DCS: Su-33 Flanker D

Manuel de Vol

Traduction Française par Kervinou
v1.x 05/11/2017 - 20:07

Dernière version : http://u.kerv.fr/4O

DCS: Su-33 pour DCS World

L'avion Su-33 Flanker-D a été développé sur la base Su-27.

Le Su-33 est un avion de chasse monoplace STOBAR basé à bord d'un navire, avec des ailes rabattables vers le haut et des surfaces de queue horizontales, et il a une capacité de ravitaillement aérien. Le Su-33 est conçu pour la défense des navires de la marine contre les menaces aériennes. Il est fabriqué à Komsomolsk-sur-Amour.

Le Su-33 aussi connu que le Su-27 est capable d'engager des cibles bien au-delà de la portée visuelle lorsqu'il est en combat en raison de sa vitesse possible incroyablement lente et de sa manœuvrabilité d'attaque à grand angle. Grâce à son radar et à son système de recherche et de poursuite infrarouge furtif, le Flanker peut utiliser un large éventail de missiles guidés par radar et infrarouge. En plus de ses puissantes capacités aériennes, le Flanker-D peut également être armé de bombes et de roquettes non guidées pour jouer un rôle secondaire d'attaque au sol.

Su-33 pour DCS World se concentre sur la facilité d'utilisation sans interaction compliquée dans le cockpit, réduisant considérablement la courbe d'apprentissage. Ainsi, le Su-33 pour DCS World est équipé de commandes clavier et joystick dans le cockpit, avec un accent sur la mission la plus critique des systèmes de cockpit.

Forum de discussion général (en anglais): http://forums.eagle.ru

Sommaire

INTRODUCTION VI

SU-33 HISTOIRE 2

SUR LE CHEMIN DU SU-33 3

279TH SEPARATE SHIPBORNE FIGHTER AVIATION REGIMENT 11

CONCEPTION GENERALE 12

CONCEPTION 13
Entrées d'Air Moteur 20
Ailes 22
Canard Horizontal 23
Ailettes verticales 23
Centrale électrique et équipement général d'aéronefs 25
Aviation Electronique 36

ARMEMENT 44
Canon 44
Missiles Air-Air 45
Bombes Non Guidées 46
Roquettes Non Guidées 47

MODE AVIONIQUE DE JEU 50

MODE NAVIGATION 51

MODE AIR AIR 52

INSTRUMENTS DE COCKPIT 55

Indicateur de Vitesse et de Mach 56
Altimètre à Pression 56
Altimètre Radar 57
Indicateur de Dispositifs Mécaniques 57
Indicateur et Accéléromètre AoA 58
Indicateur de Direction d'Attitude 58
Indicateur de Situation Horizontale 59
Indicateur de Vitesse Verticale 59
Horloge 60
Tachymètre 60
Indicateur de Quantité de Carburant 61
Indicateurs de Température de la Turbine à étage Intermédiaire 61
Affichage Tête en Bas (HDD) 62
Système d'Alerte Radar 62
Panneau PPD-SP 66

Interrupteur de contrôle direct 66
Mecanisme de Trim 67
Automatic Control System (ACS) 68

MODES DE FONCTIONNEMENT SU-33 HUD ET HDD 73
Symboles HUD de base 73
Modes Navigation 75
Modes de Combat Au-Delà de la Portée Visuelle (BVR) 76
Digital Datalink 83
Conditions de Contre-Mesures Compliquées 87
Mode de Combat Rapproché - Balayage Vertical 88
Mode de Combat Rapproché - BORE 89
Mode de Combat Rapproché - CASQUE 90
Mode de Combat Rapproché Visée Longitudinale - Fi0 91
Utilisation du Canon 92
Mode Air-Sol 94
Réticule 95

CONTRE-MESURES ELECTRONIQUES 97
Contre-Mesures Electroniques (ECM) Fréquences du Su-27 97

ARMEMENTS SU-33 100

MISSILES AIR-AIR 100

MISSILES AIR-AIR 102
R-27 (AA-10) Missiles Moyenne Portée 102
R-73 (AA-11) Missiles Courte Portée 105

ARMEMENTS AIR-SOL 109
Bombes Non Guidées 109
Roquettes Aériennes Non Guidées 113

COMMUNICATIONS RADIO ET MESSAGES 119

COMMANDES RADIO 119

MESSAGES RADIO 127

MESSAGES VOCAUX ET AVERTISSEMENTS 130

SU-33 CHECK LIST 133

Démarrage du Moteur au Sol 133
Arrêt du Moteur 133
Redémarrage du Moteur en Vol 133
Quelques Caractéristiques du Su-33 135

UTILISATION DE L'ARMEMENT 136
Combat Au-Delà de la Portée Visuelle (BVR) 136
Combat Rapproché 139

Armements Air-Sol....144

SUPPLEMENTS 147

LISTE DES ACRONYMES....147

INTRODUCTION

Le Sukhoi Su-33 (Russe: Сухой Су-33; OTAN: Flanker-D) est un chasseur tout temps bimoteur de supériorité aérienne basé sur des porte-avions, conçu par Sukhoi et fabriqué par l'Association de production aéronautique Komsomolsk-sur-Amour, dérivé du Su-27 et initialement connu sous le nom de Su-27K. Par rapport au Su-27, le Su-33 dispose d'un châssis et d'une structure renforcés, d'ailes pliantes et de stabilisateurs, tous pour les opérations à partir de porte-avions. Le Su-33 a des canards et ses ailes sont plus grandes que le Su-27 pour une portance accrue. Le Su-33 est équipé de moteurs améliorés et d'une roue à double nez, et il peut être ravitaillé en carburant.

Utilisé pour la première fois en 1995 à bord du porte-avions Admiral Kuznetsov, le chasseur est entré officiellement en service en août 1998, date à laquelle la désignation "Su-33" a été utilisée. Après le démantèlement de l'Union soviétique et la réduction ultérieure des effectifs de la marine russe, seuls 24 avions ont été produits.

Figure 1: Su-33 sur le pont

HISTOIRE

HISTOIRE DU SU-33

L'avant-projet préliminaire de l'avion de chasse Su-27K a été préparé par le P. O. Usine de construction Sukhoi en 1978. La conception était basée sur le chasseur Su-27, qui était à l'époque encore dans sa configuration prototype initiale (T-10) et qui faisait l'objet d'essais en vol l'année précédente. Le chasseur Su-27K, équipé de deux moteurs AL-31F d'une poussée de 12 500 kg, devait avoir une masse normale au décollage (sans armement) de 22 800 kg et une masse maximale au décollage de (avec missiles air-air) de 26 600 kg. La charge de combat maximale de l'avion comprenait deux missiles à courte portée R-73, six missiles à moyenne portée R-27E et 150 cartouches pour le canon interne. Avec une charge de carburant de 7680 kg, le Su-27K pourrait atteindre 1200 km de rayon de combat, et son autonomie de patrouille est de 250 km à partir du porte-avions, pendant au moins 2 heures. Par rapport à la version terrestre du prototype, le Su-27K était équipé d'une aile pliante, d'un châssis renforcé, d'un crochet d'arrêt et d'un équipement de navigation spécial. Au cours de sa construction, un certain nombre de mesures ont été envisagées pour renforcer la protection contre la corrosion du châssis, de la centrale et des équipements.

Le Su-27K surpassait de presque 1,5 fois le MiG-29K en masse au décollage et en charge; de plus, le Su-27K disposait d'une réserve de carburant presque deux fois supérieure, ce qui lui donnait une autonomie 1,5 fois supérieure. Il n' a été possible d'obtenir le même rayon tactique et la même endurance de patrouille qu'avec le MiG-29K.
Avec l'utilisation de réservoirs de carburant externes - un sous le fuselage et deux sous l'aile, ce qui a considérablement réduit la charge de combat déjà dérisoire des missiles air-air du MiG-29. La puissance de feu du Su-27K dépassait largement celle du MiG-29K: avec le même canon de 30 mm avec 150 cartouches et les mêmes missiles de courte portée R-73, le Flanker pouvait transporter six missiles de moyenne portée R-27 supplémentaires, contre un maximum de quatre sur le Fulcrum (et un minimum de deux seulement, si des nacelles de carburant externes étaient nécessaires). L'inconvénient de tous ces avantages a été la taille plus grande et les coûts de production accrus du Su-27K, ce qui a limité le nombre de ces chasseurs dans l'aile aérienne du porte-avions.

Les essais en vol du T10-3 ont débuté le 24 juillet 1982 au complexe NITKA, où le pilote d'essai N. F. Sadovnikov a effectué son tout premier décollage depuis les détentes. Le 28 août, le T10-3, également piloté par Sadovnikov, décolle de la rampe. La masse au décollage de l'avion pendant cette séance d'essai était de 18 200 kg, avec une distance au décollage de 230 m et une vitesse de décollage de 232 km/h.
Au total, la première phase d'essais du complexe NITKA, qui a duré jusqu'au 17 septembre 1982, a vu 27 décollages sur le prototype T10-3. Avec une masse au décollage de 18 000 kg, la distance de décollage de l'avion a été établie à 142 m et la vitesse de décollage a été réduite à 178 km/h. La masse maximale au décollage du T10-3 pour un décollage sur rampe était de 22 000 kg.

Compte tenu des résultats de la première étape des essais en vol au complexe NITKA, on a décidé de modifier le profil de la rampe de décollage. D'après les calculs des spécialistes du Gromov Flight Research Institute, du Central Aero-Hydrodynamic Institute et du Sukhoi Experimental Design Bureau, les meilleurs résultats pourraient être obtenus si la surface de la rampe était formée non pas par un arc d'un cylindre, comme sur le T-1, mais par une courbe cubique. Par conséquent, l'angle de sortie de l'avion de la rampe de descente passerait de 8,5 à 14,3° Alors qu'une nouvelle ski-rampe, désignée T-2, était en construction, l'été 1983 marquait le début de la deuxième étape des essais en vol de l'avion à NITKA - avec des atterrissages assistés par un train d'arrêt.

À l'été 1983, le T10-3 était équipé d'un crochet d'arrêt. Comme la durée de vie du T10-3 était déjà épuisée, il a été décidé que l'avion, une fois au sol, devait être utilisé pour tester le fonctionnement des câbles d'arrêt. Grâce à ses moteurs, l'avion a accéléré le long de la piste à une vitesse de 180-240 km/h jusqu' à atteindre les câbles d'arrêt. Ces "touchdowns" ont été effectués avec l'avion sur ses trois points d'atterrissage, ainsi qu'avec les trains avant maintenus en position haute.

La charge de décélération longitudinale de l'avion a atteint 4,5. La décélération de l'avion pendant le contact asymétrique a également été testée - avec un déplacement latéral de l'avion de l'axe de la piste jusqu' à 5 m et un angle par rapport à l'axe de la piste jusqu' à 5°. La longueur du faux-rond de l'avion a été réduite à 90 m.

Ainsi, la première phase d'essais de l'avion expérimental au complexe NITKA en 1982-1983 a confirmé la principale possibilité de mettre en œuvre, d'une part, des pistes de décollage raccourcies à partir d'une rampe de lancement, avec une course au décollage dans les limites fixées par le poste de pilotage de l'Amiral Kouznetsov (TAKP 1143.5), et d'autre part, des opérations d'atterrissage avec la mise en place de câbles d'arrêt. Des essais plus poussés, ainsi que l'exploitation des premiers chasseurs soviétiques embarqués à bord de l'Amiral Kouznetsov, ont révélé un certain nombre d'avantages significatifs du décollage en rampe de lancement par rapport au traditionnel décollage assisté par catapulte des porte-avions occidentaux.

L'intercepteur de chasseur à longue portée Su-27K a été créé sur la base du chasseur de première ligne Su-27, préservant le système d'armes existant au premier stade. Plus tard, les concepteurs ont décidé de doter le Su-27K d'un nouveau système de contrôle des incendies, ainsi que de missiles air-sol guidés destinés à être utilisés sur le chasseur Su-27M modernisé.

Sur le Chemin du SU-33

Le décret du Comité Central de la CPSU et du Conseil des Ministres de l'URSS du 18 avril 1984 a été la reconnaissance officielle des nombreuses années de travail de l'état-major du P. O. Sukhoi Machine-Building Plant consacré au projet de développement d'une version navale du chasseur SU-27. Par conséquent, des efforts massifs ont été entrepris pour élaborer les plans, puis le développement technique du chasseur naval Su-27K (code d'usine T-10K).

Tous les travaux sur le chasseur naval ont été supervisés par le concepteur général de l'usine de construction de machines de Sukhoi: Mikhaïl Petrovitch Simonov. En 1984, Konstantin Khristoforovitch Marbashev a été nommé chef du projet Su-27K au Bureau d'études expérimentales de Sukhoi.

Le SU-27K, un avion de chasse supersonique monoplace sur porte-avions, a été créé en tant que modification du chasseur Su-27, dont la production en série était déjà en cours à l'usine de Komsomolsk-sur-Amour (nommé d'après Yuri Gagarin). Tout en conservant les solutions de conception et d'agencement du modèle de base et en ayant un degré élevé de continuité avec celui-ci en ce qui concerne la centrale électrique, l'équipement et le système d'armement, le Su-27K a également dû mettre en œuvre dans sa conception un certain nombre de changements importants déterminés par les complexités et les exigences des futures opérations et missions de combat naval de l'avion. Ainsi, les concepteurs ont réussi à déterminer les changements nécessaires qui devaient être mis en œuvre pour la "navalisation" du Su-27.

Principalement, ceux-là:

- Améliorer les propriétés de portance de l'aile en mode décollage et atterrissage en augmentant sa surface et en utilisant une mécanisation plus efficace;

- Augmenter la poussée de l'avion pour assurer le décollage du porte-avions avec une courte course au décollage et des approches interrompues sûres en cas de rupture de contact avec les câbles d'arrêt.
- Renforcement et modification du train d'atterrissage, et installation d'un crochet d'arrêt pour assurer le toucher des roues en toute sécurité de l'aéronef à taux de descente élevé et des G-Forces (sans torchage ou flottement) directement sur le système d'arrêt du porte-avions;
- L'introduction d'un système de ravitaillement en vol et la possibilité d'utiliser un système de transfert de carburant à un autre aéronef pour accroître la portée et la durée des patrouilles au-dessus de la mer;
- Utilisation d'équipement spécialisé de navigation en vol pour guider l'avion sur le porte-avions et pour l'approche sur le pont;
- Modification du système de visée de la cible pour assurer le bon fonctionnement de l'avion au-dessus de la mer en tandem avec les systèmes radioélectroniques embarqués;
- Une augmentation de la capacité totale des missiles air-air sur l'avion pour augmenter son potentiel de combat en une sortie;
- Introduction de bouts d'ailes repliables pour réduire les dimensions de l'avion, assurant une augmentation du nombre maximum de chasseurs stockés dans les hangars du navire et aux positions techniques sur le pont supérieur;
- Introduction d'une protection anticorrosion spéciale du châssis et des systèmes de l'avion pour assurer son exploitation à long terme dans des conditions maritimes.

De septembre à octobre 1984, au bureau d'études expérimentales, le bureau d'études a étudié la conception préliminaire de l'avion de chasse Su-27K, qui incarnait ces améliorations, par la commission du client, dirigée par le commandant de l'escadre aérienne de la marine, le colonel-général G. A. Kuznetsov.

Bien que la commission ait approuvé l'ébauche de conception, elle a néanmoins formulé un certain nombre de commentaires. L'une des principales préoccupations soulevées concernait la nécessité d'améliorer les capacités de combat du Su-27K dans l'exécution de ses missions de combat en mer. Les exigences opérationnelles du Su-27K formulées par la 30e section de l'Institut central de recherche ont permis le déploiement de l'avion non seulement comme couverture aérienne pour le porte-avions, mais aussi pour combattre les navires de surface hostiles. Cependant, le bureau d'études expérimentales a défendu sa position selon laquelle la première étape du développement (dans l'intérêt d'accélérer le processus de développement) exigeait la création d'un avion de combat "propre", avec une harmonisation significative des systèmes d'armes avec la version terrestre du Su-27. Selon les dirigeants du P. O. Sukhoi, à la fin des années 80, une telle approche aurait permis de mettre en service les premiers chasseurs supersoniques à embarquer en série, alors que le développement de nouveaux systèmes d'armes nécessiterait beaucoup plus de temps. Ils devaient être introduits à la deuxième étape de la création du Su-27K. Néanmoins, la commission a réussi à insister sur le fait que, dans un premier temps, des moyens non guidés pour vaincre les cibles de surface (sol) - bombes aériennes et roquettes non guidées - doivent au moins être inclus dans l'armement Su-27K.

Ceci et les autres commentaires faits par la commission du client ont été pris en compte par les développeurs lors de la finalisation du projet. En conséquence, en février 1985, l'ébauche du projet Su-27K a été approuvée par les commandants de l'armée de l'air et de la marine de l'Union soviétique. L'usine de construction mécanique S. O. Sukhoi a ensuite commencé à travailler sur le développement à grande échelle de l'avion de chasse à bord du porte-avions. Au cours de sa construction, l'avion a subi plusieurs autres changements.

L'un des changements les plus importants a été la modification de l'aménagement aérodynamique du Su-27K en raison de l'installation de canards avant sur l'avion. L'idée d'équiper les avions de type Su-27 de canards avant remonte à 1977, année où il est devenu nécessaire de rétablir l'instabilité statique longitudinale du chasseur causée par le poids excessif du système de visée radar. Le poids du système radar, qui atteignait presque 200 kg par rapport aux valeurs indiquées dans le calcul préliminaire de la masse, signifiait que le centre de gravité de cette nouvelle version du Su-27 pouvait être déplacé sensiblement vers l'avant, ce qui modifiait le point de focalisation. L'avion est devenu statiquement stable le long de l'axe longitudinal et, par conséquent, il est devenu nécessaire de l'équilibrer en déviant les stabilisateurs vers le bas. Les caractéristiques de portance communes du système tout-corps/canards ont donc diminué, ce qui a entraîné une réduction de la portée et une détérioration de la manœuvrabilité de l'avion.

Les canards avant pourraient devenir l'un des moyens de réduire la stabilité statique, ce qui a été obtenu en déplaçant vers l'avant le point d'application de la levée résultante du système tout-corps/ canards. Les premiers Su-27 de série ont pratiquement perdu les avantages inhérents à la configuration instable - selon le centre de gravité, ils avaient une stabilité statique longitudinale neutre ou positive, quoi que avec une très faible marge.

L'idée d'utiliser des canards frontaux sur des avions de type Su-27 revint en 1982, quand le développement commença sur une modification (Su-27M) du chasseur avec un radar plus puissant et, par conséquent, plus lourd. Naturellement, le centre de gravité de l'avion s'est déplacé encore plus loin, et l'instabilité statique longitudinale tant convoitée devenait presque impossible à réaliser. En même temps, il a été décidé d'utiliser la déviation des canards avant pour contrôler plus efficacement l'avion aux grands angles d'attaque.

Comme on le sait, les chasseurs Su-27 peuvent voler avec succès dans une large gamme d'angles d'attaque, mais il y a une certaine valeur critique de l'angle d'attaque auquel la queue horizontale est prise dans un sillage de basse énergie généré par l'aile; son efficacité diminue, et la déflexion des stabilisateurs, même en piqué à l'angle maximum prévu, ne serait pas suffisante pour créer la force de plongée nécessaire pour ramener l'avion au vol normal. Dans ce cas, les canards avant installés devant l'aile et reliés au système fly-by-wire résolvent le problème. Plus tard encore, d'autres avantages importants de l'application des canards avants ont été découverts.

