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Su-27
FLANKER



DCS: Su-27 Flanker
Flight Manual

DCS: Su-27 for DCS World

The Su-27, NATO codename Flanker, is one of the pillars of modern-day Russian combat aviation. Built to counter the American F-15 Eagle, the Flanker is a twin-engine, supersonic, highly manoeuvrable air superiority fighter. The Flanker 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. The Flanker also includes a helmet-mounted sight that allows you to simply look at a target to lock it up! In addition to its powerful air-to-air capabilities, the Flanker can also be armed with bombs and unguided rockets to fulfil a secondary ground attack role.

Su-27 for DCS World focuses on ease of use without complicated cockpit interaction, significantly reducing the learning curve. As such, Su-27 for DCS World features keyboard and joystick cockpit commands with a focus on the most mission critical of cockpit systems.

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INTRODUCTION

The Su-27, NATO codename Flanker, is one of the pillars of modern-day Russian combat aviation. Built to counter the American F-15 Eagle, the Flanker is a twin-engine, supersonic, highly manoeuvrable air superiority fighter. The Flanker 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. The Flanker also includes a helmet-mounted sight that allows you to simply look at a target to lock it up! In addition to its powerful air-to-air capabilities, the Flanker can also be armed with bombs and unguided rockets to fulfil a secondary ground attack role.



Figure 1: Su-27

SU-27 HISTORY



SU-27 HISTORY

The Su-27, a Russian fourth-generation single-seat supersonic fighter, is recognised all over the globe as one of the best combat aircraft of the 20th century. Due to its perfect flight performances and operational characteristics, the fighter is rightfully popular with pilots and technicians. Top piloting capabilities of the Su-27 fighter demonstrated during multiple air shows around the world did not leave anyone indifferent. The Su-27 is in the top lines of the aviation record tables of the International Aircraft Federation. To the date, the Su-27 is a record-holder of 27 world class flight achievements. The Su-27 is the forefather of a combat aircraft family of various functionality, including the Su-27UB trainer, Su-33 ship-borne fighter, Su-30 twin-seat multirole fighter family, Su-34 tactical bomber and deep modernized fighter Su-35.

To achieve such impressive results, the developers of the fighter had to follow the long and difficult way. The creation of the fighter in its modern appearance with its current performances to guard the Russian aerospace as well as that of the Su-27 buyers would not have been possible without strenuous efforts made by many engineers, designers, scientists, researchers, pilots and military test experts. The most significant input in the Su-27 development was made by teams of the Sukhoi Design Bureau and Komsomolsk-on-Amur Aircraft Manufacturing Plant, developers of its powerplant, radar and guided missile system from the Lyulka-Saturn Company, Tikhomirov Instrumentation Research Institute and Vympel State-owned Design Bureau respectively. In addition to the above organisations, the Su-27 fighter was being developed by many other scientific and research institutions, including the TsAGI, CIAM, GosNIIAS, CNII, a range of other design bureaux and research institutes that designed and manufactured various systems for the Su-27 fighter. This article is dedicated to some aspects of the Su-27 development history which began 30 years ago.

Advanced Frontline Fighter Programme

A team of developers from the Kulon Machine-Building Plant headed by Pavel Osipovich Sukhoi initiated in 1969 the development of an advanced new-generation fighter for the Soviet Air Force and Air Defence Forces' aviation. By the mid-seventies, a general concept of the new fighter was formulated in co-operation with a number of science and research institutions. This concept provided for a high-maneuvrability long-range fighter with a powerful weapons system and a perfect sighting/navigation system that would allow the pilot to participate efficiently in both long-range missile exchange and dogfight. The basic performances of the new fighter were to be of top class globally while a number of characteristics was to exceed those of its American F-15 counterpart the American leadership was reasonably vesting its high hopes in. The design bureau was planning to introduce a number of major innovations and solutions into the design of the new fighter designated T-10.

In 1970, the Sukhoi design bureau developed the first version of the fighter airframe incorporating key features of the integrated aerodynamic configuration. The aircraft was to have a lifting body featuring a smooth coupling of the wing and fuselage, two turbojet engines located in isolated belly-mounted engine nacelles and two vertical stabilisers. Such an integrated design allowed a significant improvement of the fighter's aerodynamics and provided for a more spacious interior to accommodate fuel tanks and various equipment. For the fighter to achieve intended flight performances within a wide range of altitudes and speeds, the new fighter's wing had ogyval shape

and a leading edge extension. According to the developers, the leading edge extension was supposed to ensure required high-lift characteristics during the aerodynamic focus shifting at supersonic speeds and generate vortice increasing wing, tail unit and control surface efficiency. At the same time, Sukhoi was engaged in developing a traditional non-integrated version of the same fighter powered by two adjacent engines, which were located in the fuselage's aft part, and fitted with side-mounted air intakes and two vertical stabilisers. In 1972, both versions were submitted to the Air Force board for examination and consideration. The board was to assess proposals submitted by three aircraft design bureaux (Sukhoi, Mikoyan and Yakovlev) regarding development of an advanced tactical fighter slated for entering the service with the Soviet Air Force in the early eighties.



Figure 2: First prototype T-10-1

As a result of thorough evaluation and assessment of all versions submitted for consideration, the proposals presented by Sukhoi and Mikoyan were approved by the board for further development. The Su-27 (T-10) programme was to be developed into a heavy multirole advanced tactical fighter, while the MiG-29 programme was to produce a series-built light advanced tactical fighter. Among the major combat objectives the both fighters were to meet, there was the dogfight and medium-range aerial combat capability, interception of aerial targets in the front and rear hemispheres both against the sky and ground as well as the secondary task of ground target destruction. The Su-27, which had a better fuel endurance, more weapons load and more sophisticated navigation, self-defence and communication systems, was intended to operate independently within an air group deep behind the enemy lines at an operational-tactical range of up to 250-300 km, while a lighter and cheaper MiG-29 would operate only at ranges of up to 100-150 km into the enemy-held territory. The Su-27's weapons control system was expected to ensure successful countering the F-15 fighter, the most capable fighter of that time available to the potential opponent, as well as successful engagement when outnumbered by less capable but numerous fighters (for instance, YF-17, YF-16 and J-6). Besides, the Su-27 fighter was intended for entering the service with the Soviet Air Defence Forces after its appropriate reequipping and rearmament.



Figure 3: T-10-1 wing

Proceeding from the updated and more specific requirements the client set for the tactical fighter of the eighties, Sukhoi started in 1972 developing a preliminary design of the T-10 fighter subsequently followed by the conceptual design stage. During 1970-75, over 15 options of the fighter configuration were given consideration. Those configurations varied not only in general approaches to the problem (integrated or classic configuration) but differed in solutions suggested for individual problems (engine and air intake positioning, landing gear design, type of the control system, etc.). Finally, preferences were given to the aircraft design with an integrated statically unstable configuration. The Su-27 was to become the first Soviet unstable fighter with longitudinal in-flight balancing to be provided by a fly-by-wire control system. Accepting the longitudinal static instability concept (in other words, "electronic stability") promised a lot of advantages: for the aircraft to balance at a high angle of attack, the leading edge slat's upward deflection was required with its lift being added to the wing lift, which allowed significant improvement of the fighter lift with a minor increase in its drag. Due to the use of the integrated statically unstable configuration, the Su-27 was to acquire outstanding manoeuvrability allowing the fighter altitude changes unavailable to typical configuration fighters and an increase in its range of up to 4,000 km without external fuel tanks. There were no other series-produced fighter in the world boasting similar performances.

The fighter's aerodynamic configuration featured a regular scheme with the empennage being situated behind the wings on the load-carrying beams on the outer sides of the separated engine nacelles. The aircraft had twin tails mounted on the engine nacelles. The plane was to be controlled by the all-moving horizontal stabiliser whose panels could deflect in different directions, as well as by

aileron and rudder. The wing high lift devices included flaps. To enable the powerplant to produce the optimal performances at any speed and altitude, the air intakes mounted under the centrewing were made controllable by the horizontal ramp. The fore part of the fuselage housed an integral radar covered by a radio transparent nosecone as well as the cockpit featuring a canopy that provided good visibility in all directions.



Figure 4: T-10-3

The Su-27 fighter weaponry which included 30 mm high-rate cannon, K-27 medium-range air-to-air missiles and K-73 or K-14 short-range missiles was to be standardised with that of the MiG-29 light tactical fighter. The only difference in armament was the warload carried: while the MiG-29 could house only six missiles, including two K-27 missiles, the Su-27 was capable of carrying eight, including four K-27s, as well as the K-27E improved longer-range radar-homing and heat-seeking missiles.

An integrated weaponry control system of both fighters was substantially standardised and, for the first time in the history of aviation, included two complementing channels - a radar sighting system and an optoelectronic sighting system, as well as a helmet-mounted sight. The sighting system initially designed for the Su-27 fighter had better characteristics. The N001 radar was built by the Phazotron Research and Development Association under the guidance of Victor Grishin. The OLS-27 optics-based detection and ranging system combining an acquisition/tracking IR locator and a laser rangefinder was developed by the Moscow-based Geophysics Central Design Bureau headed by Chief Designer D.Khorol.

The landing gear featured a classical tricycle design with the nose strut having been moved far forward and the gear well placed under the cockpit. The main gear struts were made forward-retractable into centrewing gear wells with the wheels being turned in the process and the wells' forward doors serving as air brakes.

The Su-27 fighter powerplant included two powerful and economical AL-31F bypass turbofan engines producing thrust of 12,500 kg each. They were developed by the Saturn Mechanical Plant headed by Arkhip Mikhailovich Lyulka and supposed to ensure take-off thrust-to-weight ratio exceeding 1. Low specific fuel consumption along with about eight tonnes of fuel stored in internal tanks filling most of the airframe inner space was to ensure required operational range of the fighter.



Figure 5: T-10-1 in the Russian Air Force Museum (Monino)

The Su-27 fighter conceptual and detailed design stages were completed in 1975-1976, and after issuance of required design documentation and drawings, the manufacturing of first prototypes was initiated at the Kulon plant. Unfortunately, Pavel Sukhoi did not live long enough to see the fighter - he died in 1975 to be succeeded by Yevgeny Ivanov. From 1976 on, the Su-27 programme has been under immediate guidance of Chief Designer Mikhail Simonov. The first prototype designated T10-1 was completed in early 1977. Due to the lack of the AL-31F turbofan bypass engines, the prototype was equipped with two AL-21F-3AI engines - a modified version of the series-production AL-21F-3A engine mounted on other Sukhoi-developed fighters (Su-17, Su-24). After the completion of required ground checks and run-ups, everything was ready for test flights and on 20 May, 1977 Vladimir Ilyushin, Sukhoi's chief pilot, took the T10-1 off the ground for its maiden flight. The first prototype was used to evaluate its key flight performances as well as stability and controllability.

In 1978, the second prototype designated T10-2 was completed though its life was brief. On 7 July, 1978, the fighter suffered a mid-air accident resulting in death of test pilot Yevgeny Solovyov. The crash was triggered by the plane's oscillation in the longitudinal plane at a supersonic speed, due to which it suffered an extremely high g-load and disintegrated in midair. The black box recorder readings showed that the fighter got into an unexplored resonant mode, which caused the mid-air disintegration of the aircraft. This happened so fast that Yevgeny Solovyov, distinguished test pilot and Hero of the Soviet Union, had no chance to eject. The after-action review established the actual reasons for the tragedy and allowed the developer to introduce necessary changes into the fighter's design. During 1978, preparations for preliminary production of the Su-27 were made at the Gagarin machine-building plant situated in the Far Eastern city of Komsomolsk-on-Amur. At the same time, the Sukhoi mechanical plant commenced assembling another two Su-27 prototypes. Unlike the first two prototypes, those two fighters were to be powered by AL-31F engines. The new powerplant was 500 kg lighter, its thrust was 12 percent higher than that of the predecessor with fuel consumption being lower. In comparison with the AL-21F-3s, the AL-31F engines had smaller diameter and length while their nozzles were accommodated with a secondary (bypass) duct control system. On 23 August, 1979, Vladimir Ilyushin took the T10-3 off for its maiden flight. Two months later, the T10-4 joined the flight testing too. At first, both aircraft were used for in-flight engine testing. Then the

T10-3 was remodeled to be further tested on the Nitka training facility in support of the development of the Su-27 ship-borne version while the T10-4 was used for the further refining of the weapons control system.



Figure 6: T-10 cockpit

By the early 1980, as many as three prototypes (T10-1, T10-3 and T10-4) had been taking part in the Su-27 testing programme with first pre-series aircraft expected to join soon. It seemed that everything was in line with the schedule and the new fighter would have been fielded in a couple of years. However, there were staunch objections against commencing series production of the aircraft in the then airframe configuration, made by the Siberian aviation research institute's (SibNIA) aerodynamic experts and... Chief Designer Mikhail Simonov himself. According to the SibNIA experts who had done the bulk of aerodynamic research under the Su-27 programme, several mistakes were made during the fighter development stage. The combination of the accepted wing planform and leading-edge extension configuration caused premature vortex flow separation: the non-stationary airflow around the wing would begin as early as at the 8-to-10 angle of attack (AoA), which would cause deterioration of the airframe's lifting capability, buffeting and decrease in lateral stability. The tail unit configuration designed for the T10 would fail to provide required effectiveness of the longitudinal control surfaces, lateral and directional stability devices. The SibNIA-held T-10 wind

tunnel tests performed in 1975-76 indicated that there was a slim chance of developing a highly manoeuvrable fighter without dealing first with the above problems.



Figure 7: T-10-10 at museum, Lugansk, Ukraine

The necessity of the Su-27 programme's radical reconsideration was looming ahead. Such fundamental elements of the fighter design as the form and area of the wing, leading-edge extension configuration, horizontal and vertical control surface arrangement were have to be redesigned. Mikhail Simonov was a staunch supporter of such an approach but the Aviation Industry Ministry's brass had a different opinion. Designer Ye.A.Ivanov was not too keen on taking risk by radically revamping the design. As a result, first Su-27s were tested in their initial configuration. The flight tests of the T10-1 and T10-3 corroborated to the Siberian aerodynamics experts' doubts. To make up for the vertical stabiliser effectiveness decrease resulting in a decrease in the fighter's directional stability at a high AoA, first planes were fitted on the TsAGI advice with top-of-the-wing-mounted fences. However, the fences reduced the airframe's lifting capacity and negated the advantage of using the leading edge extension roots.

The T-10 testing also revealed the failure of the fighter's certain characteristics to match those of the performance specifications. First of all, that was true for the range: the mismatch between the required and actual ranges exceeded 20 percent. The Designer General reported to the ministry that there were two main reasons for non-compliance with certain requirements set in the performance specifications. Firstly, avionics developers failed to meet the weight limits set out in the avionics performance specifications. The summary avionics excessive weight comprised a few hundred kilograms, which, naturally, led to the aircraft's overall weight increase, hampered its manoeuvrability and reduced its range. Secondly, the engine's specific fuel consumption ordered in the performance specifications had not been achieved by the developer either. Truth be told, the issue was settled later when the requirements to the engine's specific fuel consumption were found to be a tall order which could not be met then. In spite of the T-10's considerable deficiencies revealed during the research and flight tests, Yevgeny Ivanov hoped, nonetheless, for possibility to gradually hone that

configuration through minor design modifications, fuel capacity increase, etc. Otherwise, Mikhail Simonov was pushing hard for radical aircraft reworking, since as early as in 1976-77 a team of his subordinates in cooperation with the SibNIA scientists developed on their own and later tested in the wind tunnel a new configuration of the airframe devoid of the deficiencies which the previous configuration had in abundance. Justice should be done to M.P.Simonov (who went to work for the Aviation Industry Ministry in 1979 to return to Sukhoi as Designer General in 1983) who managed to persuade the leadership to risk radical change in the configuration of the fighter that had been already undergoing tests by then. With the passage of time, this decision proved to be right and led no matter what to building the aircraft that still - almost two decades later - has been regarded as one of the best warplanes in the world. Having commenced production of the Su-27 in its final configuration, Sukhoi confirmed its reputation of a world leader of aviation industry in line with its old tradition of never fielding mediocre aircraft.

From T-10 to T-10S

The fighter's version featuring the new configuration was designated T-10S by the Sukhoi design bureau with its full-scale design work starting in 1979. Preliminary attempts to deal with the first T-10 version's glitches and meet the performance specifications' requirements, made by the design bureau and SibNIA (in the SibNIA the work was headed by Stanislav Kashafutdinov, candidate of technical sciences) resulted in setting the guidelines for modifying the initial configuration. With the developing of those guidelines, differences in design between the T-10S and T-10 became even more obvious. In the end, it became clear that the designers would have to develop an utterly different aircraft. According to Mikhail Simonov, the only things the T-10S inherited from its T-10 predecessor were the main landing gear's wheels and ejection seat. Only general principles set up for the Su-27 by P.O.Sukhoi himself, such as the integrated airframe configuration, statically unstable design with the aft centre of gravity, fly-by-wire control system, mounting the engines in isolated engine nacelles with belly-mounted air intakes, etc., were retained.

