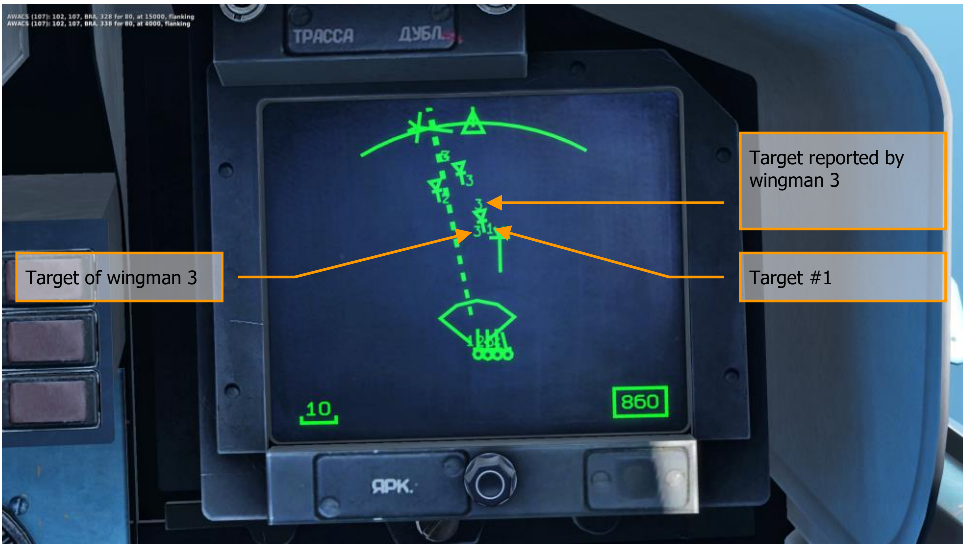


Figure 64: HDD target label

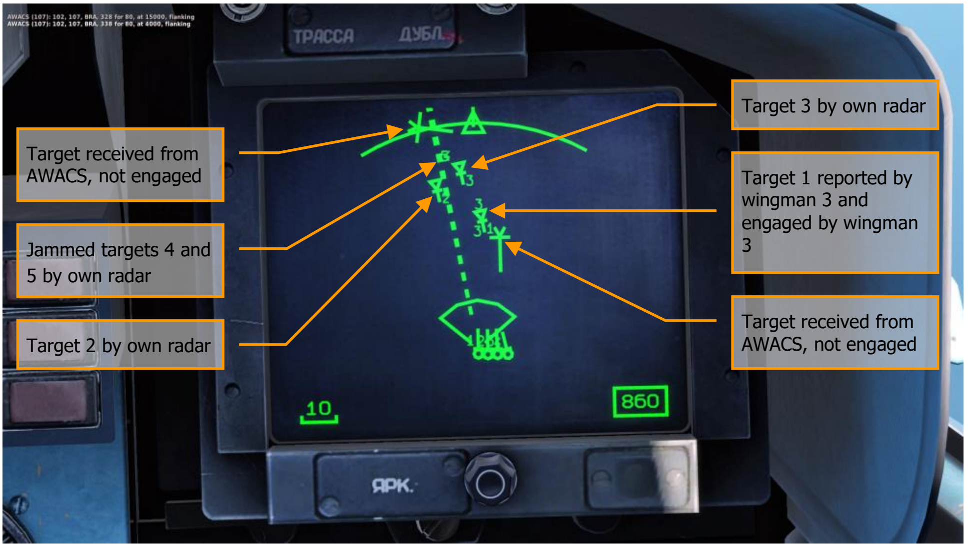


Figure 65: HDD combat situation description

Work in Complicated Countermeasures Conditions

In complicated countermeasures conditions, when the enemy uses passive and/or active radar jamming, the TWS mode cannot be used. SCAN mode should be used instead. In the conditions of strong radio-electronic countermeasures the radar cannot determine the range to the target – instead, a vertical jamming strobe of randomly flashing target marks appears in the HUD along the jammer's bearing. Detection of ECM in the radar scan pattern also causes the "АП" (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. The display on the HUD then becomes the standard SCAN mode showing the distance to the target.

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

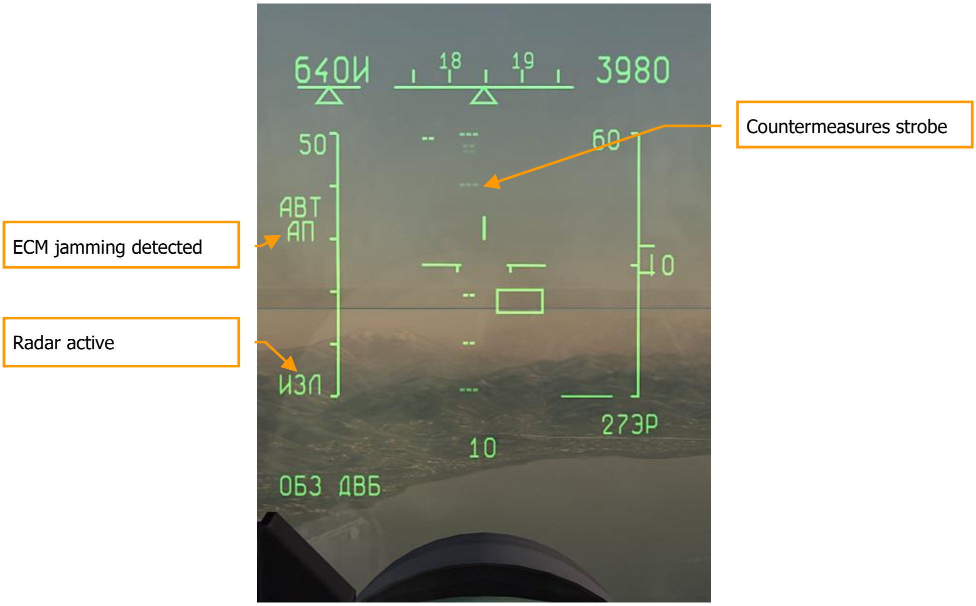


Figure 66: SCAN Mode with jammer strobe

- 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.

