DIGITAL COMBAT SIMULATOR

MiG-29A FULCRUM

Flight Manual
Early access

EAGLE DYNAMICS

DCS

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COCKPIT INSTRUMENTATION

COCKPIT OVERVIEW

The cockpit of the MiG-29 fighter is a complex, carefully thought-out set of controls, instruments and display devices, developed taking into account the high requirements for combat effectiveness, flight safety and minimization of the pilot's workload in a fast-paced air battle. The Soviet school of aircraft construction has always paid special attention to the ergonomics of the pilot's workplace, striving to ensure intuitive interaction with the aircraft's systems.

The basic philosophy of the MiG-29 cockpit is the "everything is at hand" principle. The key controls needed for navigation and combat are grouped on the aircraft control stick and engine control levers in accordance with the HOTAS – Hands-On-Throttle-And-Stick - concept. This allows the pilot to perform most critical operations without taking his hands off the primary controls and his eyes off the area in front of the aircraft or the head-up display.

The instrumentation is represented mainly by analog, "pointer" instruments and light displays. This solution, typical for aircraft of its generation, ensured high reliability and readability of readings in various lighting conditions.

Control panels with the corresponding controls and instruments are divided into four groups according to their position in the cockpit:

- Front Instrument Panel and adjacent panels
- Left Console
- Right Console
- Power Unit, installed in the cockpit behind the pilot's seat (not available for DCS pilots)

The instrument panel contains the most important and necessary instruments that are used most often by the pilot during flight.

The instrument panel consists of four panels: two left side panels, one middle panel and one right panel.

The aircraft's lighting equipment includes:

- Internal lighting, consisting of a white light illumination system for instruments and consoles
- A floodlight lighting system for instruments, consoles, and a map
- A TLP waring and signaling light panel
- Landing and taxi headlights
- External lighting.

In this chapter, we'll explore the layout and function of the primary cockpit controls and indicators found in the DCS: MiG-29 (version 9-12) fighter. This foundational knowledge is essential for mastering both flight operations and combat tactics. Familiarity with each switch, button, and display element is crucial for executing missions safely and effectively.

Front instrument panel

The Front instrument panel is the central element of the pilot's information field. It contains the most important flight and navigation instruments, power plant operation indicators and aircraft systems.

Figure 1: Front instrument panel

The central part of the instrument panel contains the main flight instruments, most crucial of them are duplicated on ILS. The panel layout corresponds to the classic T-shaped scheme.

All levers, buttons and switches used in emergency situations are marked red on frames, caps and fuses. To simplify the readings of various scales, the safe ranges are painted with Blue color, edge and threshold values with Yellow color, dangerous and prohibited values with Red.

The left side of front panel is devoted to the flight control instruments and weapon controls. Emergency and nose wheel brake levers are also placed here.

Figure 2: Weapon and flight controls

1. Master caution lamp-button
2. Combined AOA / G meter
3. Weapon control panel. PSR-31
4. Emergency brake lever
5. IAS indicator. US-1500-1
6. Altimeter. UV-30-2
7. Flight and landing indicator. IP-52-03
8. Course setting unit
9. Flight Clock. AChS-1M
10. Horizontal situation indicator. HSI. PNP-72-12
11. TAS indicator
12. Attitude director indicator. ADI. KPP-SI
13. Combined device DA-200P – vertical velocity indicator
14. Nose wheel brake lever

At the right side of the front panel, the radar altimeter, defense control unit, engine operation, fuel, hydro and oxygen systems indicators can be found along with the AEKRAN and RWR displays.

Figure 3: Right side indicators and controls

1. ADF beacon type selection toggle switch
2. Flare dispenser control panel
3. Radar altimeter indicator
4. Tachometer. ITE-2TB
5. Gas temperature meters. ITG-1
6. Combined pressure indicator
7. Life support indicator
8. Ramp position indicator
9. Radar warning station. SPO-15LM
10. Fuel flow metering system indicator. ISTR4
11. "AEKRAN" control and warning system display

Below the instrument cluster lies a central pedestal, housing the voltmeter, manometer, pitot switch, flare dispenser control unit, cockpit temperature set and weapon settings panel.

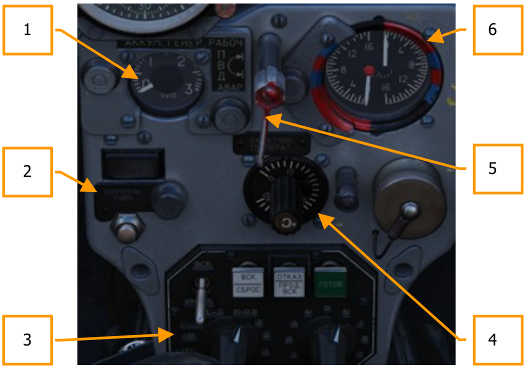


Figure 4: Central pedestal

1. Voltmeter
2. Dispenser control button
3. Weapon settings panel. PC-31
4. Cockpit temperature controller
5. Pitot selection lever
6. Manometer. M-2A

Weapon control panel. PSR-31

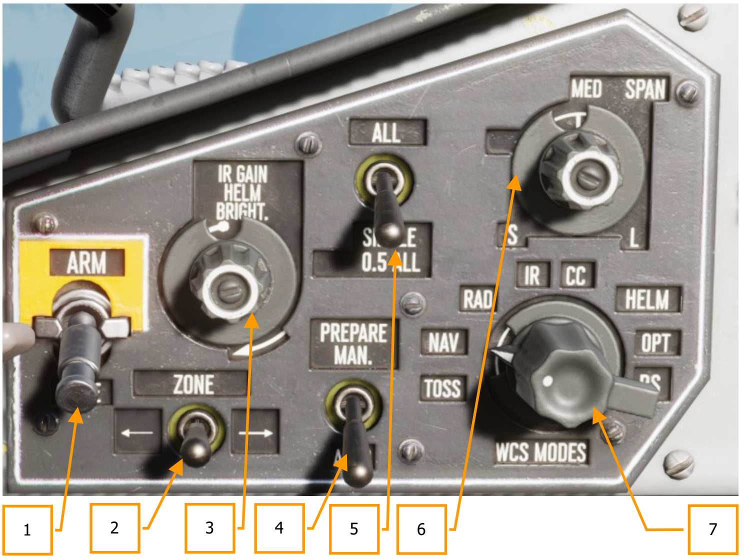


Figure 5: Weapon control panel. PSR-31.