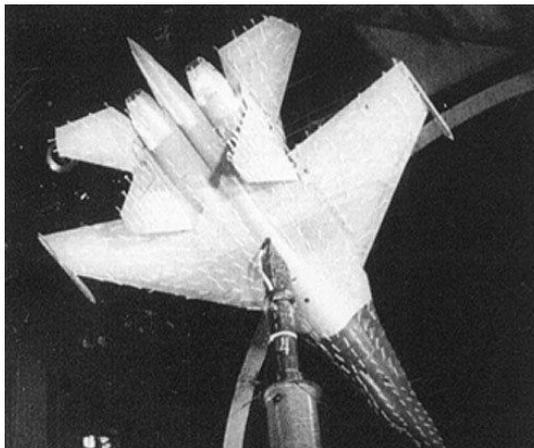


Figure 8: T-10-21 (T-10S) mockup in the air tunnel (SibNIA)

The T-10S had a new wing featuring a straight leading edge, an aerodynamic twist and a reconfigured sharp leading edge extension. Ogyval wing tips lost the ground to traditional permanent leading edge sweepback angle ones featuring pylons for air-to-air missiles, which resulted, firstly, in discarding flutter-preventing weights carried by the T-10 and, secondly, in beefing up the number of missiles from eight to 10. The wing area grew from 59.4 sq.m to 62 sq.m with the wing high-lift devices being changed drastically. Ailerons and flaps were replaced with unified control devices - flaperons, wing leading edges were fitted with slats (the T-10 had no leading edge high-lift devices), the automatic adaptive deflection mode for the flaperons and leading edge slats was ensured providing for the fighter's "polar curve envelope" flight concept. The airframe's lifting characteristics were enhanced through the use of the new wings and leading-edge extensions while maintaining the negative pitching moment at positive angles of attack and extending significantly the range of operational angles of attack, which ensured satisfactory lateral stability and prevents buffeting.

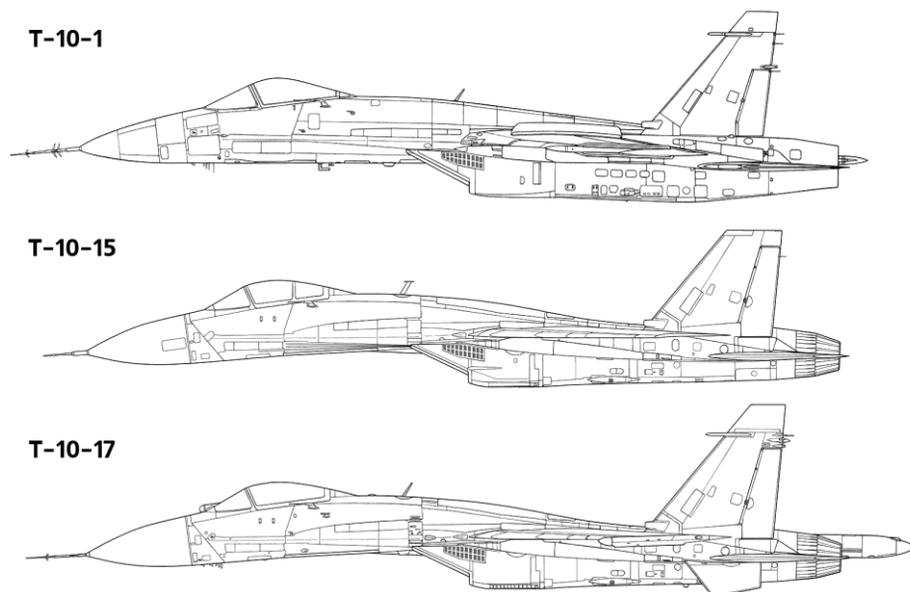


Figure 9: T-10 evolution

To reduce drag, the fore part of the airframe was reworked: the airframe cross section in front of and around the cockpit was decreased, canopy's midsection was reduced while its rearward movement was enhanced, the airframe's fore part cross section in the area of first fuel tanks was increased. Besides, airframe and spine fairing couplings were introduced along its whole length, spine fairing's lateral cross section in the airframe's midsection was reduced, central tail boom arrangement was altered through addition of a cylindrical tip which was an extension of the rear integral tank. At the same time, the total internal fuel capacity increased making up 9.4 tonnes. Making the shape of the engine nacelles more graceful while reducing their weight was achieved through fitting the T-10 aircraft with AL-31F engines featuring top-mounted aircraft and engine accessory gearbox (the T10-3

and T-10-4 were powered by the AL-31F engines featuring bottom-mounted accessory gearboxes). While preserving the general arrangement of air intakes, the new aircraft had a new foreign-object damage (FOD) system introduced for preventing FOD during taxiing, run and take-off through the use of extendable screens in the air intakes' ducts. Supplementary air inlet ramps were added to the lower surface of the air intakes.



Figure 10: T-10-17 with 10 missiles

To enhance directional and lateral stability through raising efficiency of the corresponding control surfaces, the empennage underwent substantial redesigning. The two vertical stabilisers were set wide apart at the reinforced booms on both sides of the engine nacelles with an optimum position for the stabilisers chosen in the vortex system generated by the leading edge extensions and wing panels. This resulted in considerable increase in directional stability and controllability of the fighter at high angles of attack and slipping. Also, the T-10S was fitted with ventral fins increasing its directional stability and anti-spin performances. Mounting the tails on the tail beams provided an increase in the tails' and horizontal stabiliser area, as well as to place the stabiliser's actuator fairings behind the tails. The planeform of the empennage was altered too, while the change in the position of stabiliser panel rotation semiaxes enhanced their flutter characteristics and allowed the designers to discard the anti-flutter loads mounted on the T-10. The air brakes - the main landing gear doors featured by the earlier version and discarded due to horizontal control surface flutter caused by their extending - were ousted by the large air brake mounted behind the cockpit.

The landing gear was reworked too: main struts were provided with "slant" main pivot, which made it possible to retract the gear into the wing centre section, thus requiring no folding struts to be installed. This also allowed to reduce the lifting body's cross section in the area of the landing gear wells. The nose gear strut was reinforced and moved aft, which enabled better taxiing and decreased a chance of foreign object damage during taxiing, run and take-off. In general, the fighter's configuration modification provided the lifting body midsection reduction by 15 percent, which led to reduction of drag by 18-20 percent in the subsonic and supersonic speed range. This, combined with an increase in the airframe's lifting characteristics as well as lateral and directional stability and controllability in all three planes in every flight mode, provided the aircraft with superior manoeuvrability with special emphasis put on high angles of attack and met the requirements set for the fighter's range.

Testing

In 1980, when the new-version prototype assembly was in full swing at Sukhoi, the pre-production batch assembly was nearing the end at the series production plant in Komsomolsk-on-Amur. As far as their design was concerned, they were the deadringers for the T10-1 and T-10-2 prototypes with only difference being their canted tails resembling those of the T10-3 prototype. Their powerplant still retained the AL-21F-3AI engines. Despite the fact that the planes had little in common with the future series-made Su-27, it was decided against cancellation of the pre-production batch. The decision was made to use them for honing the weapons control system and other equipment as long as first T-10S were being manufactured and put through initial stages of the testing programme. This was intended to make up for inevitable dragging behind the schedule due to the need of reequipping the production lines for manufacturing the new-configuration aircraft. The first aircraft of the pre-production batch designated T10-5 was finished in July 1980 and followed in the same year by the T10-6 and T10-9 (numbers 7 and 8 were assigned to first T-10Ss). In 1981, the Komsomolsk-based plant produced another two fighters - the T10-10 and T10-11, thus making five flying prototypes of the pre-series batch aircraft designated Su-27, Type T10-5 to discern them from future series-built aircraft. By 1982, there have been produced nine initial-configuration aircraft and one for static tests including those assembled at the Sukhoi plant.

Sukhoi completed the assembly of the first T-10S prototype designated T10-7 (a.k.a T10S-1) in early 1981 and in April 1981 it made its maiden flight piloted by test pilot V.S. Ilyushin. Also in 1981, the static version (T10-8, or T10S-0) and the second flying prototype featuring new configuration were built. From 1981 on, the Su-27 programme has been headed by Alexei Knyshev who has been the aircraft's Chief Designer ever since. The T10-7 and T10-12 were used to determine main performances of the new-configuration fighter, its stability and controllability, as well as to evaluate the new powerplant featuring top-mounted accessory gearboxes. However, both aircraft were not destined to fly long. On 3 September, 1981, the T-10-7 was lost due to a fuel system malfunction. Vladimir Ilyushin had to punch out while the fighter with its tanks nearly empty hit the ground in a fireball. On 23 December, 1981, the T10-12 crashed too due to entering uncontrolled spin while performing deceleration from the max speed. The fore part of the air frame was destroyed resulting in the aircraft hitting the ground. The test pilot, Aleksandr Komarov, died in the crash.

It proved to be impossible to determine all reasons for the crash. However, in 1983, Sukhoi's test pilot Nikolai Sadovnikov found himself in a similar situation while flying one of the first series-produced Su-27s - the T10-17. During the low-altitude high-speed level flight, Sadovnikov's fighter suffered destruction of a leading edge slat and part of the wing panel with the debris damaging vertical stabilisers. Thanks only to the high skills of the pilot (who was later awarded the title of Hero of the Soviet Union and set quite a few world records), the sortie did not end up in a crash. Nikolai Sadovnikov landed the damaged fighter with most of the wing panel missing and a tail clipped, thus providing the developers with precious information to rake their brains over. It was found out later that the

reason was a mistake in the calculation of the hinge moment emerging due to the deflection of the adaptive leading edge flap in certain flight modes. Urgent measures were taken to rework the design, including the reinforcement of the airframe and wings as well as the development of lesser-area adaptive leading edge slats.



Figure 11: T-10-17 in a test activity

In 1982, the new fighter's testing programme was joined by first new-configuration aircraft manufactured in Komsomolsk-on-Amur, namely: the T10-15 (later converted into the P-42 record-maker), T10-16 and above-mentioned T10-17. The fly-out of the first series-built Su-27 took place on 2 June, 1982. The next year, Komsomolsk-based plant delivered another nine fighters, namely, T10-18, T10-20, T10-21, T10-22, T10-23, T10-24, T10-25, T10-26 and T10-27, most of which were used in the Su-27 joint official testing held in parallel with establishing series production of the new aircraft and its fielding with line units. The work on the T10-5 pre-series batch being in full swing too. The testing resulted in the substantial reworking of the fighter design. Thus, the fore part of the airframe and the wings were reinforced with the existing fighters being outfitted with additional external reinforcing plates and those under construction being given reinforced primary structural members and skin panels. The shape of the tail tips was altered too with previously-designed tail-mounted weights being discarded. The hinged part of the canopy was made to move up and rearwards (while earlier it was rear-sliding) with an additional behind-the-headrest metal casement being incorporated into it. To house the chaff dispenser, the length and height of the flipper - a rear-fuselage bay between the centre bean and engine nacelles - were increased. The wingtips were modified to carry ECM pods instead of air-to-air missile launching rails.

In 1984, first Su-27s were fielded with the Soviet Air Force followed by almost a hundred more fighters having been produced by the end of the next year as well as by Air Force and Air Defence Forces' units mass transition to the new fighter. The Su-27 joint official testing was completed in the

mid-80s. Its results testified to the fact that a really outstanding aircraft had been made, which was second to none among the fighters as far as its manoeuvrability, range and combat effectiveness were concerned. However, certain avionics components required the additional testing held under special programmes after the joint official testing was over. With the avionics problems resolved, in 1990 the Su-27 was officially adopted in the inventory of the Soviet Air Force and Air Defence Forces aviation.



Figure 12: T-10-33

Due to the fact that the Su-27 differed considerably from the rest of Soviet fighters both in performances and weapons control system, navigation suite and other equipment, its twin-seat combat trainer version designated Su-27UB had to be designed. It was supposed that retaining the full avionics and weapons suites inherited from the combat version would enable the twin-seater to be used as an effective combat aircraft. Moreover, considering the Su-27's range and fuel endurance, the crew of two was supposed at times to be a better option.

The Sukhoi team had begun designing the Su-27UB (developer's designation T-10U) in the late seventies even before the testing of first new-configuration aircraft commenced. The developer was tasked with providing a high degree of unification of the single-seater and twin-seater's avionics design with the fighter retaining its superior performances. In 1980, the predesign work was completed. The Su-27UB's aerodynamic configuration mainly matched that of the single-seater. The primary differences lay in the design of the airframe fore part which incorporated a two-seat tandem

cockpit, as well as in the design of the tails whose area had to be increased to preserve directional stability. To provide good visibility from the back seat, the rear part of the cockpit was elevated a little in relation to the forward part with both cockpit parts having been equipped with a single up-and-backwards opening hinged part of the canopy to ensure the ease of operation and ejection safety. Placing the backseat crew member higher than the pilot required changing the fuselage spine fairing shape above the forward fuel tank and centrewing with the aircraft acquiring a hunchback appearance. However, this allowed the plane to retain the design and configuration of the nose wheel and its well with two lateral avionics bays having been placed under the rear cockpit. This also prevented the reducing of the fuel capacity and extending the fuselage length. Each tail of the twin-seater comprised a single-seater tail panel and a 420 mm spacer that increased the area by 1.55 sq.m.

41 records of the Su-27

Late in 1986, the press reported new rate of climb records established by the new Soviet jet - P-42. On 27 October, 1986, pilot V.G.Pugachov climbed to an altitude of 3,000 m in 25.4 seconds while on 15 November he climbed to 6,000, 9,000 and 12,000 m in 37.1, 47.0 and 58.1 sec respectively, thus exceeding by over 2 sec the decade-long records set by American pilot R.Smith flying the F-15. The records were set in two classes simultaneously - both in the class of jet aircraft and in that of 12-16 t service aircraft. The latter raised quite a few brows among experts who realised fast enough that the P-42 designation was applied to the new fighter - the Su-27. The point is the 20 t fighter could hardly fit the 16 t aircraft class, and, as was revealed later, the IAF protocols had the P-42's take-off weight at 14,100 kg, which is as much as two tonnes lighter than an empty Su-27. This was simple enough: to set records, Sukhoi's leadership took a decision to use one of the first series-built Su-27s - the T10-15 that by then had completed its testing programme. According to Designer General M.P.Simonov, the aircraft's unusual designation was used due to the following reason: "it was designated P-42 to commemorate the turning point of the Stalingrad battle in November 1942. Then, the Soviet aviation's role in defending that stronghold was crucial." The plane was stripped of the weapons control system and radar to make it fit the weight constraints. Besides, it had the central tail boom shortened, tail area reduced, drag chute and fences removed, wing high lift devices keyed, radar nosecone was replaced with a lighter metal one. Some other measures to reduce weight were taken too. To perform the record flights, the aircraft had only a limited amount of fuel in the tanks, that was enough only for take-off, achieving the goals and landing. The designers managed to soup up the engines with each having its thrust increased by over 1,000 kg/f (the R-32 engines and the thrust of 13,600 kg/f were included into IAF protocols). The measures taken allowed the designers to achieve a unique take-off thrust-to-weight ration totalling nearly 2. Due to this, the P-42 was capable of accelerating and even crossing the sonic barrier during the vertical climb.



Figure 13: P-42 record plane

However, the aircraft's great thrust-to-weight ratio evoked a very peculiar problem: the P-42's brakes were unable to hold it at the starting position when the engines went in afterburner. So, a rather ingenious solution was made: the plane was linked up with a towrope and a special lock to a powerful tractor protected from the exhausts with an armoured plate. The tractor would go to the runway and keep the aircraft from the premature run by its impressive weight. At a predetermined moment, the lock would separate the towrope from the plane, the cameras and stopwatches would be switched on and the P-42 would rush to set new world records. The work on the P-42 record preparation was headed by leading engineer (later - Chief Designer) R.G.Martirosov. On 10 March, 1987, the P-42 flown by N.F.Sadovnikov exceeded its own 9 and 12 km climb records by another three seconds - 44.2 sec and 55.5 sec respectively. On the next day, the aircraft was used in the STOL class. The rate of climb to an altitude of 3, 12 and 15 km was 25.4, 57.4 and 75.7 sec respectively. On 10 June, 1987, the P-42 flying as a STOL-class aircraft set a record for the level flight altitude that amounted to 19,335 m. The last of the official records set by V.G.Pugachov while flying the P-42 was a climb to 15,000 m in 81.7 sec with a weight of 1 tonne. All in all, the aircraft had established 27 world records during 1986-1988 with world record-holder diplomas having been issued to V.G.Pugachov, N.F.Sadovnikov, O.G.Tsoy and Ye.I.Frolov.

In Service

The deliveries of Su-27 fighters to the combat units began in 1984. When under development, a decision was taken that the aircraft of the class would be operational in fighter air regiments of two types - in Air Force and Air Defence Forces' units. In so doing, the Air Force tactical aviation and ADF fighter units were supposed to have in service virtually the same aircraft, with the development of specialised RusAF and ADF versions not envisaged. It is noteworthy that earlier the Russian fighters had only one 'master' as a rule, with the MiG-21 operated exclusively by Air Force units and the Su-9, Su-11, Su-15, Tu-128, and MiG-25P by the ADF. The only aircraft, which used to be operated by both the Air Force and Air Defence, is the MiG-23. And still, there was a special version developed for ADF units designated MiG-23P, while the ADF's MiG-23M aircraft differed greatly from the version operated by the Air Force in the settings of the weapons control system and a range of weapons employed. The same situation preserved in the 1980s when the MiG-29 tactical fighters started

entering the inventory of the Air Force, with ADF units adopting MiG-31 interceptors. Thus, the Su-27 became the first Russian fighter capable of effectively accomplishing missions both in Air Force tactical fighter and Air Defence Forces interceptor roles. Such versatility was ensured by high characteristics of the weapons control system, perfect weaponry, as well as superb performances. The fighters operational in Air Force regiments were sometimes designated Su-27S, while those in ADF units - Su-27P. However, on the whole they were virtually same aircraft, with their procurement financed by different MoD directorates (that is why different designations were used, which, by the way, failed to take root).



Figure 14: Su-27s in the Kilpyavr airbase (Kola Peninsula)

The ADF fighter regiment stationed in the Far East was the first line unit to adopt the Su-27. The plant engaged in the aircraft mass production was situated in the same region, which made it possible to be fast in tackling problems that inevitably arise at the outset of operation of any new aircraft. Traditionally, Combat Employment and Personnel Retraining Centres (CEPRC) were the first to fly out new fighters and work out recommendations as to their piloting and combat employment. They were also responsible for retraining regimental pilots. That is why before the Su-27s became operational in combat regiments, they had been delivered to the Lipetsk Air Force CEPRC and Savostleika Air Defence CEPRC. In 1990, the centres operated 15-16 aircraft each. Later, the new fighters entered service with another training unit - the training regiment of the Krasnodar-based Higher Joint Flight Technical School.