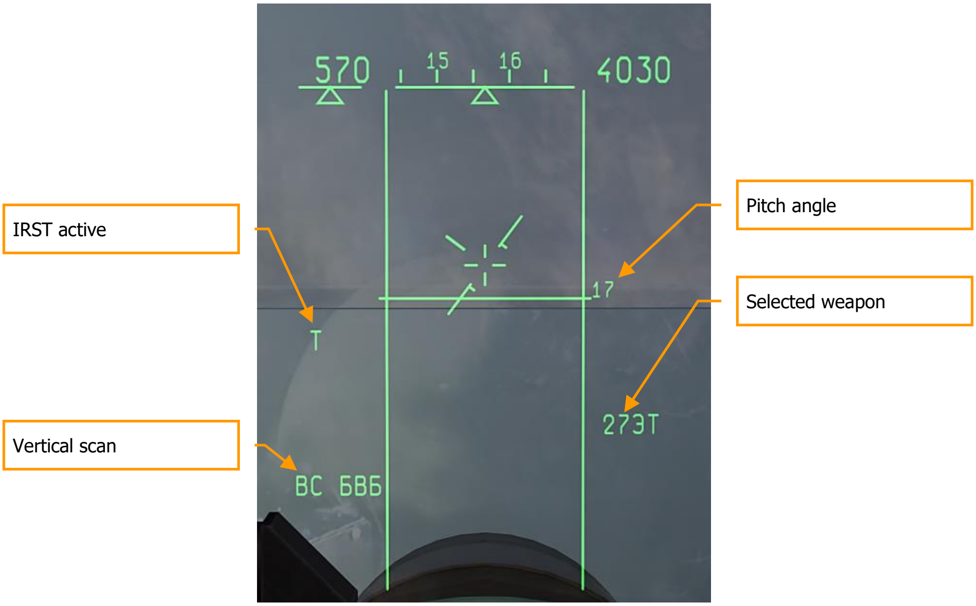


Figure 67: VS MODE

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.

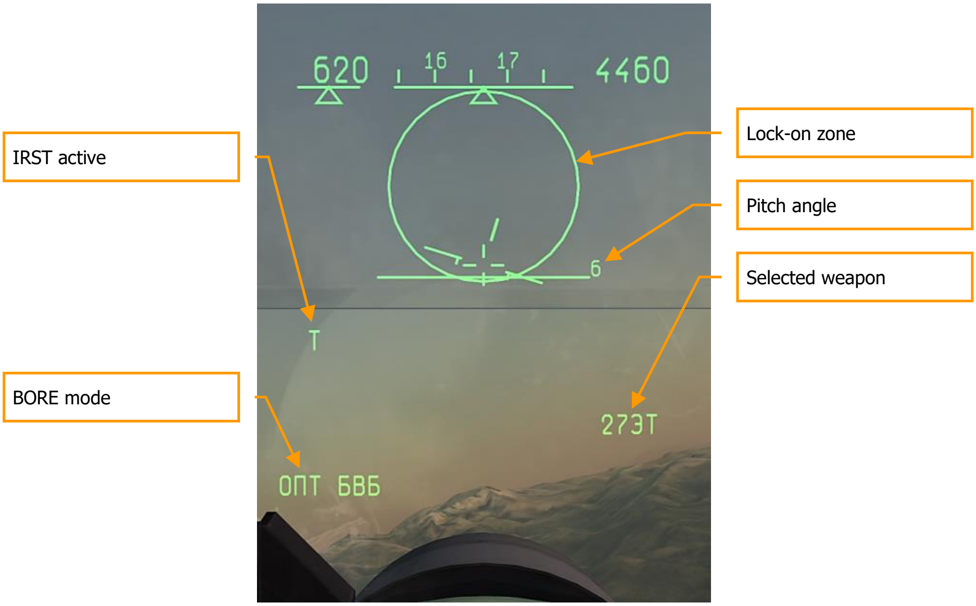


Figure 68: BORE Mode

BORE mode selects the IRST sensor by default. The default weapon is the IR missile 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 69: 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.

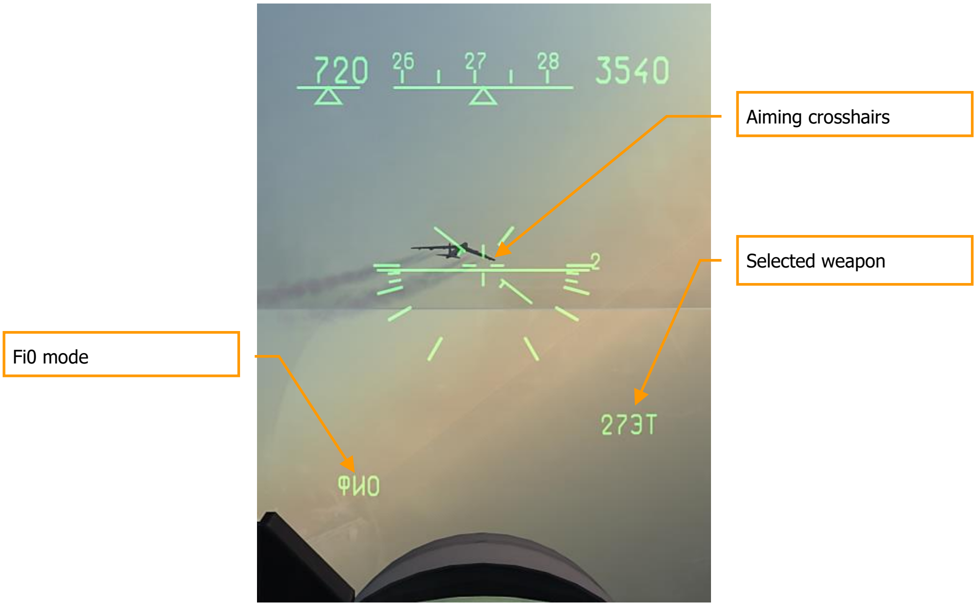


Figure 70: Fi0 (Longitudinal) MODE

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.