Le concepteur général M. P. Simonov est devenu l'initiateur des essais en vol du canard avant sur avion expérimental. Afin d'évaluer l'influence des canards avant sur les caractéristiques de stabilité et de manœuvrabilité d'un avion de chasse en conditions réelles de vol, l'un des premiers Su-27 de série, le T10-24, a été choisi comme "laboratoire de vol" des testeurs. Les essais ont débuté en mai 1985, avec l'avion piloté par V. G. Pugachev. Montées sur T10-24 à la fin de l'afflux d'ailes, les canards dévient automatiquement et proportionnellement à l'angle d'attaque de l'avion. Les canards ont accentué l' "instabilité" de l'avion, ce qui a permis de réduire les pertes d'équilibrage lors des manœuvres et d'assurer une descente en toute sécurité à partir de grands angles d'attaque lorsque les principaux plans horizontaux étaient obscurcis.

Un résultat inattendu des essais effectués sur le T10-24 avec les canards avant a également été la découverte d'une augmentation significative de la portance maximale de l'avion due à l'interférence favorable des canards et du tout-corps avec le schéma de disposition choisi. Grâce à tous ces avantages, il a été décidé que les canards avant devaient être utilisés comme un élément intégral de l'aménagement aérodynamique des nouvelles variantes du Su-27, dont le premier devait être le chasseur naval Su-27K.

L'installation des canards avant a nécessité de modifier les contours de l'afflux de l'aile du chasseur et de finaliser le système fly-by-wire, ainsi que le système hydraulique de l'avion, dans lequel les unités de commande des canards ont été incorporées. Il a été décidé que le Su-27 devait être réalisé à l'aide de l'implémentation à trois canaux des principes de la commande électrique des gouvernes,

non seulement dans le canal longitudinal (comme c'est le cas dans le Su-27), mais aussi dans les canaux latéraux. Le schéma aérodynamique modifié et le système fly-by-wire ont permis de réaliser le degré d'instabilité statique longitudinale de 5-7% sur le Su-27K, ce qui a permis d'obtenir un gain important de qualité aérodynamique en modes subsoniques grâce à la réduction de la perte d'assiette.

Un autre changement majeur dans la conception du chasseur porte-avions a été un changement dans le plan des ailes pliantes et l'introduction de canards pliants. Cela s'explique par le fait que, dans la version originale du plan, la largeur totale de la Su-27K avec les consoles à ailes pliées était d'environ 10 m, alors que l'autre modèle de chasseur porteur, la MiG-29K, n'avait que 7,8 m. Compte tenu d'un fuselage plus long de 4 m (21,2 m contre 17,3 m), il a été conclu que la MiG-29K présentait l'avantage par rapport à la Su-27K. En conséquence, le conseil d'administration du ministère de l'Industrie aéronautique au milieu des années 80 a même soulevé la question de la fin du programme de développement Su-27K et du transfert du groupe aérien Admiral Kuznetsov exclusivement aux chasseurs MiG-29K plus légers.

Après avoir mené des recherches sur plusieurs nouvelles variantes d'ailes pliantes au Bureau d'études de Sukhoi, (au cours de laquelle il a été envisagé la possibilité d'aménagements d'ailes pliantes doubles, dans lesquels chaque console devait être composée de trois parties: une partie fixe et deux parties tournantes, l'une par rapport à l'autre), la décision a été prise de mettre en œuvre un schéma plus simple et plus technologique. L'aile devait maintenant se replier approximativement au milieu de la travée générale (la distance entre les axes de pliage étant de 7,0 m, le rapport d'envergure des parties fixes et rotatives de l'aile étant de 1:3), tout en préservant les compartiments du réservoir de carburant dans les parties fixes et rotatives.

La largeur hors tout de l'avion de chasse avec l'aile repliée sous le nouveau schéma a été réduite à 7,4 m et est devenue encore plus petite que celle du MiG-29K. Étant donné que le balayage des canards du Su-27K était de 9,9 m, il a été décidé de replier son panneau à peu près à mi-chemin le long de leur travée. (la distance entre les axes de pliage et l'aile étant de 7,0 m). De plus, pour réduire la longueur hors tout de l'aéronef dans le hangar du navire, les concepteurs ont également envisagé la possibilité de rabattre vers le haut la poutre de queue centrale du fuselage et de relever le cône de nez qui abritait le système radar. Cette dernière idée a toutefois été abandonnée par la suite, en raison des limites imposées par le repliage de la barre du réservoir à pression d'air.
Ces mesures ont permis d'augmenter le nombre de chasseurs Su-27K à bord du navire, réfutant ainsi la première vague d'arguments contre le projet de ses opposants au ministère. Le développement de l'avion s'est poursuivi.

En outre, afin de créer le Su-27K, le Bureau d'études de Sukhoi au milieu des années 80 a finalisé plusieurs modèles des avions Su-27 et Su-27UB. En 1984-1987, jusqu' à l'apparition des premiers prototypes du Su-27K, un grand nombre d'essais ont été réalisés sur ces machines au complexe NITKA afin de développer et d'améliorer la technique des décollages raccourcis à partir de la rampe de décollage ainsi que des atterrissages sur le système d'arrêt.

En 1986, la section de production expérimentale de l'usine de construction mécanique P. O. Sukhoi a commencé à assembler les premiers, puis les deuxièmes prototypes du Su-27K, qui a reçu les désignations T10K-1 et T10K-2.

L'une des principales différences entre le Su-27K et le Su-27K est la conception de l'aile. Avec la préservation de l'envergure précédente (14,7 m), la surface de l'aile du Su-27K a augmenté de près de 10% par rapport au Su-27, atteignant 67,84m2.

Ce résultat est principalement attribuable au changement et à l'augmentation de la zone de mécanisation, qui a été dictée par les exigences visant à réduire la vitesse d'atterrissage de l'avion et à augmenter les propriétés de roulement de l'aile pour faciliter les courts décollages à partir du poste de pilotage. Le flaperon monobloc a cédé la place à deux éléments de commande séparés - d'une part, à un volet en deux sections monobloc avec un angle de déflexion augmenté à 45° (une section sur la partie fixe de l'aile, la seconde sur la section pliante) et d'autre part, aux ailerons suspendus (flaperons). La surface totale de mécanisation du bord de fuite de l'aile a augmenté de 84% par rapport au modèle de base Su-27. Les bords d'attaque, maintenant composés de trois pièces, ont vu leur superficie augmenter de 17 %. La face inférieure de la partie fixe de chaque panneau a vu l'installation d'un pylône supplémentaire pour la suspension des missiles air-air.

L'ensemble de modifications suivant concernait les dispositifs de décollage et d'atterrissage de l'avion. Le support principal et le support avant du train d'atterrissage de l'avion ont été renforcés, tandis que le support avant était équipé d'une crémaillère télescopique et de deux engrenages. Toutes les jambes de suspension du train d'atterrissage étaient équipées d'unités d'amarrage et de remorquage; des phares d'atterrissage supplémentaires et un dispositif de signalisation tricolore ont été installés sur la jambe de suspension avant, dont les feux informaient l'agent des signaux d'atterrissage de la position de l'avion sur la trajectoire de descente.

Un crochet d'atterrissage abaissable a été installé sous la poutre de queue centrale (tige) fixée au fuselage. Le crochet est équipé d'un système de déploiement, de levage et d'amortissement. Le système de freinage parachute de la poutre de queue centrale a été enlevé, et les blocs de contre-mesure passifs ont été déplacés du " flipper " arrière (sa configuration a également été fortement modifiée) vers la partie arrière du fuselage, à proximité des compresseurs du moteur. La configuration de l'aiguillon central et de son extrémité change aussi: la poutre est raccourcie, relevée et la surface inférieure est aplatie.

Afin d'augmenter la poussée initiale de l'avion pour assurer un décollage court à partir du poste de pilotage et une approche interrompue en toute sécurité en cas de tentative infructueuse d'atterrissage sur le système d'arrêt, il a été prévu d'équiper l'avion de moteurs AL-31F de série 3 modifiés qui, par rapport au AL-31F en série, étaient équipés d'un mode de fonctionnement spécial supplémentaire, dans lequel la poussée est augmenté pendant une courte période pour atteindre 12 800 kg. Le moteur modifié se distinguait également du modèle standard par son matériau structural et son revêtement qui offraient une résistance élevée à la corrosion. Un système de commande automatique des gaz a également été proposé pour le système de commande du moteur afin de simplifier le contrôle de l'avion pendant l'approche sur la trajectoire de descente abrupte du porte-avions sans l'arrondi avant le toucher des roues.

Tout en conservant presque la même réserve de carburant que sur le Su-27 de base, la conception du Su-27K a modifié la configuration des réservoirs de carburant du fuselage, et de nouveaux compartiments de réservoir ont été installés dans les sections repliables du panneau de l'aile. La réserve de carburant totale de l'avion était de 9500 kg (comparativement à 9400 kg pour le Su-27). Une vidange de carburant d'urgence a été installée sur l'avion afin d'assurer un atterrissage d'urgence sur le navire, ce qui a donné au pilote quelques minutes pour réduire la masse de l'avion en vol afin de permettre un atterrissage en toute sécurité sur le pont.

Un système de ravitaillement en vol a été mis en place afin d'augmenter la portée de vol maximale de l'avion et la durée des patrouilles en mer. En même temps, il était prévu que tous les avions Su-27K seraient équipés d'un barreau de carburant escamotable. Avec le pack de ravitaillement "ddy" (équipés d'un tuyau déployable) monté sur un pylône central, un Su-27K pourrait à lui seul servir d'avion ravitailleur pour les autres.

Pour le ravitaillement en vol de l'aéronef, le pilote doit libérer la tige réceptrice et la placer dans le cône du tuyau de ravitaillement du pétrolier. Une fois qu'un contact fiable est établi entre la tige et le cône, le processus de ravitaillement commence et le carburant sous pression commence à passer à travers le tuyau de ravitaillement.

A cette époque, le système de ravitaillement en vol utilisant le schéma " cône " en tandem avec les packs de ravitaillement était déjà maîtrisé par les pilotes du Bureau d'études de Sukhoi, et adopté en service avec le Su-24M. Son introduction dans la flotte Su-27 n' a donc pas posé de problèmes particuliers.

Le tube de carburant escamotable est situé sur le Su-27K, à l'avant et à gauche du poste de pilotage du pilote, tandis que le capteur de recherche et d'alignement infrarouge (IRST) a été déplacé à droite de l'axe de symétrie de l'avion. Dans les conditions nocturnes, la barre et le cône de ravitaillement ont été éclairés par des phares spéciaux qui se sont détachés des côtés gauche et droit de la tête du fuselage.

Les modifications apportées à la structure de l'avion ont également entraîné des modifications importantes au circuit hydraulique, qui a reçu des fonctions additionnelles : commande des canards et de la mécanisation des ailes; repliage des extrémités et des stabilisateurs des ailes; déploiement et rétraction du crochet d'atterrissage, des tiges de ravitaillement en carburant, etc. Le système pneumatique a également été modifié pour permettre le largage d'urgence du crochet d'atterrissage et de la bielle de ravitaillement.

L'équipement de navigation du chasseur naval comprenait également des systèmes d'assistance pendant les vols au-dessus de la mer et pour les approches à l'atterrissage du porte-avions. L'instrument principal d'atterrissage était le dispositif radio automatique A-380 pour la navigation à courte portée, les commandes de vol, l'approche et l'atterrissage des aéronefs embarqués, l'aide à l'atterrissage Resistance-K42. Afin d'assurer un fonctionnement efficace et d'éviter les interférences électriques, tous les équipements radioélectroniques aéroportés de l'avion ont été mis en conformité avec les exigences de compatibilité électromagnétique avec l'équipement radioélectronique du navire.

Le système de contrôle des armes du Su-27K était en grande partie analogue à celui du Su-27: il utilisait le même radar N001 développé par l'Institut de recherche scientifique de Tikhomirov. Cependant, à la place de l'IRST OLS-27 présent sur le Su-27, un nouvel IRST OLS-27K a été utilisé - la principale différence étant le logiciel d'exploitation. Le système amélioré de contrôle des armes du chasseur Su-27K (SU-33) a permis d'intercepter avec succès des cibles aériennes dans les conditions de combat prévues.

L'arsenal d'armes air-air utilisé par le nouveau chasseur correspondait également aux armements employés par le modèle de base Su-27, mais le modèle Su-27K a vu le nombre total de points durs des missiles passer à 12, ce qui a entraîné une augmentation de la charge de combat. Le Su-27K pouvait charger jusqu' à six missiles R-27ER, deux R-27ET et quatre R-73 simultanément. Le Su-27K avait également la possibilité d'utiliser des munitions air-sol/surface non guidées, d'une masse totale pouvant atteindre 6 500 kg: bombes en fer de 100 à 500 kg, armes à sous-munitions, bombes incendiaires, fusées non guidées S-8, C-13 et C-25 et autres munitions de ce type.

La modernisation du Su-27K pour un nouveau système de contrôle des armements, développé principalement pour le Su-27M, a été planifiée.

Compte tenu de l'ensemble des modifications apportées à la conception, de l'installation de nouveaux équipements, ainsi que du renforcement du châssis, du fuselage et de la structure des ailes (en raison des exigences rigoureuses d'atterrissage sans étincelles, des vitesses verticales G et de descente beaucoup plus élevées que celles rencontrées à l'atterrissage sur les aérodromes conventionnels), la masse à vide de l'avion a fortement augmenté de plus de 3000 kg par rapport au modèle de base Su-27, atteignant 19 600 kg (comparé au 16 400 kg du Su-27). En conséquence, les caractéristiques de vol du chasseur se sont détériorées. Sa plage de vol maximale a diminué de 30 à 40 %, tandis que sa vitesse de vol maximale et son plafond de service ont diminué de 7 à 9 %.

En même temps, le Su-27K pouvait décoller du pont avec un poids jusqu' à 33 000 kg (la masse maximale au décollage du Su-27 était de 28 000 kg), avec jusqu' à 6 500 kg de sa charge de combat à bord (le Su-27 pouvait supporter jusqu' à 2 500 kg).

La masse normale au décollage du Su-27K avec une charge de carburant inférieure à la pleine charge, en fonction du nombre de missiles qu'il transportait, variait de 25 à 28 tonnes, alors qu'il avait une poussée de départ de 0,9 à 1,0 et qu'il pouvait décoller à partir de la première ou de la deuxième position de décollage sur le pont du navire (distance de course au décollage de 105 m). Avec une pleine charge de carburant et la charge maximale des missiles air-air, la masse au décollage de l'avion est passée à 32 tonnes et son rapport de poussée à la masse a diminué à 0,8. Dans ce cas, le décollage de l'avion commencerait à partir de la troisième position de décollage (avec une distance de 195 m). De là, l'avion pouvait décoller même avec une charge de combat maximale de bombes et de roquettes non guidées.

Malgré une augmentation importante de la masse à l'atterrissage par rapport au Su-27, l'introduction de nouveaux mécanismes d'aile et de canards avant a permis de réduire sa vitesse d'approche à 240 km/h (alors que le Su-27 effectue habituellement des approches à l'atterrissage à une vitesse d'environ 270 km/h, ce qui le fait descendre à 225-240 km/h pendant l'arrondi, selon sa masse à l'atterrissage). En même temps, la longueur de la course à l'atterrissage du Su-27K le long du pont, avec l'aide d'un câble d'arrêt, ne devait pas dépasser 90 m.

Ces caractéristiques de vol ont permis d'obtenir la parité Su-27K avec les avions de combat modernes employés par l'adversaire potentiel et, en termes de maniabilité - manœuvrabilité, taux de virage et d'ascension - étaient nettement supérieurs. L'important approvisionnement interne en carburant et la possibilité de ravitaillement en vol ont assuré au Su-27K l'endurance nécessaire pour effectuer des patrouilles prolongées au-dessus de la mer à proximité de son groupement tactique, mené par le porte-avions. Le temps de patrouille maximal du chasseur, avec un chargement de deux missiles R-27E à moyenne portée et de deux missiles de combat rapproché R-73, à une altitude de 11 km et à une distance de 250 km du porte-avions, même sans ravitaillement en vol, pourrait atteindre 2 heures.

Au cours de l'été 1984, l'installation de la nouvelle rampe T-2 (avec une hauteur de 5,6 m, une longueur de 53,5 m, une largeur de 17,5 m et un angle de descente de 14,3°) a été achevée au complexe NITKA, reproduisant ainsi la conception de la rampe sur le porte-avions Admiral Kouznetsov en cours de construction. Le nouveau profil de la rampe, formé par une courbe de troisième ordre, a été conçu pour permettre une montée en douceur des G au décollage.

Le complexe NITKA a vu non seulement l'essai des procédures d'atterrissage du système de décollage et d'arrêt, mais aussi l'essai de l'équipement d'aide à l'atterrissage conçu pour le navire: le "Luna-3" et le "NITKA". Les systèmes d'atterrissage optique "Glissada-N" - le système d'atterrissage radar et le système d'atterrissage aux instruments. Le système optique "Luna-3" a été conçu pour permettre l'atterrissage visuel de jour, tandis que le système optique "Luna-3" a été conçu pour permettre l'atterrissage visuel de jour. L'ILS "Glissada-N" a été conçu pour les atterrissages visuels de nuit. Le système radiotechnique "Resistance" avait pour but d'assurer l'approche de l'avion pour l'atterrissage en mode semi-automatique et directionnel, jour et nuit, dans des conditions météorologiques simples et difficiles.

D'août à octobre 1984,160 approches ont été effectuées par les aéronefs T10-25 avec un atterrissage et une deuxième approche, dont 44 approches automatiques, 9 atterrissages sur le système d'arrêt et 16 décollages à partir de la rampe de ski T-2. Malheureusement, la carrière de vol du T10-25 devait atteindre une fin abrupte: le 23 novembre 1984, pendant le vol sur les terrains d'essais de l'Institut national d'essai scientifique Banner rouge de la Force aérienne à Akhtubinsk, en raison de la destruction des canalisations du système hydraulique menant aux gouvernes de direction, le pilote, N. F. Sadovnikov, a dû s'éjecter. Le pilote a été éjecté à une altitude de 1 000 m et à partir d'une position inversée, mais il a réussi à atteindre le sol en toute sécurité et, heureusement, il a pu continuer à voler. Voici comment N. F. Sadovnikov a décrit l'incident : "Pendant ce vol d'essai, j'ai eu une urgence qui, malheureusement, a entraîné la perte de l'avion. A 2000 m d'altitude et à une vitesse de 1270 km/h, un signal est soudain apparu sur le tableau de bord m'avertissant d'une chute de pression: d'abord dans un circuit hydraulique, puis après quelques

instants, dans l'autre. L'avion est devenu incontrôlable. J'ai dû l'abandonner... Suite aux conclusions du tableau d'accident, des améliorations ont été apportées au circuit hydraulique, et c'était le dernier de ces incidents."

Au cours de l'été 1986, un avion d'essai T10-24 équipé de canards frontaux a été amené au complexe NITKA pour y subir des essais. Comme les canards étaient destinés à être utilisés sur les chasseurs Su-27K de série, des recherches ont commencé sur le T10-24 concernant l'effet des canards avant sur l'aérodynamique du décollage de la rampe de décollage de l'avion. Cependant, seulement 6 vols ont été effectués selon ce programme: le 20 janvier 1987, le T10-24 a été impliqué dans un autre accident, le pilote d'essai, A. Puchkov, réussissant à s'éjecter. Le rôle du T10-24 dans le NITKA a été rempli par un autre avion d'essai, le T10U-2, équipé du système de ravitaillement en vol et d'un crochet d'arrêt. En deux mois, les pilotes d'essai ont effectué 12 vols sur le T10-U2, après avoir perfectionné la procédure d'approche pour les atterrissages de nuit assistés par le système Glissada-N. Cependant, le destin allait décider que ce prototype serait lui aussi perdu plusieurs années plus tard dans un accident.