The Weapon Control Panel (PSR-31) controls major combat parameters of the armaments, sensors and HUD:

1. **MASTER ARM switch**. "ARM" - "SAVE". Connecting combat triggers on stick to the weapons circuits.
2. **Three-position "ZONE" toggle switch**. Selects radar operating zone by azimuth "LEFT" - "CENTER" - "RIGHT."
3. **"IR GAIN/HELM BRIGHT." potentiometer**. Adjusting the sensitivity of the IR optical-laser receiver (KOLS) in the scan mode or the brightness of the HMD symbology in the "HELMET" mode
4. **"PREPARE MAN" - "AUTO" switch**. Missile launch preparation mode. Normally – "AUTO", but can be switched to manual if required or if the WCS computer fails to detect the target range.
5. **"ALL" - "SINGLE 0.5 ALL" selector – Ammunition Release Mode**. Determines the release pattern of the selected munitions:
   "ALL" - paired launch per trigger press.
   "SINGLE 0.5 ALL " - single launch per trigger press.
   Note, the label "SINGLE 0.5 ALL" reflects a localization artifact—likely a direct translation from Russian lettering—found in the German version of the aircraft. It may appear cryptic, but it essentially denotes a single-release mode with half the quantity per launch compared to "ALL".
6. **"SPAN" potentiometer**. Tunes target wing span control system with digitization in meters and indexes MED, C, B ("**MED**" - medium, "**S**" - small, "**L**" - large) - to set the target size for indirect DLZ range computing along with setting to semi-radar R-27R missile.
   S – DLZ computation for cruise missiles
   MED - for targets such as MiG-21, F-15, F-16
   L - for targets such as Tu-16, F-III, SR-71, B-1.
7. **"WCS MODES" Switch**:
   "TOSS" – enables loft bombing calculations

"NVG" – temporarily disables the combat modes of the WCS and FCS and enables navigational modes across the UIS (Unified indication system)
"RAD" – enables the radar operating mode
"IR" – IR sensor mode using the KOLS receiver unit only. Main IR mode with manual target designation by TDC.
"CC" – IR KOLS operating mode for close combat - with automatic lock on a visible target without preliminary manual designation
"HELM" – enables HMD target acquisition in the direction of the pilot view.
"OPT" – enables the OEPrNK sighting system to engage visually visible air and ground targets by guided munitions with the laser rangefinder
"BS" – Air to Air Missile boresight mode using missile seeker.

IAS indicator.

1. Speed scale in knots x 100
2. Pointer

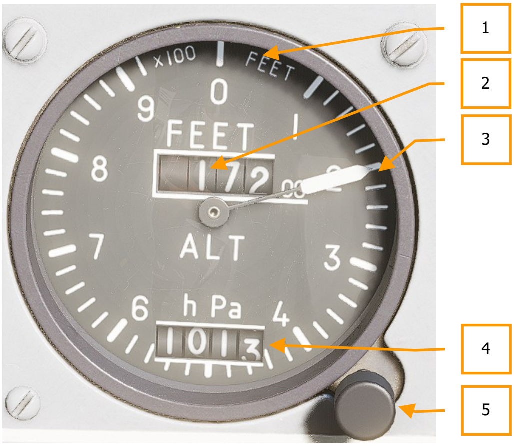
Figure 6: IAS indicator.

The instrument airspeed indicator USM-2AE displays indicated airspeed. A single pointer indicates airspeed values between 0 and 800 kts on a non-linear scale. Mach number is indicated on the inner scale.

The pneumatic inputs for the indicator are impact and static pressure supplied by the main or the backup pitot tube.

Since the indicator is directly driven by the pneumatic outputs of one of the pitot tubes, the indicated Mach number may differ from the real value by as much as M 0.05 due to non-linearities of those pitot tubes.

Altimeter. UV-30-2



1. Altitude scale in feet
2. Altitude counter
3. Pointer
4. Pressure meter P_0
5. Pressure P_0 setting knob.

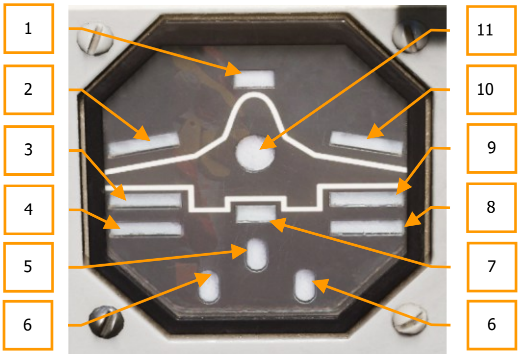
Figure 7: Height indicator. UV-30-2

The altitude indicator UV-30-2 is designed to indicate the relative barometric altitude from 0 to 100 000 ft. Electrical power is supplied by the ADC system, since the altimeter is an integral part of this system.

Device equipped by **scale** [1] in feet, **four-digit counter** [2] and **pointer** [3].

A barometric setting **knob** [5] adjusts the barometric setting on the hPa counter of the altimeter between 700 and 1080 hPa on **four-digit counter** [4].

Flight and landing indicator. IP-52-03



1. Upper speedbrake
2. Left wing toe
3. Left wing flap, "TAKE OFF" position
4. Left wing flap, "LANDING" position
5. Nose landing gear
6. Main landing gear
7. Lower speedbrake
8. Right wing flap, "LANDING" position
9. Right wing flap, "TAKE OFF" position
10. Right wing toe
11. Red light

Figure 8: Flight and landing indicator. IP-52-03

The device is designed to monitor the position of the chassis, flaps, brake flaps, slats, and to warn the pilot about the need to release the gear.

Attitude director indicator. ADI. KPP-SI

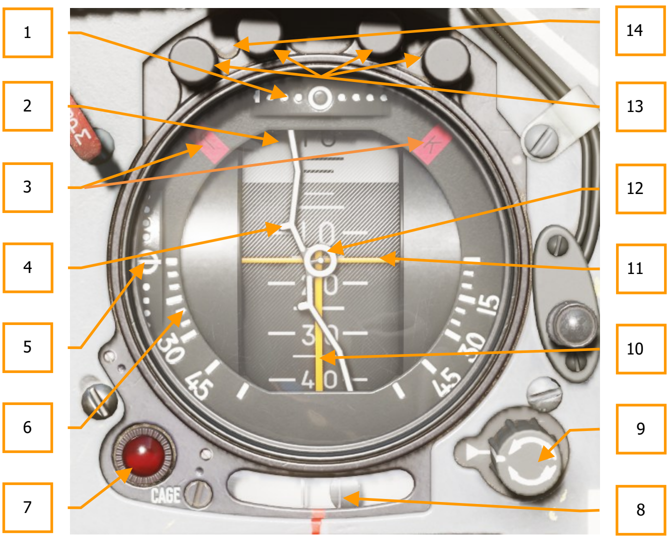


Figure 9: ADI.

The attitude director indicator displays the aircraft's attitude in pitch, roll and slip. The slip indicator is built into the lower part of the device. The position is indicated by the aircraft symbol relative to the horizon, the pitch is indicated by the position hemisphere. The device is also equipped with the navigational helper directors.

On the front of the device are located:

1. Pointer, indicating the position of an aircraft relative to a horizontal plane
2. The pitch angle scale in the center consists of movable tape scale with numbers corresponding to ±80° of pitch angle, the division value is 5° and digitized every 10°. The pitch tape scale is painted white above the horizon line and black below the horizon line.
3. Pitch off flag "T", azimuth off flag "K". These flags are dropped by the signals from AFCS or landing system.
4. Silhouette of an aircraft relative go horizon line.
5. Pointer indicating the position of an aircraft relative to a given flight path trajectory in the vertical plane
6. Fixed scale for measuring roll angles, graduated within ±60 and digitized through 15° to 45°. The scale smallest division value is 5° up to 30° and 15° on the remaining sections of the scale
7. "CAGE" button-lamp
8. Slip indicator
9. Aircraft symbol position adjustment knob
10. The command (director) bar showing the right or left side moves relative to the center of flight trajectory.
11. The command (director) bar showing up or down side moves relative to the center of the flight trajectory.
12. Zero index circle
13. Illumination lamps

The operating angles at which correct readings are given are 0-360° roll and 0-360° pitch, with the exception of the 80-100° angle zone during climb or descend.