According to the released information from the Data Exchange Protocol within the framework of the CFE treaty, in late 1990, there were 367 such aircraft stationed in the European part of the USSR with 138 fighters in the Air Force inventory and 229 aircraft in service with the Air Defence Forces fighter regiments. Two Su-27 regiments as part of the Soviet Air Force were stationed abroad - in Poland, on the Kluczevo-based and Khoina-based airfields; one - in Ukraine, in the city of Mirgorod. The aircraft of the type were also operated by one of the squadrons of the composite air regiment

based in the Kubinka AFB. In 1991, an aerobatics team, which got a name of Russkiye Vityazi or Russian Knights, was established on the basis of that squadron, and later the Kubinka-based regiment proper was reorganised into an Aircraft Show Centre named after Air Marshal I. Kozhedub. The Leningrad, Arkhangelsk, and Tbilisi separate AD air forces operated two Su-27 regiments each (airfields in the towns of Vainede, Nivenskoye, Killpyavr, Rogachovo, Krymsk, and Gudauta). According to foreign estimates, in the early 1990s, the USSR operated approximately 600 Su-27s (to all appearances, beside the Su-27 single-seaters based in the European USSR, that number included the Su-27UB two-seat combat trainers as well as fighters stationed beyond the Urals).



Figure 15: Su-27P on the ramp

The break-up of the Warsaw Pact followed by dissolution of the Soviet Union led to the redeployment and deactivation of a number of AF and ADF units including those that operated the Su-27 fighters. Besides, almost 100 aircraft were left in the former Soviet republics of Ukraine and Belarus. In summer, 1992, the air regiments of the former USSR left Poland. According to foreign analysts, in early 1996, the Russian Air Force operated about 130 Su-27s, with approximately 300 aircraft in the inventory of ADF units. Besides, 24 Su-27Ks came under the ship-borne fighter air regiment of the Russian Navy in the Northern Fleet (part of the Su-27s were on board the Admiral Kuznetsov heavy aircraft-carrying cruiser, with the rest stationed on the coastal airfield).

GENERAL DESIGN



GENERAL DESIGN

Design

The main feature for the success of the Su-27 design is its aerodynamic configuration, known as 'integrated aerodynamic concept' by its designers. This configuration is one with extremely blended wing and fuselage. The low-aspect ratio trapezoidal midwing is fitted with large leading-edge root extensions (LERX) and blending into the fuselage creating a single lifting body.

The aircraft has a near-zero static stability and thus require a fly-by-wire system. The SDU-10 pitch-only fly-by-wire system controls the pitch of the aircraft to ensure stability and controllability for the pilot, increase aerodynamic performance, limit overload and angle of attack when needed and decrease the airframe aerodynamic load.

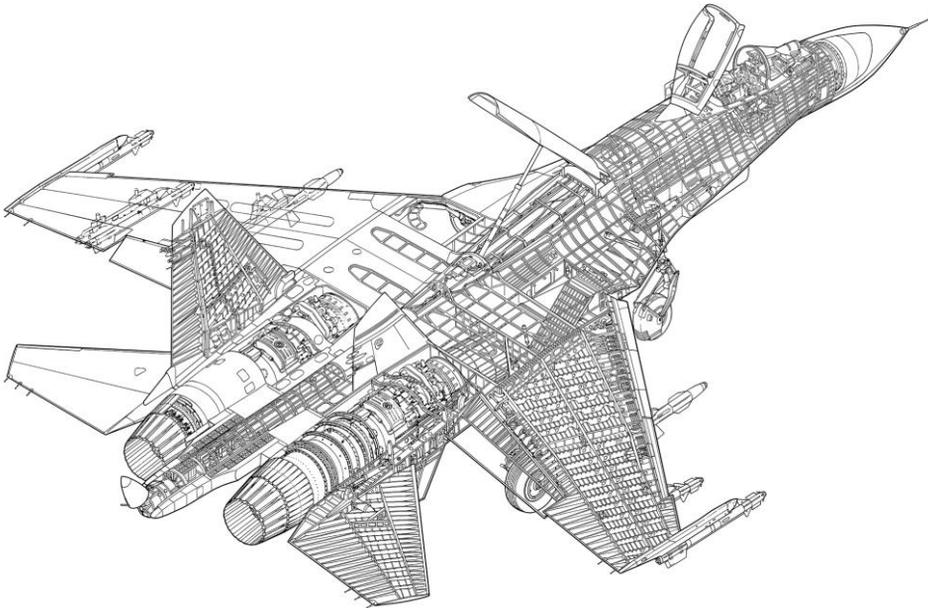


Figure 16: Su-27S cutaway

Two AL-31F afterburning turbofans are placed in separate, widely spaced engine nacelles that are mounted under the lifting body. The air intakes are fitted with variable ramps.

The Su-27 has twin vertical fins fitted on the outer sides of the fuselage and twin central fins underneath. The airbrake is placed in the center of the mid-section of the aircraft behind the cockpit.

The tricycle landing gear of Su-27 and Su-27UB has a single wheel on each strut. The nose wheel is fitted with a mudguard to protect against foreign object damage (FOD).

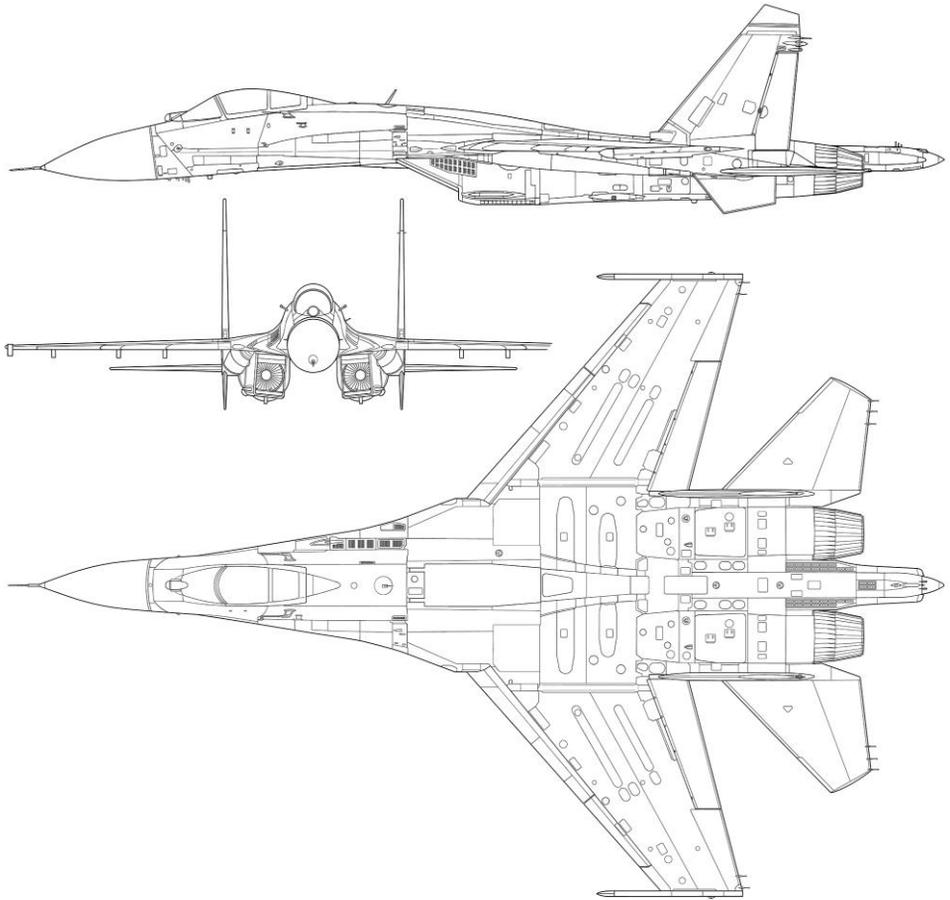


Figure 17: Su-27S

Systems and Avionics

The basic Su-27 is fitted with the SUV-27 fire control system, which incorporates the RLPK-27 radar sighting system, OEPS-27 electro-optical sighting system, SEI-31 integrated indication system, IFF interrogator and built-in test system. The fire control system is integrated with the PNK-10 flight navigation system, radio command link, IFF system, data transmission equipment and EW self-defence system.



Figure 18: N001 radar

The RLPK-27 system is controlled by the Ts-100 digital computer and includes the N001 pulse-Doppler lookdown-capable radar with a range of 80-100 km in the front hemisphere and 30-40 km in the rear hemisphere for a fighter-sized target. It can simultaneously track up to ten aerial targets in track-while-scan mode and provide interception of the top priority target.



Figure 19: OLS-27 IRST

The OEPS-27 electro-optical sighting system consist of the OLS-27 infrared/laser search-and-track system (IRST) and the Shchel-3UM helmet-mounted target designator and is controlled by the Ts-100 digital computer. The OLS-27 sensor is placed forward of the cockpit canopy in the centre. The system acquires and tracks aerial targets by their thermal signatures. The helmet-mounted sight and the laser range finder of the IRST can also be used to visually acquire and determine coordinates of air and surface targets.

The SEI-31 integrated indication system provides flight, navigation and sighting data on the ILS-31 head-up display (HUD) and head down display. The EW self-defence systems provides warning to the crew when illuminated by enemy radar and employs both passive and active countermeasures. The aircraft is equipped with the SPO-15 Beryoza RWR and APP-50 IR decoy dispenser. Chaff dispensers are placed in the tail section between the engine nozels. In addition, the aircraft can carry the Sorbtsiya active ECM pods on its wingtips.

Cockpit

The cockpit is fitted with the K-36DM Series 2 ejection seat. The seat-back is being inclined at an angle of 17 degrees. In the two-seat Su-27UB version, the seats are placed in tandem with the rear-seat being elevated to ensure good forward vision. The basic Su-27 cockpit layout consist of analogue instruments, HUD and head down display to display data from radar and electro-optical sight (IRST). On both sides of the HUD control panel, there are sensors for the helmet-mounted target designator system. On the right side below the head down display the RWR indicator is placed.



Figure 20: Su-27P cockpit

Aircraft performance	
Takeoff weight:	
- normal (including 2xR-27R + 2xR-73, 5270 kg fuel), kg	23,430
- maximum, kg	30,450
Maximum landing weight, kg	21,000
Max landing weight, kg	23,000
Maximum internal fuel, kg	9,400
Maximum ordnance, kg	4,430
Service ceiling (without external ordnance and stores), km	18.5
Maximum flight speed at sea level (without external ordnance and stores), km/h	1,400
Max Mach (without external ordnance and stores)	2.35
G-limit (operational)	9
Maximum flight range (with missiles 2xR-27R, 2xR-73 launched at half distance):	
- at sea level, km	1,340
- at height, km	3,530
Maximum airborne time, hours	4.5
Take-off run at normal takeoff weight, m	450
Landing run at normal landing weight (with braking parachute), m	620
Aircraft dimensions:	
- length, m	21.9
- wingspan, m	14.7
- height, m	5.9
Crew	1
Powerplant	
Number and type of engines	2 x AL-31F
Thrust:	
- in afterburner, kgf	12,500
- at full power, kgf	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.

Game Avionics Mode Radar Display

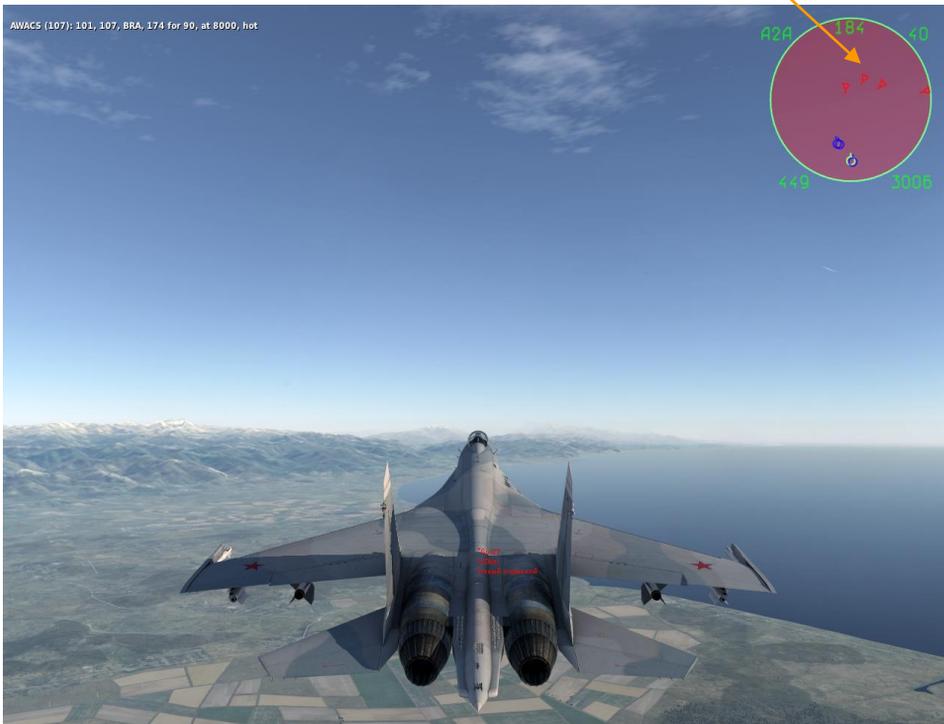


Figure 21: Game Avionics Mode Radar Display

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

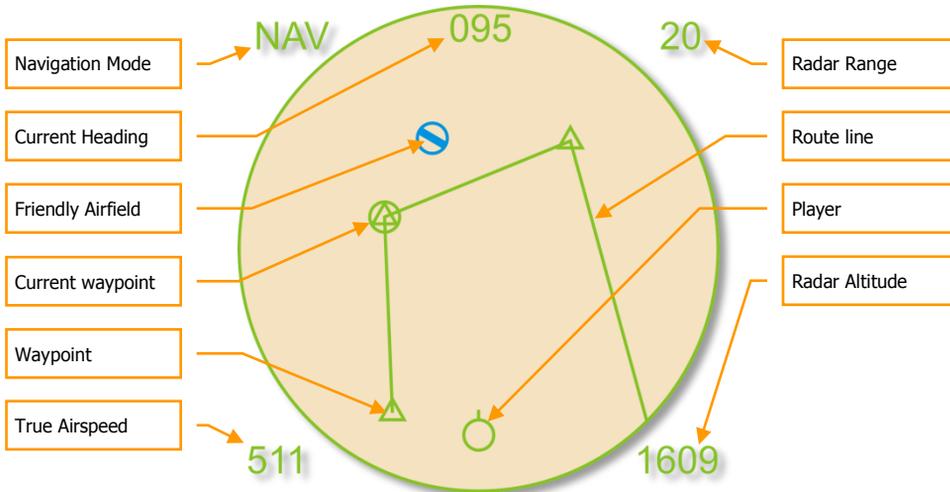


Figure 22: Navigation Mode

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

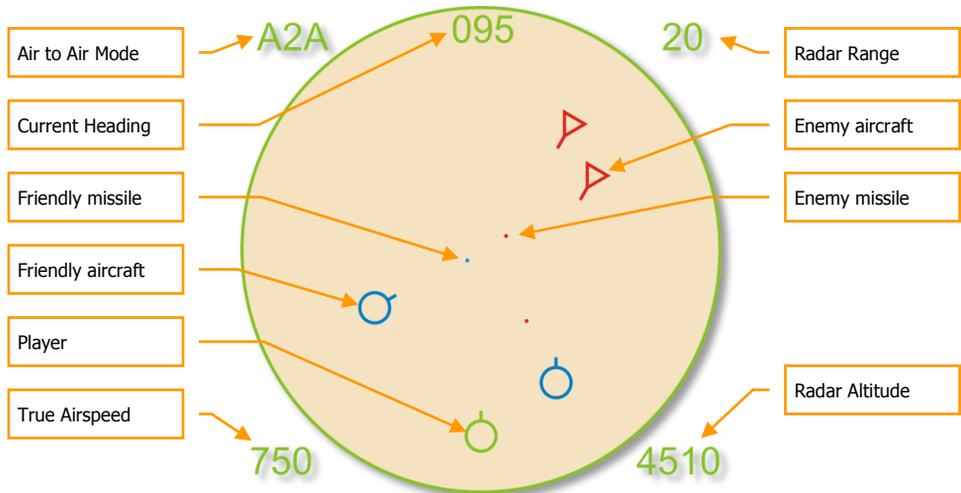


Figure 23: Air to Air Mode

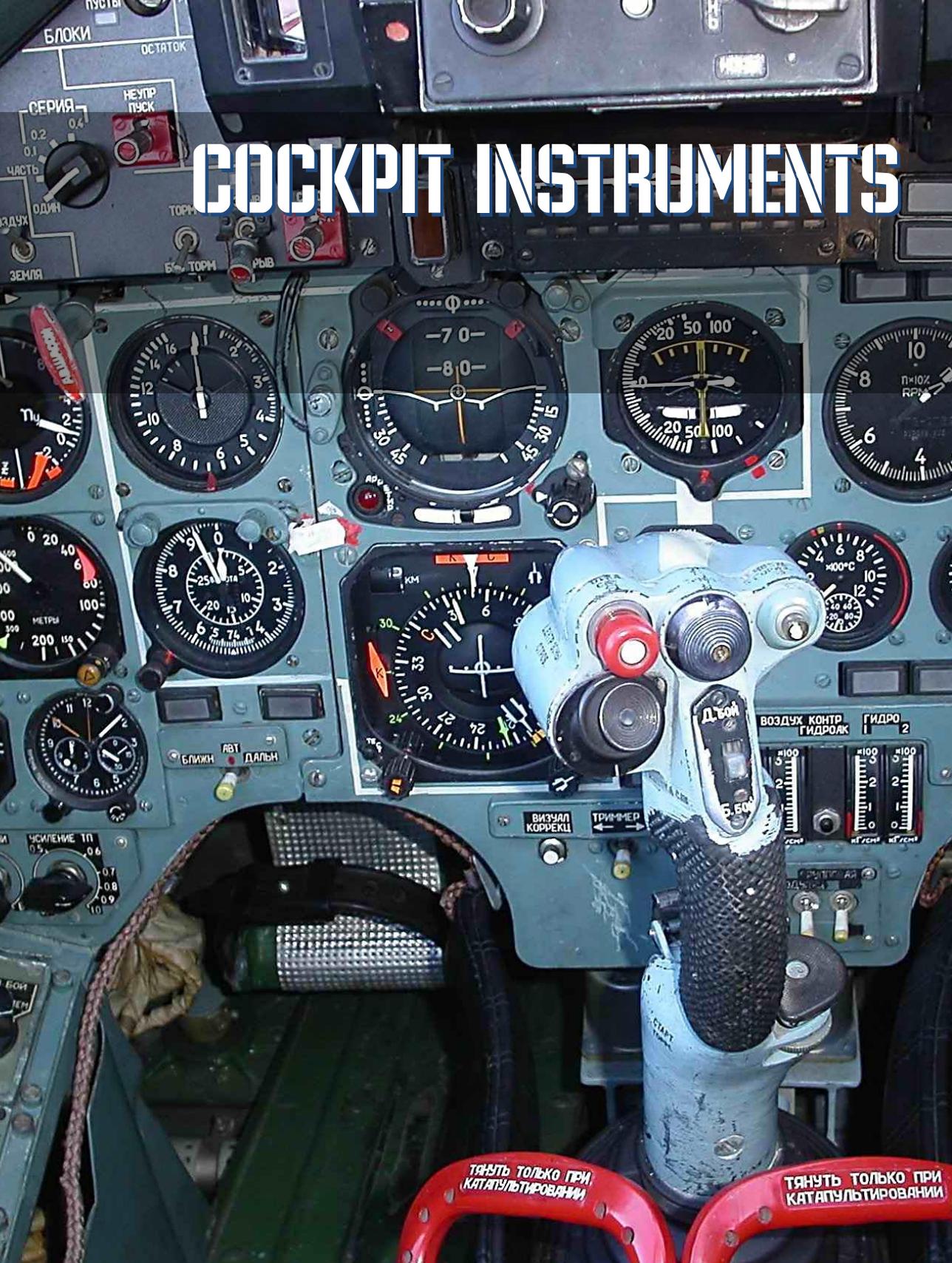
Unique symbols of the Air to Air mode include:

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

COCKPIT INSTRUMENTS



COCKPIT INSTRUMENTS

This chapter will instruct you about the Su-27 cockpit instrumentation. For successful piloting, you must understand the function and position of all cockpit instruments.

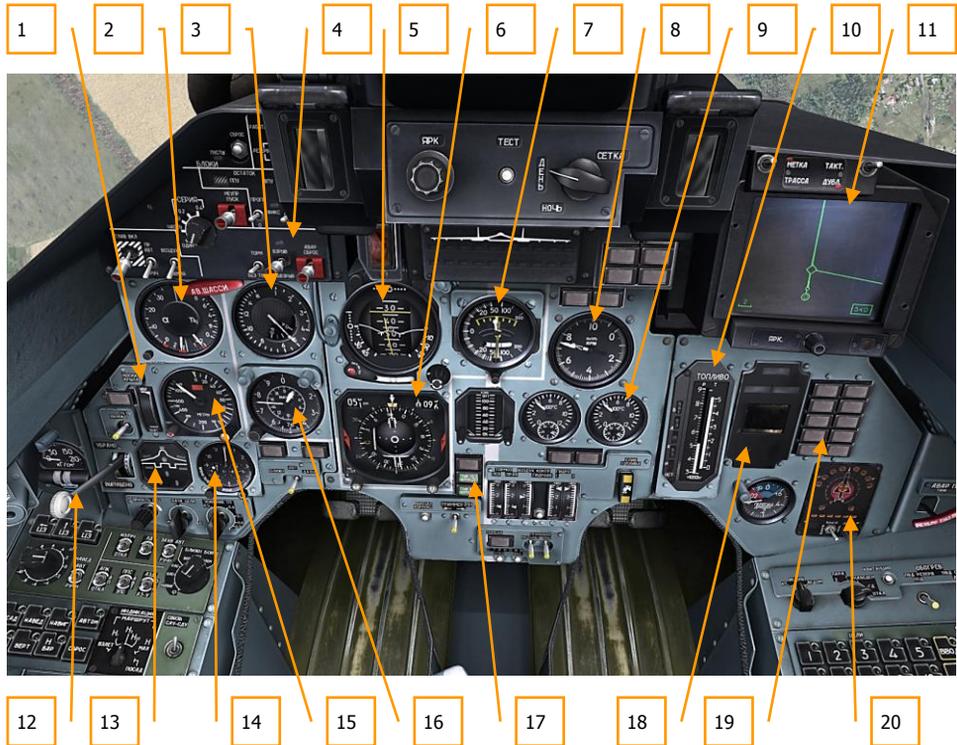


Figure 24: Su-27 instrument panel

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

8. Tachometer
9. Interstage turbine temperature indicators
10. Fuel quantity indicator
11. Head Down Display (HDD)
12. Landing gear control valve
13. Mechanical devices indicator
14. Clock
15. Radio altimeter
16. Pressure altimeter
17. Trimming lights neutral position indicator in pitch, roll and yaw channels
18. "Ecran" integrated information system panel
19. Warning lights
20. 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 25: Airspeed and Mach indicator

Pressure Altimeter

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



Figure 26: 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 27: Radar altimeter

Mechanical Devices Indicator

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

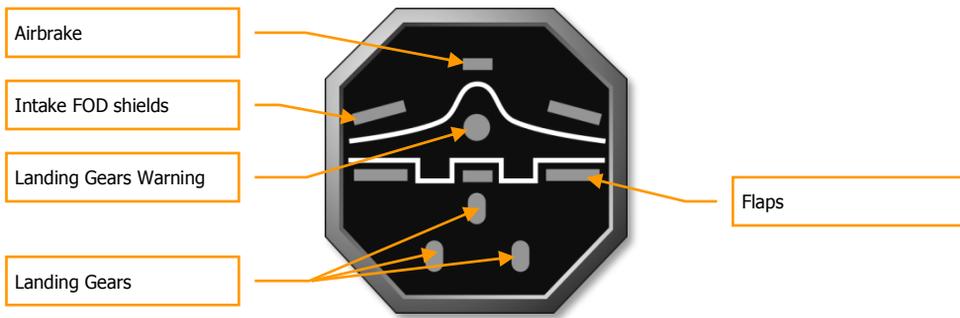


Figure 28: Mechanical Devices Indicator

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.

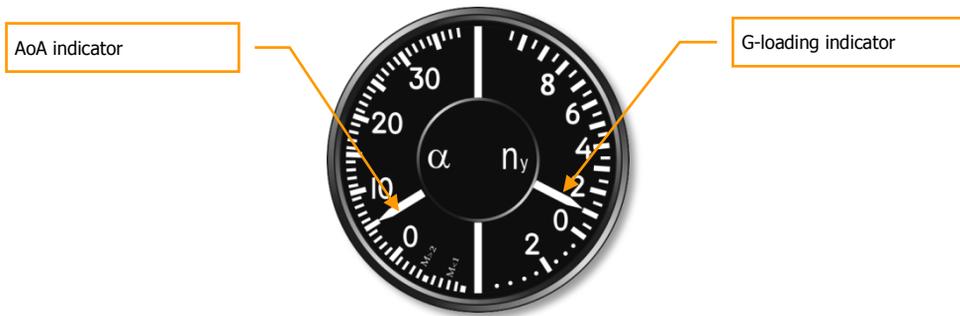


Figure 29: AoA indicator and Accelerometer

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.

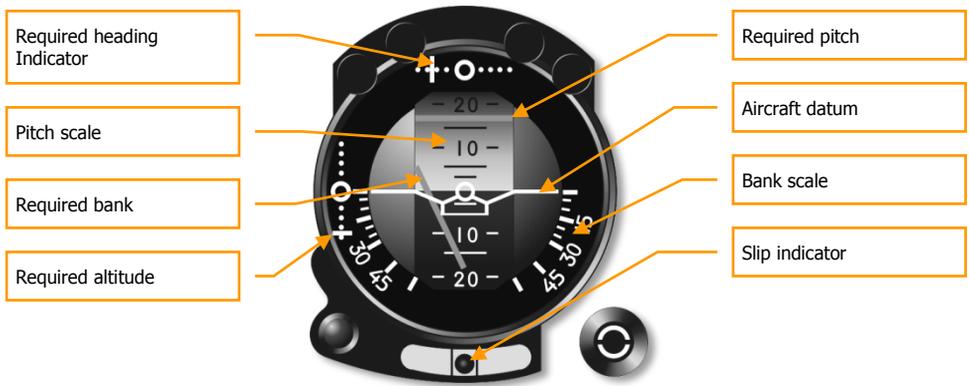


Figure 30: ADI

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 31: HSI

Vertical Velocity Indicator

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

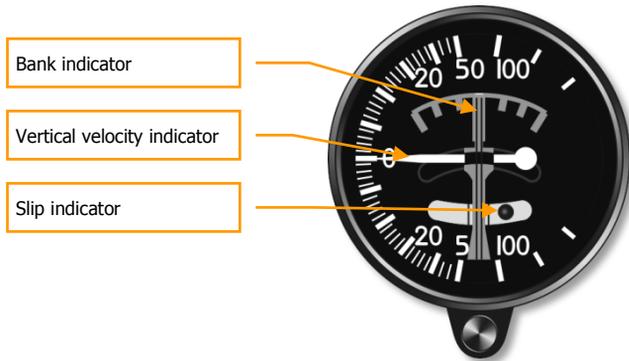


Figure 32: Vertical velocity indicator

Aircraft Clock

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



Figure 33: 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 34: Tachometer

Fuel Quantity Indicator

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

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

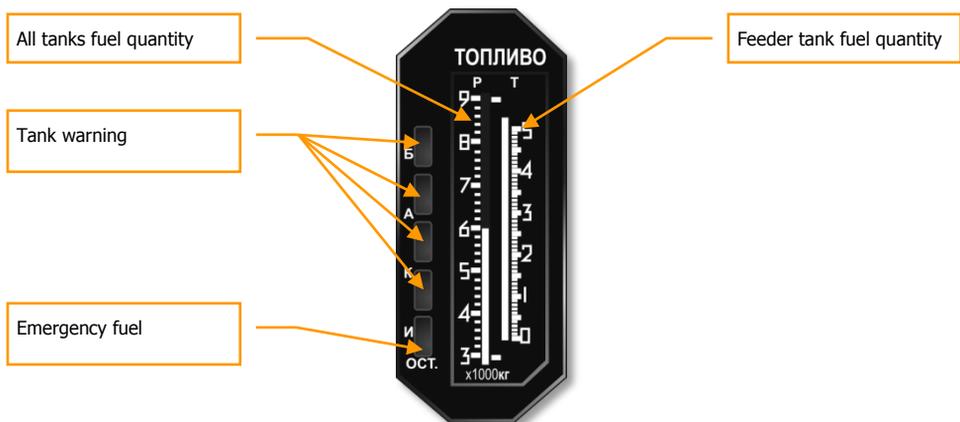


Figure 35: Fuel quantity indicator

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 36: 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 37: 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 very close to the actual system installed in the Su-27.

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

The maximum number of threats on screen: Unlimited.

The threat history display duration time: 8 seconds.

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

Threats types:

П – airborne radar

З - long-range radar

X - medium-range radar

H - short-range radar

F - early warning radar

C - AWACS

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

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

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

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

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

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

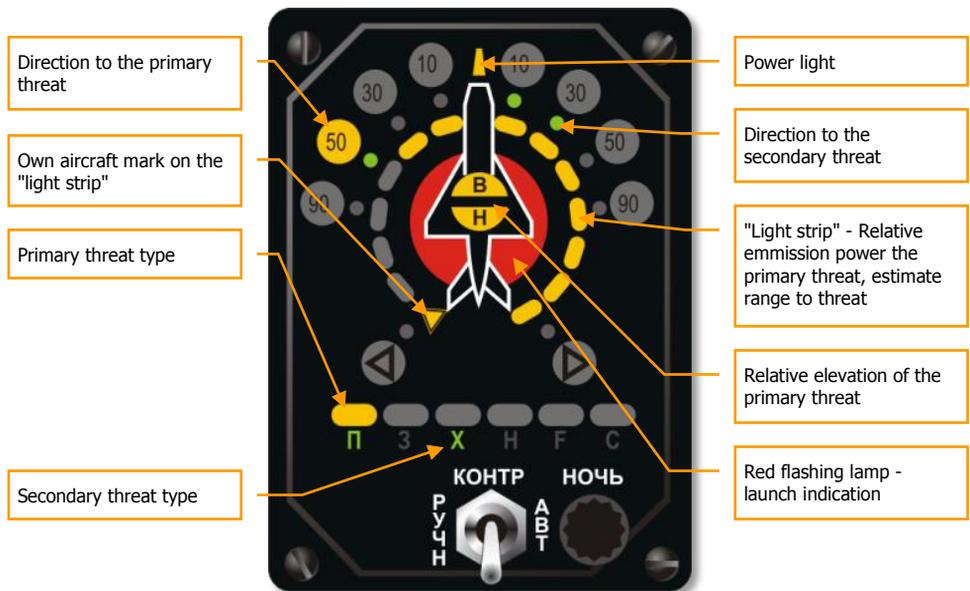


Figure 38: "Beryoza" SPO-15LM indicator

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

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

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

1. The primary threat at 50 degrees left (10 o'clock) is indicated in the form of a large yellow lamp. The lamp above "П" symbol, which means "interceptor", is lit. This type of threat includes all fighters. The circular scale of signal power ("light strip") consists of yellow segments that show the relative emission power of the primary threat's radar. The large red circle under the aircraft symbol indicates that your aircraft has been locked by the primary threat radar. The lit, yellow hemispheres marked as "B" and "H" in the center of the aircraft silhouette, indicates the threat's relative altitude to yours. In this situation, the primary threat is at the same altitude as your own, within 15 degrees in elevation. Consequently, the display can be interpreted in the following way: your primary threat is a fighter approaching from 10 o'clock; it is near co-altitude with you; and judging by the signal strength and lock light, it is ready to launch a missile.
2. The secondary threat is positioned at 10-30 degrees azimuth (1-2 o'clock right), and this is indicated by the two green lamps. The green "X" symbol in the threat types line indicates that your being targeted by a medium-range radar. There is no additional data on secondary threats.

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

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

PPD-SP Panel

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



Figure 39: PPD-SP panel

Direct control switch

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

- Insufficient pitching stability of the aircraft
- 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.

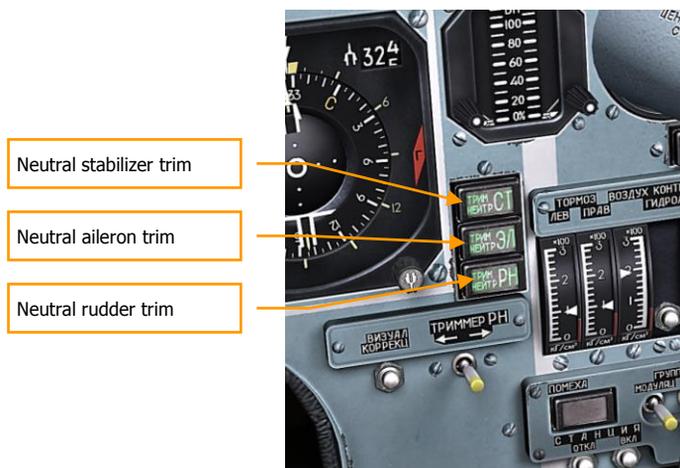


Figure 41: Trim annunciators

Setting of the trimming 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 the 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:

- Autostabilization of the aircraft pitch/bank and barometric altitude
- Automatic leveling of the aircraft in roll and pitch
- Stabilization of absolute altitude in accordance to the radar altimeter signals at altitudes between 100-1000 m, with automatic ground collision avoidance
- Automatic control of climbing and descending
- Automatic control in the horizontal plane in accordance with signals from the navigation system during enroute navigation mode
- Automatic return to the programmed airfield and landing approach down to the altitude of 50-60 m in accordance with input from the navigation system

Actuators of the fly-by-wire system and trimming 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"** mode). 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 42: Manual Control annunciator

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



Figure 43: ACS push-light 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 mode and the mode of barometric altitude stabilization. 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.

[LAIt -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.

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

[LAIt -3] – Level up 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 44: "ПРИВЕД К ГОРИЗ" (Level up to the horizon) annunciator

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

[LAIt -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.

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

[LAIt -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.