Au cours de l'été 1987, la section de production expérimentale de l'usine de construction mécanique de P. O. Sukhoi a finalement vu l'achèvement de l'assemblage du premier prototype Su-27K - l'avion T10K-1, qui a reçu le numéro de queue de 37. Le numéro de queue a été déterminé par le fait que le T10K-1, d'après la numérotation de bout en bout du bureau expérimental, était le 37e appareil de la famille Su-27 qui a été transmis au bureau d'études pour les essais (et donc, son code d'usine était T10-37). Initialement, le T10K-1 avait une aile non pliante et des canards, empruntés à la base Su-27. Six mois plus tard, le deuxième exemplaire du Su-27K-T10K-2 (avec un numéro de queue de 39 et une deuxième désignation de T10-39), également assemblé à partir des unités Komsomol, était déployé pour les essais: la principale différence étant la présence des ailes pliantes destinées au chasseur porteur, une surface d'aile agrandie et de nouveaux mécanismes d'aile. Des travaux intensifs ont été effectués sur les deux prototypes pour déterminer les caractéristiques de vol de base de l'avion modifié, pour en évaluer les caractéristiques de stabilité et la manœuvrabilité, pour vérifier un certain nombre des améliorations de conception mises en œuvre, notamment le nouveau système fly-by-wire, les canards avant et le système de ravitaillement en vol (pour lequel le pack de ravitaillement a été utilisé, le T10-U2 le transportant).

L'été 1988 voit le T10K-1 équipé d'un jeu d'ailes pliantes. Son premier vol avec cette modification a été effectué le 25 août, mais après seulement un mois, le 27 septembre 1988, l'avion s'est écrasé. Le pilote du T10K-1, N. F. Sadovnikov a dû effectuer plusieurs tâches en même temps pendant le vol d'essai: la détermination de la résistance de la conception de l'avion en vol supersonique, l'étude de la stabilité et de la manœuvrabilité de l'avion à de grands angles d'attaque et l'imitation de la défaillance du moteur due à des défectuosités du circuit hydraulique. Il y a eu une défaillance du système de commande des canards horizontaux, à la suite de laquelle l'avion est entré en décrochage, et le pilote a donc été forcé de s'éjecter et de quitter le premier Su-27K.

Le deuxième Su-27K, piloté par V. G. Pugachev, a ensuite été laissé pour effectuer la majeure partie des essais en vol en usine après l'accident du T10K-1. Au cours de l'année qui a suivi la perte du premier prototype et jusqu'au début des essais en vol basés sur le transporteur, environ 300 vols ont été effectués sur le T10K-2. Une partie importante d'entre eux a été exécutée au complexe NITKA.

Les premiers vols mettant en œuvre des approches d'atterrissage sans étincelles et utilisant le système d'atterrissage optique Luna ont été effectués par des testeurs militaires sur un avion de chasse Su-27 à la fin de 1988. Sur la base de ces études et aux fins d'essais et d'entraînement ultérieurs, les atterrissages sur des trajectoires de descente "navire" avec des angles d'inclinaison jusqu' à 3° ont été autorisés sur Su-27, en utilisant le système Luna, avec une masse inférieure à 18 500 kg et une vitesse de 240 km/h.

Les essais de développement en vol de l'avion Su-27K, lancé le 17 juillet 1987, ont été officiellement terminés le 28 décembre 1990. Deux avions d'expérimentation et deux avions de production y ont pris part.

Les essais d'état de l'avion Su-33 ont commencé en mars 1991. Ils ont été détenus aux aérodromes de la branche Crimée de l'Institut Suky et Kirovskoye de recherche sur la défense aérienne et directement à bord du porte-avions en mer Noire. Sept chasseurs de production Su-33 ont participé aux essais - du T10K-3 au T10K-9. Simultanément, l'entraînement des pilotes de combat du 100è régiment de chasseurs de navires, formé en 1986 à Saki dans le but de piloter le Su-33, a commencé à l'aérodrome de Saki et au complexe NITKA.

Les essais d'état de l'avion Su-33, ainsi que plusieurs phases d'essais en vol spéciaux, ont été complétés. La première campagne océanique du porte-avions avait également réussi, mais l'avion ne pouvait travailler à partir du porte-avions que pendant la journée et au crépuscule. Il devint nécessaire de résoudre le problème des vols de nuit à partir du navire. C'est ainsi qu'une autre phase d'essais a commencé le 8 septembre 1997 dans le complexe NITKA en Crimée, dans le but d'améliorer les procédures de décollage et d'atterrissage de nuit.

Après avoir terminé les évaluations sur les possibilités d'atterrissage du Su-33 et du Su-25UTG dans des conditions nocturnes sur le complexe NITKA, il a été décidé d'effectuer des essais similaires sur l'amiral Kouznetsov. Les essais n'ont été effectués que de septembre à octobre 1999. Après plusieurs vols sur le Su-25UTG, la décision a été prise de piloter le Su-33 et de permettre aux pilotes de combat de voler de nuit sur le Su-25UTG. Le 28 octobre 1999, les essais en vol du Su-33 ont été menés à bien pendant la nuit.

Les vols de nuit sur l'amiral Kouznetsov allaient devenir les derniers essais du Su-33 au siècle dernier. L'année précédente, le 31 août 1998, le Président de la Fédération de Russie avait signé un décret sur l'introduction du Su-33 dans le service militaire. Cet événement résume les nombreuses années de travail acharné des ingénieurs, concepteurs, scientifiques, ouvriers et autres spécialistes du Bureau d'études de Sukhoi, de l'usine de production de Komsomolsk-sur-Amour, d'un grand nombre d'entreprises, d'usines, d'instituts et d'organisations militaires, pour créer le premier avion de chasse russe.

279è Régiment d'Aviation de Chasseurs Navals

Les quatre premiers chasseurs Su-33 sont arrivés à la Flotte du Nord, au port d'attache du porte-avions Admiral Kouznetsov, le 5 avril 1993. Avec leur arrivée, commença la phase pratique de la création du premier groupe aérien naval russe, avec des avions de chasse supersoniques à voilure fixe. En février 1992, il a été décidé d'organiser l'aile aérienne de Kouznetsov sous la forme d'une division aérienne composée: la 57e Division aéroportée mixte Smolensk Red Banner, composée du 279e Régiment d'aviation de chasseurs navals, équipé des nouveaux chasseurs Su-33, et le 830e régiment d'hélicoptères anti-sous-marins embarqués, équipé des hélicoptères Ka-27, Ka-27PS et Ka-29.

Les chasseurs Su-33 transportés par navire devaient joindre deux escadrons du 279th Naval Fighter Aviation Regiment de la Northern Fleet Air Force.

CONCEPTION GENERALE

CONCEPTION GENERALE

Conception

Le Su-33 est construit selon un schéma aérodynamique normal avec des pylônes avant supplémentaires et a une configuration intégrée.

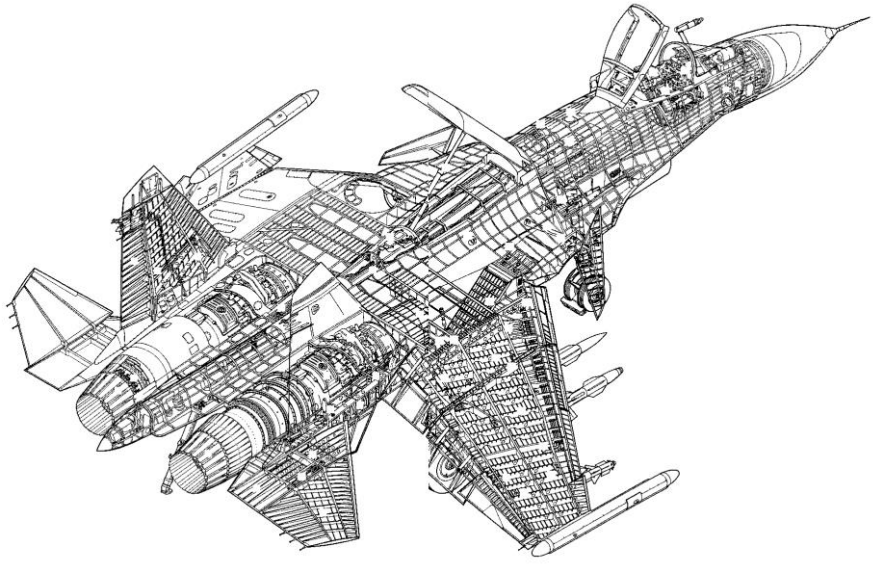

Figure 2: Su-33 coupe

L'aile trapézoïdale centrale à faible allongement, équipée de rallonges de bord d'attaque, se joint harmonieusement au fuselage, formant un seul corps porteur.
Deux moteurs à turboréacteurs AL-31F de 3e série à deux circuits avec post-combustion sont placés dans des nacelles séparées placées sous le châssis de l'avion séparément l'une de l'autre, ce qui élimine leur interférence aérodynamique et permet de placer les armes de l'avion, ainsi que le système de ravitaillement des coéquipiers, dans l'espace entre les deux.
Les prises d'air supersoniques variables sont situées sous l'aile centrale et sont équipées d'un dispositif de protection qui empêche les corps étrangers d'entrer dans les moteurs pendant les phases de décollage et d'atterrissage de l'avion.

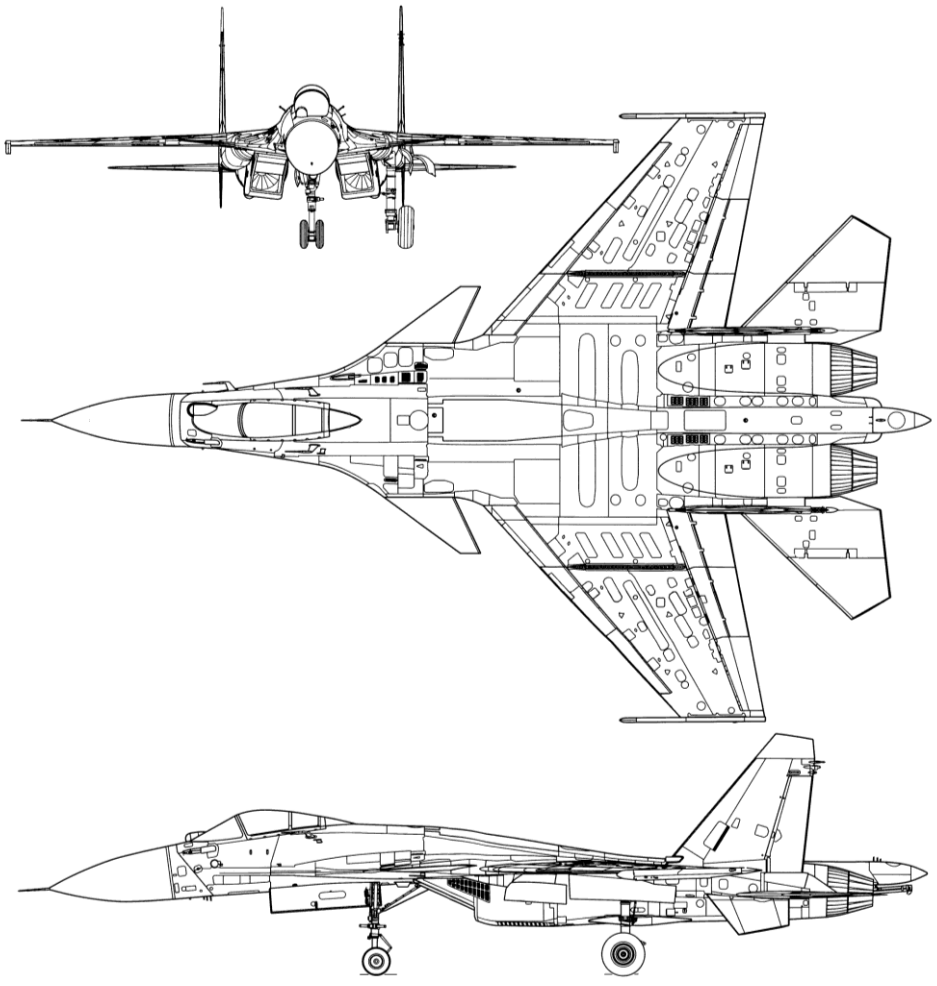

Figure 3: Su-33 croquis

Les carénages du châssis se fondent en douceur dans les poutres de queue, servant de plates-formes pour l'installation des panneaux stabilisateurs tout en mouvement avec un axe de rotation droit, des ailettes de queue de deux kilos espacées des bords extérieurs de l'élevon et des quilles. Les panneaux des canards avant, installés sur l'extension de l'apex (bord d'attaque de l'aile), servent à accroître les propriétés de portance et à améliorer les caractéristiques de vol de l'avion aux grands angles d'attaque. Pour réduire la taille de l'avion lors du stockage dans le hangar et du stationnement aux positions techniques du pont supérieur, les hayons et les empennages horizontaux peuvent être repliés. L'avion est équipé d'un train d'atterrissation trois points escamotable avec jambes de force télescopiques sur les supports principal et avant, d'une roue freinée sur chaque support principal ainsi que d'un support avant réglable aux deux roues.

Pour assurer l'atterrissage sur le système d'arrêt du navire, l'avion est équipé d'un crochet d'arrêt.

L'avion est conçu selon le concept de "stabilité relaxée" et n'est pas équipé d'un système de commande mécanique classique, mais d'un système de commandes de vol électrique, également connu sous le nom de "Fly-by-Wire". Les surfaces de contrôle de base de l'avion sont: des élevons monobloc, des canards avant, des gouvernails et des flaperons. La mécanisation adaptative de l'aile est composée de volets à une seule fente, de volets et de bords d'attaque déflectables en deux sections et de trois sections, dont la déflexion automatique augmente les propriétés de portance de l'aile dans tous les modes de vol.

Figure 4: Su-33 in the Severomorsk airbase

Les déflecteurs agissent comme les volets et les ailerons de l'avion. En mode vol, la déviation différentielle des flaperons, déterminée par les mouvements de la manette de commande, assure la maîtrise du chasseur le long de l'axe de roulis (avec la déviation différentielle des moitiés stabilisatrices), la déviation en phase avec les signaux des commandes de vol électrique automatique.
Selon l'angle d'attaque, les flaperons augmentent les propriétés de portance de l'aile. Dans les modes de décollage et d'atterrissage, les volets sont déviés de façon synchrone à un angle fixe.

Pour un freinage efficace de l'avion pendant les manœuvres de combat et d'atterrissage, un grand panneau de freins à air est installé sur la surface supérieure du fuselage derrière le poste de pilotage.

Le fuselage de l'avion est intégré dans les ailes et est divisé technologiquement en deux parties principales :

- La partie tête/frontale du fuselage;
- La partie centrale du fuselage;
- La partie arrière du fuselage;
- Les prises d'air.

La partie frontale du fuselage est de conception semi-monocoque entièrement métallique, commençant par l'axe symétrique radiotransparent de l'antenne du radar embarqué, comprend le compartiment avant qui abrite le système radar ainsi que le système de recherche et de poursuite infrarouge et la perche de ravitaillement en vol. Dans cette section du fuselage se trouvent également le cockpit, les systèmes électriques sous et derrière le cockpit, ainsi que le logement de la jambe de suspension frontale du train d'atterrissage. Le tube de Pitot est installé dans la partie avant du boîtier radar, incliné vers le bas à partir de la construction du fuselage par un angle de 7,5° Pour l'accès d'entretien à l'antenne et au radar, le cadre de fixation (#1) situé entre le compartiment avant et le boîtier transparent du radar est incliné et le boîtier radiotransparent avec le pourtour métallique est incliné vers le haut. Le cadre monobloc du système radar, associé à l'antenne avec le cône surélevé transparent au radar, peut être étendu pour permettre l'accès aux unités radar et IRST. Pour réduire la taille de l'aéronef pendant le stockage dans les hangars du porte-avions, le tube de Pitot peut être replié.

Figure 5: Cockpit et Verrière

Le poste de pilotage du pilote est hermétiquement fermé et comporte un auvent en deux parties composé de la partie frontale fixe (le pare-brise) et d'une partie arrière déployable séparée qui peut être larguée en cas d'urgence (soit pendant l'éjection, soit manuellement par le pilote). L'auvent protège le pilote des conditions de vol difficiles et, grâce à la grande surface vitrée du poste de pilotage et à la présence de rétroviseurs, offre une vue presque circulaire. Le cockpit offre un angle de vision vers l'avant de 14° vers le bas.

La partie avant de l'auvent, vitrée en plexiglas, peut supporter des impacts d'oiseaux d'un poids de 1,8 kg à des vitesses de 450 km/h sans endommager le pare-brise. Pour éviter le givrage du pare-brise, un système de dégivrage à base d'alcool est utilisé.

Le siège du pilote est équipé d'un siège K-36DM avec éjection en 2 secondes installé avec un angle du dossier de 17° vers l'arrière du cockpit. La station IRST est installée juste à l'avant et un peu à droite du pare-brise du cockpit. Les tubes de Pitot sont également situés le long des côtés du fuselage, à l'arrière du poste de pilotage.

Figure 6: Su-33 tribord

La verrière du cockpit est composée d'une partie avant fixe avec un cadre central et deux parties arrière (gauche et droite). Ce dernier peut être enlevé pendant les opérations d'entretien et de décollage des sièges éjectables, aux besoins de l'éjection d'urgence, ou en vol sans avoir à engager le processus d'éjection.

Deux blocs d'équipements radioélectroniques sont logés dans les compartiments situés sous le cockpit (un central et deux latéraux). La partie frontale du fuselage est complétée par un compartiment étroit, dans lequel se trouve la majeure partie de l'équipement radioélectronique, ainsi que le compartiment des munitions pour le canon intégré. Le carter du train d'atterrissage avant est également situé dans le compartiment arrière du poste de pilotage de la section avant du fuselage.

Les parois du compartiment du poste de pilotage arrière sont reliées aux rallonges bâbord et tribord de la racine du bord d'attaque. Le côté tribord abrite le canon GSh-301 de 30 mm à tir rapide intégré avec un système de chargement des munitions, d'éjection des cartouches usagées et de ramassage des agrafes; une boîte à cartouches contenant les munitions du canon est installée dans le compartiment exigu et occupe une partie du LERX et le compartiment arrière du poste de pilotage. Le côté tribord contient également des fentes et des branchies spéciales pour le refroidissement du pistolet et pour protéger le châssis contre les gaz incandescents produits lors du tir du canon dans la zone de la fente du canon. Un panneau en acier résistant à la chaleur est installé juste devant le canon du pistolet. Le LERX bâbord abrite les systèmes aéronautiques et les équipements électroniques. Les panneaux canard avant (avec un angle de rotation droit) sont installés sur les bords avant du LERX.

La section frontale du fuselage dans le design est un semi-monocoque entièrement métallique avec une surface intégrée.

La partie centrale du fuselage est divisée dans les compartiments technologiques suivants:

- Le réservoir de carburant frontal (compartiment n° 1), situé le long de l'axe de symétrie de l'avion entre la tête du fuselage et l'aile centrale;
- l'aile centrale (la surface portante principale de l'aéronef), formée sous la forme d'un réservoir de carburant (compartiment no 2) à parois transversales et d'une rangée de nervures. Les surfaces supérieure et inférieure de l'aile centrale sont réalisées sous forme de panneaux (le panneau supérieur est fraisé et fabriqué à partir d'alliages d'aluminium; le fond est soudé et fait de feuilles d'alliage de titane);
- Le carénage central du fuselage, qui est un compartiment conçu pour accueillir les communications et l'installation des équipements;
- le compartiment frontal de l'aile centrale (droite et gauche) est situé sur les côtés extérieurs du réservoir de carburant frontal / compartiment no 1 et se compose des bords d'attaque de l'aile centrale et du logement du train d'atterrissage principal.