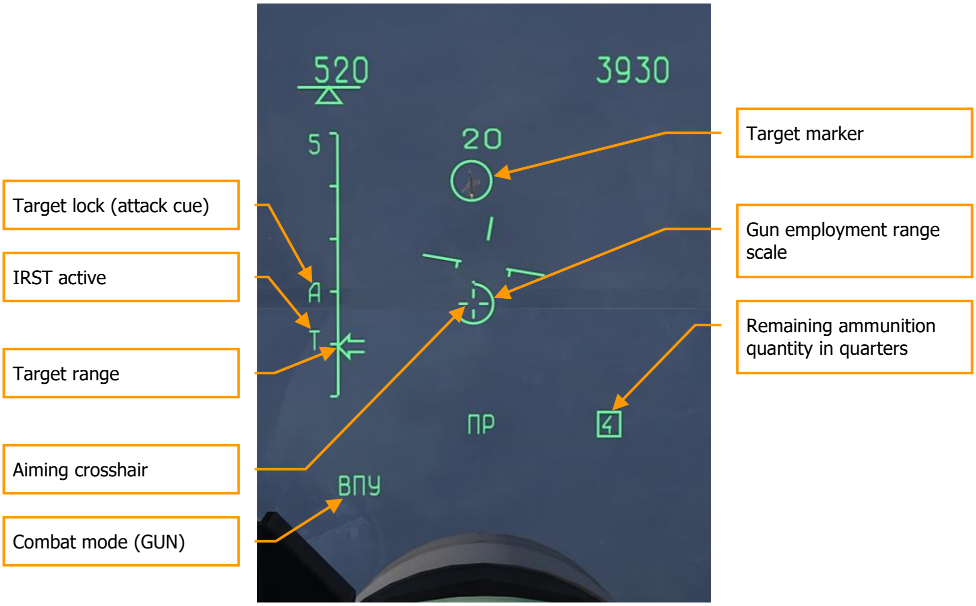


Figure 71: Lead Computed Opitcal Sight (LCOS) mode

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

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

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

Figure 72: 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 Su-27 can carry a limited variety of air-to-ground weapons. This includes unguided "iron" bombs and rockets (RKT).

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

Figure 73: 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 pipper indicates the computed point of weapon impact.