Su-27 HUD and HDD Operational Modes

Basic HUD symbols

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

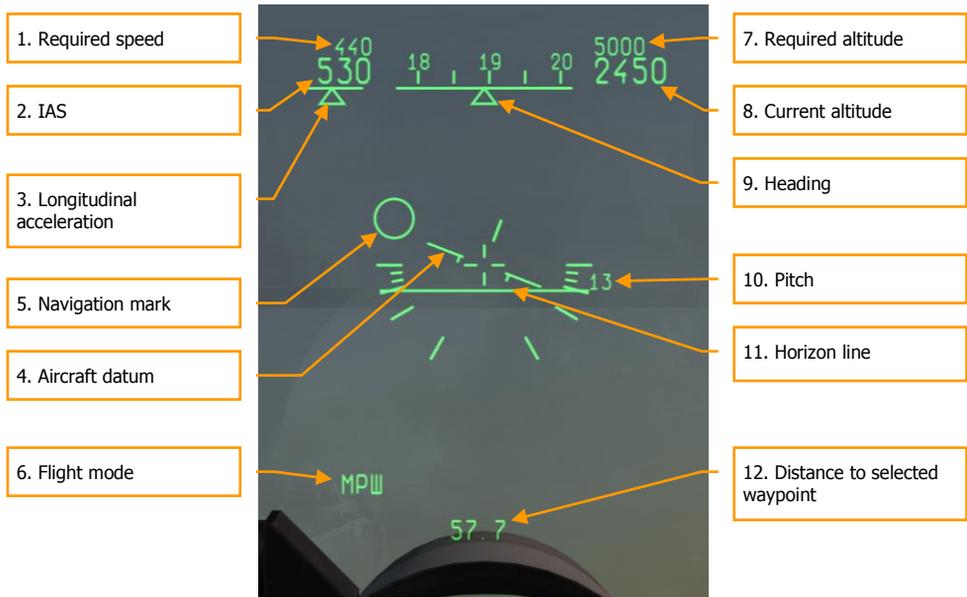


Figure 45: HUD basic symbols

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.

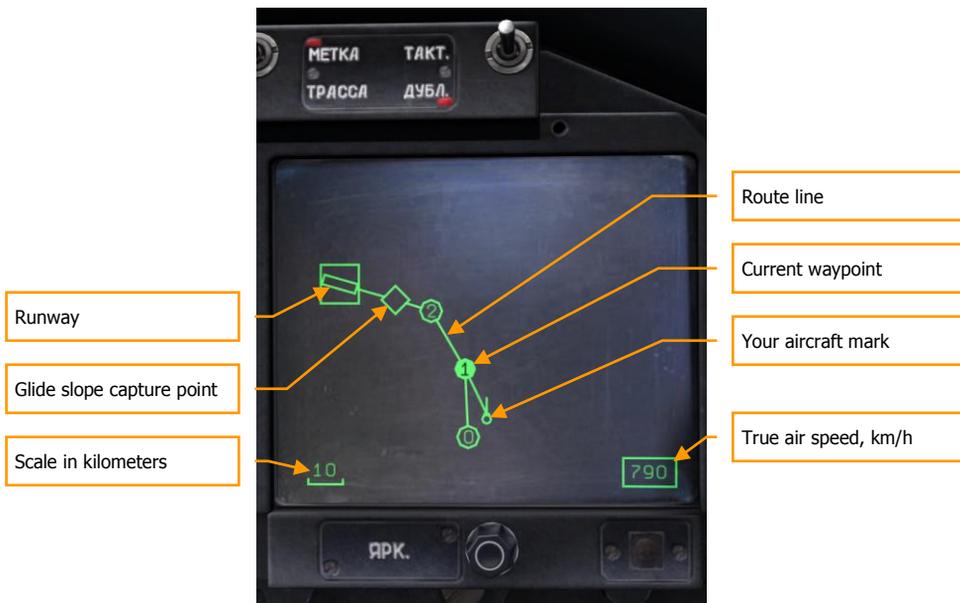


Figure 46: HDD in navigation mode

- 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: **МПШ (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.

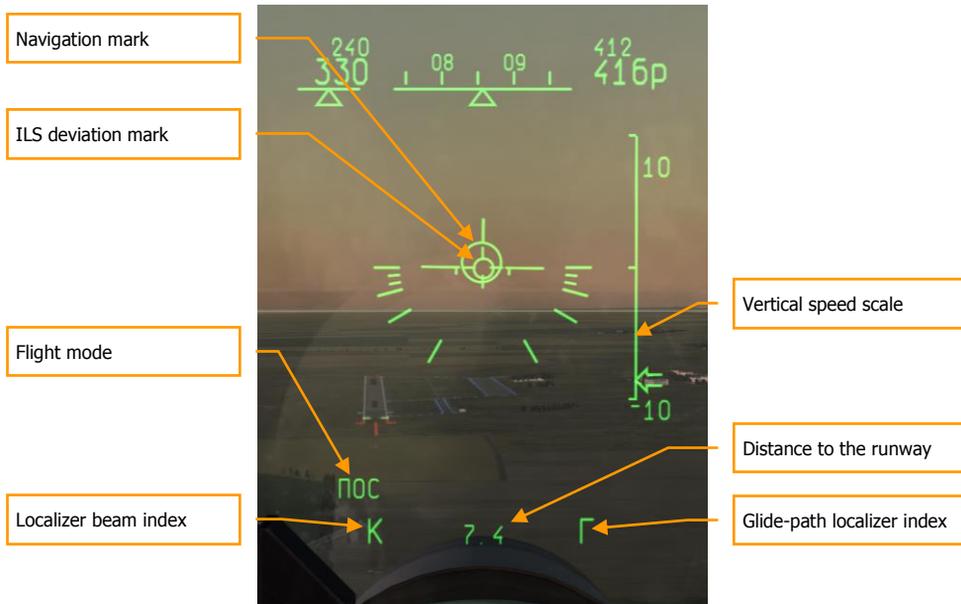


Figure 47: ILS landing

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, "ЧП" (TWS) – track-while-scan, and "РП" (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 orIRST) 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.

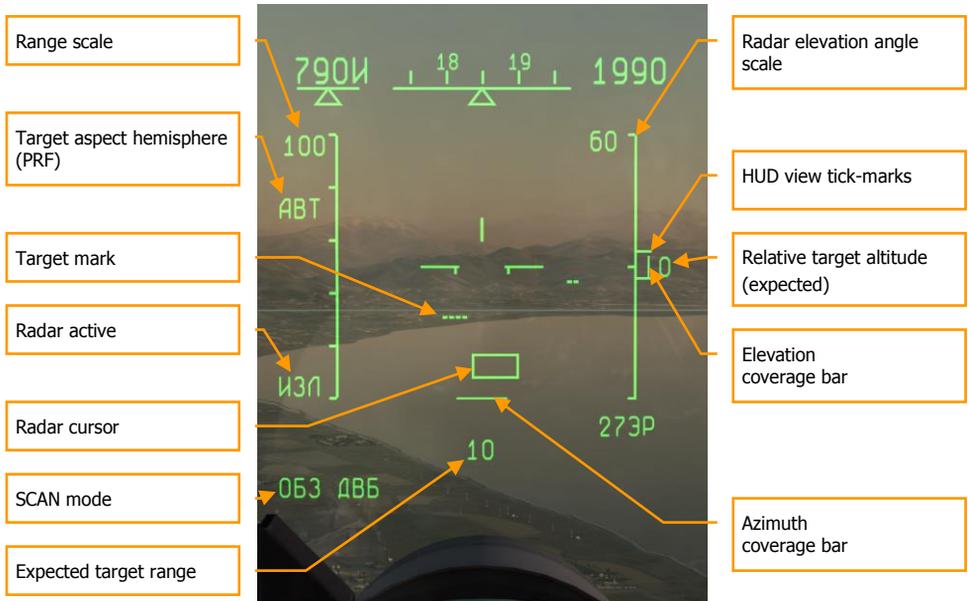


Figure 48: "OБ3" (SCAN) mode - BVR

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 [;], [,], [.] and [/] 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:

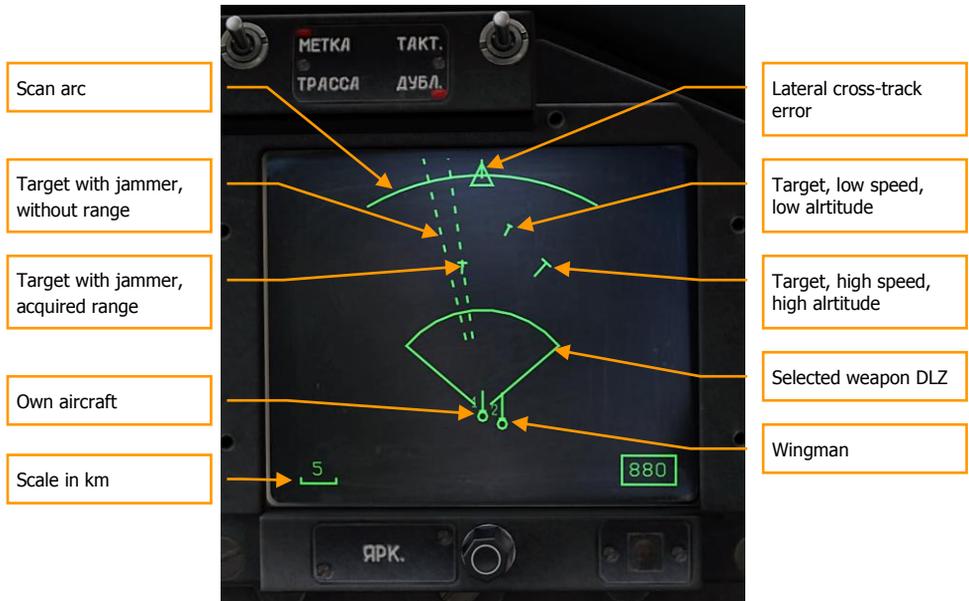


Figure 49: HDD in BVR modes

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

"ЧП" (TWS) MODE

Another BVR combat mode is "ЧП" (Track-While-Scan or TWS). It is activated from the "ОБЗ" (SCAN) mode by pressing **[RAIt-I]**. The radar can correlate tracks for up to 10 targets simultaneously in "ЧП" (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.

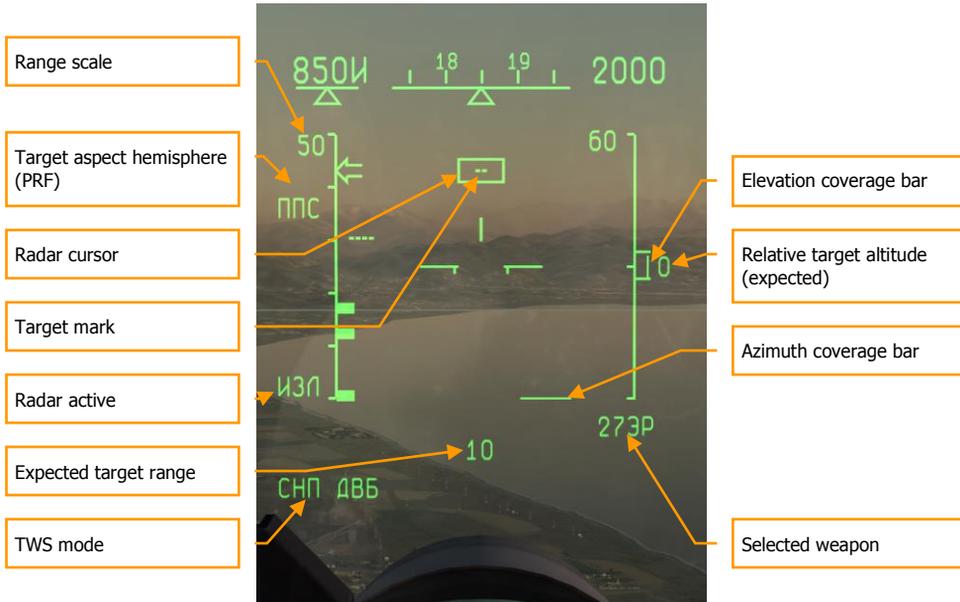


Figure 50: "СНП" (TWS) MODE

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 **273Р** 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:

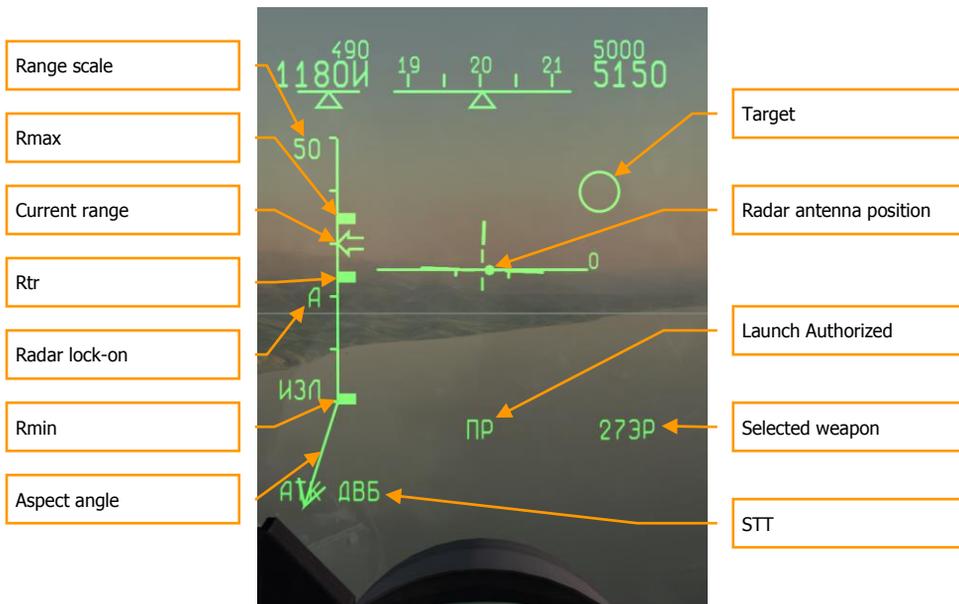


Figure 51: "АТК ДВБ" (STT BVR) MODE

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

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

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



Figure 52: HDD "АТАКА – РНП" (АТТАСК – STT)

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

The STT target mark has a solid triangle above.

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

When semiactive radar homing (SARH) missiles 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.

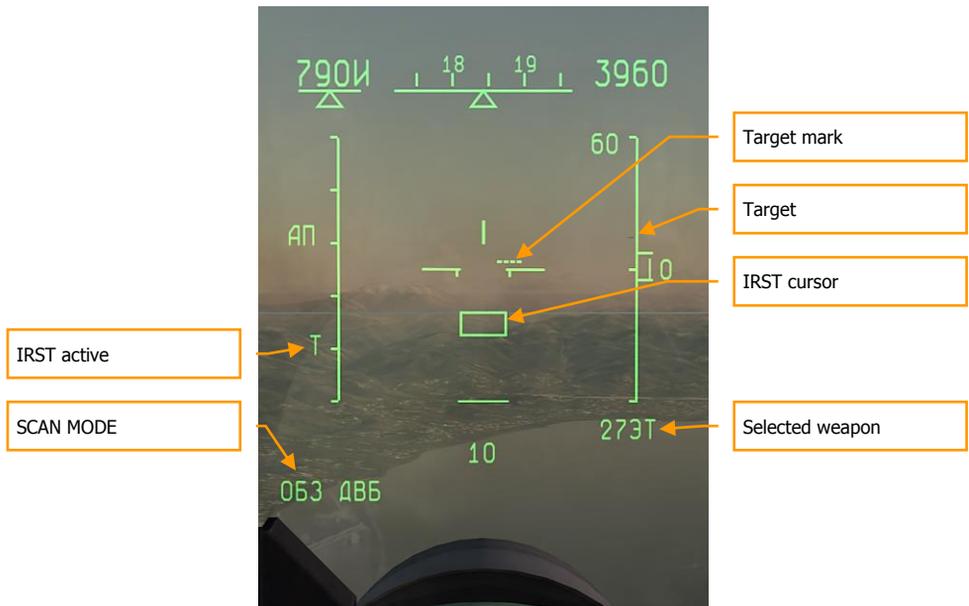


Figure 53: "053 ДББ" (SCAN BVR) Mode with IRST as chosen sensor

- 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 the necessary radio equipment to receive digital target information directly from off-board sensors (A-50 AWACS aircraft and ground-based EW radars) without using voice communications. The command post transmits the air combat tactical situation to the fighter, and this data is then displayed in a top-down view on the HDD to improve the pilot's situational awareness. This tactical display shows the positions of all aircraft detected by off-board sensors,

using the fighter's own position as a reference. The digital datalink is automatically active when the fighter radar is first turned on ([I] key), so long as a friendly AWACS aircraft or early warning (EW) ground radar station is available in the mission. The datalink will remain active, and targets will continue to be displayed on the HDD, even if the radar is thereafter switched off.

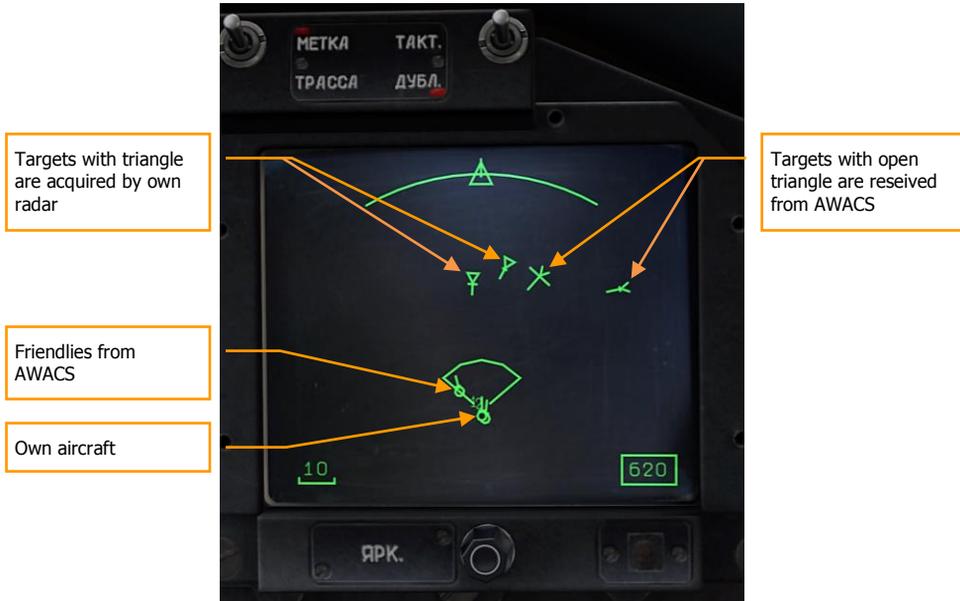


Figure 54: HDD with active AWACS datalink

It should be noted that some AWACS-detected targets appearing into 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 own radar should be controlled with the help of the HUD display.