Horizontal situation indicator. HSI. PNP-72-12

The Horizontal Situation Indicator (HSI) presents a horizontal representation of the aircraft's position relative to its navigational environment. Its rotating compass card ensures that the aircraft's current heading is always aligned beneath the course index.

The displayed information on the HSI varies depending on the selected navigation source. The instrument operates on 36 VAC power and provides a unified indication from aircraft to ground, covering the following parameters:

– Current course
– Selected/Set course
– Desired course angle
– Drift angle
– Distances from 0 to 999 nm
– Course deviation from the specified angle
– Azimuth and heading angle to the primary radio station
– Flight path deviation
– Lateral deviation

Figure 10: Horizontal situation indicator. PNP-72-12

1. Range indicator
2. Range indicator curtain when inoperative
3. Azimuth to WP or NDB. Bearing pointer
4. Desired course pointer
5. Current azimuth A1 and NDB sensor failure flag "VL"
6. Combined scale
7. Current course scale
8. Test control button
9. Localizer directors (ILS indicators)
10. Desired Course set knob
11. Equisignal round mark of the localizer radio beacon deviation
12. Glide path deviation indicator scale
13. Desired course (heading) pointer
14. Glide path radio receiver failure flag "GS"
15. Desired course angle (heading) window
16. Desired course angle (heading) indication
17. Current course (heading) index
18. Sensor failure flags.

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.

Course setting controls

Figure 11: Course setting instruments

1. Magnetic course auto adjustment button
2. Desired course (heading) mode selector switch from "AUTO" to "MANUAL".

Master caution lamp-button

Figure 12: Master caution lamp-button

A master caution light flashes whenever a warning light illuminates on the TLP (red lights) or an AEKRAN warning signal is displayed. When pressed, it switches off and the corresponding TLP displays switch from flashing to continuous or "off" mode.

Combined AOA / G meter

Figure 13: Combined AOA / G meter

1. Reset button for G-Index tab.
2. AOA pointer
3. AOA scale
4. 15° marker
5. 25° marker
6. Red sector
7. Red mark on 7g
8. g scale
9. g pointer

The AOA pointer [2], for the left scale [3], is electrically connected to AOA probes located at the left and right forward section of the aircraft.

G-loads are indicated on the right scale [8] by a main pointer indicating instantaneous g-loads [9].
The g-meter is electrically connected to an external g-sensing transducer. Reset button [1] have not action yet.

Combined indicator DA-200P

The device indicator consists of three independent devices: a variometer VVI, a turn indicator and a slip indicator, located in one housing.

The VVI indicates the rate of climb or descent of the aircraft. The indicator is connected to the static pressure system and actuation of the pointer is controlled by the rate of change of the atmospheric pressure.
It can register a rate the altitude changes in climb or descend.

A turn and slip indicator are also incorporated. The turn needle indicates direction of turn but does not provide accurate turn rate.

The slip indicator [5] is a curved glass tube with notches and ball inside, and located below the center. At the bottom of the device there is an adjustment knob [6] designed to set the variometer pointer to initial zero before the flight.

Figure 14: Combined indicator DA-200P

1. Variometer scale
2. Variometer pointer
3. Direction indicator scale
4. Direction indicator pointer
5. Slip indicator
6. Adjustment knob

TAS indicator

1. Indicator scale
2. Shorter pointer, counting the number M
3. Longer pointer, indicating true speed

Figure 15: TAS indicator

The TAS indicator UMS-2,5-2U provides a combined display of TAS and Mach number. Electrical power is supplied from the air data computer (ADC). The longer pointer [3] rotates at the linear outer scale [1] to indicate values between 100 and 1400 kts. The shorter pointer [2] traverses the inner Mach number scale. The input signals rely on ADC signals and air temperature.

Clock. AChS-1M

1. Large scale
2. Flight Time Scale
3. Stopwatch scale
4. Right head
5. Left head.

Figure 16: Air watch. AChS-1M

The AChS-1M air watch is designed for:

- Displaying the current time in minutes and seconds
- Measuring short time intervals up to 30 minutes, in minutes and seconds
- Measuring flight time in hours and minutes.

The AChS-1M device consists of three mechanisms:

- The mechanism of a conventional mechanical watch for keeping track of the current time
- A stopwatch mechanism for measuring and counting short periods of time
- A flight time mechanism for indicating the time the aircraft has been in flight.

All three mechanisms have a kinematic connection in the form of a lever system and operate from the drive of the watch mechanism.

The mechanism of a regular watch works continuously, the hour and minute hands move during the operation of the mechanism, and the flight time and stopwatch mechanisms can be switched on and off, i.e. these mechanisms can work separately and simultaneously. The time mechanism consists of two spring movers (drives), a gear train, a starter and an oscillating system.

The operation of the flight time mechanism is determined by three positions:
- Start the mechanism
- Stop the mechanism
- Return the hands to their original position.

The operation of the stopwatch is determined by three positions:
- Start the mechanism
- Stop the mechanism
- Return the hands to their original position.

The watch dial has three scales:

- The large scale is designed to count time in hours and minutes and the operating time of the stopwatch in seconds
- The "Flight Time" scale is designed to count flight time in hours and minutes
- The "Stopwatch" scale is used to count the minutes of the stopwatch operation.

The clock is controlled by two heads:
- Left, designed for winding the watch, moving the hands, starting, stopping and returning the hands of the flight time mechanism to zero
- The right one, designed to start and stop the watch
- Start, stop and return to zero the stopwatch hands.

The right head has an arrow indicating the direction in which to turn the head to start the watch.

To set the hands, pull the left crown out as far as it will go and turn it counterclockwise to set the time.

The hands should be moved after the flight time mechanism has been switched off – a white signal should be visible in the signal hole on the dial.

To set the hands to the exact time, you need to:
- Stop the watch by turning the right head clockwise
- Press the right head, return the second hand of the watch and the minute hand of the stopwatch to zero
- Set the minute and hour hands to the exact current time
- When the exact time is sent via radio, turn the right head counterclockwise to start the watch.

To ensure accuracy, the watch must be wound once every two days.
The watch is wound by turning the left winding crown counterclockwise.
The clock runs for three days.
The watch starts working after two full turns of the winding crown.

Nose wheel brake handle

Figure 17: Nose wheel brake handle

Vertical position – brake engaged.
Horizontal position – brake disengaged.

ADF mode toggle switch

Figure 18: Toggle switch for selecting the type of NDB beacon (outer or inner)

For ease of maneuvering during landing, switching [1] from the outer to the inner one is performed automatically when switching to inner the "BEACON INNER" display lights up [2].

Countermeasures dispenser control panel

Flares and chaff are used against missiles.

The control panel contains of an emergency jettison button[1] and a three-position toggle switch [2] for selecting one of three programs – "GROUND", "FHS" – front sphere, "RHS" – rear sphere.

There is also a count indicator.