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

Reticle

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

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

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

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

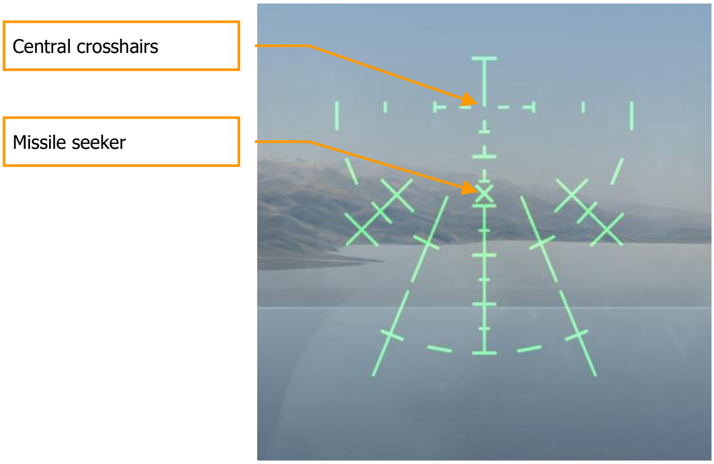


Figure 74: Reticle

Electronic Countermeasures

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

Electronic Countermeasures (ECM) Stations of Su-27

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

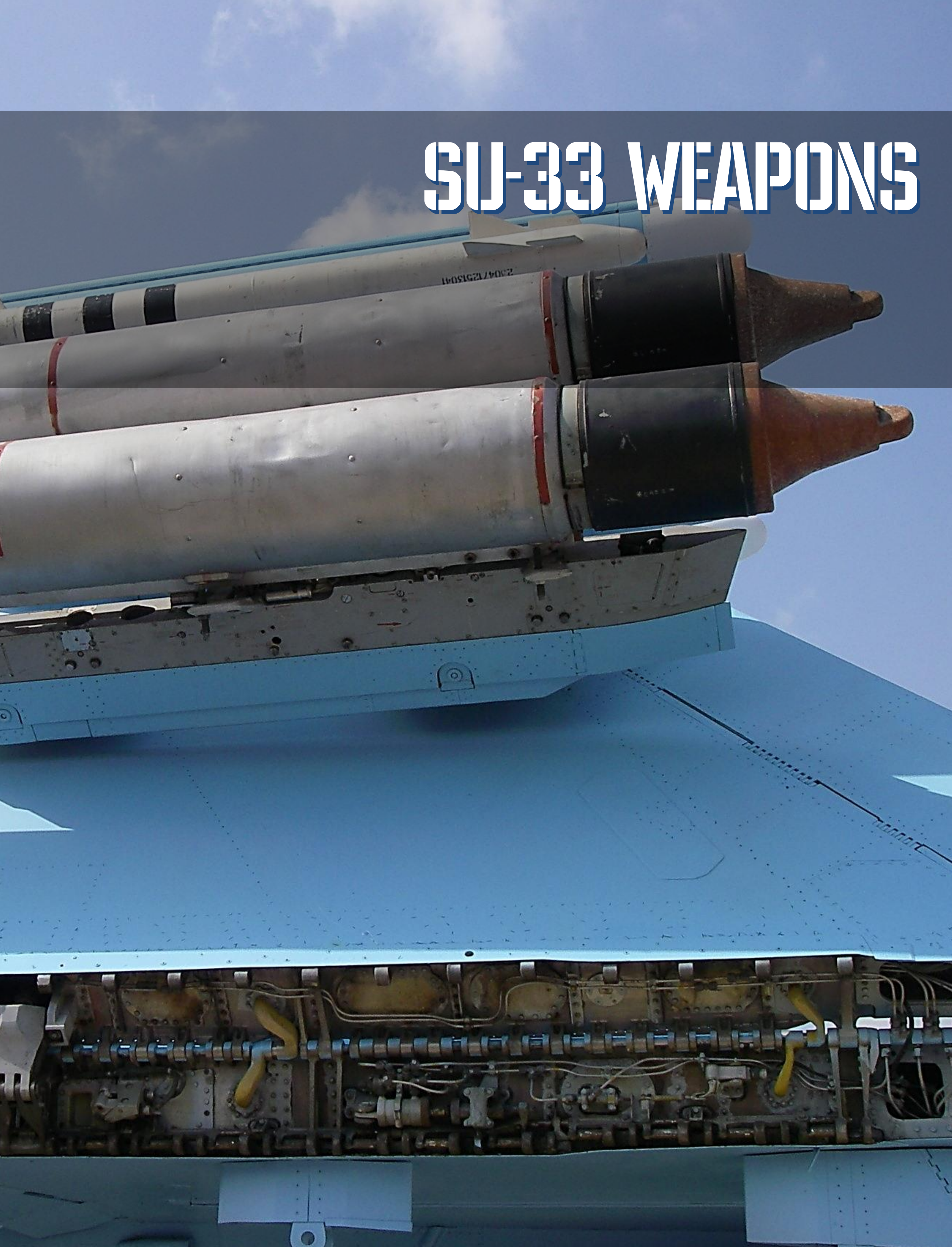
Figure 75: SPS-171 Sorbtsiya pad

When the player-flown aircraft is equipped with such an ECM system (internally, or carried on a weapon station as a pod), it can be toggled on and off during a mission by pressing the **[E]** key. The lamp on the right panel will flash during activation of the ECM system (about 15 sec) and steady light when the system is fully active.

Figure 76: ECM lamp

The active jammer will then work to reduce the tracking range of enemy radars and degrade the performance of incoming radar-guided missiles. The player's use of such active ECM may come at a price, however. The ECM may interfere with the player's own radar-guided missiles during or after launch, hostile radars experiencing reduced tracking range may nevertheless enjoy increased detection range, and hostile missiles may see active ECM as a beacon, and pursue it in a secondary "Home On Jam" (HOJ) mode. For the best defense against missiles, active ECM is best combined together with passive jamming (chaff) and perpendicular ("beaming") maneuvers at low altitude.

SU-33 WEAPONS



SU-33 WEAPONS

The Su-33 is generally armed with the same weapons as the Su-27. This includes a single 30 mm Gryazev-Shipunov GSh-30-1 cannon in the starboard wingroot and up to 12 hardpoints for missiles, bombs and rockets. Its standard air-to-air combat armament is a mixture is of R-27 (AA-10 'Alamo') and R-73 (AA-11 Archer) missiles. The Su-27S can also be armed with bombs and unguided rockets to fulfil a secondary ground attack role.

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 ballisticly until it hits the ground or self destructs.

Maximum missile launch range is not a constant value; it depends on a number of variables: 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 and HDD/VSD.

Air-To-Air Missiles

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. The APU-470 rail launcher is intended for missiles loaded under the wings and the AKU-470 catapult device is used for missiles loaded underneath the fuselage or wings.

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

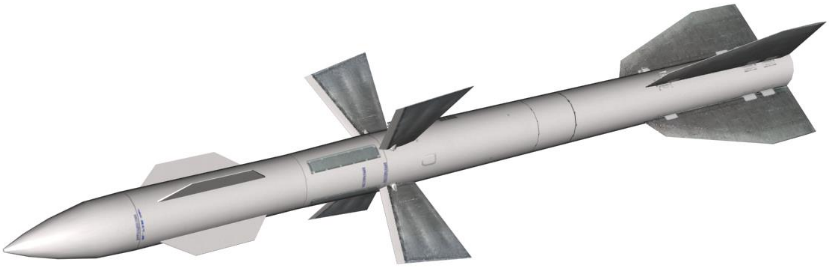


Figure 77: R-27R missile

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

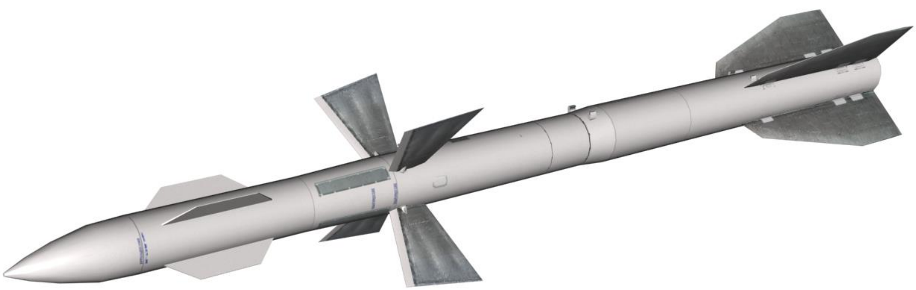


Figure 78: R-27ER missile

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

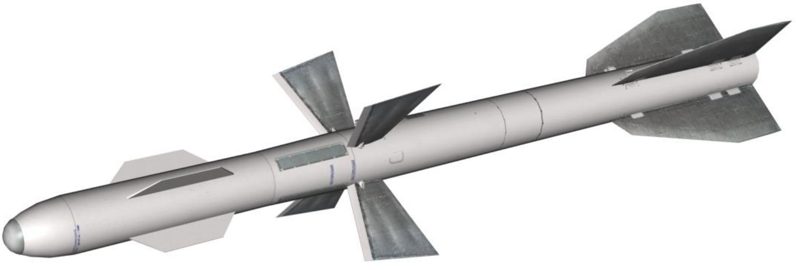


Figure 79: R-27T missile

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

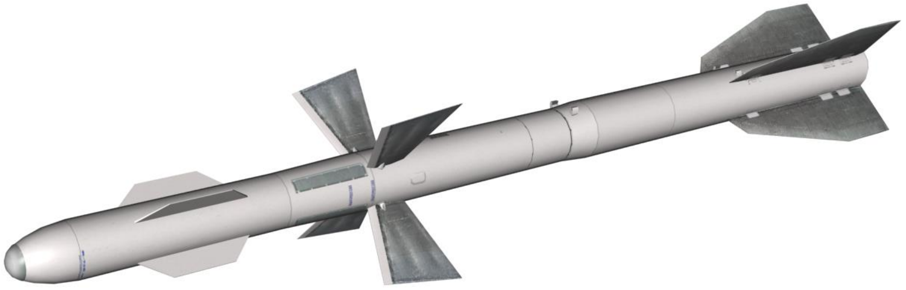


Figure 80: R-27ET missile

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 avanproject, a resolution dated July 26, 1974 defined the requirements of the future Su-27 and MiG-29, entrusted "Molniya" design bureau with development of a highly-maneuverable, small, close air combat missile - the K-73. The missile was first envisioned as an enhanced P-60, but taking into account the high maneuverability requirements, it was allowed to increase its weight to be between the R-60 and R-13.