Work in Complicated Countermeasures Conditions

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

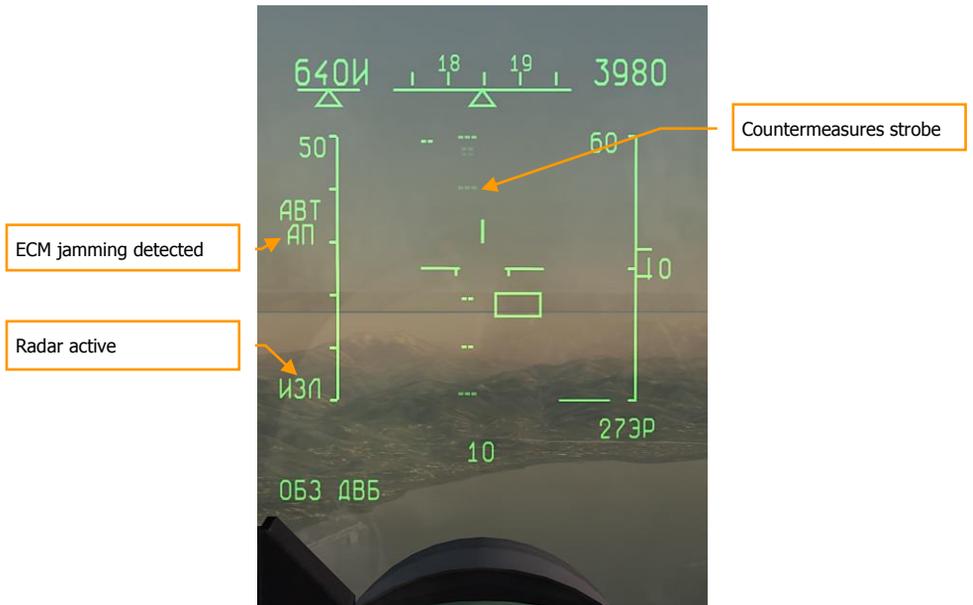


Figure 55: SCAN Mode with jammer strobe

- 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 "AN" active jamming indicator is displayed when electronic countermeasures are detected in the fighter radar scan zone.

Vertical Scanning - Close Combat Mode

This sub-mode [3] is the most frequently used mode in close maneuvering air combat. In this sub-mode the radar or IRST scan pattern is a vertical bar with width of 3 degrees and vertical elevation angle limits of $-10+50$ degrees. The HUD displays two vertical lines denoting the boundaries of the scanned zone. Lock-on is possible when a target moves into the scan zone, which starts at the lower edge of the HUD and extends above it by about two more HUD lengths. To lock-on by maneuvering the fighter so that the target is placed into this scan zone and pressing the lock-on [Enter] key. If [Enter] key is not pressed the lock-on is forbidden.

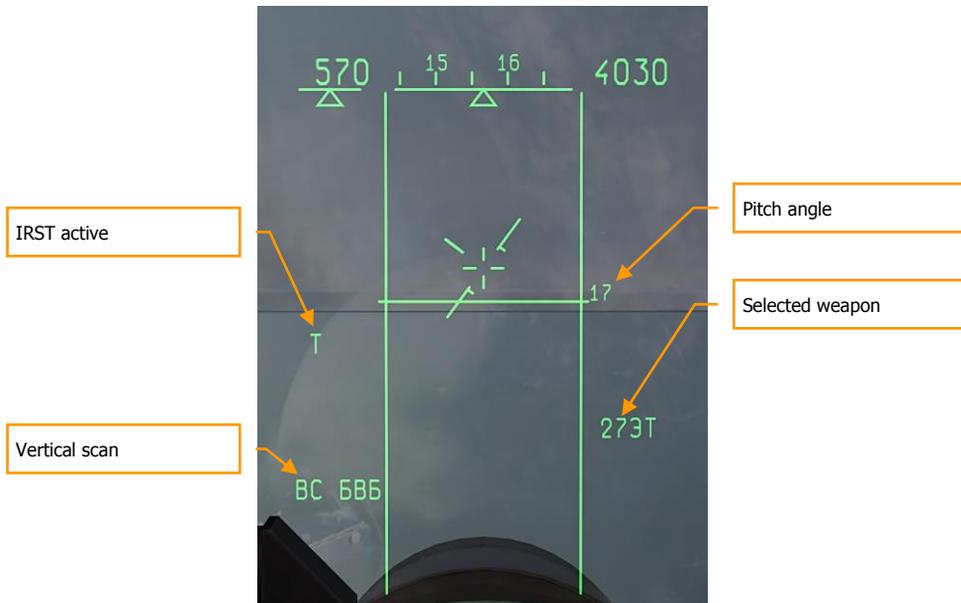


Figure 56: VS MODE

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 57: BORE Mode

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

HELMET - Close Combat Mode

This unique mode is useful for maneuvering combat, and selected with the [5] key. The pilot can aim weapons at the target simply by turning his head to look at it, with the help of the Schel-3UM helmet-mounted sight (HMS). The sighting ring on the screen emulates the HMS sighting system viewfinder located in front of the pilot right eye. The pilot can superpose the viewfinder over the target by panning the view. The viewfinder is not a HUD symbol remains in the center of the screen even when the view is panned off the HUD. This mode is used in close combat to get an advantage

in guided missile launch as HMS permits lock-on and missile launch from high off-bore sight angles, without turning the whole fighter to point at the target. After locking the target by superposing the sighting ring and pushing the **[Enter]** key, if all the launch criteria are satisfied, the ring starts flashing at a frequency of 2 Hz, signaling "ПП" (launch authorized). If the target moves out of the missile seeker's angular gimbal limits, an "X" symbol will appear above the ring.



Figure 58: 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 can 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.

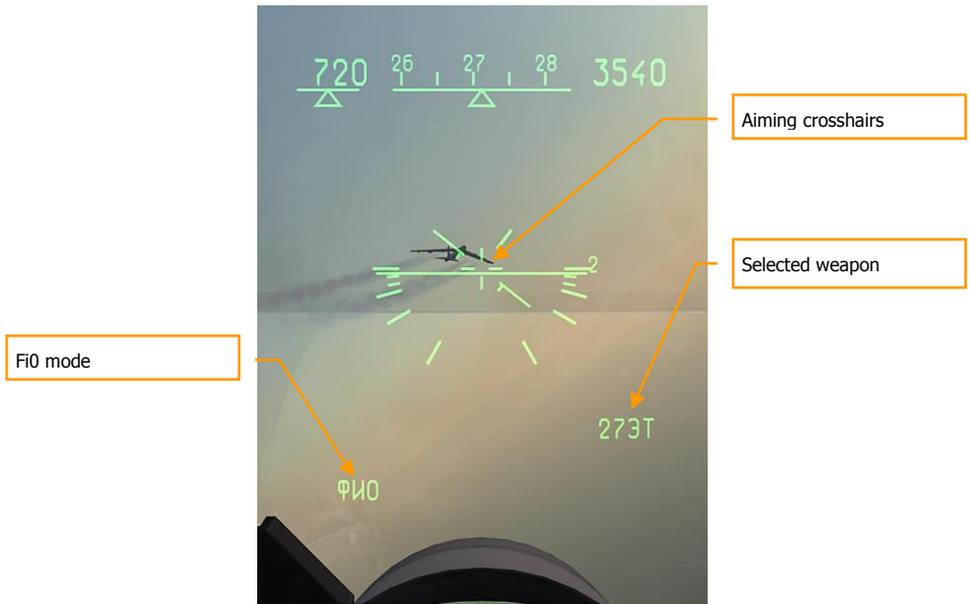


Figure 59: Fi0 (Longitudinal) MODE

Gun Employment

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

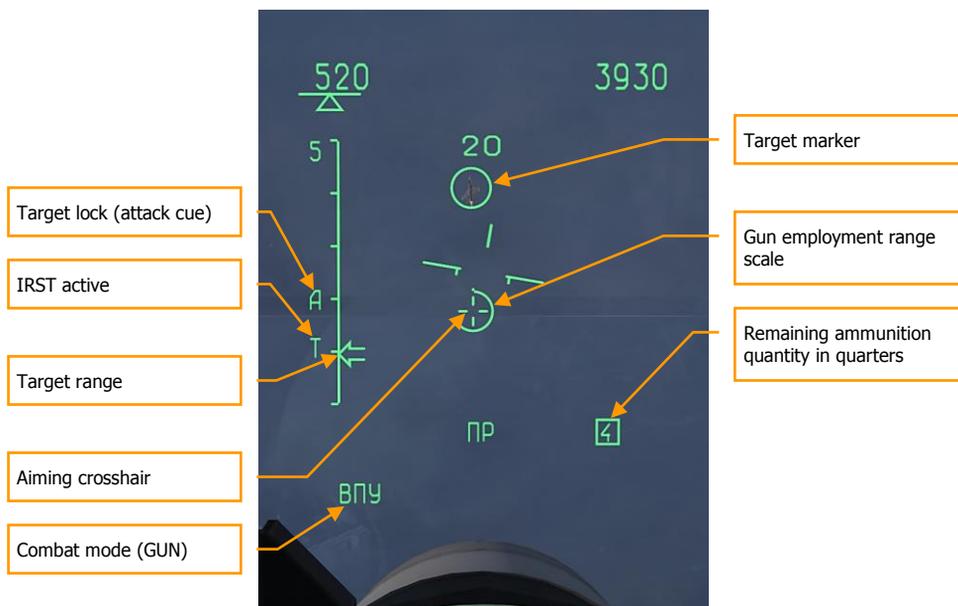


Figure 60: Lead Computed Optical Sight (LCOS) mode

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

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

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

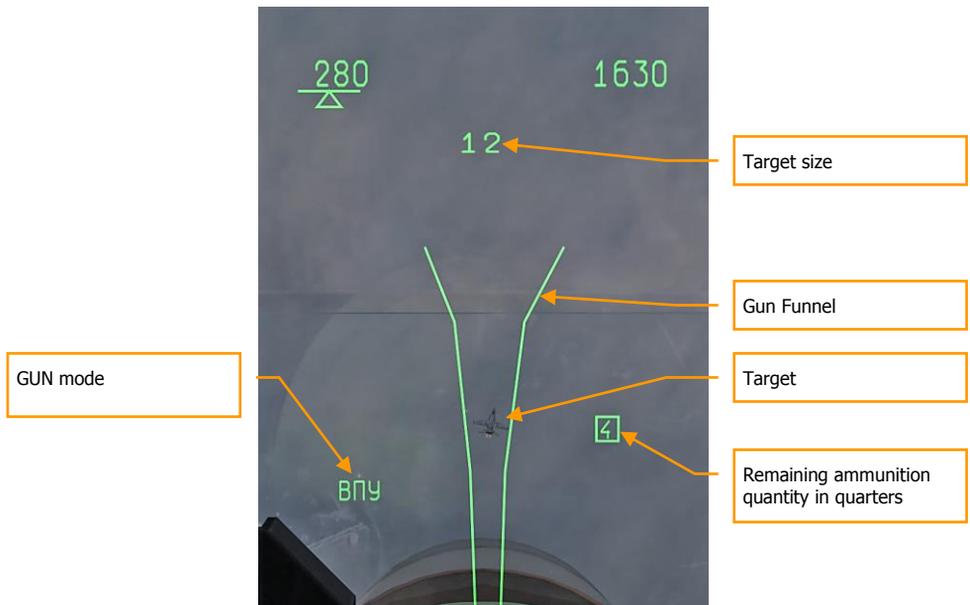


Figure 61: Gun Funnel mode

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 **[RAIt--]**, **[RAIt++]** 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.

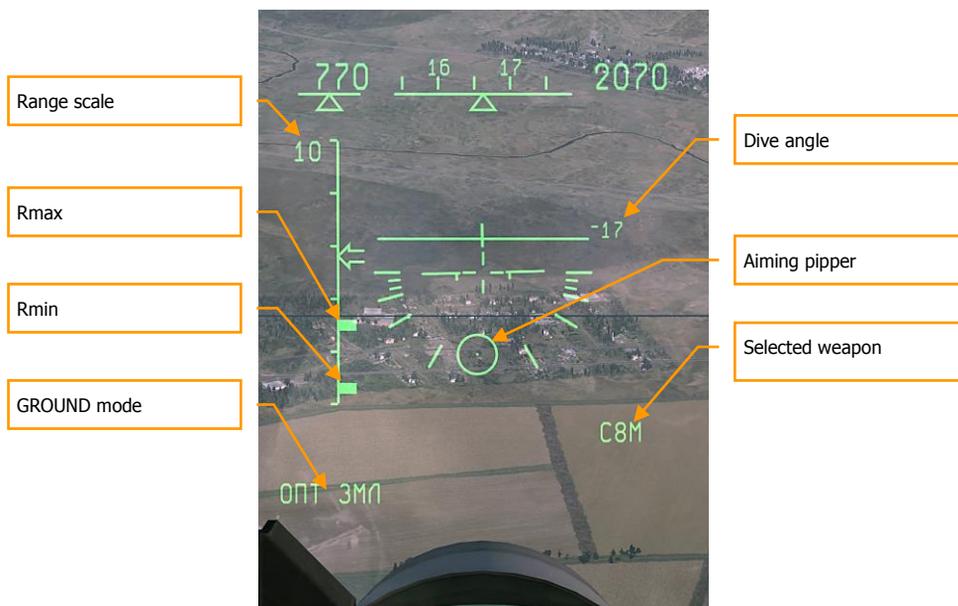


Figure 62: VISUAL GROUND mode

- 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.

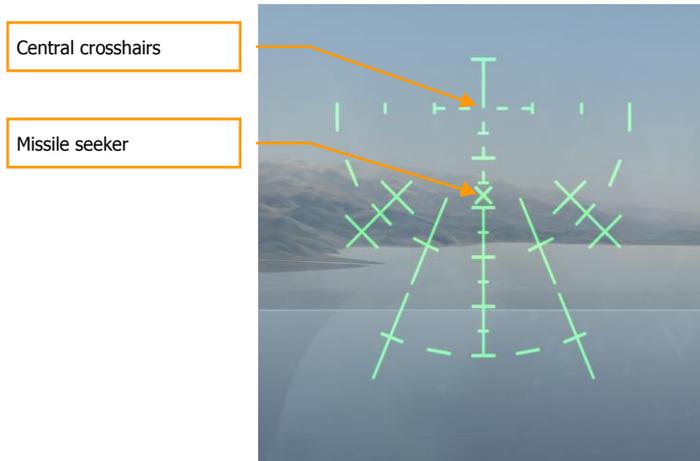


Figure 63: Reticle

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 "Sorbtziya" 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 64: SPS-171 Sorbtziya pod

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 at the right panel is blinking during activation of ECM system (about 15 sec) and steady light when emission goes.



Figure 65: 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-27 WEAPONS



SU-27 WEAPONS

The Su-27 is armed with a single 30 mm Gryazev-Shipunov GSh-30-1 cannon in the starboard wingroot, and has up to 10 hardpoints for missiles, bombs and rockets. Its standard air-to-air combat armament is a mixture 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 influence a missile's MEZ. The launch range increases when you and the target are flying towards each other. This is termed a high aspect engagement. When you attempt to attack a target from behind, the target is flying away from you and greatly reduces a missile's MEZ. This is termed a low aspect engagement. To increase the range of your attacks, attempt high aspect intercepts.

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

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

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

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

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

These missiles use a variety of guidance systems:

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

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

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

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

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

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

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

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

target is flying towards the missile. Near ground level where the air density is very high, the launch range is more than halved.

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

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

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

Su-27 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 Vypel 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.

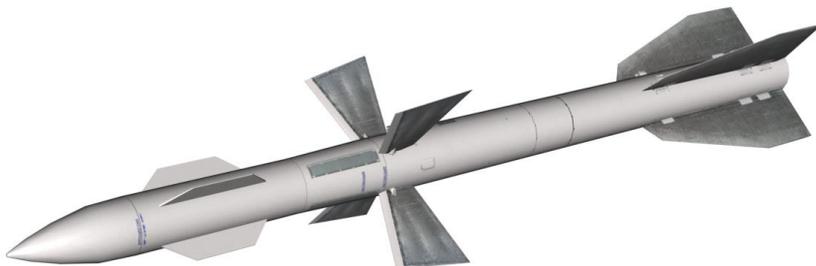


Figure 66: R-27R missile

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.

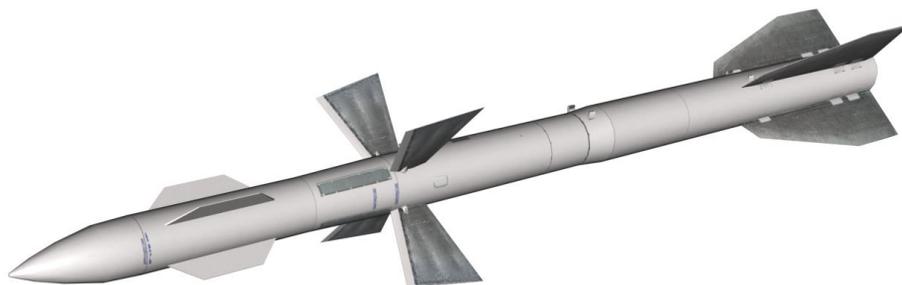


Figure 67: R-27ER missile

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.

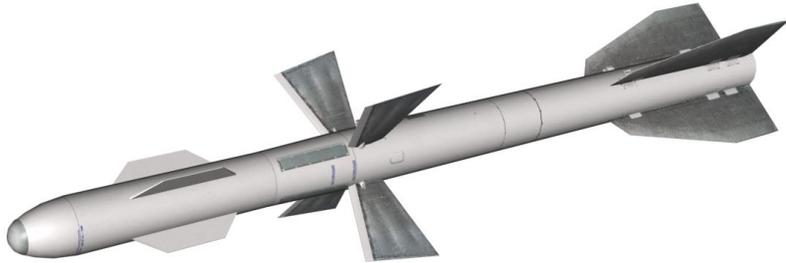


Figure 68: R-27T missile

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.