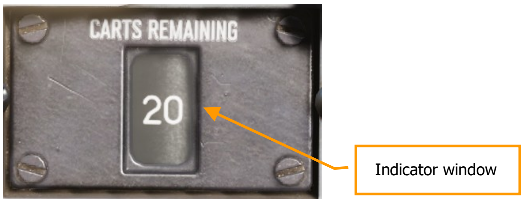


Figure 19: Count indicator

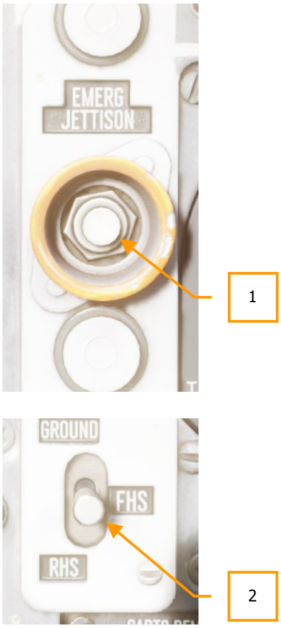


Figure 20: Countermeasures dispenser control panel

Radar altimeter indicator

The radio altimeter is designed to measure the true altitude of an aircraft above the ground surface. The radio altimeter operates in the decimeter wave range and measures the true altitude from 0 to 3000 ft regardless of visibility conditions and the nature of the earth's surface. The indicator scale [2] is graduated accordingly.

The radio altimeter indicator provides continuous display of altitude by pointer [1], it provides data for light signaling and voice information about the aircraft passing through a "low" altitude threshold [5] in descending. The threshold is set by the handle [4].

If the red flag [6] is not dropped – the altimeter functions normally and indication should be considered as reliable.

The indicator is equipped with a status check button [3]

Figure 21: Radio altimeter indicator A-037

Engine RPM Tachometer. ITE-2TB

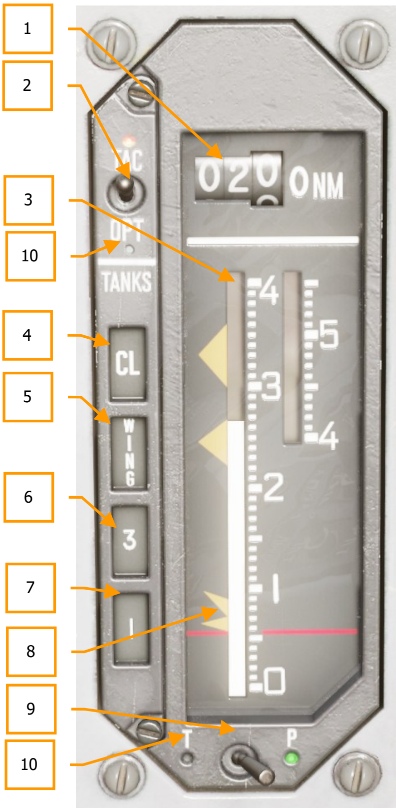
The tachometer – engine RMP indicator is designed for continuous measurement of the angular velocity of engine main shaft, expressed as a percentage of the maximum shaft speed.

The ITE-2TB measuring device has a scale [3] and two pointers, showing the speed of the left [1] and right [2] engine respectively from 0 to 110% with 1% accuracy.

Figure 22: Tachometer ITE-2TB

Fuel flow metering system indicator. ISTR4

The device is designed to display the remaining fuel and flight rang estimations.



1. Estimated flight distance indicator
2. Toggle switch for "TAC" - "OPT" estimations
3. Total fuel gauge
4. External tanks empty light "CL"
5. Wing fuel tank empty light "WING"
6. Tank 3 empty light "3"
7. Tank 1 empty light "1"
8. Minimum fuel marker 550 kg
9. Switch "T" - "P"

Figure 23: Fuel flow metering system indicator ISTR4

On the front panel of the ISTR4 indicator there is a switch "T-R" [9], to select information about remaining fuel base on direct in-tank measurement or based on flow-measuring calculations of STR system; a switch "TAC. – OPT." [2], change estimated distance indication: for max fuel conservative flight modes "OPT" or for actual flight mode fuel consumption.

The ISTR4 scale provides fuel readings in hundreds of kilograms. The estimated distance in EN cockpit in nautical miles.

Gas temperature meters. ITG-1

Thermoelectric thermometers are designed to measure the temperature of the exhaust gas flow behind the engine turbine.

Figure 24: Gas temperature meters. ITG-1

1. Left engine gas temperature scale
2. Left engine gas temperature pointer
3. Right engine gas temperature scale
4. Right engine gas temperature pointer

The ITG-1 meter is a magnetoelectric millivoltmeter, has a scale with a measurement range from 200°C to 1100°C, digitized at the points: 200, 400, 600, 800 and 1000°C with a mark of 100°. The readings must be by 100.

The scales have the yellow and red painted marks on a rim:

– The maximum permissible temperature when starting the engine in flight and on the ground
– The maximum permissible temperature when operating at maximum, afterburner and transient modes.

Combined oxygen indicator

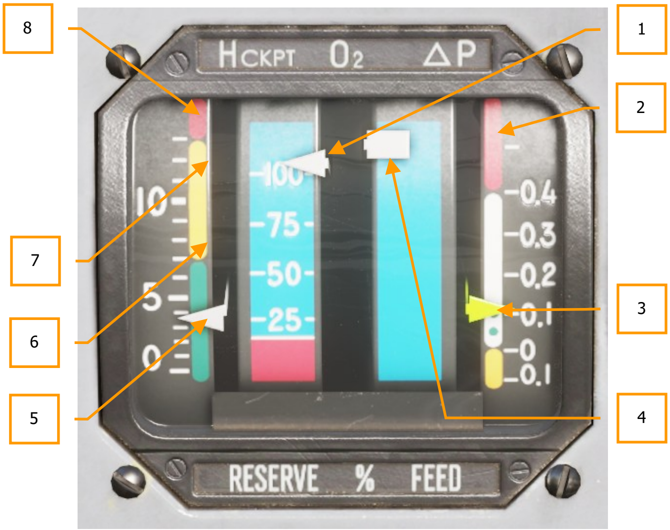


Figure 25: Combined life support indicator. IKG-1

The device is designed to monitor the condition of oxygen equipment systems.

1. Oxygen quantity in %
2. Cockpit pressurization failure
3. Cockpit pressure differential index
4. Oxygen flow indicator
5. Cockpit altitude index x 3300 ft (1000 m)
6. Cockpit alt 0 to 23000 ft (0…7000 m)
7. Cockpit alt 23000 to 42700 ft (7000…13000 m)
8. Cockpit alt above 42700 ft (13000 m)

Combined pressure indicator

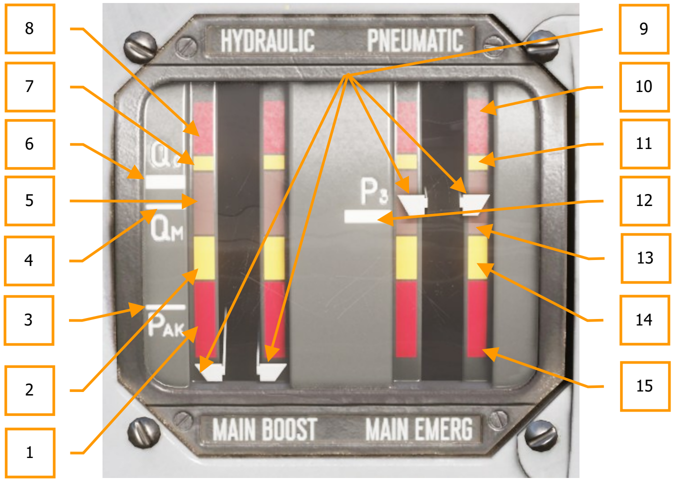


Figure 26: Combined pressure indicator. IKG-1

The combined pressure indicator IKG-1 is designed for in-cockpit display of the hydraulic pressures and the air pressure in the main and emergency pneumatic systems of the aircraft.