Figure 81: R-73 missile

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

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

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

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

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

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

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

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

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

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

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

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

The table below compares the characteristics of R-27 missiles family.

Parameters	R-27R/T	R-27ER/ET
The year it entered service	1987	1990
Aircraft/number carried	MiG-29/4; Su-27/4; Su-33/6	
Weapon control system	SUV S-29; SUV S-27; SUV S-27M	
Aerodynamic design	Canard with destabilizers	
Weight, kg	253	354
Warhead weight, kg	39	
Warhead type	Rod-type	
Body diameter, m	0,23	0,23/0,26
Length, m	3,96	4,56
Control surface span, m	0,77	0,8
T/W ratio, Kgs/Kg	62	94
Motor type	single-mode	double-mode
Seeker gimbal limits	±50° for radar TSD; ±55° for IR TSD	
Guidance system type	Inertial guidance with radio correction; self-guidance with semi-active TSD with lock-on after launch; infrared TSD cooled by nitrogen	
Guidance method	Proportional guidance	
Target maximum speed, km/h	3500	
Target maximum range, km	0,03 - 25	0,03 - 27

Maximum launch range in forward/rear hemisphere, km	45/18	70/30
Minimum launch range in rear hemisphere, km	0,5	
Maximum target G, units	8	

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 Su-27 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

Su-27 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 82: FAB-500 High-Explosive Bomb

Figure 83: 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 84: BetAB-500ShP Concrete Piercing Bomb

SAB-100 Illumination Bomb

Figure 85: SAB-100 Illumination Bomb

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

RBK-250, RBK-500 Cluster Bomb

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

Figure 86: 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 87: 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 88: KMGU-2 Sub-munitions Dispenser

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

Unguided Aerial Rockets

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

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

S-8 rocket

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

Figure 89: B-8M1 Rocket Launcher

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

S-13 rocket

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

Figure 90: UB-13 Rocket Launcher

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

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

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

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

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

S-25 Rocket

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

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

Figure 91: S-25 Rocket

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

Figure 92: S-25 Unguided Rocket in its Launch Tube

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

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

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

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

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 well respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, "**(x) Negative**," or "**(x) Unable**," where (x) is the flight member.
		Trail	The player is the lead aircraft and aircraft two .5 miles behind the player. Aircraft three is .5 miles behind aircraft two and aircraft four is .5 miles behind aircraft three.	
		Echelon	Standard formation	
		Close Formation	Player requests that the formation or wingmen decrease aircraft separation.	
		Open Formation	Player requests that the formation or wingmen increase aircraft separation.	

AWACSes	AWACS callsign	Request BOGEY DOPE	Player requests the bearing, range, altitude and aspect of the nearest enemy aircraft.	If AWACS/GCI has contact with an enemy aircraft then: **"(a), (b), bandits bearing (x)(x) for (y)(y)(y). (c) (d),"** where (a) is the callsign of the player, (b) is AWACS callsign, (x)(x) is the bearing to the threat in degrees, (y)(y)(y) is the range to the threat in miles if AWACS is western or kilometers if AWACS is Russian, (c) is the altitude of the contact, and (d) is the aspect of the contact. If AWACS/GCI does not have contact with any enemy aircraft then: **"(a), (b), clean,"** where (a) is the callsign of the player and (b) is AWACS callsign. If enemy aircraft are within five miles of player then: **"(a), (b), merged"** where (a) is the callsign of the player and (b) is AWACS callsign.
		Vector to Home Plate	Player requests the bearing and range to the nearest friendly airfield.	**"(a), (b), Home bearing (x)(x) for (y)(y)(y),"** where (a) is the player's callsign, (b) is AWACS callsign, (x)(x) is the bearing to the airfield in degrees, and (y)(y)(y) is the range in miles or kilometers depending on American or Russian AWACS.
		Vector to Tanker	Player requests the bearing and range to the nearest friendly tanker aircraft.	**"(a), (b), Tanker bearing (x)(x) for (y)(y)(y),"** where (a) is the player's callsign, (b) is AWACS callsign, (x)(x) is the bearing to the airfield in degrees, and (y)(y)(y) is the range in miles or kilometers depending on American or Russian AWACS. If no friendly tanker is present in the mission, then: **"(a), (b), No tanker available"**

		Request PICTURE	Player requests the bearing, range, altitude and aspect of the all enemy aircraft in zone.	If AWACS/GCI has contact with a enemy aircraft: **"(a), (b), bandits bearing (x)(x) for (y)(y)(y). (c) (d),"** where (a) is the callsign of the player, (b) is AWACS callsign, (x)(x) is the bearing to the threat in degrees, (y)(y)(y) is the range to the threat in miles if AWACS is western or kilometers if AWACS is Russian, (c) is the altitude of the contact, and (d) is the aspect of the contact. If AWACS/GCI does not have contact with any enemy aircraft: **"(a), (b), clean"**
ATC - Tower	Airfield callsign	Request Taxi to Runway	Player asks tower permission to taxi to runway.	ATC will always respond **"(a), Tower, Cleared to taxi to runway (x)(x),"** where (a) is the callsign of the player and (x)(x) is the heading number of the runway.
		Request Takeoff	Players asks permission from tower to takeoff.	If no aircraft are taking off from the runway and/or no aircraft are on final on that runway, then ATC will respond **"(a), Tower, You are cleared for takeoff,"** where (a) is the callsign of the player.
		Inbound	Player requests permission to land at the nearest friendly airbase	**"(a), (b), fly heading (x)(x), QFE, runway (y) to pattern altitude"** where (a) is the player's callsign, (b) is the airbase call sign, (x)(x) is the heading, and range, QFE is a Q-code Field Elevation, (y) the heading number of the runway.
Ground Crew		Rearm...	Player requests ground crew to rearm aircraft according to package selection.	Ground crew answers: "Copy ". After rearming informs: "Rearming complete ".
		Refuel...	Player requests ground crew to refuel	

		Request Repair	Player requests ground crew for repair	Complete repair is made within 3 minutes.
Other	Other messages specified by mission creator via trigger events.			