Figure 7: Su-33 au décollage

Sur la surface supérieure du fuselage central, un panneau de frein à air comprimé sans membrane (d'une surface de 2,6 m2) est déployé au moyen de l'entraînement hydraulique. L'angle de déviation du blindage est de 60° vers le haut. Le desserrage du panneau de frein est utilisé pour réduire les vitesses pendant l'approche à l'atterrissage et les manœuvres de combat à des vitesses de vol aux instruments pouvant atteindre 1 000 km/h.

La partie arrière du fuselage est divisée dans les compartiments technologiques suivants:

- Deux groupes motopropulseurs dont chacun est divisé en deux parties;

- poutres de queue adjacentes aux côtés extérieurs des nacelles moteur: ces poutres sont le prolongement du compartiment du logement du train d'atterrissage principal et servent de plate-forme pour l'installation des ailerons arrière de l'avion;
- La poutre centrale du fuselage, qui comprend le compartiment central de l'équipement, le réservoir de carburant arrière (compartiment n° 4), l'extrémité de l'aileron central et les ailettes latérales.

Figure 8: Su-33 Moteurs

Les entrées d'air moteur du Su-33 sont situées dans les parties centrales des nacelles moteur situées sous l'aile centrale; sur le châssis principal de chaque section centrale se trouve un verrou qui s'enclenche lorsque les bras principaux du train d'atterrissage sont déployés; sur la surface inférieure se trouvent les points durs de la suspension de l'arme; dans les coins extérieurs supérieurs se trouvent les agrégats et les lignes de communication des systèmes aéronautiques. Les compartiments moteur sont équipés d'AL-31F ser. 3 moteurs avec une disposition supérieure de la boîte de vitesses d'accessoires à distance. Un démarreur turbo, un alternateur, une pompe hydraulique et une pompe à carburant.

Le moteur installé est retiré de l'avion par un chariot spécial; le cône de queue est détachable afin de faciliter le remplacement du moteur. Lorsque les moteurs sont démontés, les accessoires distants de la boîte de vitesses restent sur l'avion. Ceci réduit le temps de remplacement du moteur. Des trappes de commande permettant d'accéder à la boîte de vitesses et aux groupes moteurs principaux se trouvent dans la partie supérieure des sections motorisées. Les nacelles moteur ont un plan semi-monocoque à peau portante, renforcé d'un ensemble transversal (au moyen de cadres) et d'un ensemble longitudinal (au moyen de longerons).

La partie arrière des poutres de queue (sur les deux côtés) est portante; sur sa surface supérieure, il y a des nœuds pour supporter les ailerons verticaux et horizontaux, ainsi que les servos stabilisateurs. Les compartiments pour les équipements aéronautiques sont situés dans les poutres arrière, juste devant leurs sections porteuses.

L'équipement des systèmes aéronautiques et les systèmes de propulsion sont logés dans le compartiment central de l'empennage central. Sur la surface inférieure de l'aiguillon central se

trouvent les points durs des armes et le point de fixation du crochet d'arrêt qui est relâché à l'atterrissage sur le système d'arrêt du porte-avions. Pour minimiser la taille de l'avion pendant le stockage dans les hangars du porte-avions, l'extrémité de l'aileron est pliée vers le haut.

Entrées d'Air Moteur

Les entrées d'air moteur sont des prises d'air variables de section rectangulaire, placées sous l'aile LERX et équipées de dispositifs de protection pour empêcher les débris de corps étrangers d'entrer dans les moteurs pendant les modes de décollage et d'atterrissage. Les surfaces de freinage d'admission d'air sont placées horizontalement : le coin de freinage s'éloigne de la surface du châssis porteur et un espace est formé entre l'aile et le coin pour drainer la couche limite.

Figure 9: Prises d'Air

Les portes de décharge d'aspiration sont situées sur la surface inférieure des prises d'air dans la zone où se trouve le dispositif de protection. Les vannes sont "flottantes", c'est-à-dire qu'elles s'ouvrent et se ferment en réponse à des chutes de pression.

Pour contourner les couches limites d'air, une perforation spéciale est prévue sur les parois latérales extérieures et intérieures de chaque entrée d'air, qui est fermée de l'extérieur par des panneaux avec des fentes profilées. La diffusion supersonique optimale dans le diffuseur de l'entrée d'air est assurée par l'installation de ces éléments réglables dans des positions calculées par le système de contrôle automatique de l'entrée d'air. La position des panneaux d'admission d'air réglables, ainsi que celle des dispositifs de sécurité, est indiquée dans la cabine du pilote sur des panneaux et plaques-étiquettes spéciaux.

Le dispositif de protection de chaque entrée d'air est un panneau en titane perforé avec un grand nombre de trous de 2,5 x 2,5 mm. Le déclenchement des dispositifs de sécurité d'admission d'air pour l'atterrissage et leur retrait au décollage se fait automatiquement, en fonction du signal de compression de la jambe de train d'atterrissage. En position débloquée, les panneaux du dispositif de protection recouvrent toute la section transversale de l'admission d'air et empêchent ainsi l'entrée de corps étrangers dans le moteur depuis la surface de la piste (ou, dans le cas du Su-33, dans le poste de pilotage du porte-avions) pendant les phases d'atterrissage, de décollage et de roulage. En vol, les panneaux des dispositifs de protection en position rentrée sont pressés contre la surface inférieure du conduit d'admission d'air. L'axe de rotation est situé derrière la gorge d'entrée dans la partie diffuseur du canal.

Les ailes de l'avion sont libres. Les parties détachables (panneaux) des ailes ont un angle de balayage le long du bord d'attaque de 42.5° et sont constituées d'un support structural de type P44M avec une épaisseur relative de 4.9% (dans la racine) et 4.0% (à la fin). Le rapport d'aspect de l'aile est de 3,48, tandis que l'étranglement est de 3,76. La surface de base de l'aile est de 67,84 m2, alors que l'envergure de l'aile est de 14,7 m (avec la suspension des missiles sur les points durs du bout de l'aile - 14,948 m).

La mécanisation de l'aile est constituée des flaperons (ailerons suspendus) avec une surface de 2,4 m2 servant de volets et d'ailerons, ainsi que de deux volets monoblocs de 6,6 m2 et d'un bord d'attaque en trois sections de 5,4 m2.

Les flaperons ont des angles de déflexion en vol de +15 à -20°. Dans la configuration décollage: + 15... - 25° (avec un angle d'accrochage de -14°). L'angle de dégagement des volets au décollage est de 15/25°, où l'angle du bord d'attaque est de 0 à 30° Le relâchement des flaperons (en mode volets) et la déflexion du bord d'attaque en vol sont effectués pour augmenter les propriétés de portance de l'aile lors de manœuvres à des vitesses aux instruments allant jusqu' à 860 km/h.

Pour réduire les dimensions de l'aéronef stationné sur le pont ou entreposé dans le hangar du porte-avions, les ailes sont repliées. La largeur hors tout de l'avion avec les bouts d'aile repliés est réduite à 7,4 m, contre 14,7 m avec les bouts d'aile déployés. Le repliage des bouts d'aile se fait au moyen du système hydraulique. Les vérins de commande hydraulique responsables du repliage des extrémités d'aile se trouvent dans les parties fixes des panneaux.

Structurellement, chaque panneau d'aile est constitué de cellules de puissance des parties fixes et rotatives (pliage), des sections d'étrave et de queue, de la mécanisation et des extrémités. Les cellules de la partie fixe de l'aile et les cellules de la partie tournante de l'aile sont scellées hermétiquement et forment des compartiments de réservoir de carburant.

Un point dur supplémentaire est installé sur chaque extrémité d'aile pour monter soit un missile air-air à courte portée, soit une capsule de brouillage actif par point dur. Le poids de chaque gousse de bourrage est de 205 kg, avec une longueur de 4200 mm et un diamètre de 300 mm.

Ailes

Les ailes de l'avion sont composées de deux panneaux d'un stabilisateur à déflexion différentielle entièrement mobile avec un axe de rotation droit et un dispositif de roulement dans les panneaux des ailes. Les poutres contreventées du stabilisateur sont fixées en place dans les poutres arrière du fuselage.

Figure 10: Su-33 avec ailes pliées

Les ailerons horizontaux ont une forme trapézoïdale (avec un angle de balayage le long du bord d'attaque de 45°). L'envergure des ailes du stabilisateur est de 9,9 m, avec une surface de 12,3 m2. L'angle de la dièdre des ailes est de 0°. Les angles de déflexion du stabilisateur sont de +15 à -20°. Pour le contrôle de roulis, une déviation différentielle de ± 10° est possible. La déflexion des stabilisateurs est entraînée par l'entraînement hydraulique.

Pour réduire les dimensions de l'avion lorsqu'il est entreposé dans les hangars de navire, les ailes sont pliables à la moitié de leur portée.

Canard Horizontal

Figure 11: Canards

Le canard de l'avion est installé à l'extrémité des rallonges radiculaires du bord d'attaque de l'aile et se compose de deux panneaux entièrement mobiles d'une portée de 6,43 m et d'une surface de 2,99 m2. L'angle de balayage le long du bord d'attaque des panneaux est de 53,5°. L'angle du dièdre des panneaux est de 4.7° Les angles de déflexion des canards sont de +3,5 à -51,5° Les entraînements hydrauliques des canards sont placés dans le LERX de l'aile.

Ailerons Verticaux

Les ailerons verticaux sont composés de deux ailerons en forme de flèche avec un angle de balayage de 40° le long du bord d'attaque et une surface de 15,1 m2. Les ailettes sont installées avec un angle de carrossage de 0°. Chaque ailette est équipée d'un safran (la surface des deux safrans est de 3,49 m2, avec des angles de déflexion de ± 25° dans chaque direction). Dans la partie supérieure des ailettes, équipées d'embouts en fibre de verre, et le long de leur bord d'attaque sous les carénages radiotransparents, se trouvent des antennes de divers dispositifs de radiotechnique.

Le mouvement des gouvernes de direction est entraîné par des blocs de vérins hydrauliques installés à l'intérieur des ailettes. Chaque gouvernail est commandé par un cylindre-bloc.

Afin d'améliorer les caractéristiques anti-"STALL" de l'avion et accroître sa stabilité directionnelle, deux crêtes de sous-faisceaux d'une superficie de 2,47 m2 avec un angle de balayage de 38° le long du bord d'attaque sont installées sous les poutres de queue.

L'avion est équipé d'un train d'atterrissage à trois voies escamotable et d'une jambe de suspension frontale contrôlable. Les vérins principaux équipés de crémaillères télescopiques disposent chacun d'une roue de frein de dimensions 1030 x 350 mm.

Le vérin frontal est télescopique et comporte deux roues non freinantes de dimensions 620 x 180 mm. La commande est entraînée par le mécanisme hydraulique de direction-amortisseur qui y est installé, ce qui permet à l'avion d'effectuer des manœuvres avec un rayon de braquage très faible pendant le roulage. L'angle de braquage en contrôle manuel est de ± 45°, alors qu'en mode aérodynamique (auto-orientation) il est de ± 70°.

Figure 12: Su-33 replié

Tous les supports du châssis sont rétractés vers l'avant pendant le vol: les montants principaux se replient dans les niches de l'aile centrale, tandis que le montant frontal pénètre dans le compartiment situé sous la partie frontale du fuselage, sous le cockpit. Des serrures hydromécaniques maintiennent le train d'atterrissage en place en vol.

Le système de déploiement/rétraction du train d'atterrissage est actionné hydrauliquement. En cas de panne, un système pneumatique d'urgence est utilisé pour déployer le train d'atterrissage à l'aide d'azote comprimé. Le freinage des roues pendant le roulage au sol et pendant le roulement à l'atterrissage, ainsi que le freinage automatique des roues pendant la rentrée, sont tous actionnés par le circuit hydraulique.

Le système d'amortissement du train d'atterrissage est pneumatique et hydraulique. Deux feux d'atterrissages et un feu de circulation sont fixés à l'avant, ainsi qu'un dispositif de signalisation tricolore servant à l'atterrissage sur le navire.

L'équipement de décollage et d'atterrissage comprend également un crochet d'arrêt servant à immobiliser l'avion au toucher des roues sur le pont et à maintenir le contact avec le système d'arrêt. Le déploiement et la rétraction du crochet est actionné par le système hydraulique au moyen d'un amortisseur-grue installé entre le cadre du crochet et le fuselage. En position rétractée, le crochet est maintenu par un verrou hydromécanique. Pour un accrochage stable avec les câbles du système d'arrêt et la prévention du "rebondissement" lorsqu'il heurte le pont lors de l'atterrissage, un dispositif d'amortissement est utilisé. En cas de défaillance du système de déploiement hydraulique, le crochet peut être relâché pendant l'atterrissage au moyen du système pneumatique auxiliaire.
L'état de déploiement du train d'atterrissage et du crochet d'arrêt est indiqué par l'indicateur d'état situé dans le cockpit.

Moteurs et Equipements de l'Avion

Les moteurs constitués de deux AL-31F ser. 3. sont des turboréacteurs à deux circuits avec postcombustion, prises d'air avec panneaux réglables, portes de décharge d'aspiration, conduits d'aération et système de commande; système de refroidissement du moteur; boîtes de vitesses auxiliaires à distance contenant les démarreurs de la turbine à gaz; système d'alimentation en carburant; protection du moteur contre les débris étrangers; extincteur automatique; système de dégivrage et système de surveillance du moteur.

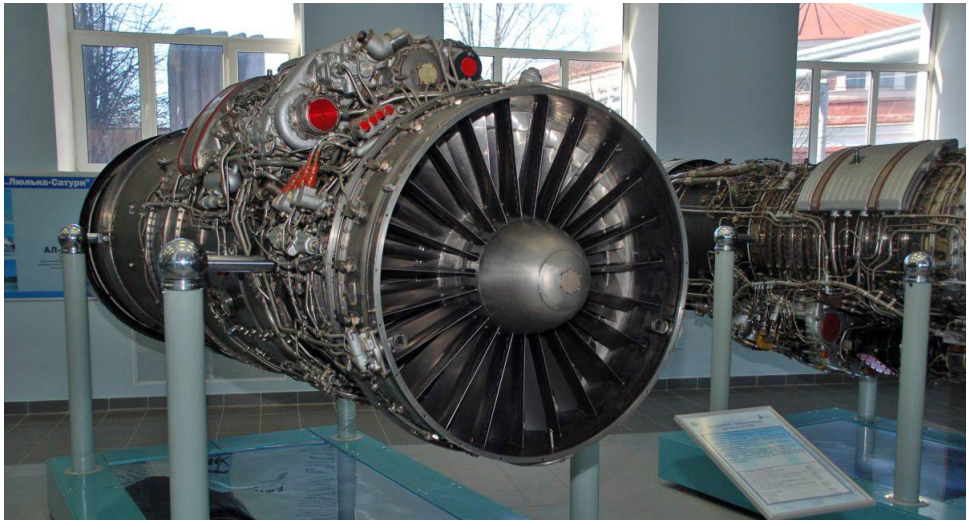

Figure 13: Moteur AL-31F

L'équipement de l'avion comprend :

- Un système Hydraulique;
- Un système Pneumatique;
- Un système d'alimentation électrique;

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

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

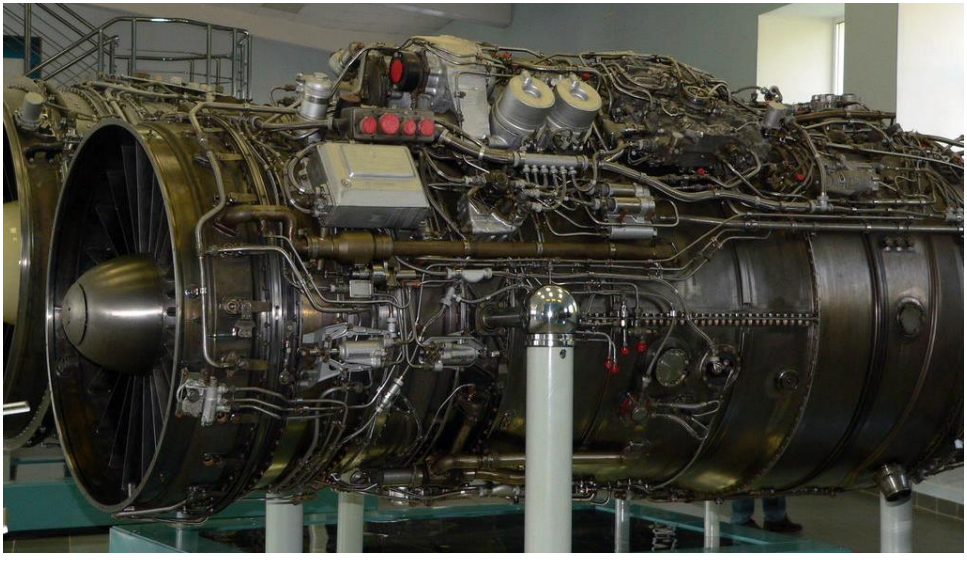

Figure 14: AL-31F Engine

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

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

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

Figure 15: AL-31F Nozzle

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

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

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

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

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

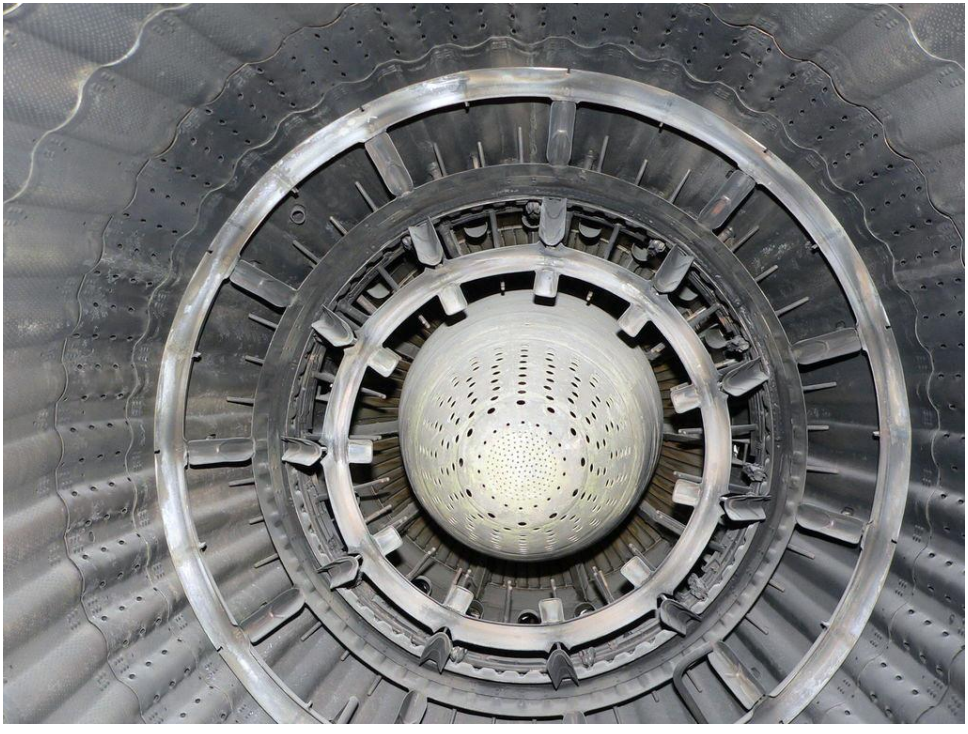

Figure 16: AL-31F Afterburner Duct

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

The start of the two engines can be carried out either sequentially or simultaneously. The spin-up of the engine rotors, when started up on the ground, is provided by gas turbine starters, which in turn are started by electric starters, the voltage to which is supplied either from ground-based power sources or from storage batteries. Airborne engine-startup occurs when their rotors rotate under the influence of the oncoming air flow in the autorotation mode, and reliable start-up is possible practically throughout the entire range of the aircraft's flight speeds. It may occur automatically (if

the engine switches off spontaneously), semi-automatically (after pulling the throttle to "Stop" and then back to "Idle" during rundown or windmilling) or forced (with the help of the duplicate start switches in the cockpit). There is also a system for engine relighting in the event of a drop in their speed below a certain level during the usage of aircraft weapons (i.e. during missile launch.) The engines are started in the air with an oxygen boost.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

surfaces (control stick and rudder pedals) equipped with loading and trimming mechanisms, as well as the mechanical wiring of the wings and canards in the wing control channels.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The electronic equipment liquid cooling system of the aircraft is designed to cool the most heat-stressed elements in electronic units. The necessary temperature profile for the operation of these electronic units is maintained by the system pumping the cooling liquid. The liquid, which is hot while

it passes through the cooling blocks, is cooled by fuel in the fuel-liquid heat exchanger. Circulation of the liquid is carried out by means of the pump.