IKG-1 has a pressure displays the hydraulic system pressures from 0 to 300 kp/cm^2, and for the pneumatic system from 0 to 260 kp/cm^2

The profile scale of the indicator "HYDRAULIC" "MAIN BOOSTER" is graduated into the ranges:

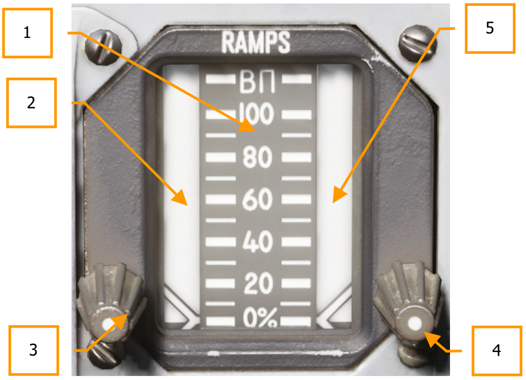
– red [1], corresponding to pressure from 0 to 100 kp/cm^2,
– yellow [2] – from 100 to 150 kp/cm^2,
– brown [5] – from 150 to 220 kp/cm^2
– yellow [7] – from 220 to 240 kp/cm^2
– red [8] – from 240 to 300 kp/cm^2, and designations
– $P_{ак}$[3] – pressure in hydraulic accumulators,
– $Q_М$ – maximum pump performance[4],
– Q0 – pump performance is zero [6].

The profile scale of the "PNEUMATIC" "MAIN EMERG" indicators are divided between the corresponding ranges:

– red [10], corresponding to pressure from 0 to 86.5 kp/cm^2,
– yellow [11] – from 86.5 to 130 kp/cm^2,
– brown [13] – from 130 to 191 kp/cm^2,
– yellow [14] – from 191 to 208 kp/cm^2,
– red [15] – from 208 to 260 kp/cm^2
– designation $P_З$ [12] – charging pressure.

The beginning of the scales in ICG-1 indicator starts from bottom.

Air duct ramp position indicator



1. Ramp position scale
2. Left ramp position marker area
3. Left ramp setting handle
4. Right ramp setting handle
5. Right ramp position marker area

Figure 27: Ramp position indicator.

Magnetic compass. KI-13

The magnetic liquid compass KI-13 (Figure 28) is designed to determine the aircraft's heading and serves as emergency reserve for the main flight direction indicators.

Figure 28: Magnetic compass

The accuracy of compass readings may be influenced by magnetic and electric fields.

AEKRAN

The built-in monitoring and warning system "AEKRAN" is part of the aircraft's warning and information system. It combines display event monitoring and recording units.

AEKRAN display and stores the information about the failures, registered excessive parameters and other data displayed in a form of short messages. After the aircraft has landed, the AEKRAN can be read, providing to the technicians the events that had happened during the flight.

The system consists of a logic and control unit (LCU) and a display unit.

The "AEKRAN CALL" button is a main control button to operate the system.

The logic unit requests the state of individual sensors monitoring the operating parameters of the aircraft according to the "OK"-"FAILURE" principle. If any operating parameter of an aircraft unit or system exceeds the norm or if one or more sensors fail, the corresponding message is generated, displayed and recorded. The logic unit issues information on display in order of priority.

Failure indication is displayed with the flashing "MASTER CAUTION" lamp-button with the voice command "See AEKRAN " issued to the VIVAS. The information on the display stays visible until the pilot presses the "AEKRAN CALL" button and if other messages are present, display switches to show next until all has been reviewed by the pilot.

If there are no more messages in the queue, it disappears from the "AEKRAN" display and the MEMORY light goes lit. All messages from the memory might be called out by pressing the "AEKRAN CALL" button if there are no more unchecked messages in the "queue".
If a message of a higher priority arrives, the message with a lower priority will go back the "queue" - the QUEUE lamp lights up, and the "higher" message is displayed. The same with the failures. All messages are recorded and saved in the EPROM unit of AEKRAN.

If the information received by the logic unit does not belong to the dedicated list of displayed messages, it only saved in EPROM without being displayed.

The " AEKRAN" system has three operating modes:

1. The BIT mode is performed by pressing the "AEKRAN CALL" button before starting the engines with the "BATTERY ON-BOARD. AIRFIELD" and "NAVIGATION" switches on if the "FAILURE" lamp of the system is not lit.

15 seconds after pressing the " AEKRAN CALL" button, the signals "SELFTEST" and "AEKRAN READY" should be printed in sequence.

If self-test is not performed before starting the engine, AEKRAN will fail

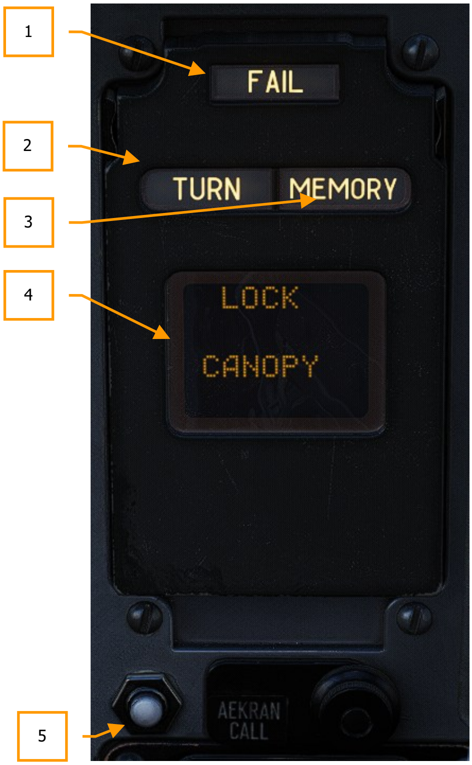
If the "AEKRAN" malfunctions, the following signs of failure may appear:
- the "FAILURE" light board might appear and no messages or distorted will appear in 15 sec.

If the AEKRAN equipment fails in flight, continue with your mission and rely on VIVAS solely.

The built-in control of the AEKRAN is performed by the pilot before the engine start procedures.

2. Ground check of AEKRAN system is performed by technical personnel.

3. Normal operation and monitoring – this mode is switched on automatically right after the "ENGINE START" button is pressed.



1. "FAIL" light
2. "TURN" light
3. "MEMORY" light
4. Message Display
5. "AEKRAN CALL" button

Figure 29: "AEKRAN" unit front view

RHAW. SPO-15LM Radar warning station.

Figure 30: RHAW. SPO-15LM display unit

1. Device ready light
2. Main threat azimuth light
3. Threat azimuth light
4. Tracking Warning Light - RED
5. Emitter power level indicator
6. Own aircraft silhouette
7. Threat azimuth indicator (rear channels)
8. Primary threat azimuth indicator (rear channels)
9. Main threat type light
10. Threat type light
11. Brightness control knob
12. BIT switch "MANUAL" - "AUTO" - starts manual or automatic SPO check.
13. Main threat position light (N/I)
14. Elevation angle indicators. "B" is the upper hemisphere, "H" is the lower hemisphere.