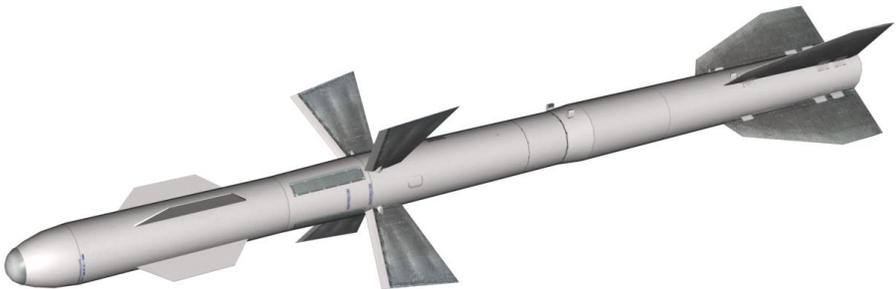


Figure 69: R-27ET missile

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 70: R-73 missile

The same day, another resolution entrusted "Vypel" 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 "Geophysica" 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 than 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 destabilizers. Like the P-60, this also ensured air flow straightening before the aerodynamic control surfaces.

A set of sensors, destabilators 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, "Vypel", 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 .038 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; MiG-29SMT/4; Su-27/4; Su-35 /4; Su-34/4; Su-33/6	
Weapon control system	SUV S-29; SUV S-29M; 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 71: FAB-500 High-Explosive Bomb



Figure 72: FAB-250 High-Explosive Bomb



Figure 73: FAB-100 High-Explosive Bomb

BetAB-500ShP Concrete Piercing Bomb

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



Figure 74: BetAB-500ShP Concrete Piercing Bomb

SAB-100 Illumination Bomb



Figure 75: 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 76: 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 m².



Figure 77: 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 78: 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° – 30° . The pilot maneuvers the entire aircraft to put the aiming piper on the target before firing.

S-8 rocket

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



Figure 79: 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 80: 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.

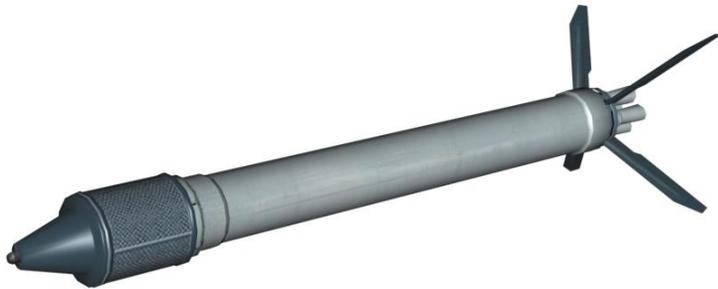


Figure 81: S-25 Rocket

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 weighs 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 82: 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-80FP	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 will respond, " (x) Copy, " " (x) Roger, " or " (x) Affirm, " where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, " (x) Negative, " or " (x) Unable, " where (x) is the flight member.
		Trail	The player is the lead aircraft and aircraft two .5 miles behind the player. Aircraft three is .5 miles behind aircraft two and aircraft four is .5 miles behind aircraft three.	
		Echelon	Standard formation	

		Close Formation	Player requests that the formation or wingmen decrease aircraft separation.	
		Open Formation	Player requests that the formation or wingmen increase aircraft separation.	
AWACSeS	AWACS callsign	Request BOGEY DOPE	Player requests the bearing, range, altitude and aspect of the nearest enemy aircraft.	<p>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.</p> <p>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.</p> <p>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.</p>
		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	"(x) Ejecting," or "(x) I'm punching out," where (x) is a

from aircraft	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	"(x) Request permission to attack," where (x) is the flight member. Example: "Two, Request permission to attack."

	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	" (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."

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

Voice Messages and Warnings

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

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

Voice Message System Messages

Message Trigger	Message
The right engine is on fire.	"Engine fire right"
The left engine is on fire.	"Engine fire left"
Flight control systems have been damaged or destroyed.	"Flight controls"
Landing gear is deployed over 250 knots.	"Gear down"
Landing gear is not deployed and player is on ILS final approach.	"Gear up"
The aircraft has just enough fuel to reach the closest friendly airbase.	"Bingo fuel"
Fuel is at 1500 pounds/liters	"Fuel 1500"
Fuel is at 800 pounds/liters	"Fuel 800"
Fuel is at 500 pounds/liters	"Fuel 500"
The automated control system is not functional	"ACS failure"
Navigation systems failure	"NCS failure"

ECM is not functional	"ECM failure"
Flight control system hydraulics are not functional	"Hydraulics failure"
The missile launch warning system (MLWS) is not functional	"MLWS failure"
Avionics systems failure	"Systems failure"
The EOS is not functional	"EOS failure"
The radar is not functional	"Radar failure"
ADI in the cockpit does not function.	"Attitude indicaton failure"
Damage to aircraft systems that does not include fire or flight control systems.	"Warning, warning"
Aircraft has reached or exceeded its maximum angle of attack.	"Maximum angle of attack"
Aircraft has reached or exceeded its maximum G level.	"Maximum G"
Aircraft has reached or exceeded its maximum speed or its stall speed.	"Critical speed"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is in front of the player, and is at a lower altitude than the player.	"Missile, 12 o'clock low"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is in front of the player, and is at a higher altitude than the player.	"Missile, 12 o'clock high"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is behind of the player, and is at a lower altitude than the player.	"Missile, 6 o'clock low"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is behind of the player, and is at a higher altitude than the player.	"Missile, 6 o'clock high"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is to the right of the player, and is at a lower altitude than the player.	"Missile, 3 o'clock low"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is to the right of the player, and is at a higher altitude than the player.	"Missile, 3 o'clock high"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is to the left of the player, and is at a lower altitude than the player.	"Missile, 9 o'clock low"
An enemy missile that is targeting the player's aircraft is within 15 km of player, is to the left of the player, and is at a higher altitude than the player.	"Missile, 9 o'clock high"

THEORETICAL TRAINING



THEORETICAL TRAINING

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

Indicated Air Speed and True Airspeed

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

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

THE AIRSPEED INDICATOR SHOW THE AIRCRAFT'S INDICATED AIR SPEED

Velocity Vector

The total velocity vector indicator is a common feature on western HUDs; it is also called the Flight Path Marker (FPM). The velocity vector indicates the actual flight direction of the aircraft, which may not correspond with where the nose of the jet is actually pointed. If you place the velocity vector on a point on the ground, eventually, the aircraft will fly directly into that point. This indicator is important tool for pilots and can be used from combat maneuvering to landing approaches. Modern, highly maneuverable aircraft like F-15C can fly at high angles-of-attack (AoA) - when the aircraft flies in one direction but the longitudinal axis is directed in another.

Angle-of-Attack (AoA) Indicator

As described above, the velocity vector may not coincide with the longitudinal axis of the aircraft. The angle between the velocity vector projection and the aircraft's longitudinal axis is termed angle-of-attack. When the pilot pulls the control stick back, he generally increases the aircraft angle-of-attack.

If during a straight and level flight the pilot reduces the engine thrust, the aircraft will start to lose altitude. To continue the level flight, one needs to pull back on the stick and thereby increasing AoA.

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

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

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

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

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

Turn Rate and Radius of Turn

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

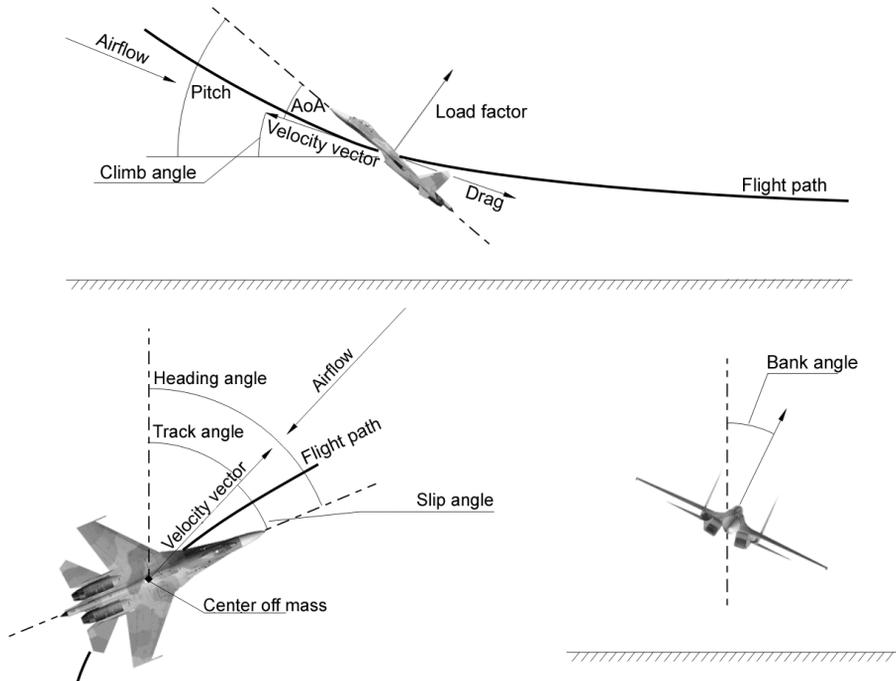


Figure 83: Aircraft aerodynamic forces

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

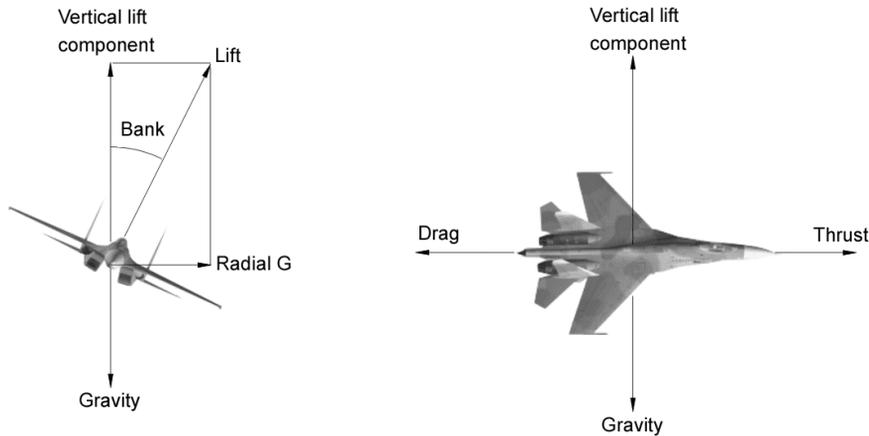


Figure 84: Forces acting at the aircraft maneuver

Turn Rate

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

THERE IS AN OPTIMAL BALANCE AT WHICH MAXIMUM POSSIBLE TURN RATE IS ACHIEVED WITH THE SMALLEST POSSIBLE TURN RADIUS.

IN A DOGFIGHT, YOU MUST TO STAY CLOSE TO THIS AIRSPEED

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

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

For example: performing a sustained turn at 900 km/h, the pilot, if necessary, can pull maximum G to increase turn rate to 20-degrees per second for a short time period. This simultaneously decreases turn radius. Doing this, the aircraft will slow down due the high-G excursion. By then entering a

sustained G-loading turn, the turn rate will increase up to 22 degrees per second with noticeably decreasing of turn radius. By keeping the aircraft at AoA close to maximum you can hold this turn radius and maintain a sustained turn with a constant airspeed 600 km/h. Using such a maneuver will help either achieve a positional advantage or to break a bandit off your six.

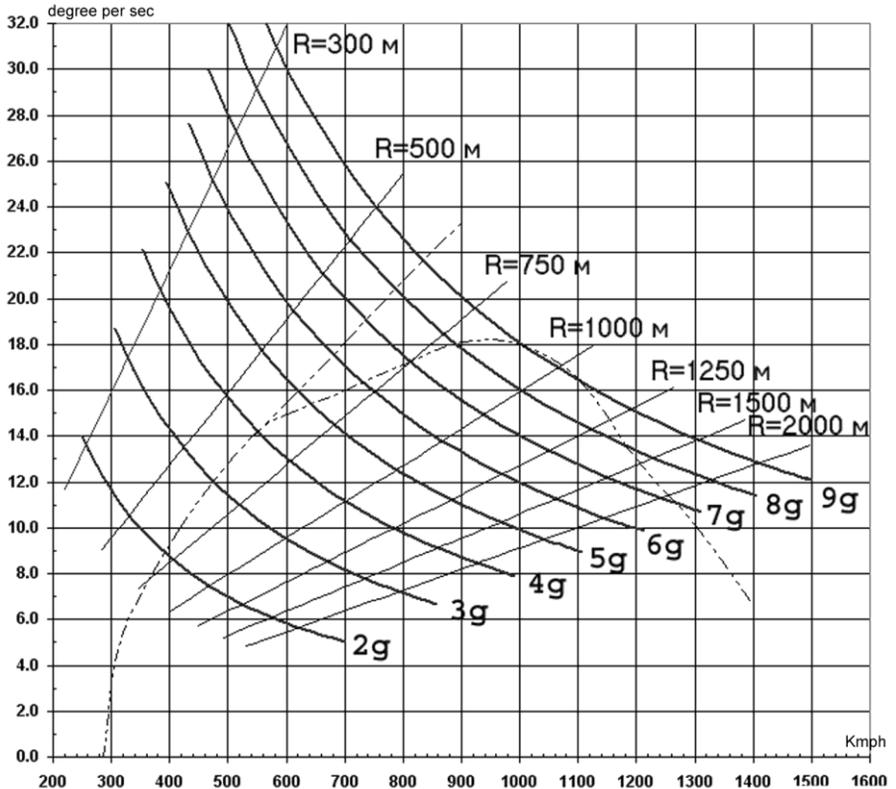


Figure 85: Typical turn rate vs KIAS "dog house" plot of a modern fighter

Sustained and Instantaneous Turns

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

REGULAR, INSTANTANEOUS TURNS RESULT IN SIGNIFICANT AIRSPEED LOSS

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

Energy Control

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

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

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

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

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

SU-27 IMPLEMENTATION



SU-27 IMPLEMENTATION

Flight Control System (FCS)

The Su-27 is controlled by a combination of mechanical and fly-by-wire sub-systems. The longitudinal control is maintained by the synchronous deflection of stabilizers and lateral control is maintained by the differential deflection of flaperons, stabilizers, and rudders. Directional control is maintained by the deflection of rudders.

The mechanical control system is intended for differential deflection of flaperons as part of the lateral control system; synchronous deflection of flaperons during takeoff and landing; rudder deflection during pedal movement; and artificial flight control loading and trimming.

The fly-by-wire system is intended for manual control of the aircraft via longitudinal and lateral channels to provide desired stability and control qualities; to limit angle-of-attack and g load; to control wing leading edges; and for synchronous control of flaperons during maneuvering.

Longitudinal Channel

In order to improve maneuvering performance, the Su-27 has a low degree of pitch stability, which resulted in the necessity of using the fly-by-wire system for augmenting control stability of the aircraft.

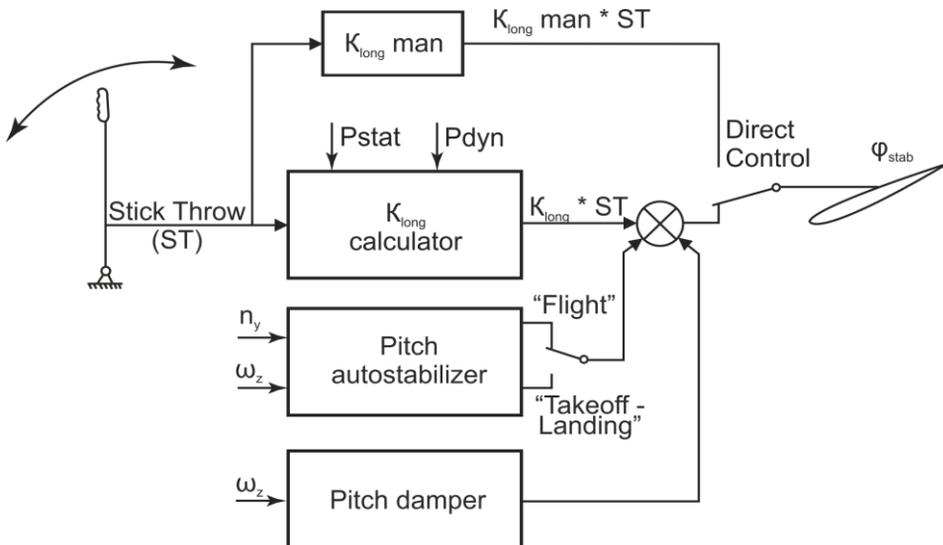


Figure 86: Longitudinal channel stabilizer control schematic block diagram

The longitudinal channel of the fly-by-wire system has three operational modes:

- TAKEOFF-LANDING mode: In this mode, the stabilizer deflects in accordance with control stick inputs and rate of pitch.
- FLIGHT mode: In this mode, the stabilizer deflects in accordance with the control stick inputs, rate of pitch, and g force.
- DIRECT CONTROL EMERGENCY mode: in this mode, the stabilizer deflects in accordance with the control stick inputs only.

The TAKEOFF-LANDING and FLIGHT modes of the fly-by-wire system are switched automatically in accordance with landing gear position.

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

- Insufficient pitching stability of the aircraft
- Low aerodynamic damping
- Increased longitudinal stick sensitivity

When in this mode, compensate for the aircraft's tendency to change pitch by using short, preemptive stick inputs. Refrain from abrupt, large stick inputs. Angle of attack in this mode should not exceed 10 degrees (the flight envelope limiter does not restrict the angle in this mode); perform turns with a bank no more than 45 degrees.