Radio Messages

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

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

Radio Messages

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

	Illuminated by enemy airborne radar	**"(x), Spike, (y) o'clock,"** where (x) is the flight member and (y) is a number one through twelve. Example: "Two, spike three o'clock."
	Illuminated by enemy ground-based radar	**"(x) Mud Spike, (y) o'clock,"** where (x) is the flight member and (y) is a number one through twelve. Example: "Two, mud spike three o'clock."
	Surface-to-Air Missile fired at wingman	**"(x) Sam launch, (y) o'clock,"** where (x) is the flight member and (y) is a number one through twelve. Example: "Two, Sam launch three o'clock."
	Air-to-Air Missile fired at wingman	**"(x) Missile launch, (y) o'clock,"** where (x) is the flight member and (y) is a number one through twelve. Example: "Two, Missile launch three o'clock."
	Visual contact on enemy aircraft	**"(x) Tally bandit, (y) o'clock,"** where (x) is the flight member and (y) is a number one through eleven or nose. Example: "Two, Tally bandit three o'clock."
	Performing defensive maneuver against threat	**"(x) Engaged defensive,"** where (x) is the flight member. Example: "Two, Engaged defensive."
	Shot down enemy aircraft	**"(x) Splash one,"** **"(x) Bandit destroyed,"** or **"(x) Good kill, good kill,"** where (x) is the flight member. Example: "Two, Splash my bandit."
	Destroyed enemy ground structure, ground vehicle, or ship	**"(x) Target destroyed,"** or **"(x) Good hits,"** where (x) is the flight member. Example: "Two, Target destroyed."
	Wingman has spotted enemy aircraft and wishes to attack	**"(x) Request permission to attack,"** where (x) is the flight member. Example: "Two, Request permission to attack."
	Iron bomb or cluster bomb released	**"(x) Bombs gone,"** where (x) is the flight member. Example: "Two, Bombs gone."
	Air-to-ground missile fired	**"(x) Missile away,"** where (x) is the flight member. Example: "Two, Missile away."
	Air-to-ground, unguided rockets fired	**"(x) Rockets gone,"** where (x) is the flight member. Example: "Two, Rockets gone."

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

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

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

Radio Assistance Voice Warning System

Below list of warnings about missile attack will be heard when Radioassistent option is turned on in the Gameplay panel of Options.

Message Trigger	Message
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"

SU-33 CHECK LIST

SU-33 CHECK LIST

The powerplant of the Su-33 includes two AL-31F engines, each of which has its own turbine starter GTDE-117. Because both engine have a separate starter, both individual and simultaneous starting of both engines is possible.

Engine Ground Start

In order to start the engines on the ground, one should:

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

After this, the engine starter doors will open, the door limit switch actuates and puts the starter circuit into operation. Based on the starter circuit command, fuel is provided to the turbine starter and the annunciator **"ЗАПУСК"** (START) is lit in the cockpit.

The starter circuit turns on the electrical starter motor, ignites the turbine starter, and supplies oxygen to the turbine starter. After ten seconds, the turbine starter will turn off these accessories and simultaneously starts ignition of the main chamber. The turbine starter spins up the engine compressor and the fuel control unit controls fuel flow to the main chamber. After ignition in the main chamber, the turbine comes into operation and accelerates the engine compressor together with the turbine starter. At 35% of the engine RPM, the ignition exciter in the main chamber switches off. At 53% of the engine RPM, or after 50 seconds, the turbine starter and starter circuit are switched off, which is indicated by the annunciator **"ЗАПУСК"** (START) turning off. The engine then reaches IDLE mode automatically.

For taxi to engage the nose gear steering **[RAlt + Q]**.

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

Restarting an engine while in flight is performed by placing the throttle from the **"СТОП"** (STOP) position to any non-afterburning position (with the landing gear retracted only). At the same time, a micro-switch connected to the throttle turns on the starter circuit, which turns on the following accessories for 20 seconds: ignition exciter of the main chamber, the booster pump, oxygen supply to the engine, and the annunciator **"ЗАПУСК"** (START).

There is no need to use the turbine starter due to engine autorotation.

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

Some features of the Su-33

The landing hook can be lowered with the landing gear switch **[LAlt-G]** when in the down position, because the hydraulic power is also supplied from the landing gear hydraulic lines.

The in-flight refueling probe is retracted within 2 minutes after commanded **[LCtrl-R]**, at this time, the system is purged of fuel.

Aerial refueling lights **[LAlt-R]**, that can be used during air refueling in the night.

Please do not use the air intake anti-FOD shields **[LAlt + I]** for deck takeoff because they decrease engine efficiency thrust on 12%.

In order to increase the initial thrust of the aircraft to ensure a short takeoff from the flight deck, and a safe missed approach in case of an unsuccessful attempt of recovery, the AL-31F series 3 engines are equipped with a special afterburner mode of operation. This adds an additional 12800 kgf of thrust.

This mode has a 10 minute operational limit.

- Engage special afterburner mode – full throttle, wait afterburner to light and then press command **[LSift-E]**.
- Disengage special afterburner mode – set throttles to military power.

Note: This special mode can only be engaged from afterburner.

The special mode light is located in the central notification lights block.

Figure 93: Afterburner and special mode lights

Mid-air Refuelling

Mid-air refueling typically takes place at altitudes of 2000 to 9000 meters, and at indicated airspeeds of 500 to 570 kph. For a successful refueling process the pilot must enter the refueling area by means of a SHORAN device (not implemented in the module) set to RENDEZVOUS mode, given that there is two-way radiocommunication with the tanker aircraft.

In order to perform a mid-air refueling, the pilot must first contact the tanker aircraft through the radiomenu function "Tanker – Intent to refuel." If the tanker is ready for fuel transmission, it will respond with "proceed to pre-contact."

After acquiring confirmation that the tanker aircraft is ready for the procedure, the crew of the receiving aircraft must perform the following:

- Maintain a distance of 250 to 100 meters, and a negative altitude difference of 15 to 20 meters from the tanker aircraft.
- Deploy the refueling boom with the key command **[LCTRL-R]** (the indicator panel on the aircraft dash will display "BOOM DEPLOYED")
- Switch on the REFUELING mode control system for switching aircraft control profile to position-based control **[RCTRL-R]**.
- Switch on the refueling floodlights with **[LALT-R]** if flying at night. This also activates the lights on the refueling boom and refueling zones.