The RHAW system is powered up by the "SPO" switch on the control unit panel – Figure 31.

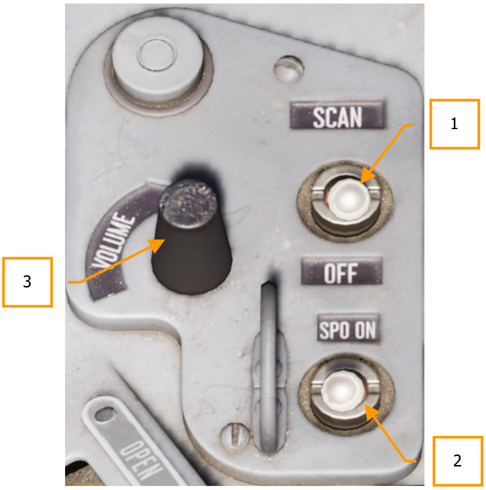


Figure 31: SPO-15LM control unit panel in the cockpit of Mig-29

1. SCAN mode switch
2. Power on\off
3. Audio volume

Dispenser control button

Figure 32: Dispenser control

Dispenser check button is not currently implemented.

Voltmeter

Figure 33: Voltmeter

The voltmeter is designed to measure onboard 28V DC voltage supply circuits: DC generator, batteries, ground DC power source.

1. Voltmeter scale
2. Volts pointer

Pitot selection lever

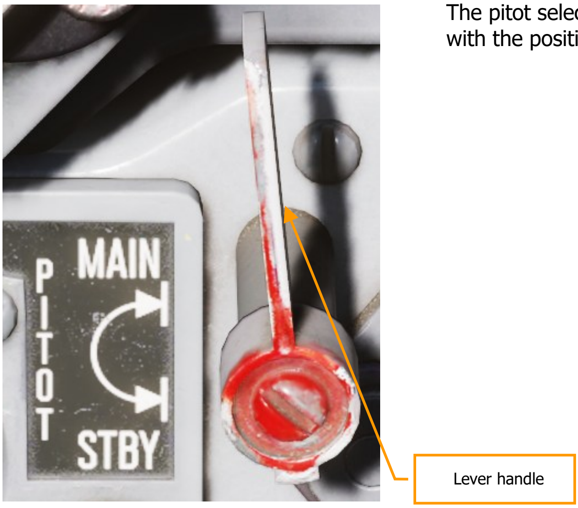


Figure 34: Pitot selection lever

The pitot selector lever is located on the pedestal panel with the positions - MAIN and STBY

Brake air pressure manometer. M-2A

The M2A pressure gauge is designed to measure air pressure present in brake hoses and cylinders in the range from 0 to 16 kp/cm².

The M2A device consists of two independent identical pressure gauges, mounted in one housing.

Both scales of the device are graduated uniformly from 0 to 16 kp/cm² with digitization at points 0, 4, 8, 12, 16 with a division value of 0.5 kp/cm².

Figure 35: Manometer. M-2A

1. LH main wheel brake pressure
2. MAX normal brake pressure 8±0,5 kp/cm²
3. MAX run-up brake pressure 11±1,0 kp/cm²
4. RH main wheel brake pressure

Cockpit temperature setter

Figure 36: Cockpit temperature setter

Weapon settings panel. PC-31

Figure 37: PC-31

Not implemented

Emergency Landing gear handle

Figure 38: Emergency Landing gear handle

A red handle, marked EMERG GEAR is located beneath the left front panel. It is used to lower the landing gear pneumatically.

After the landing gear has been extended with the emergency gear lowering system, normal gear retraction is impossible until ground serviced.

Right console

The right console contains equipment that does not require frequent adjustments during operation.

The right console consists of vertical and horizontal panels to control illumination, radio equipment, power sources.

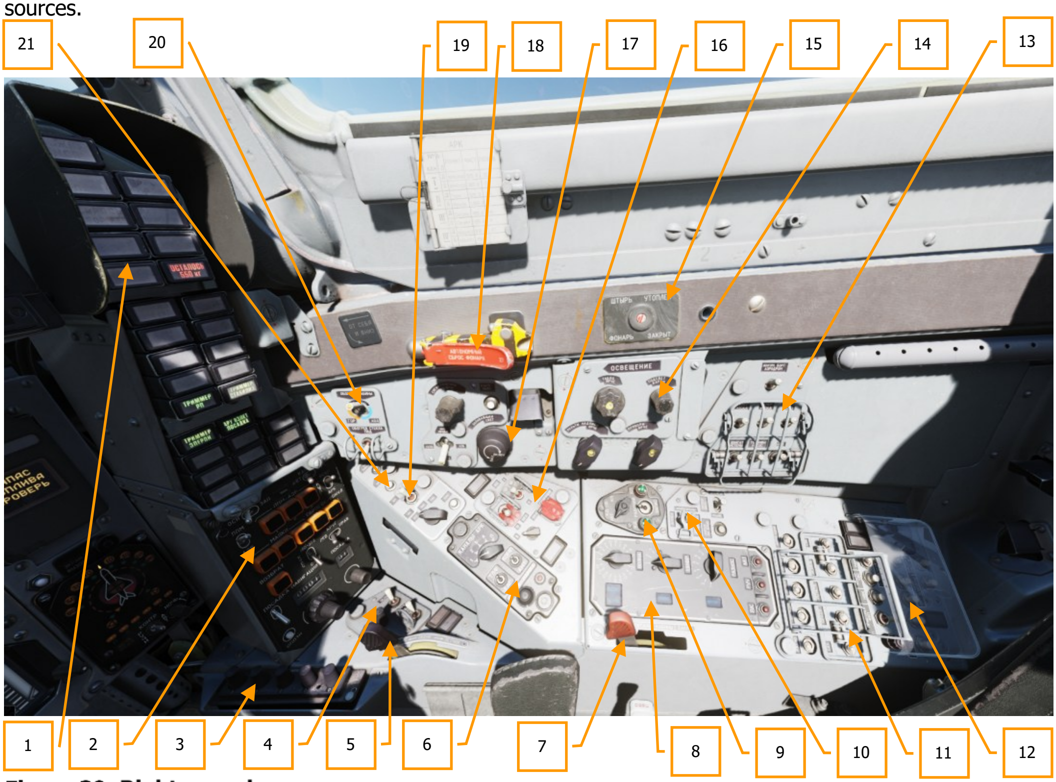


Figure 39: Right console

1. Annunicator panel or Telelight panel – TLP.
2. Navigation system control panel. A-323
3. ID index coder. Not implemented.
4. RHAW SPO-15LM control panel
5. Cockpit air blow distribution lever
6. ADF control panel
7. Cockpit air supply lever
8. Guidance system panel. Not available.
9. KD system panel. Not available

10. Engine startup panel
11. System power panel
12. Control and test panel
13. Electrical power panel
14. AFT lightning control panel
15. Canopy close check pin
16. IFF transponder. Not implemented yet.
17. FWD lightning control panel
18. Emergency canopy jettison lever
19. AM/FM switch
20. Cockpit air conditioning control panel
21. Voice information and warning system. VIWAS controls

TLP. Annunicator Panel

The Telelight Panel abbreviated as TLP in German manual, is an aircraft annunciator panel that provides immediate warning and status display on various system events and conditions. Red lights correspond to critical events and conditions; the green lights correspond to normal state conditions.