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

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

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

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

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

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

Aviation Electronic

On-board radio electronic equipment of the aircraft includes:

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

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

Figure 17: N-001 Radar

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

management system, an IFF interrogator, a single indication system and a live monitoring and recording system.

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

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

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

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

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

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

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

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

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

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

Figure 18: OLS-27

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

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

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

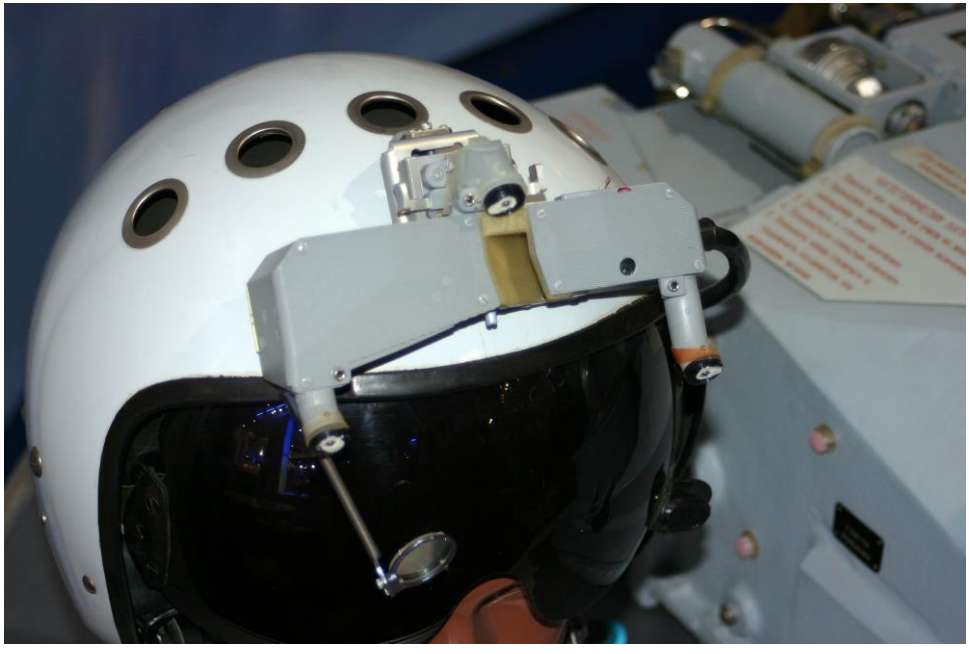

Figure 19: "Shchel-3UM-1" Helmet-mounted Target acquisition System

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

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

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

Figure 20: ILS-31 HUD

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

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

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

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

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

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

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

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

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

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

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

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

The aircraft's navigation instrumentation facilitates the following:

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

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

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

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

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

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

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

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

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

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

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

Armament

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

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

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

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

Aircraft Gun Armament

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

Figure 21: GSh-301 Gun

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

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

Air-To-Air Missiles

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

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

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

The R-73 missile is equipped with a heat-seeking homing head and is designed for close air combat to intercept and destroy high-manoeuvrability manned and unmanned means of air attack by the enemy in day and night conditions, from any aspect, into the front and back hemispheres of the

target, against the background of terrain and with active electronic countermeasures employed by the enemy. The missile is constructed according to the "duck" scheme with destabilizers in the head part of the hull and aerodynamic control. A distinctive feature of the construction is the presence of an aerodynamic device that allows for control over the thrust vector of the propulsion system. This gives the missile a high degree of maneouverability, ensuring its ability to reach and destroy targets maneuvering with G-forces of up to 12 units.

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

Unguided Bombs

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

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

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

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

Unguided Rockets

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

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

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

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

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

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

GAME AVIONICS MODE

GAME AVIONICS MODE

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

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

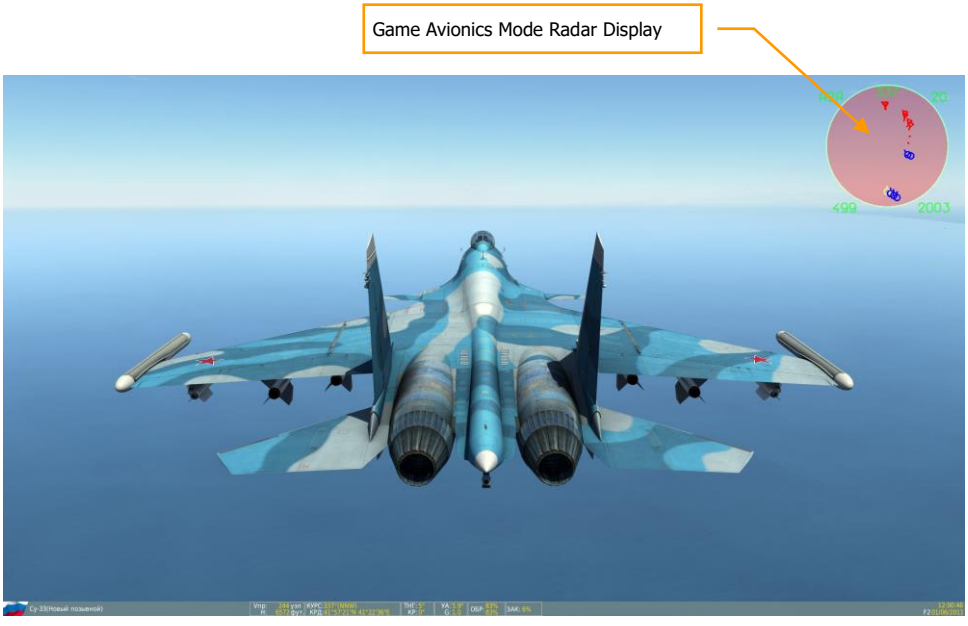

Figure 25: Game Avionics Mode Radar Display

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

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

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

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

Mode keys:

  - Navigation: **[1]**

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

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

Radar range keys:

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

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

Navigation Mode

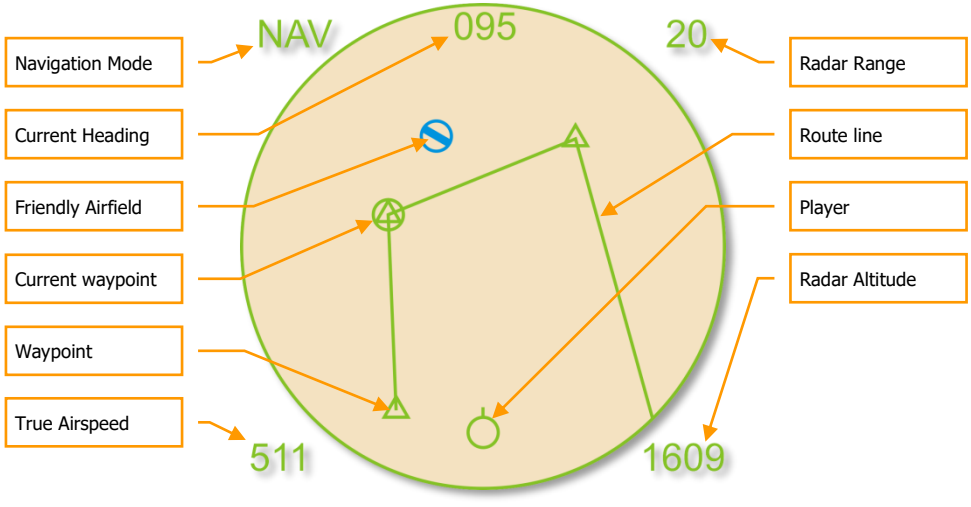

Figure 26: Navigation Mode

Unique symbols of the Navigation mode include:

- **(Player symbol)**. Your aircraft is indicated as a green circle at the bottom of the display.

- **(Friendly Airfield symbol)**. This blue symbol indicates friendly airfields.
- **(Current waypoint symbol)**. This green circle indicates your current waypoint. You can cycle your waypoint with the **[LCtrl - ~]** (tilde) key.
- **(Waypoint symbol)**. This green triangle indicates other waypoints in your flight plan.
- **(Route line)**. Green route lines connect the waypoints in your flight plan.

Air to Air Mode

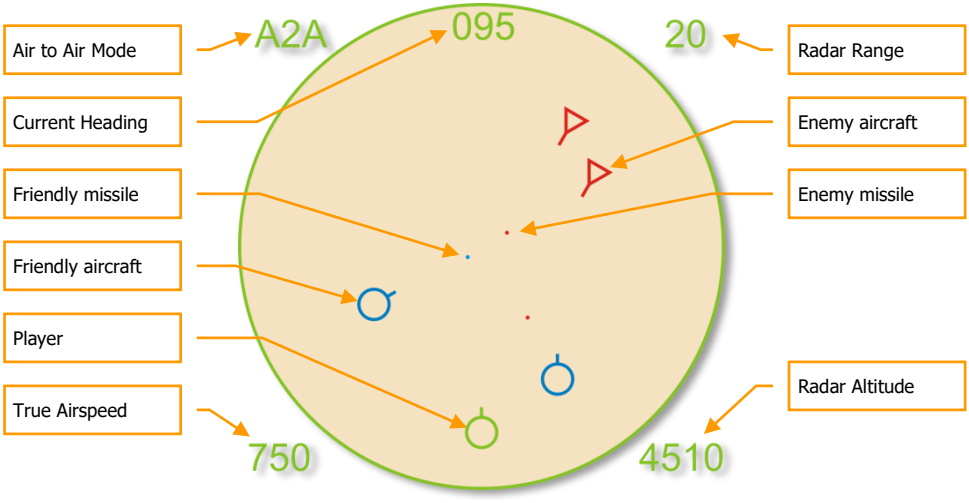

Figure 27: Air to Air Mode

Unique symbols of the Air to Air mode include:

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

Useful key commands when in Air to Air mode include:

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

COCKPIT INSTRUMENTS

COCKPIT INSTRUMENTS

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

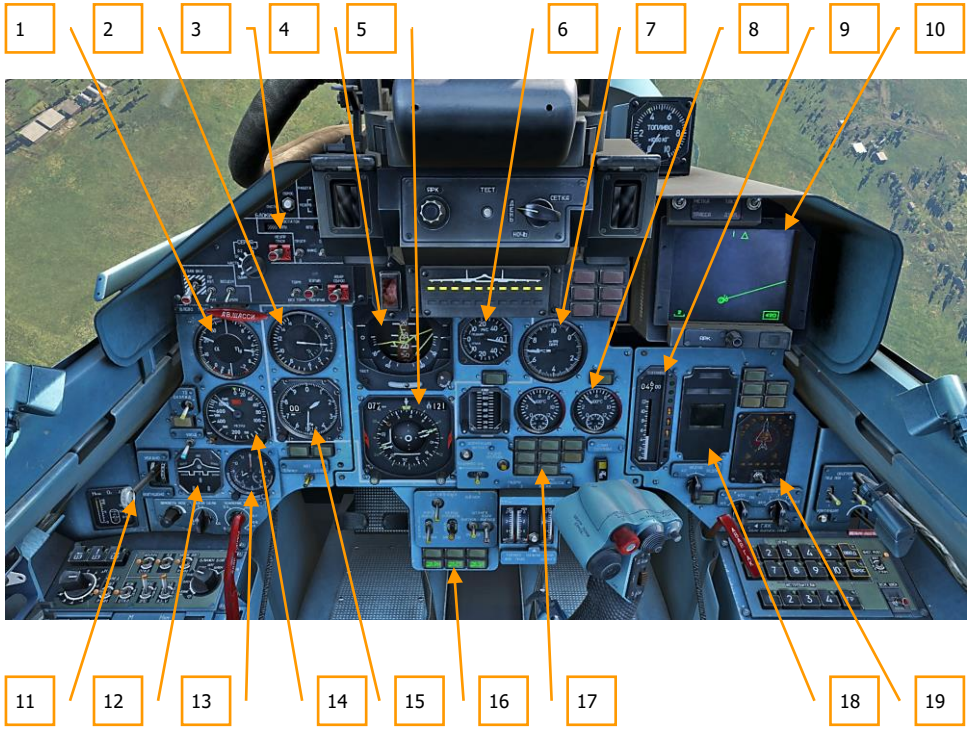

Figure 28: Su-33 instrument panel

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

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

Airspeed and Mach Indicator

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

Figure 29: Airspeed and Mach indicator

Pressure Altimeter

The barometric air pressure altimeter indicates the aircraft's altitude above sea level. The 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 30: Pressure altimeter

Radar Altimeter

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

Figure 31: Radar altimeter

Mechanical Devices Indicator

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

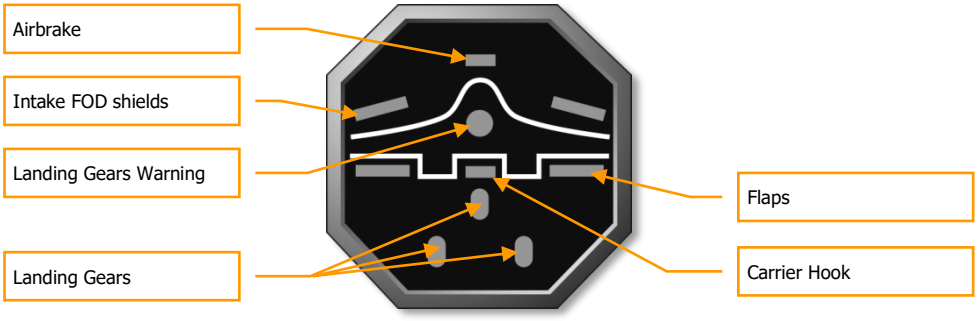

Figure 32: Mechanical Devices Indicator

AoA Indicator and Accelerometer

The Angle of Attack (AoA) indicator and accelerometer displays the current angle of attack and G-load. The left portion of the indicator shows the AoA in degrees and the right portion shows G-loading. An index mark shows the maximum G recorded during a flight.

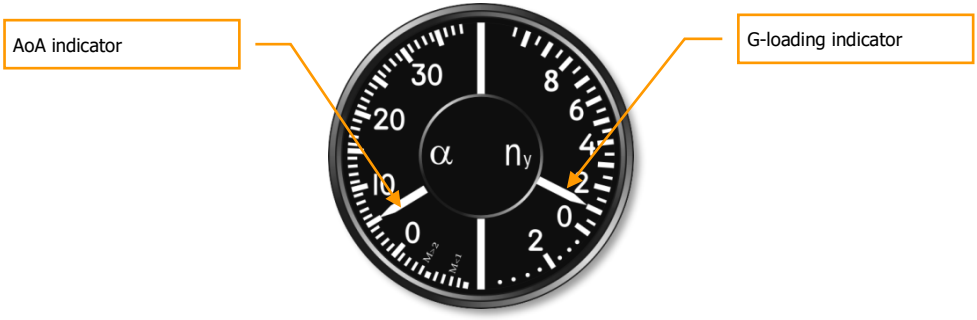

Figure 33: AoA indicator and Accelerometer

Attitude Direction Indicator

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

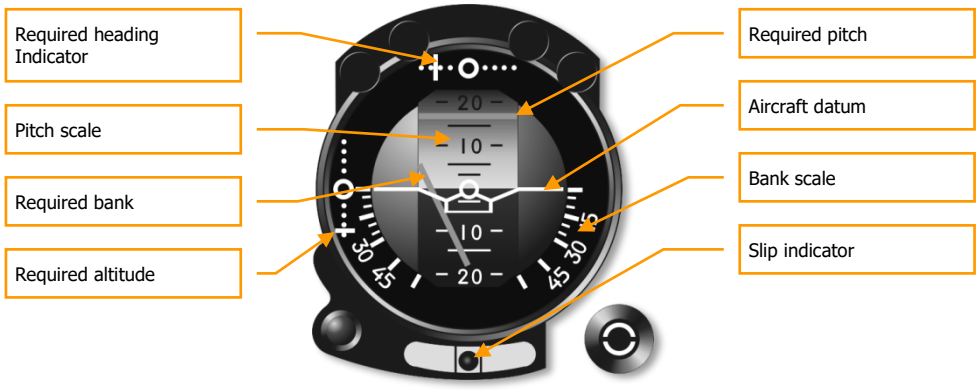

Figure 34: ADI

Horizontal Situation Indicator

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

Figure 35: HSI

Vertical Velocity Indicator

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

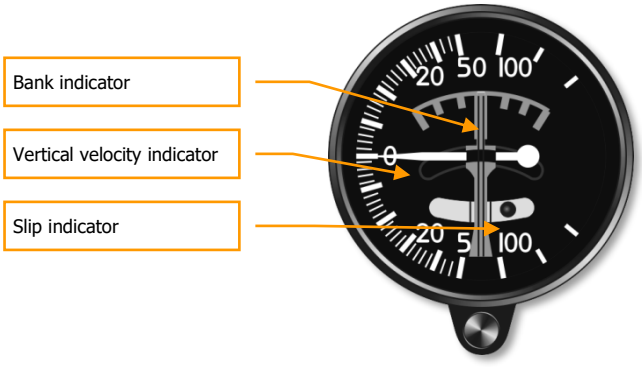

Figure 36: Vertical velocity indicator

Aircraft Clock

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

Figure 37: Aircraft clock

Tachometer

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

Figure 38: Tachometer

Fuel Quantity Indicator

Fuel quantity (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-33 cannot be loaded with external fuel tanks.

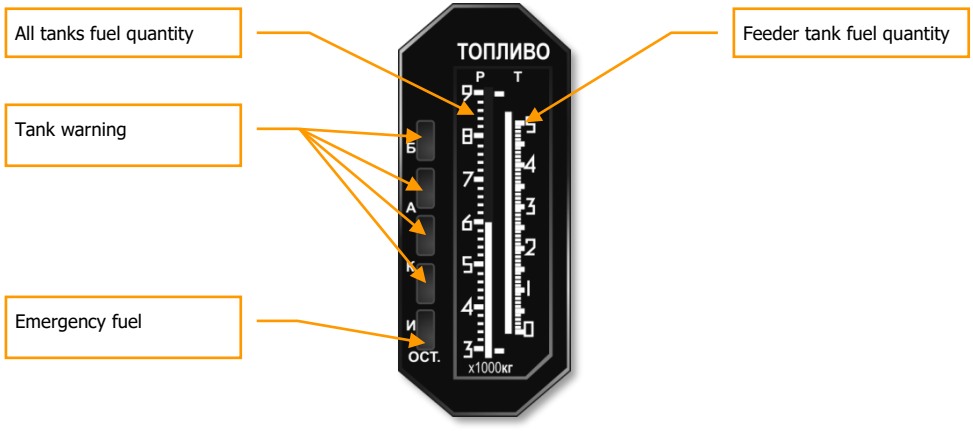

Figure 39: Fuel quantity indicator

Interstage Turbine Temperature Indicators

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

Figure 40: Interstage turbine temperature indicators

Head Down Display (HDD)

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

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

Figure 41: HDD

Radar Warning System

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

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

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

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

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

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

RWS DOES NOT DEFINE THE DISTANCE TO THE EMITTER

SPO-15 Radar Warning System

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

The SPO-15 model implemented in game is close to the actual system installed in the Su-27/33.