After deploying the boom and stabilizing the aircraft behind the tanker, the pilot must inform the tanker aircraft that they are "ready to pre-contact." If all the prerequisite conditions are met, the tanker will respond with "cleared contact" and will deploy the refueling hose from one of UPAZ refueling pod.

When the refueling pod on the tanker aircraft begins to display a flashing green light alongside a solid red light, the pilot of the receiving aircraft must close with the refueling cone to a distance of 10 to 15 meters, an interval of 1 to 0.5 meters to the right, and a negative altitude difference of 3 to 6 meters relative to the cone. The aircraft must be held in this position for 20 to 30 seconds, after which contact must be made.

After contact between the hose and boom is made, the tanker will inform the pilot with "contact" and "you are taking fuel." Fuel transmission begins automatically.

After contact is made and the indicator panel begins to display "REFUEL", assume the refueling formation with an appropriate distance between the two aircraft (indicated by a green light on the refueling pod), and a negative altitude difference of 3 to 6 meters relative to the refueling pod.

During fuel transmission, the player's task is to maintain stable flight and matching airspeed with the tanker; a light signal is fixed on the refueling pod to assist with this process.

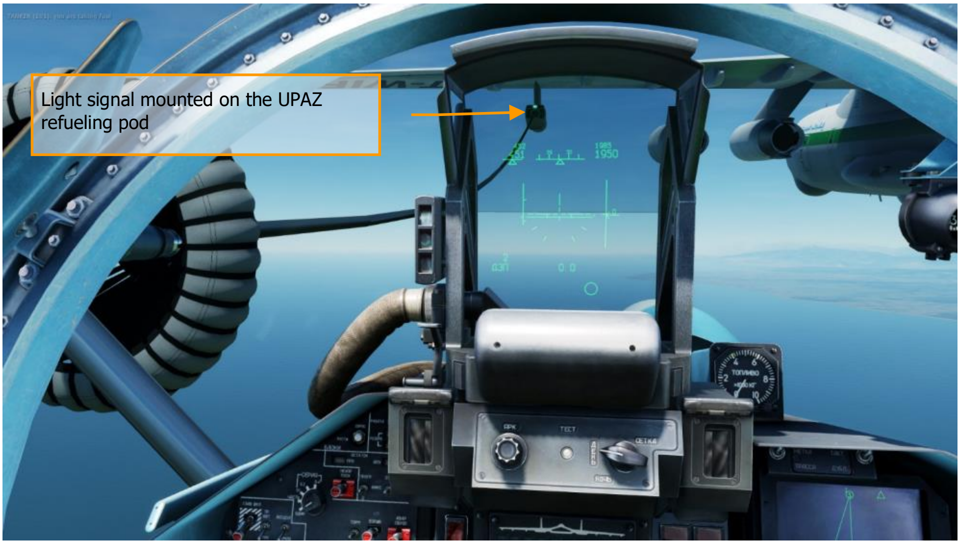


Figure 94: Light signal mounted on the UPAZ refueling pod

The light signal is composed of three yellow, green, and red-coloured lamps. These lights reflect the length of the deployed refueling hose – that is, the distance of the refueling cone from the refueling pod.

Markup scheme of the UPAZ refueling pod hose and the light signaling system

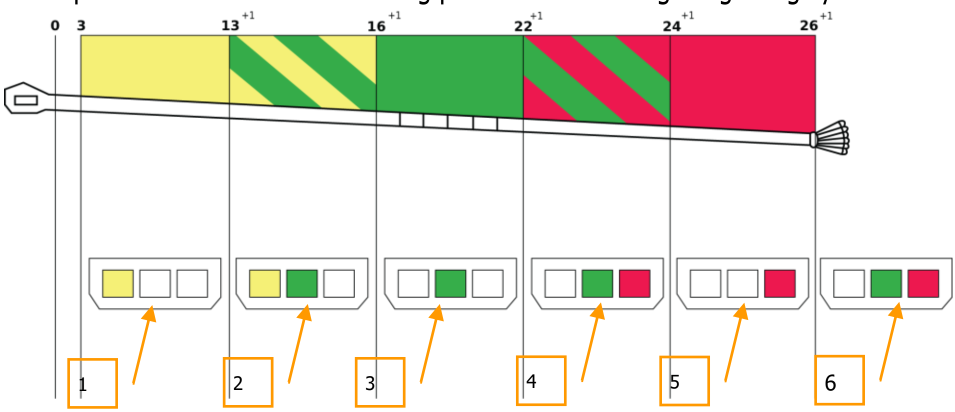


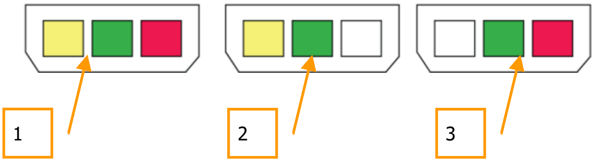
Figure 95: Markup of the refueling pod hose and the light signaling system

1. Yellow – distance of the cone to the refueling pod from 3 to 13 meters

2. Yellow and green – distance of the cone to the refueling pod from 13 to 16 meters.
3. Green – distance of the cone to the refueling pad from 16 to 22 метров.
4. Green and red - distance of the cone to the refueling pod from 22 to 24 meters.
5. Red – distance of the cone to the refueling pod from 24 to 26 meters.
6. During hose deployment and extension to its effective length, and during contact authorization, the signaling system will display a flashing green light alongside a solid red.

The optimal distance to maintain is from 16 to 22 meters, indicated by a solid green light.

Special light modes



1. All lights flashing - refueling cessation and disconnection.
2. Yellow light flashing – rate of closure greater than 0.4 m/s.
3. Red light flashing – rate of separation greater than 0.4 m/s.

The relative speed of closure when attempting contact must be within 0.5 to 1.8 m/s (0.8 to 1.5 m/s is recommended during contact itself.) This relative speed must be visually determined by the pilot. After contact is made, the closure/lag speed must be kept under 0.4 m/s – a lag speed of greater than 2.5 m/s will lead to a loss of contact between the two ends, and a closure speed of greater than 0.6 m/s may lead to a buckling failure of the refueling boom.