Normally every malfunction is indicated by a flashing red light on TLP in conjunction with the MASTER CAUTION light flashing. After MASTER CAUTION light has been reset, the warning light on TLP goes steady until problem is resolved.

Figure 40: TLP. Annunciator panel

Navigation system control panel. A-323

This panel plays a central role in making up the flight path and during the autonomous navigation, with or without NDB coverage in the flight zone. It can store up to 9 navigation points, each defined by a set of coordinates. These points are logically categorized into three types: WP (waypoints), A/D (airfields), and BEACON. The categorization is logical rather than physical—any stored point can be used as a navigation target during long-haul flights.

Figure 41: Navigation system control panel. A-323

1. **GYRO Switch**. A two-position toggle switch, positions marked "MAIN"-"STBY", selects the appropriate gyro system used for navigation
2. **"WP" - "A/D" Buttons**
   Three combined pushbutton-lights, marked 1, 2, 3, to select a navigation point or an aerodrome
3. **"WP" –"A/D" Switch**
   A two position toggle switch, marked WP-A/D, selects appropriate function of the corresponding pushbuttons

4. **"BEACONS" Buttons**
   Three combined pushbutton-lights, marked 1, 2, 3, to select a beacon for NAV system update
5. **"RETURN" Button**
   A combined pushbutton and indicator light activates RETURN
6. **"LANDING" Switch**
   A two position toggle switch to select the ILS if not automatically switched in.
   7. **"IDENT" Button**. Signal upon request from the ground, not available
8. **RSBN Channel Selector Knob**
   Selects desired RSBN type in MAN
9. **RSBN Channel Selector Knob**
   Selects desired RSBN channel in MAN
10. **ILS Selector Knob**
    Selects desired ILS channel
    11. **"NAVIGATION" Channel Window**
        Manually selected RSBN beacon type and channel for navigation
    12. **LANDING Channel Window**
        Displays manually selected ILS channel Window for indicating the frequency code of the channel (FCC) of the PRMG beacon
13. **"COURSE" Switch**
    A two position toggle switch, positions marked "0 - 179°" and "180 - 359°", selects appropriate hemisphere for approach
14. **"CIRCLE" Switch**
    A two position toggle switch, positions marked "LEFT"-"RIGHT", selects direction of LDG pattern
15. **"RESET" Button**
    A combined pushbutton-light to deselect the previously selected BEACON.
16. **"COMP. ZERO" Button**
    A combined pushbutton-light to reset the computation results in NAV computer
17. **"REL BEARING" Switch**
    A two position toggle switch, positions marked "RSBN"-"ADF", selects RSBN or ADF display on the HSI when navigating to beacons.
18. **"CHANNELS" Switch**
    A two position toggle switch with following functions:
    "AUTO" – automatic use of beacons
    |MAN| - for manual input of beacon type and channel
    19. **"CORR" lamp display**. This lamp turns on when the radio correction has been applied in auto modes.
20. **"D<21" lamp display**. Turns on when the distance to target nav point is less than 21 nm.

Voice information and warning system. VIWAS

The VIWAS provides voice warning to focus the pilot's attention to a critical event indicated on the annunciator panel or AEKRAN.

In case of multiple malfunctions, the voice warnings are queued according to the priority list.

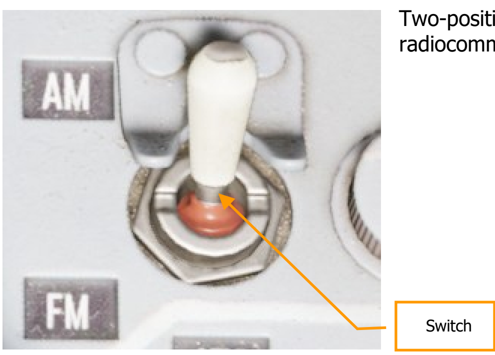
The VIWAS is switched-on with the battery power-up. Two pushbuttons are provided for operation on the RH control panel.

The "CHECK VOICE WARN" button is used to initiate a self-test. Pressing the "REPEAT VOICE WARN" button repeats the last warning.

1. Voice message repeat button
2. Speech informant unit test button

Figure 42: Voice information and warning system controls

AM/FM switch



Two-position switch to select modulation type in voice radiocommunication.

Figure 43: AM/FM switch

Control panels for lighting equipment

The aircraft's lighting equipment includes:
– Internal lighting, consisting of a white light illumination system for instruments and consoles; a floodlighting system for instruments, consoles, and a map; an in-cockpit light signaling system,
– Electrical headlight control system,
– External signal lighting.

Figure 44: Control panels for lighting equipment

The **"CONTROL LAMP" button** [1] turns on the lamps and the display to check their functionality.

The knob **"LTS ILLUM BRIGHT"** [2] controls the brightness of flight and landing indicator IP-52-03

The air navigation lights are controlled by a toggle switch "**NAV LTS"** [4] in four positions: down – off, left – full brightness 100%, right – dim, 10%, up – flashing.

The **"PANEL"** [5] knob controls the brightness of the indicator inscriptions on the light boards and has two functions: in the pressed position, the adjustment is performed manually, in the unpressed position - automatically.

The **"INSTRUMENT"** [8] knob controls the illumination conditions for convenient view and readability of the cockpit instruments.

The "**CONSOLE"** [7] knob controls the brightness of the inscriptions found on consoles.

The **"FLOODLIGHT"** [3] knob controls the brightness of white floodlight.

The **"MAP ILLUM"** [6] knob controls the brightness of kneeboard map illumination.

Automatic direction finder control panel. ADF

The ADF is actually a dedicated radio receiver that provides direction finding or radio monitoring in autonomous navigation. Eight different stations can be programmed on the ground for inflight use. It can home to NDB or any broadcast radio station with for the following tasks:
– Flight to and from the radio station with visual indication of the course angle;
– Determination of radio station bearings using the course indicator;
– Performing landing approaches together with the other stations;
– Receiving and listening to signals from medium-wave radio stations in available frequency range.

The ADF has the following technical data:
– Operating frequency range of the receiver 150…1299.5 kHz;
– Error in outputting the heading angle to the PNP device ±30;
– When working with the PAR-8 ground radio station, the radio compass ensures stable operation at a range of at least 183 nm at a flight altitude of 33000 ft and at least 97 nm at a flight altitude of 3300 ft.

Device has two operating modes:
1. Automatic bearing mode – "COMP", or compass.
In this mode, the beacon or radio station homing direction detected by ADF is displayed on HSI;
2. The "ANT" mode provides no homing, just listening to broadcast or Morse call sign of a beacon. In this mode, the radio compass operates as a conventional medium-wave receiver with sufficiently high sensitivity and noise reduction.

Figure 45: ADF control panel

The control panel controls for channels, modes and antenna.

1. **ADF Channel select switch**. 1, 2, 3, 4 or P
2. **"VOICE" - "CW" switch**. Selects the receiver mode – voice or Morse telegraph.
3. **Volume control knob**
4. **"LOOP" button**. Turns on the frame (loop) antenna for receiving radio beacon signals
5. **"COMP" - "ANT" mode switch**, compass or non-directional antenna mode.