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

The maximum number of threats on screen: Unlimited.

The threat history display duration time: 8 seconds.

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

Threats types:

П – airborne radar

З - long-range radar

Х - medium-range radar

Н - short-range radar

Ф - early warning radar

С - AWACS

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

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

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

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

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

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

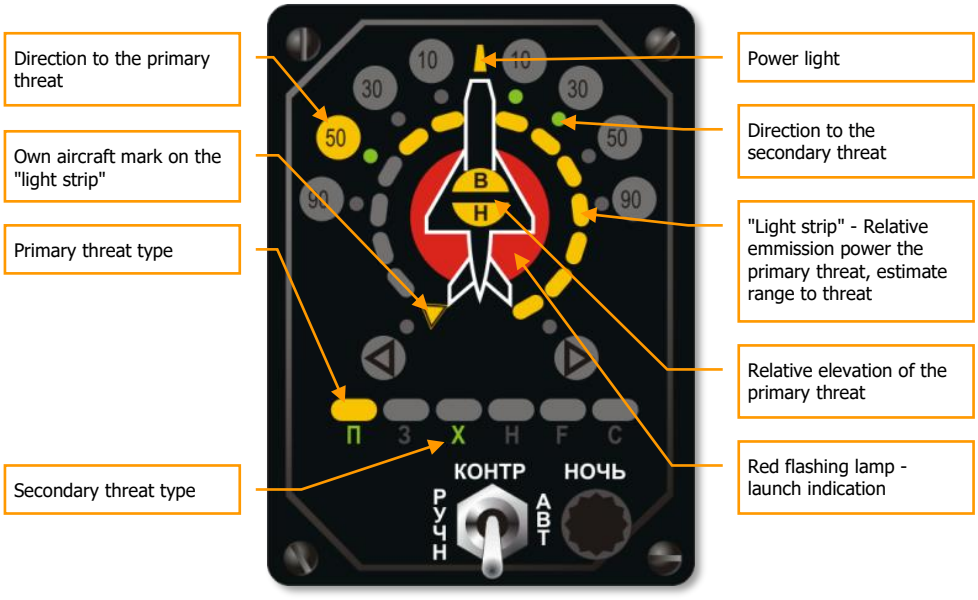

Figure 42: "Beryoza" SPO-15LM indicator

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

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

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

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

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

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

PPD-SP Panel

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

Figure 43: PPD-SP panel

Direct Control Switch

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

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

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

Figure 44: Direct control switch

Trim Mechanism

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

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

Trim ranges are as follows:

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

The neutral position of the trim mechanism is controlled by three annunciators: "ТРИММ. СТ. НЕЙТР." (neutral stabilizer trim), "ТРИММ. ЭЛ. НЕЙТР." (neutral aileron trim), and"ТРИММ. Р.Н. НЕЙТР." (neutral rudder trim) in the lower part of the main cockpit panel.

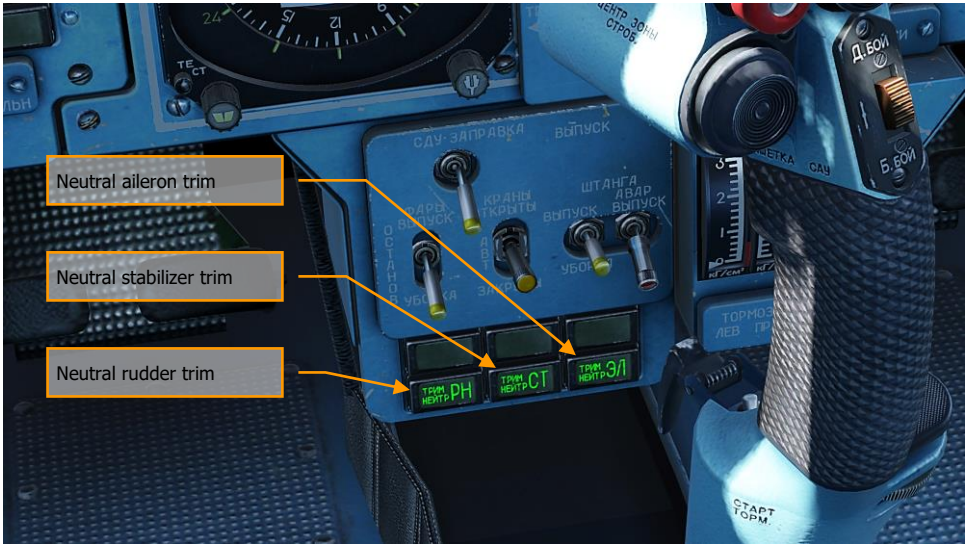

Figure 45: Trim annunciators

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

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

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

Automatic Control System (ACS)

ACS provides:

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

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

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

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

Figure 46: Manual Control annunciator

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

Figure 47: ACS push-lights and switches

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

To control the ACS, the following commands are used:

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

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

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

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

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

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

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

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

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

[LAlt -6] – Ground collision avoidance mode.

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

Figure 49: Ground collision avoidance mode annunciator and switch

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

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

[LAlt -A] – Autopilote override button.

Combined Aircraft Control

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

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

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

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

Su-33 HUD and HDD Operational Modes

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

Basic HUD symbols

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

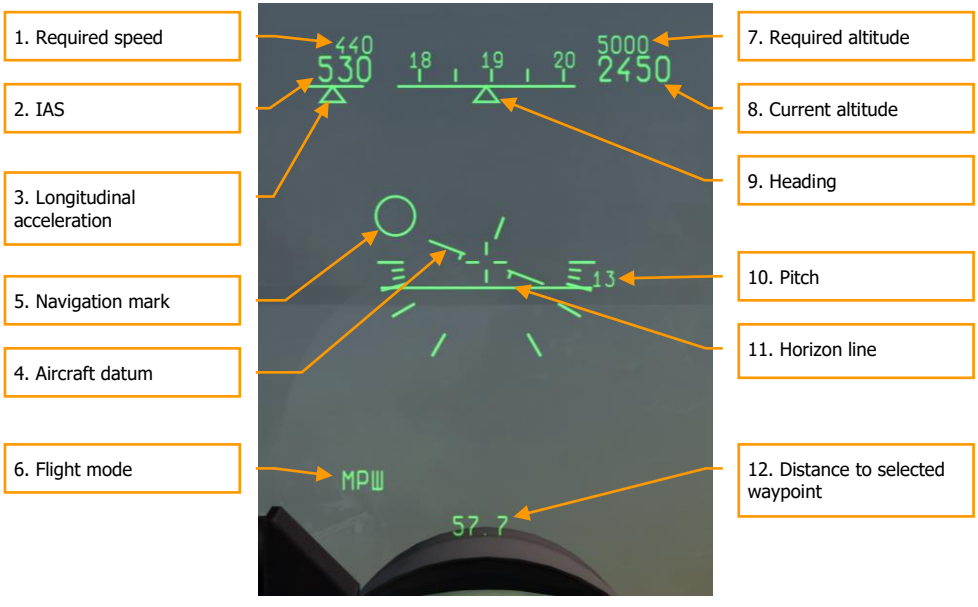

Figure 50: HUD basic symbols

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.

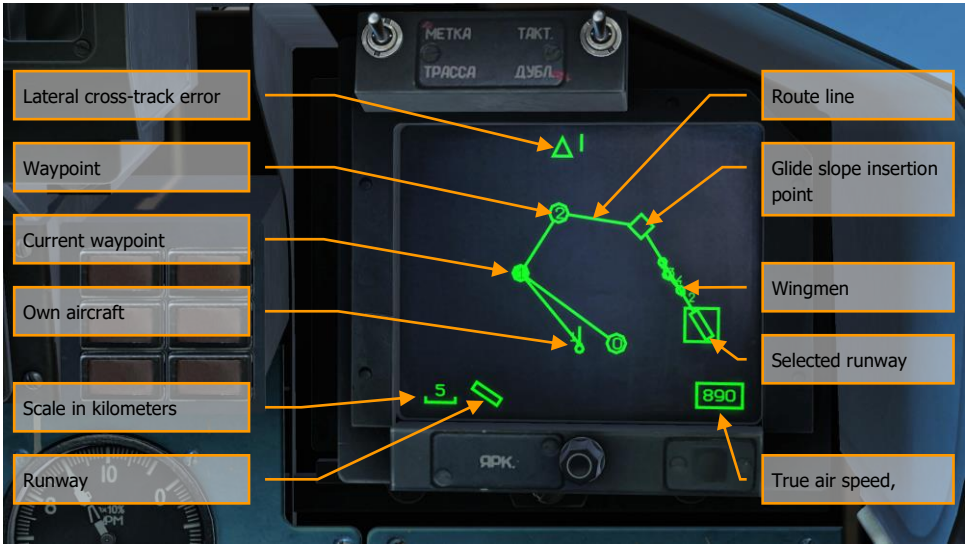

Figure 51: HDD in navigation mode

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

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

The next route and waypoint will be displayed on HDD.

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

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

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

Navigation Modes

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

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

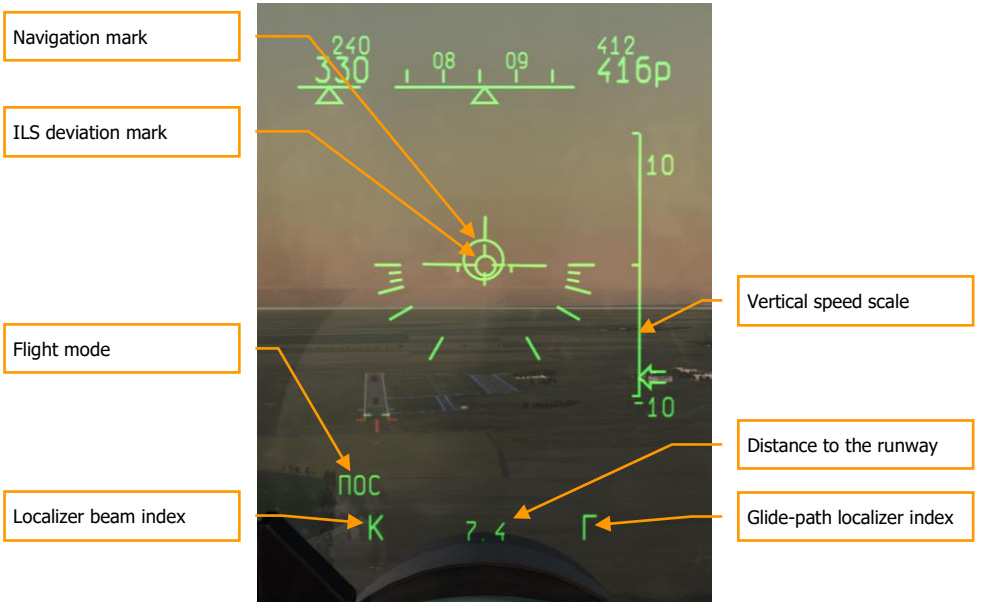

Figure 52: ILS landing

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

Beyond Visual Range Combat Modes

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

"ОБЗ" (SCAN) MODE

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

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

aircraft using the **[RShift-;]** and **[RShift-.]** jeys, also in kilometers. The expected range you set is indicated under the azimuth coverage mark at the bottom of the HUD, and the expected elevation difference is indicated to the right of the elevation coverage mark on the right side of the HUD.

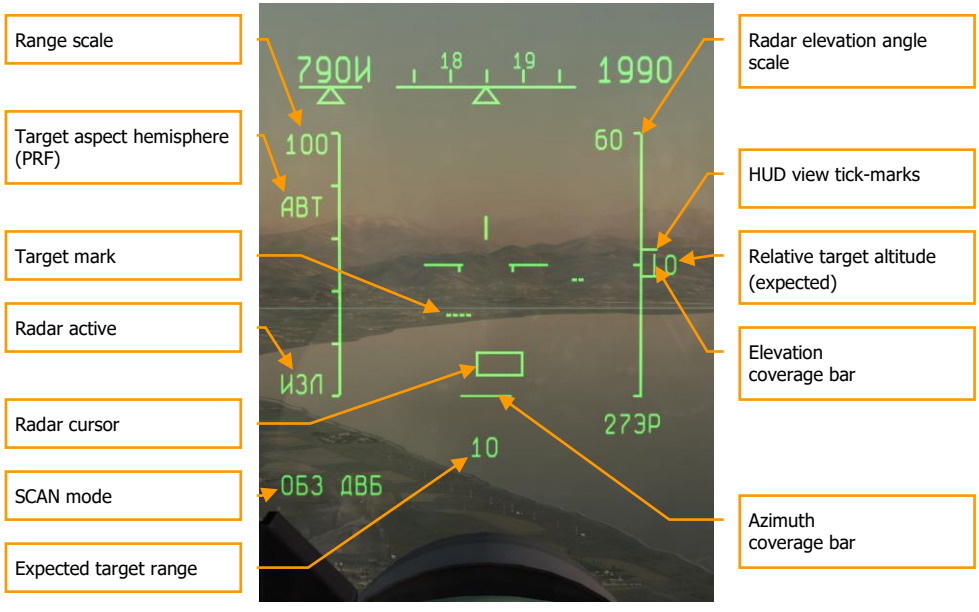

Figure 53: "ОБЗ" (SCAN) mode - BVR

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

- Range scale is changed by the **[+]** and **[-]** keys.
- The expected target aspect hemisphere is controlled with the **[RShift-I]** key. ABT (ILV) mode can be used if the target aspect is unknown. The expected target aspect determines the pulse repetition frequency (PRF) to be used by the fighter radar in search mode. High PRF (HPRF), which provides the longest detection range against approaching forward-hemisphere targets, is indicated by ППС (HI), whereas medium PRF (MPRF) for receding rear-hemisphere targets is indicated by ЗПС (MED). In ABT (ILV) mode, high and medium PRFs are interleaved on alternate bars of the radar scan pattern. This provides all-aspect target detection at the expense of a 25% reduction in maximum range.
- An air target is indicated on the HUD as a horizontal row of dots. The number of dots corresponds to the approximate size of the target as measured by its radar cross-section (RCS). One dot indicates a target RCS of 2 sq. m or less, two dots – from 2 up to 30 sq. m, 3 dots – from 30 up to 60 sq. m, and four dots - 60 sq. m or more. Tactical fighters typically have RCS values between 3 and 30 sq. m, dependent upon the type, external

payload, and aspect angle. Most fighters are thus usually displayed on the HUD as a row of 2 dots. Friendly aircraft have an identification marking in the form of a second row of dots positioned above the main one.

- The "**ИЗЛ**" symbol on the left side of the HUD indicates that the radar is turned on and actively transmitting.
- The radar cursor for target designation is moved by using the **[;], [,], [.], [/]** keys.
- The expected (manual) range to target (often derived from AWACS and GCI data), as set by **[RCtrl-+]** and **[RCtrl--]** keys and is indicated at the bottom of the HUD under the azimuth coverage bar. The elevation coverage of the radar scan pattern is calculated from this parameter.
- The expected relative altitude of the target with respect to your aircraft, as set by the **[RShift-;]** and **[RShift-.]** keys is indicated on the right side of the HUD, next the elevation coverage bar. This parameter is also used to calculate the scan pattern elevation coverage.

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

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

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

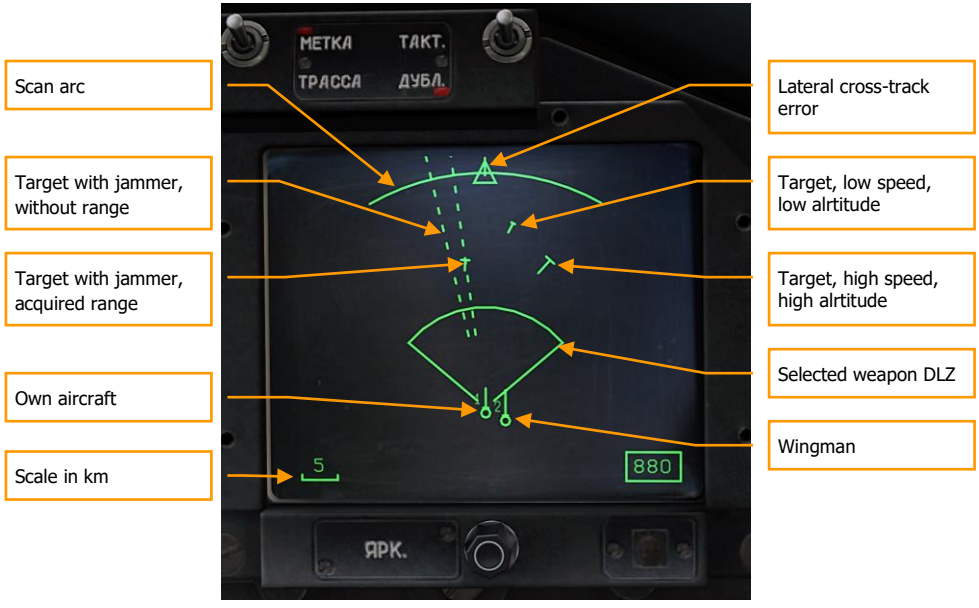

Figure 54: HDD in BVR modes

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

"СНП" (TWS) MODE

Another BVR combat mode is "СНП" (Track-While-Scan or TWS). It is activated from the "ОБЗ" (SCAN) mode by pressing **[RAlt-I]**. The radar can correlate tracks for up to 10 targets simultaneously in "СНП" (TWS). The main distinction from SCAN mode is that the radar retains target parameters, like elevation and velocity vector, while continuing to search for additional targets.

The HDD provides a top-down view of the tactical situation including all tracked targets, together with their direction of travel and position.

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

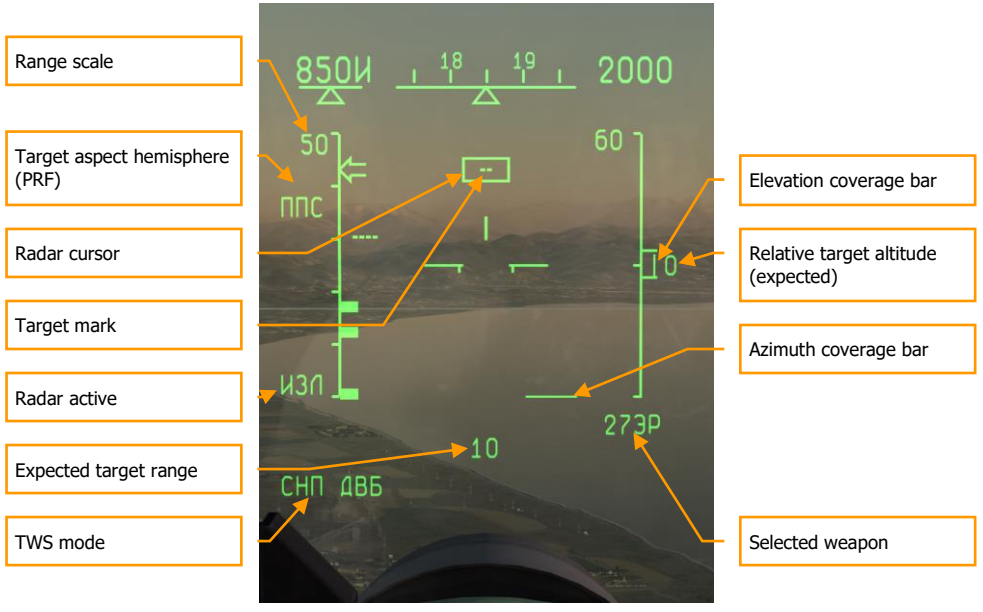

Figure 55: "СНП" (TWS) MODE

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

- "СНП ДВБ" (TWS BVR) in the lower left corner of the HUD indicates the current mode.
- The chosen weapon is indicated in the lower right corner of the HUD, beneath the elevation angle scale. The **27ЭР** above indicates R-27ER missiles.
- The range scale at the left side of the HUD features three thick inwards facing tick marks. Going from the top downwards, these are: Rmax - maximum permitted launch range vs. non-maneuvering target, Rtr - maximum permitted launch range vs. maneuvering target ("no-escape zone"), and Rmin - minimum permitted launch range.