Refueling is impossible when the refueling pods displays a yellow light. When this happens, the pilot must increase the distance between their aircraft and the tanker. Upon entering the green zone the pilot must then maintain formation and continue the refueling process, keeping a negative altitude difference of 3 to 6 meters. When the pod begins to show a solid red light alongside a flashing green light, the pilot must break and reestablish contact in order to prevent damage to the refueling boom.

After successful completion of the refuelling process, the indicator showing "REFUEL" will go out. The pilot will then have to break contact with the tanker and move to a safe distance. Flying in the docked state after the termination of the refuelling process is not recommended.

During separation all three lamps will begin to flash.

Upon completing the refueling process the pilot must retract the refueling boom with the key command **[RCTRL-R]**. Please note that the refueling boom will be automatically retracted 2 minutes after the command, once the drainage from the remaining fuel has ceased.

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 two primary radar acquisition modes **SCAN** and **TWS** for long-range missile employment. The **TWS** mode provides more detailed target information, permits a tactical situation picture to be displayed on the Head Down Display (HDD), and can lock targets in an automated mode. However, it cannot be used to detect targets in a heavy ECM environment or simultaneously detect high and low targets aspect. In such a situation, it's best to use **SCAN** mode. To search for both high and low targets aspect, use the **"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 and HDD in km with the **[+]** and **[-]** keys. If the situation permits, you may choose to enter **"СНП"** (TWS) mode by pressing the **[RAlt-I]** key. Select the best missile for the range and target by cycling the **[D]** key and confirm the selection on the HUD.

Step 2

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

Step 3

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

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

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

Step 4

After you have oriented the scan zone in the direction of the target, you may have to wait up to six seconds before the target is detected. This is only accomplished after the radar has completed several scanning cycles. After the radar has detected a target, a contact mark is displayed on the HUD and HDD. 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.

Step 5

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

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

When in **"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.

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.

Missile Engagement with IRST as the Active Sensor

Using the "ОЛС-27" - 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 and R-73 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 Su-27 the azimuth scan zone moves discretely and has three positions: central ±30 degrees, left –60 - 0 degrees and right 0 - +60 degrees. If the target is out of the central ±30 degrees zone, than it is required to move the scan zone to the left or right by the **[RShift-,]** and **[RShift-/]** keys.

Step 3

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

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

Step 4

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

Step 5

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

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

Step 6

Once in STT mode and the distance to target is 85% or less than that of the maximum range of the selected missile, the LA – "launch authorized" message will appear on the HUD. With this authorization, you may launch the missile by pressing the launch weapon button on your joystick or by pressing the **[Space]** key. 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 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. 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. Y 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 pipper on the target and press the weapon release button on your joystick or the **[Space]** key on your keyboard.

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

Close Air Combat – 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 pipper on the target and press the weapon release button on your joystick or the **[Space]** key on your keyboard.

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

Close Air Combat – Shlem (Helmet) Mode

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

The lock and launch steps are as follows:

Step 1

When an air target is visually detected, activate **SHLEM** mode by pressing the **[5]** key. The IRST sensor will become active automatically; this allows an attack without active sensors. If you then select a SARH-type missile, you will need to manually activate the radar by pressing the **[I]** key. Select the desired missile by cycling the **[D]** key. 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 Su-27 can carry limited types of air-to-surface weapons. This arsenal includes free-fall bombs and unguided rockets.

General Purpose, Low-Drag Bombs

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

Step 1

Visually identify the target.

Step 2

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

Step 3

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

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 pipper 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

SUPPLEMENTS

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Acronym List

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

DC	Direct Current
DCS	Digital Combat Simulator
DH	Desired Heading
DR	Drift Angle
DST	Distance
DT	Desired Track
DTA	Desired Track Angle
EDP	Engine Dust Protectors
EEG	Electronic Engine Governor
EGT	Exhaust Gas Temperature
EO	Electro Optical
ETA	Estimated Time of Arrival
ETP	Estimated Touchdown Point
FAC	Forward Air Controller
FARP	Forward Arming and Refueling Point
FEBA	Forward Edge of Battle
FOV	Field Of View
FPL	Flight Plan
FSK	Function Select Key
GG	Gas Generator
GNSS	Global Navigation Satellite System
GS	Ground Speed
HDG	Heading
HE	High Explosive
HMS	Helmet Mounted Sight
HSI	Horizontal Situation Indicator
HUD	Head Up Display

IAF	Initial Approach Fix
IAS	Indicated Air Speed
IDM	Inertial Doppler
IDS	Information Display System
IFF	Identify Friend or Foe
IFR	Instrument Flight Rules
IFV	Infantry Fighting Vehicle
INU	Inertial Navigation Unit
IWP	Initial Waypoint
LAT	Latitude
LLT	Linear Lead Turn
LONG	Longitude
LWR	Laser Warning Receiver
LWS	Laser Warning System
MANPADS	Man-Portable Air Defense System
ME	Mission Editor
MILS	Abbreviation for milliradian; Bomb/Gun sight settings were expressed in mils, an angular measurement; one degree was equal to 17.45 mils.
MRB	Magnetic NDB Bearing
MWL	Master Warning Light
NATO	North Atlantic Treaty Organization
NDB	Non Directional Beacon
NVG	Night Vision Goggles
OEI	One Engine Inoperative
PT	Free Turbine

PNK	Russian "ПНК". Aircraft Flight and Navigation system
PrPNK	Russian "ПрПНК". Aircraft Targeting, Flight and Navigation System
RAIM	Receiver Autonomous Integrity Monitoring
RALT	Radar Altitude
RB	Radio Bearing
RMI	Radio Magnetic Indicator
RPM	Revolutions Per Minute
ROF	Rate Of Fire
RTB	Return To Base
SAI	Stand-by Attitude Indicator
SAM	Surface-to-Air Missile
STP	Steerpoint
TAS	True Air Speed
TCA	True Track Angle
TH	True Heading
TOW	Takeoff Weight
TP	Target Point
TV	Television
TVM	Television Monitor
UHF	Ultra High Frequency
UTC	Coordinated Universal Time
VHF	Very High Frequency
VFR	Visual Flight Rules
VMU	Voice Message Unit
VNAV	Vertical Navigation
VOR	VHF Omnidirectional Range

VVI	Vertical Velocity Indicator
WCS	Weapon Control System
WPT	Waypoint
XTE	Cross Track Error

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