It is in this mode that the "Pougachev's Cobra" aerobatic maneuver is performed. The mode is switched off by pressing the [S] key again. The on/off control setting is seen on the left cockpit console.

The fly-by-wire system is a trajectory control system. In other words, if the control stick remains in the same position, the system will hold the set flight path. This is why the reduction of airspeed (for example) and resulting decreased lift and increasing angle of attack, will lead to the aircraft attempting to hold the initial flight path and prevent the aircraft from descending. This will result in the airspeed stability degradation up to neutral stability.

The longitudinal control system includes an airspeed trimming law that generates a signal proportional to the ram air. When the indicated airspeed is increased, the FCS causes the stabilizers deflection (up to 5 degrees) nose down. When decelerating, it causes the nose to come up. This imitates the airspeed stability of the aircraft, which is neutral in the presence of a g loading feedback signal. The airspeed stability imitation allows the pilot to use the control stick like he or she would with a stable aircraft.

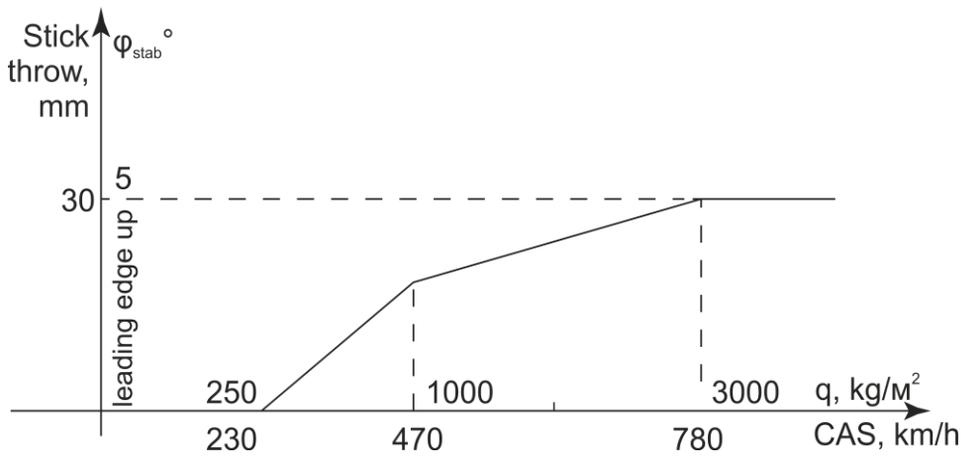


Figure 87: Stabilizer trimming (ST) – ram-air flow (CAS) diagram

This is a logic law of the FBW and is based on stick longitudinal deflection vs ram air pressure. This control law makes the pilot "feeling" of flying at an airspeed-stable aircraft. The law is also intended to increase the flight safety when decelerating. As the aircraft is neutrally stable by airspeed, it should increase the angle of attack in decelerated flight. The aforementioned control law prevents from this by deflecting stabilizers to decrease the AoA.

When accelerating, to keep the aircraft level, it should be trimmed "nose down" as the airspeed increases.

Lateral Channel

Roll control is performed by flaperons working as ailerons (flaperons are also deflected down as flaps when in the takeoff-landing mode) and by differential stabilization. With increased angle of attack, the rudders are used to control roll (see Directional channel).

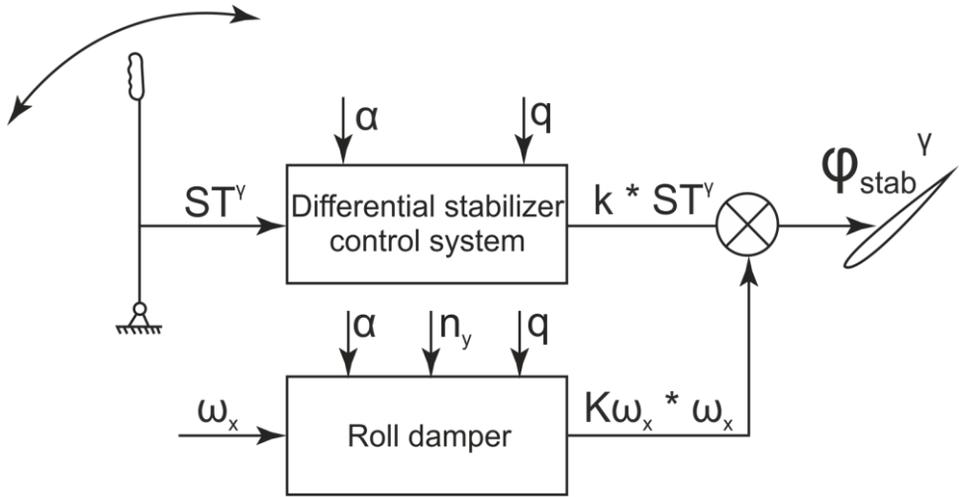


Figure 88: Lateral channel stabilizer control schematic block diagram

The flaperons and rudders belong to the mechanical part of the control system. The lateral channel of the fly-by-wire system, which includes differential control mechanism and roll damper, controls the differential stabilizer deflection.

The differential control mechanism is actuated by side stick inputs and provides differential stabilizer deflection. The degree of this deflection depends on the indicated airspeed and angle of attack.

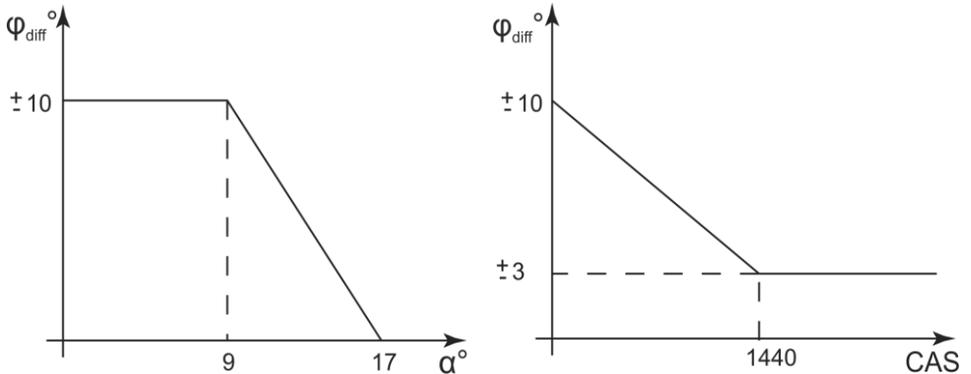


Figure 89: AoA and CAS correction of the differential stabilizer

Reduction of differential stabilizer deflection as V increases excludes large loads on the fuselage tail section at high indicated airspeeds and their reduction with the angle of attack increase excludes manifestation of roll yaw reversal.

The roll damper provides differential stabilizer deflection by roll rate, and it is intended to counteract short-period, roll oscillations.

As indicated airspeed increases at low-to-medium altitude, the maximum roll rate $\omega_x \max$ is increased, reaching the highest value within an indicated airspeed of 600...800 km/h. Here, the maximum ease of the lateral aircraft control is observed.

With a further increase of the indicated airspeed, the lateral handling gradually deteriorates, which becomes noticeable at airspeeds greater than 1200 km/h.

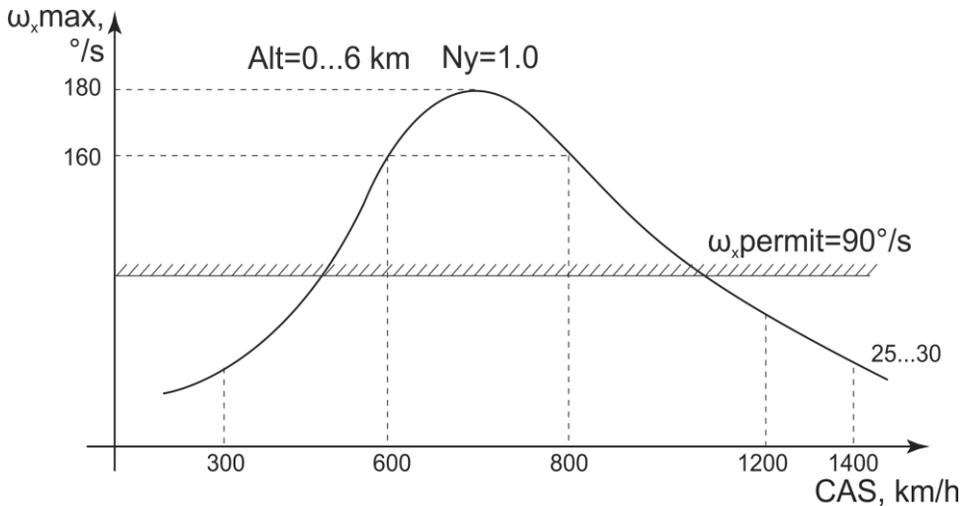


Figure 90: Roll rate – CAS diagram

Such dependence of the lateral handling based on indicated airspeed is accounted for by the following factors:

- An increase of $\omega_x \max$ to VIAS =600...800 km/h is caused by a ram air pressure increase along with high efficiency of flaperons and differential stabilizer.
- A decrease of $\omega_x \max$ with VIAS = over 800 km/h is caused by a reduction of available angular deflections of the flaperons due to insufficient power of the hydraulic actuators and a decrease of the available differential stabilizer deflection aimed to limit loads on the "flexible" fuselage tail section.

Directional Channel

Directional yaw control is performed by symmetrical deflection of the rudders. Transmission of inputs from pedals to the rudders is conducted by means of a mechanical linkage. Additionally, yaw sub-channel servo units of the fly-by-wire system are mechanically connected to the rudders with half-travel authority.

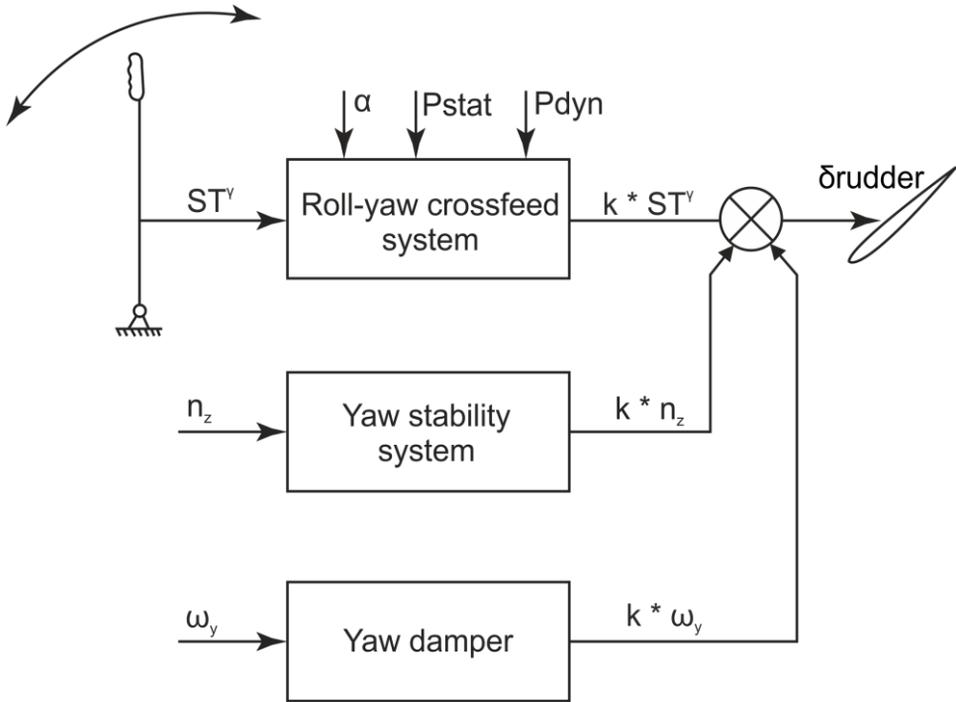


Figure 91: Directional channel rudder control schematic block diagram

The yaw sub-channel of the fly-by-wire system includes the following automatic devices:

Roll-Yaw crossfeed system operates in accordance with side stick inputs. It deflects the rudders to the same side as the control stick. This eliminates adverse sideslip caused by the difference in drag by half-wings. It also improves a lateral controllability, especially at high angles of attack.

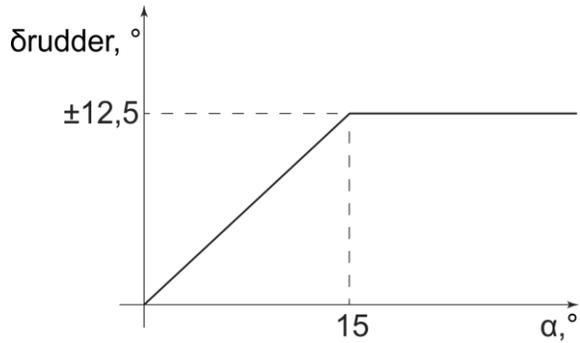


Figure 92: Rudder – AoA diagram

Due to this, lateral control is preserved up to an angle of attack of 28 degrees and there is no roll reversal due to control stick movement.

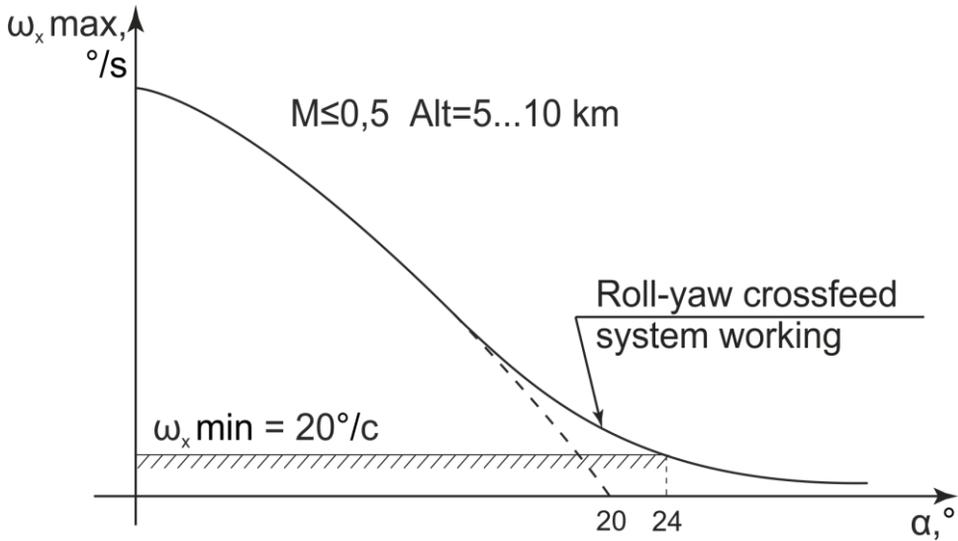


Figure 93: Roll rate – AoA diagram

Yaw stability system operates in accordance with lateral acceleration inputs and it provides required characteristics for aircraft yaw stability due to the aircraft having relaxed static yaw stability. This is due to the peculiar properties of the Su-27's aerodynamic configuration aft of the center of gravity, elongated lateral wing area of the fuselage, and forward fin displacement. The operating principle of the Su-27's yaw stability system is similar to that of the pitch stability augmentation system.

Yaw damper provides the required characteristics needed for lateral dynamic stability.

In order to decrease loads on the fins and the aft fuselage as a whole at the speeds of over 600 km/h, and when the landing gear is up, a spring mechanism is connected to the directional control system providing for the locking stop in the mid-travel of the pedals to each side. It is forbidden to override the locking stop of the pedals at the airspeeds over 600 km/h. This is why pedal travel at these speeds is reduced by half in this simulation.

Nozzle Control System

The nozzle control system is intended to change the diameter of the exhaust nozzle in accordance with the desired law.

Before engine start, during the ignition and when in IDLE mode, the nozzles are completely open to provide the most favorable conditions for engine start: the greatest torque of the turbine, minimum overheating, and the minimum thrust during IDLE mode. When the throttle is moved forward to 77-81% of the engine RPM, the nozzles close partially in order to produce improved thrust characteristics. When the afterburner is switched on, the nozzles open in order to maintain the turbine exhaust temperature. As the thrust augmentation ratio increases, the nozzles open.

When the landing gear is extended, the nozzles partially close in order to preserve the power margin and to avoid nozzle contact with the runway during the touchdown. Due to this, the thrust is increased when on the glide path. In order to decelerate, the speedbrake should be used.

SU-27 CHECK LISTS



SU-27 CHECK LISTS

The powerplant of the Su-27 includes two АЛ-31Ф (AL-31F) engines, each of which has its own turbine starter ГТДЭ-117 (GTDE-117). Because both engines 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 turns on ignition of the main chamber. The turbine starter spins up the engine rotor 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 rotor 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.

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 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 the 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).

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 **"ABT"** (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 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 **"0Б3"** (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 **[RAIt-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 "CHN" (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 "PIP" (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 launch weapon button at least 1 sec until missile launch.

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 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, then 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 theIRST to search each increment for four to six seconds; this allows theIRST 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, theIRST 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 launch weapon button at least 1 sec until missile launch.

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 from -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 **"PIP"** (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 launch weapon button at least 1 sec until missile launch.

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

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

Close Air Combat – STROB (BORE) Mode

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

The lock and launch steps are as follows:

Step 1

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

Step 2

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

Step 3

Once in STT mode and the distance to target is less than that of the maximum range of the selected missile, the "PIP" (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 launch weapon button at least 1 sec until missile launch.

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

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

Close Air Combat – Shlem (Helmet) Mode

This is a unique close air combat mode. With the Schel-3UM helmet-mounted cueing system (HMCS), a pilot turning his head can control the aircraft targeting systems and direct weapons to the target placed in his monacle 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 "**ТИП**" (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 launch weapon button at least 1 sec until missile launch.

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 are 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 (Reticule) 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 launch weapon button at least 1 sec until missile launch.

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 "PP" (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 "NP" (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

SUPPLEMENTS

Acronym List

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

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

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

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

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

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