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

"Атака – РНП" (ATTACK – STT) MODE

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

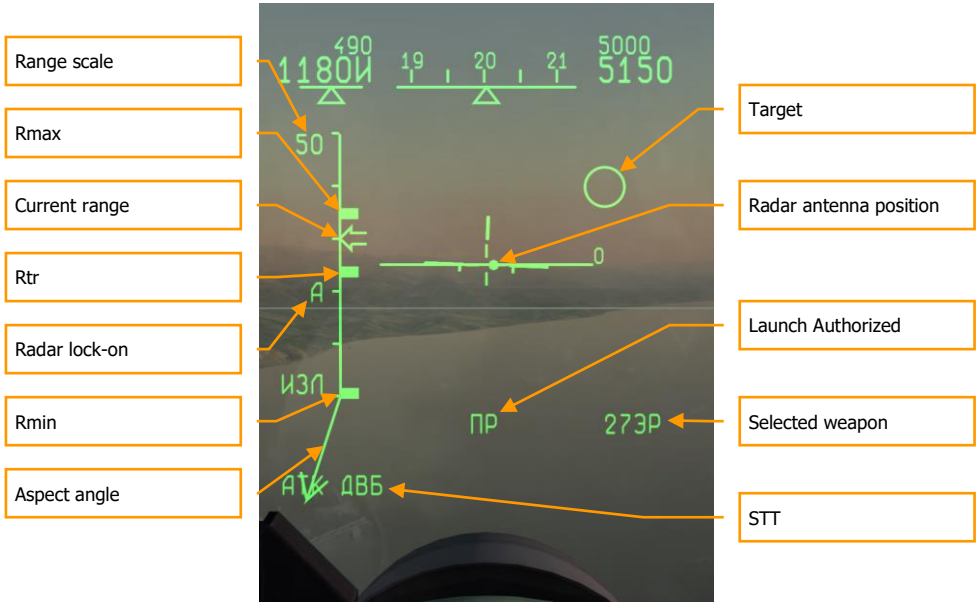

Figure 56: "АТК ДВБ" (STT BVR) MODE

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

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

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

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

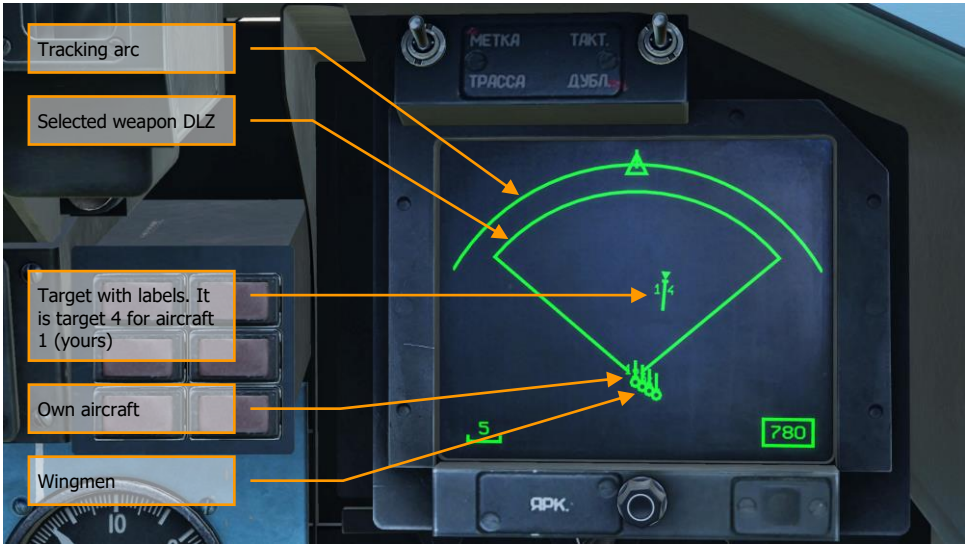

Figure 57: HDD "АТАКА – РНП" (ATTACK – STT)

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

The STT target mark has a solid triangle above it.

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

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

SCAN – IRST MODE

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

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

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

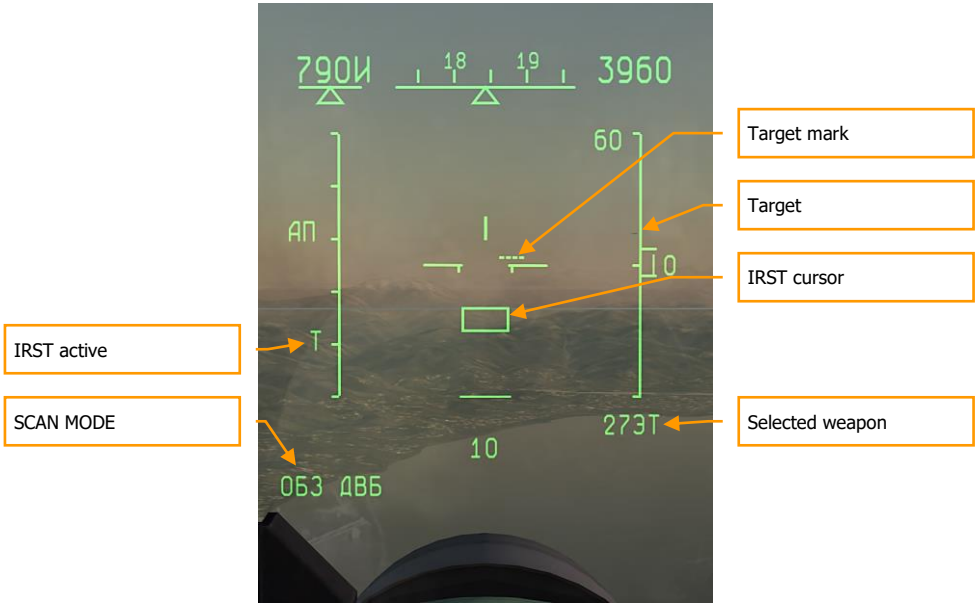

Figure 58: "ОБЗ ДВБ" (SCAN BVR) Mode with IRST as chosen sensor

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

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

Digital Datalink

The Su-27 carries radio equipment to receive digital target information directly from off-board sensors (A-50 AWACS aircraft and ground-based EW radars) without using voice communications. The command post transmits air combat tactical situation to the fighter, and this data is then displayed in a top-down view on the HDD to improve the pilot's situational awareness. This tactical display shows the positions of all aircraft detected by off-board sensors, using the fighter's own

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

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

HDD Datalink Symbology

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

Figure 59: HDD target symbology

Target label description.

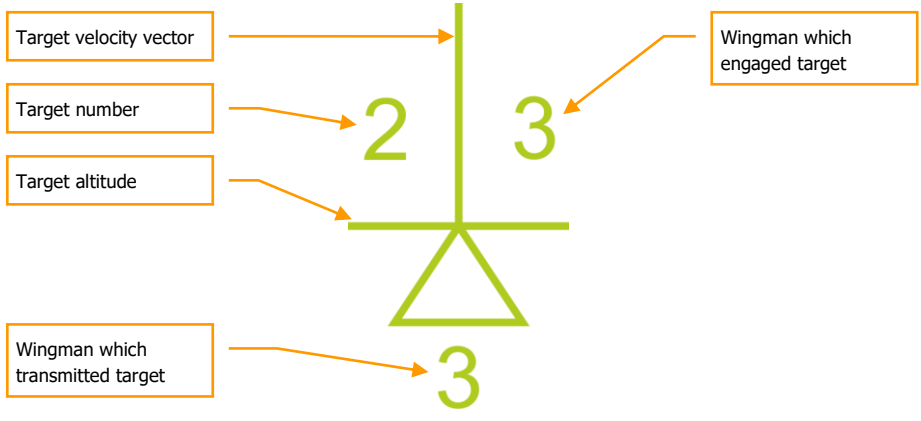

Figure 60: Target label

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

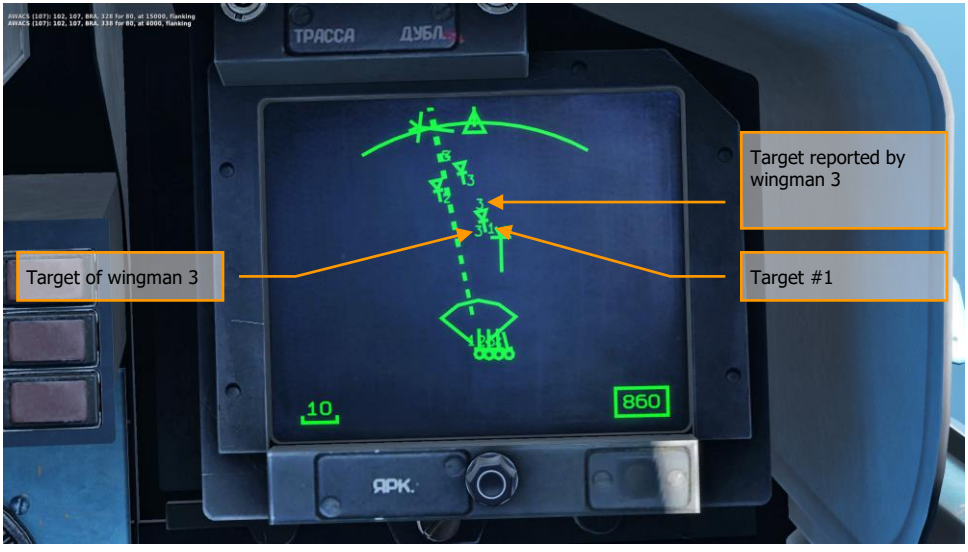

Figure 61: HDD target label

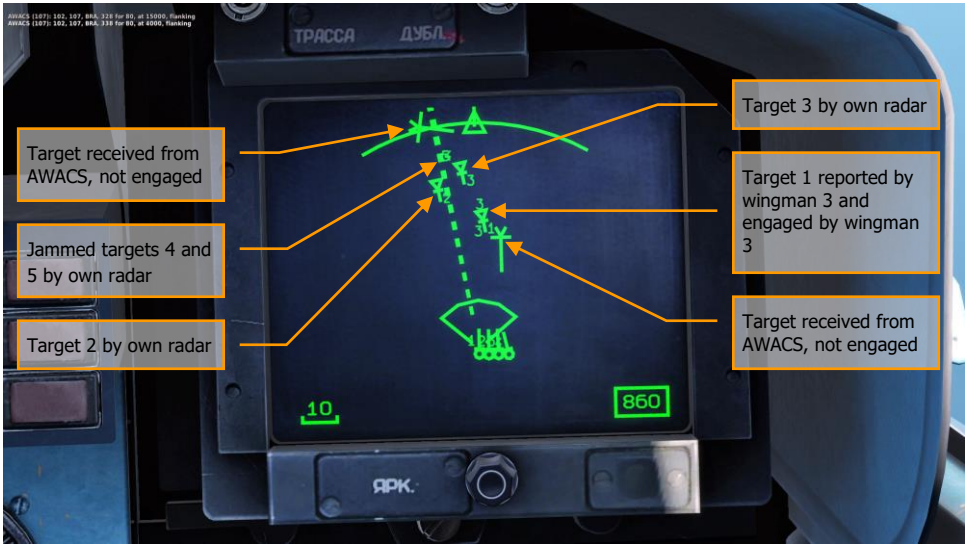

Figure 62: HDD combat situation description

Work in Complicated Countermeasures Conditions

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

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

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

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

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

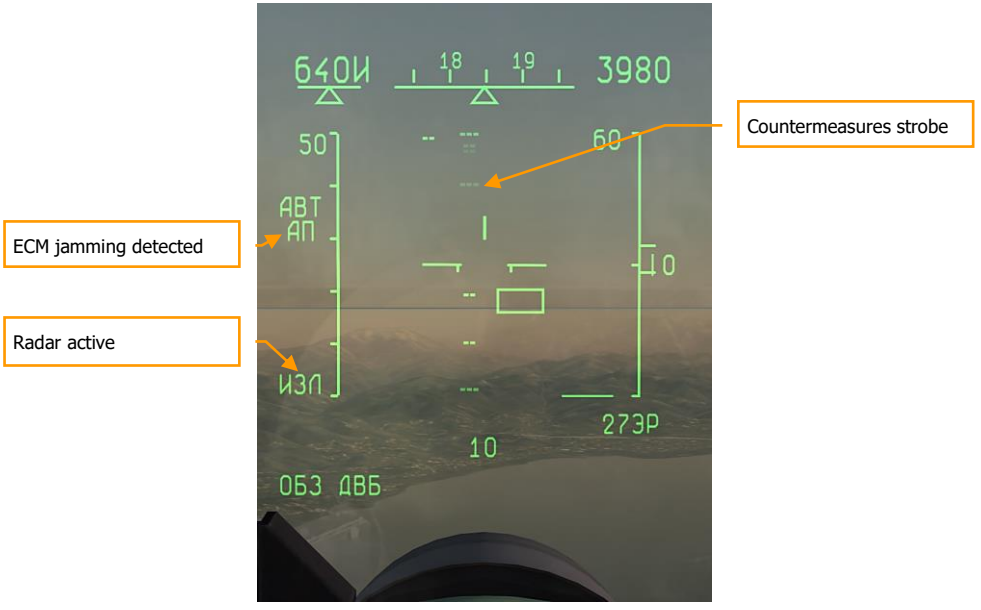

Figure 63: SCAN Mode with jammer strobe

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

Vertical Scanning - Close Combat Mode

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

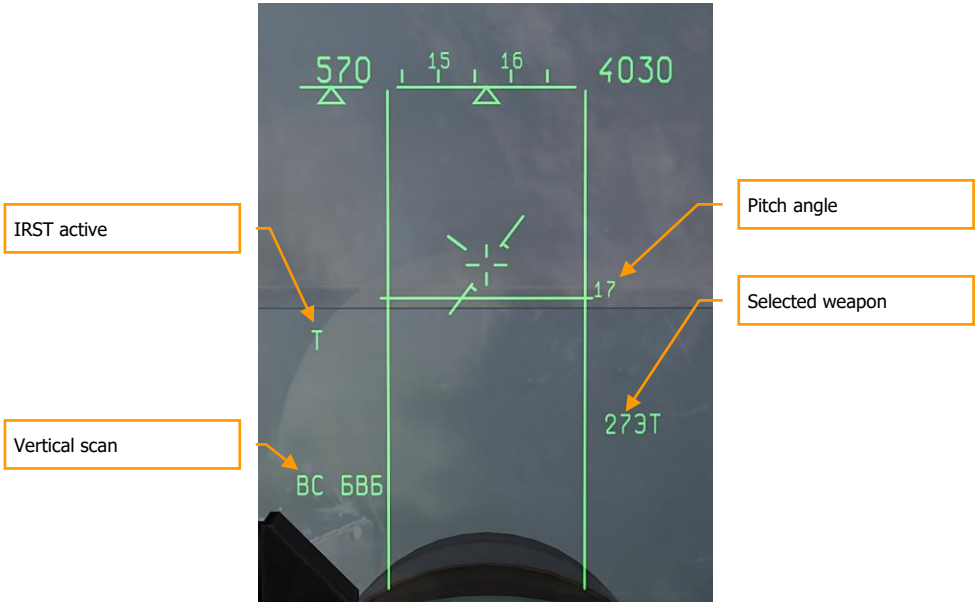

Figure 64: VS MODE

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.

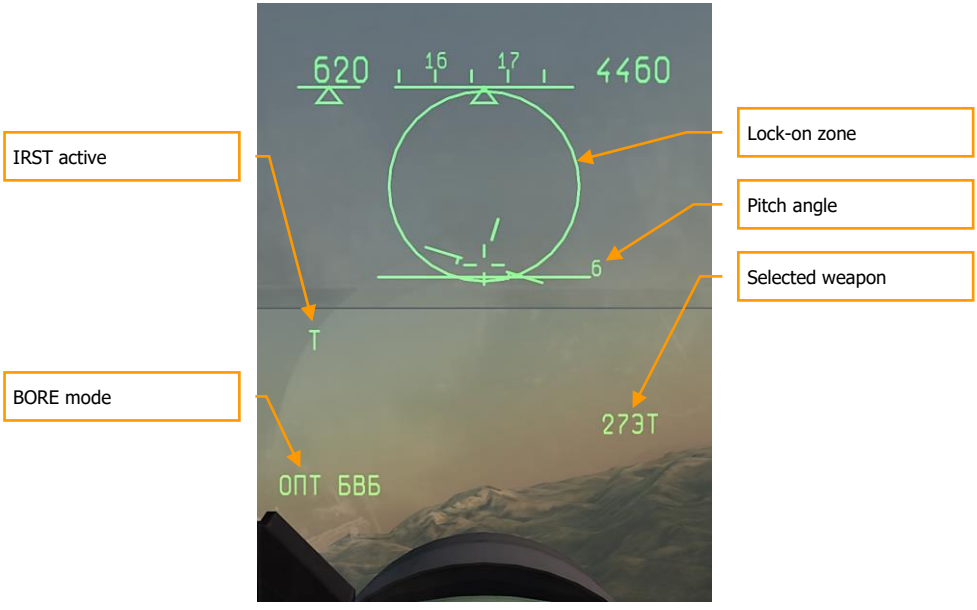

Figure 65: BORE Mode

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

HELMET - Close Combat Mode

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

Figure 66: HELMET mode

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

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

Fi0 – Longitudinal Aiming

Close Combat Mode

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

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

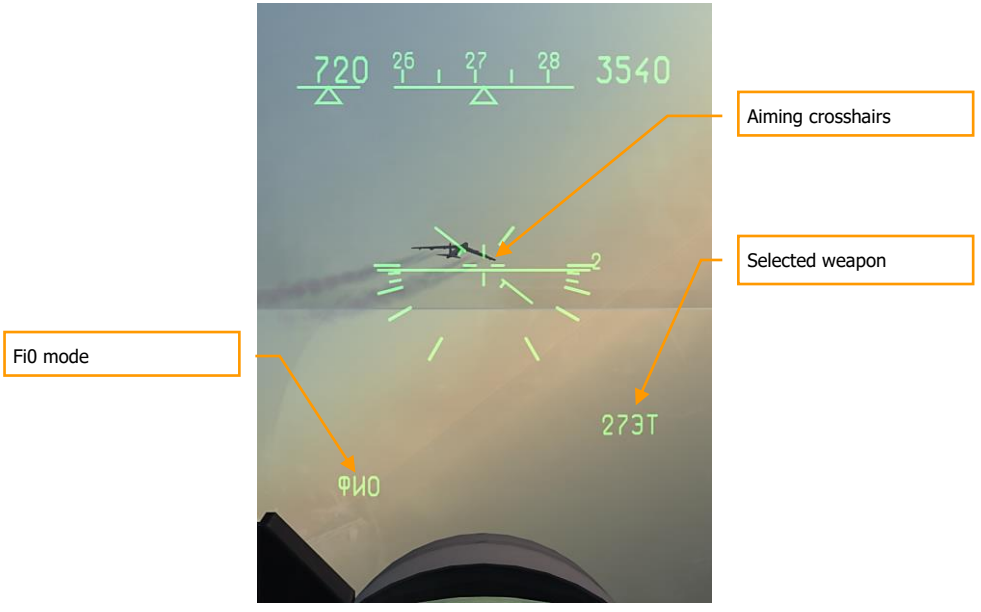

Figure 67: Fi0 (Longitudinal) MODE

Gun Employment

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

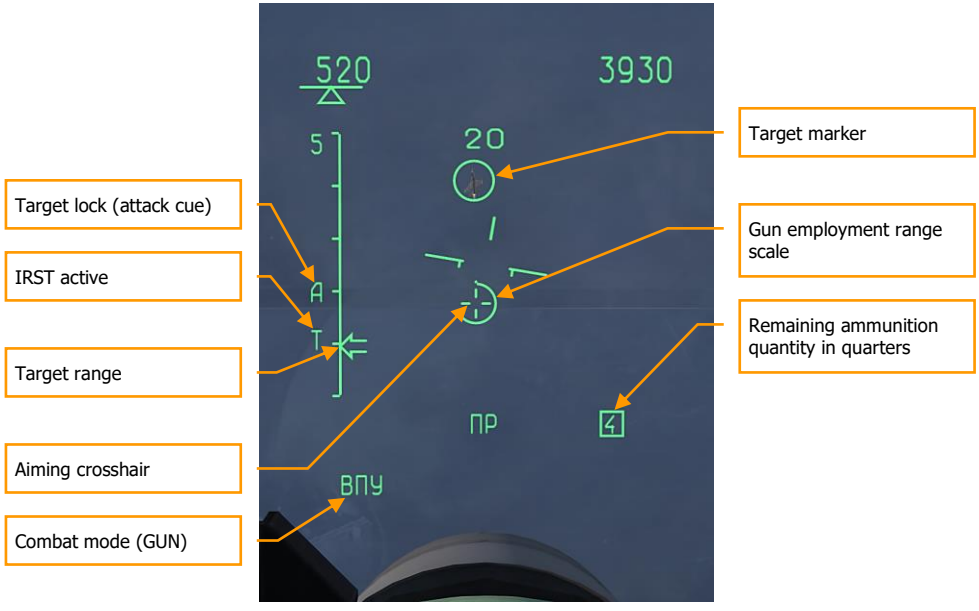

Figure 68: Lead Computed Opitcal Sight (LCOS) mode

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

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

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

Figure 69: Gun Funnel mode

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

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

Air-to-Ground Mode

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

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

Figure 70: 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.

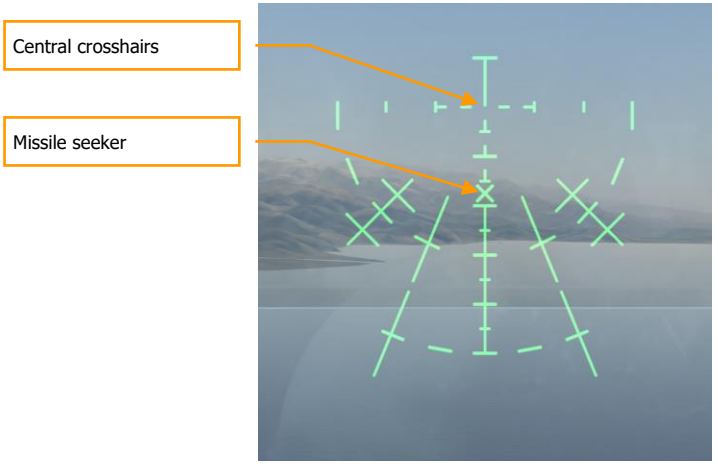

Figure 71: Reticle

Electronic Countermeasures

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

Electronic Countermeasures (ECM) Stations of Su-27

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

Figure 72: SPS-171 Sorbtsiya pad

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

Figure 73: ECM lamp

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

SU-33 WEAPONS

SU-33 WEAPONS

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

Air-To-Air Missiles

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

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

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

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

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

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

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

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

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

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

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

These missiles use a variety of guidance systems:

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

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

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

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

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

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

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

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

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

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

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

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

Air-To-Air Missiles

R-27 (AA-10) Medium Range Missiles

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

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

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

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

In addition to the seekers, the missile control system also includes an inertial navigation system with radio correction. The all-aspect R-27 attacks the target at its any initial position within a 50 degree gimbal limit for the semi-active radar seeker and 55 degrees for infrared. Maximum aircraft G loading

at the launch can be up to five units. The R-27 can intercept targets flying at speeds up to 3500 km/h and altitudes from 20 m to 27 km. Maximum target and launch aircraft altitude difference can be up to 10 km. Maximum target G is eight. The combined launch of R-27 missiles with different seeker variants increases the resistance to target counter measures. The R-27 family of missiles was developed by the Vympel design bureau and went into operational service between 1987 and 1990. Today, all versions of the MiG-29 and Su-27 fighters are equipped with these missiles.

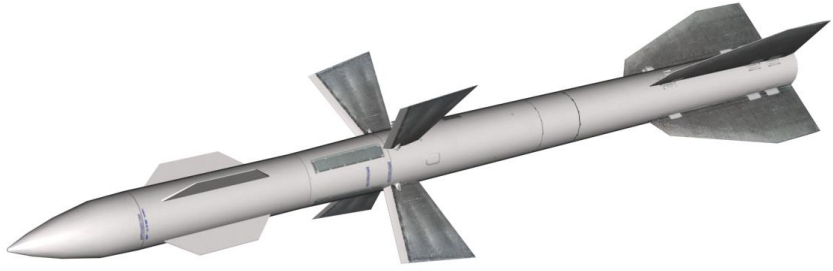

Figure 74: R-27R missile

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.

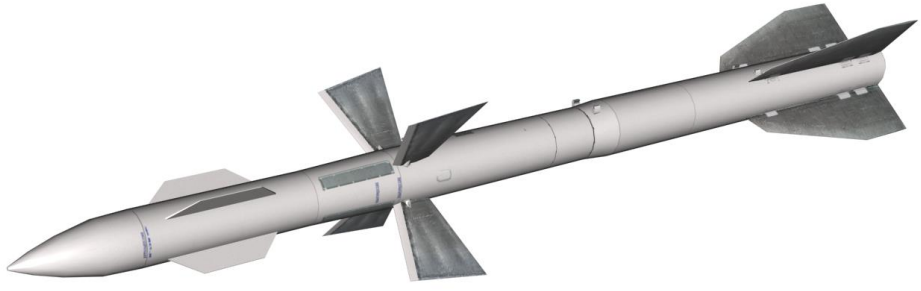

Figure 75: R-27ER missile

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.

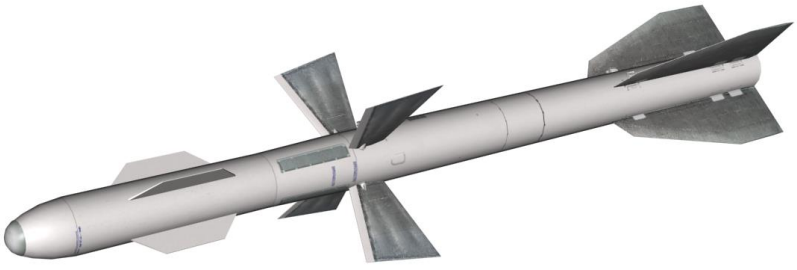

Figure 76: R-27T missile

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.

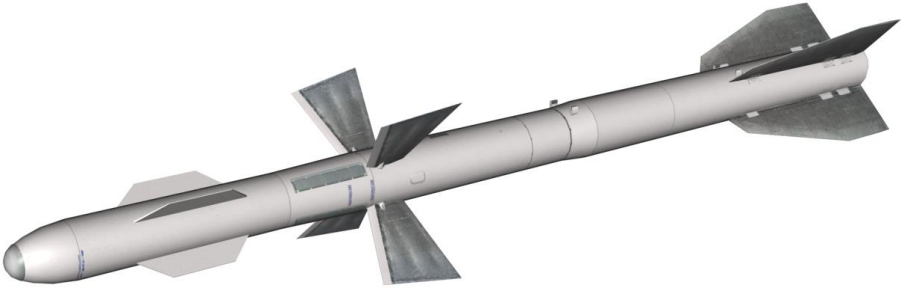

Figure 77: R-27ET missile

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 78: R-73 missile

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

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

Given the assumption of the first K-73 variant's small size and weight, an all-aspect seeker was not envisioned. Nevertheless, at Kiev "Arsenal" design bureau, which earlier worked with the Moscow "Geophisica" design bureau, developed a rather compact seeker "Mayak" (OGS MK-80) with a new seeker. The new seeker provided target acquisition up to 60°, which was 12 times greater that the corresponding seeker for the R-60. Later, the K-73 gimbal limits were increased to 75° with a

maximum angle speed of up to 60 degrees per second. "Mayak" seeker also included new, efficient anti-countermeasures (flares) implemented. In addition to an increased sensitivity range for the photo-detector array, a pulse-time signal modulation was applied, and a digital signal processing unit with several independent channels was introduced. To increase engagement efficiency, the steering point logic was adjusted to aim for a point forward of the targets engine nozzles. This allowed the warhead to damage more critical parts of the aircraft system, such as the pilot.

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

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

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

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

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

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

The R-73 was exported abroad as the K-73E variant; the first deliveries were made to East Germany in 1988. The missile was named AA-11 Archer in western terminology. The R-73, when combined with helmet mounted cueing device "Shel-3UM", enables a pilot to achieve air superiority in close air

combat. This was confirmed during initial joint trainings of the former Warsaw Pact countries (in particular, East Germany) with NATO pilots who flew some of the best western fighters.

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

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

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

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

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

Air-To-Surface Weapons

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

Originally Su-27 can use only unguided bombs and rockets.

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

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

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

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

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

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

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

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

Free-fall Bombs

Su-27 has some limited ground attack capability, being able to carry free-fall bombs and unguided rockets in place of air-to-air missiles.

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

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

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

Figure 79: FAB-500 High-Explosive Bomb

Figure 80: FAB-250 High-Explosive Bomb

Figure 81: 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 82: BetAB-500ShP Concrete Piercing Bomb

SAB-100 Illumination Bomb

Figure 83: 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 84: RBK-250 Cluster Bomb

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

There are several types of RBK cluster bomb.

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

Figure 85: 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 86: KMGU-2 Sub-munitions Dispenser

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

Unguided Aerial Rockets

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

Hit accuracy is dependent on the rocket's flight range, which in turn varies according to rocket type and caliber. Error accumulates with longer ranges, since the rockets fly without any trajectory

guidance. The permissible launch zone for each type of unguided rocket is defined between its maximum range, and the minimum safe blast distance. The minimum safe distance depends on the warhead type and weight, and protects the firing aircraft from exploding fragments. Rockets are usually fired at airspeeds of 600 – 1000 km/h with a dive angle of 10^0 – 30^0. The pilot maneuvers the entire aircraft to put the aiming pipper on the target before firing.

S-8 rocket

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

Figure 87: 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 88: 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 89: S-25 Rocket

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

Figure 90: S-25 Unguided Rocket in its Launch Tube

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

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

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

Unguided rocket	Effective range, km	Weight, kg	Warhead type
S-8OFP	2,2	15,2	Blast-fragmentation

S-8TsM	2,2	15	Smoke (target designation)
S-13-OF	2,5	68/67	Blast-fragmentation
S-24B	2	235	Blast-fragmentation
S-25-OF	4	480	Blast-fragmentation

RADIO COMMUNICATIONS

RADIO COMMUNICATIONS AND MESSAGES

In the early days of air combat, communication between pilots was difficult, and often impossible. Lacking radios, early pilots were basically limited to hand signals. Coordination between pilots, especially during a dogfight, was generally impractical.

Although modern electronics have greatly improved communications capability, communications still faces some frustrating limitations. There may be dozens, if not hundreds, of combatants using any given radio frequency. When those people all try to talk at once in the heat of battle, the resulting conversations generally become jumbled, cut-off, and unintelligible. Pilots, therefore, strive to adhere to a strict radio discipline with each message, conforming to a standard **Callsign, Directive, Descriptive**. The "callsign" indicates who the message is intended for and who it is from, the "directive" contains brief instructions for the recipient, and the "descriptive" specifies additional information. For example:

Chevy 22, Chevy 21, hard right, bandits low 4 o'clock

This message was sent by #1 of Chevy flight to #2 of "Chevy" flight. Chevy 21 has instructed Chevy 22 to execute a hard right turn. The descriptive portion of the message explains why… there are bandits at Chevy 22's four o'clock low position.

RADIO MESSAGES SHOULD BE BRIEF AND TO THE POINT

There are three types of radio communications in game:

- Radio commands that the player issues to other aircraft.
- Radio messages sent to the player from other aircraft, ground controllers, etc.
- Voice messages and warnings from the player's own aircraft.

Radio Commands

The following table describes the kinds of messages that the player may send and lists the key strokes needed to send each message. Depending on the type of command, it will take either two or three keystrokes to issue the desired message. There are also hot keys that allow the sending of a complex message as a single keystroke.

- Message target – This column indicates who the message is intended for, and may be the entire flight, a specific wingman, an AWACS/GCI controller, or an air traffic controller.
- Command – The command indicates the type of message you intend to send (such as an "Engage" command, or a "Formation" command, etc.)

Sub Command – In some cases, the sub-command specifies the exact type of command (such as "engage my target" or "Formation, line abreast.")

As illustrated in the table below, depending on the type of command, it takes either two or three keystrokes to generate the desired message. For example, to order the #3 wingman to engage the player's target, press F3, F1, F1.

Player-Generated Radio Commands

Message Target	Command	Sub Command	Definition of Command	Response(s) to Command
Flight or Wingmen	Engage...	My Target	Player requests wingmen to attack the target that is the focus of a sensor (radar or EOS) or padlock. When the target is destroyed, wingmen will return to formation.	If wingman is capable of carrying out this command, he will respond **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
		My Enemy	Player requests wingmen to attack enemy aircraft that is attacking him.	If wingman is capable of carrying out this command, he will respond **"(x) Copy," "(x) Roger," or "(x) Affirm,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative," or "(x) Unable,"** where (x) is the flight member.
		Bandits	Player requests wingmen to leave formation and engage bandits (enemy aircraft) within sensor range. When the target is destroyed, wingmen will return to formation.	If wingman is capable of carrying out this command, he will respond **"(x) Engaging bandit,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.

		Air Defenses	Player requests wingmen to leave formation and attack any air defense units they detect. When the target is destroyed, wingmen will return to formation.	If wingman is capable of carrying out this command, he will respond **"(x) Attacking air defenses,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
		Ground Targets	Player requests wingmen to leave formation and attack enemy ground targets. Valid ground targets include any structure or vehicle assigned as enemy in the mission editor. When the target is destroyed, wingmen will return to formation.	If wingman is capable of carrying out this command, he will respond, **"(x) Attacking target,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
		Naval Targets	Player requests wingmen to leave formation and attack any enemy naval target within sensor range. When the target is destroyed, wingmen will return to formation.	If wingman is capable of carrying out this command, he will respond, **"(x) Attacking ship,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
		Mission and Rejoin	Player requests that wingmen leave formation and attack the mission objective as identified in the mission editor. Once complete, the wingman will rejoin formation with player.	If wingman is capable of carrying out this command, he will respond, **"(x) Attacking primary,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.

		Mission and RTB	Player requests that wingmen leave formation and attack the mission objective as identified in the mission editor. Once complete, the wingman will return to base.	If wingman is capable of carrying out this command, he will respond, **"(x) Attacking primary,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
Flight or Wingmen	Go to…	Return To Base	Wingmen will leave formation and land at their designated airfield. If no airfield is designated, they will land at the nearest friendly airfield.	If wingman is capable of carrying out this command, he will respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
		Route	Wingmen will leave formation and proceed to route by mission editor plan.	If wingman is capable of carrying out this command, he will respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
		Hold Position	Wingmen will leave formation and fly around current point.	If wingman is capable of carrying out this command, he will respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
Flight or Wingmen	Radar…	On	Player requests that wingman to activate radar to search.	Wingman will respond, **"(x) Radar On,"** where (x) is the flight member.
		Off	Player requests wingman to deactivate radar.	Wingman will respond, **"(x) Radar Off,"** where (x) is the flight member.

Flight or Wingmen	ECM…	On	Player requests wingmen to activate ECM.	The wingman will respond, **"(x) Music On,"** where (x) is the flight member.
		Off	Player requests wingmen to deactivate ECM.	Wingman will respond, **"(x) Music Off,"** where (x) is the flight member.
Flight or Wingmen	Smoke	On	Player requests wingmen to activate smoke containers.	Wingman will activate smoke generators and respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member.
		Off	Player requests wingmen to deactivate smoke containers.	Wingman will activate smoke generators and respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member.
Flight or Wingmen	Cover Me		Player requests wingmen to attack the airplane which is nearest to the player's aircraft.	Wingman will respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member.
Flight or Wingmen	Jettison Weapons		Player requests wingmen to jettison weapons.	If wingman is capable of carrying out this command, he will respond, **"(x) Copy," "(x) Roger,"** or **"(x) Affirm,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.
Flight	Go Formation	Rejoin Formation	Wingmen will cease their current task and rejoin formation with the player.	If wingman is capable of carrying out this command, he will respond, **"(x) Copy rejoin,"** where (x) is the flight member. If wingman is incapable of carrying out command, he will respond, **"(x) Negative,"** or **"(x) Unable,"** where (x) is the flight member.

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

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

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

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

Radio Messages

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

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

Radio Messages

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

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

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

	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"

SU-33 CHECK LIST

SU-33 CHECK LIST

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

Engine Ground Start

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

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

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

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

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

Engine Shutdown

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

In Flight Engine Restart

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

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

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

Some features of the Su-33

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

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

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

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

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

This mode has a 10 minute operational limit.

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

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

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

Figure 91: Afterburner and special mode lights

Weapons Delivery

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

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

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

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

Beyond Visual Range Combat

Missile Engagement with Radar as the Active Sensor

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

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

Step 1

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

Step 2

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

Step 3

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

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

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

Step 4

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

Step 5

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

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

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

Step 6

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

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

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

TO USE SARH MISSILES, YOU MUST LOCK THE TARGET IN STT MODE THE ENTIRE TIME OF MISSILE FLIGHT.

Missile Engagement with IRST as the Active Sensor

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

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

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

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

Step 1

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

Step 2

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

Step 3

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

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

Step 4

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

Step 5

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

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

Step 6

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

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

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

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

Close Air Combat

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

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

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

Several targeting modes used in CAC are described below:

Close Air Combat – Vertical Scan Mode

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

The lock and launch steps are as follows:

Step 1

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

Step 2

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

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

Step 3

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

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

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

Close Air Combat – STROB (BORE) Mode

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

The lock and launch steps are as follows:

Step 1

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

Step 2

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

Step 3

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

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

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

Close Air Combat – Shlem (Helmet) Mode

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

The lock and launch steps are as follows:

Step 1

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

Step 2

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

Step 3

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

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

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

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

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

Fi0 (Longitudinal) Mode

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

The lock and launch steps are as follows:

Step 1

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

Step 2

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

Step 3

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

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

Air-to-Ground Weapons

The Su-27 can carry limited types of air-to-surface weapons. This arsenal includes free-fall bombs and unguided rockets.

General Purpose, Low-Drag Bombs

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

Step 1

Visually identify the target.

Step 2

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

Step 3

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

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

General Purpose, High-Drag Bombs

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

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

Step 1

Identify the target visually.

Step 2

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

Step 3

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

Unguided Rockets and Internal Gun

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

Step 1

Identify the target visually.

Step 2

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

Step 3

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

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

SUPPLEMENTS

SUPPLEMENTS

Acronym List

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

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

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

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

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

Sources

Фомин А., Су-33. Корабельная эпопея. М.: Интервестник 2003

http://www.sukhoi.org/planes/military/su33/

http://www.airwar.ru/enc/fighter/su33.html

Photos by Mike Syritsa http://instagram.com/aviafan