Cockpit air conditioning devices

Figure 46: Cockpit air supply control lever

To select air for blowing into the cockpit, move it to the "OPEN" position.

Figure 47: Blower control lever

In the "OPEN" position, the extracted air is used to blow air onto the canopy glass.
In the "PILOT" position, the flow is directed to the suit ventilation.

Heating control panel

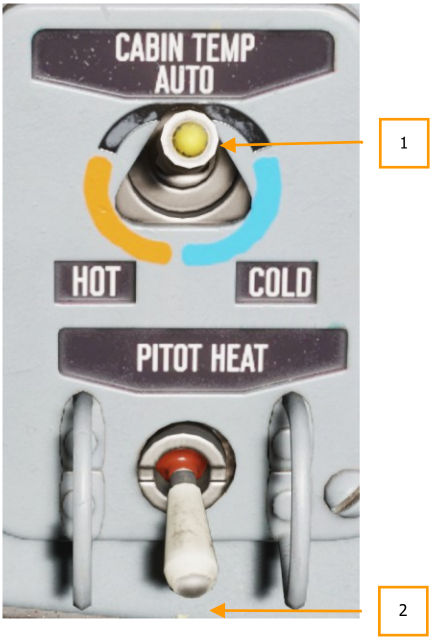


Figure 48: Heating control panel

1. **Four-position heating mode switch**.
   – "AUTO" – automatic mode in accordance with the temperature setter
   – "HOT" – heating on
   – "COLD" – cooling on
   – Central position of the switch turns off the heating circuits.
2. **PITOT heat switch**. Powers the pitot tubes and cockpit glass

Electrical power panel

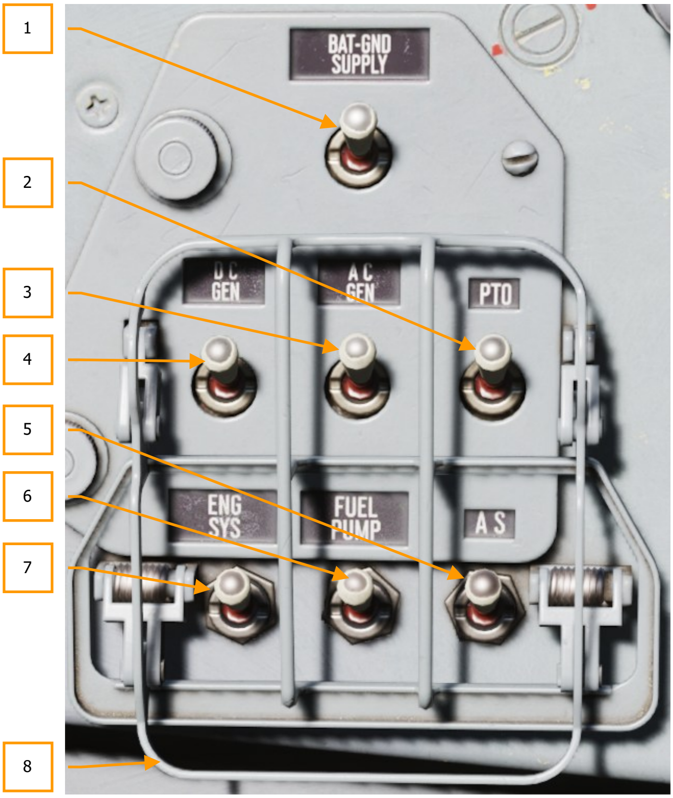


Figure 49: Electrical power panel

It contains the switches for the electrical power system and for essential engine control components. The two-position toggle switches that turn on the following:

1. Engages main power source circuits, both battery and ground power.
2. Engages DC / AC converter
3. Engages AC generator
4. Engages DC generator
5. Powers of the engine anti-surge system
6. Power supply for engine actuators and sensors
7. Activation of the engine fuel pump
8. "ALL ON" convenient frame type handle.

IFF controls

Identification index encoder

Figure 50: Identification index coder set нandles (not implemented yet).

The index is used to set the board identifier.

IFF transponder mode switch

Figure 51: IFF transponder mode switch

IFF transponder controls

Figure 52: IFF Transponder control (not implemented yet)

Control panels for the state identification system and guidance

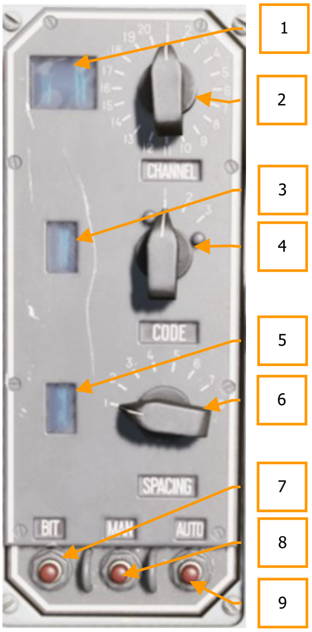


Figure 53: IFF Status control panels (not implemented yet)

Canopy lock pin (check) indicator

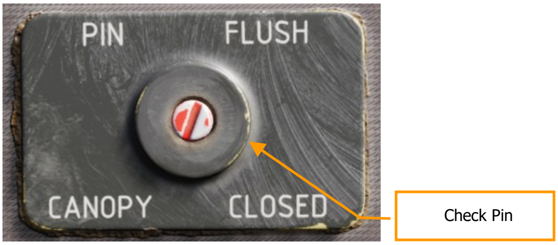


Figure 54: Canopy lock pin indicator

Lock pin indicator indicates if canopy is closed stiffly. If the canopy is not closed, the pin is extended outside the rim, if the canopy is closed successfully, the pin is recessed.

Engine start control panel

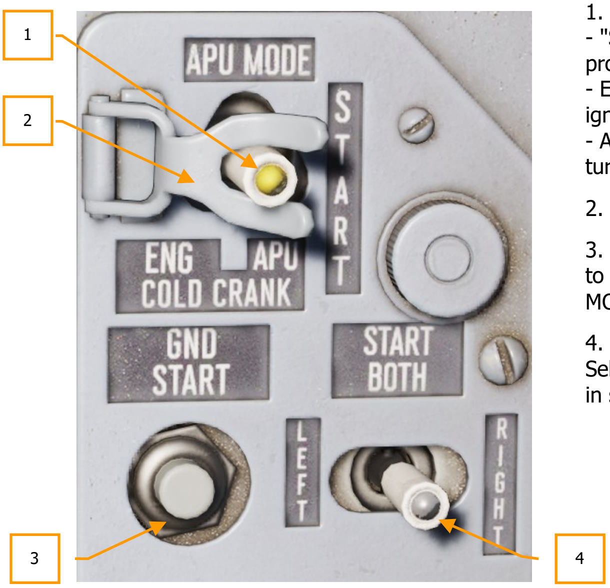


Figure 55: Engine start control panel

1. **APU MODE switch.** Three positional.
- "START" – normal position, guarded by a protective bracket.
- Engine cold crank – for idle cranking without igniting.
- APU cold crank – the same function for APU turbo-starter engine.

2. **APU MODE switch protective bracket**

3. **"GND START" button.** Used on the ground to fulfill the procedure defined by the APU MODE switch.

4. **Three-position engine selector switch.** Selects either left or right or both engine start in sequence.

Emergency canopy jettison handle

Figure 56: Canopy jettison handle

System power panel, test and check panel

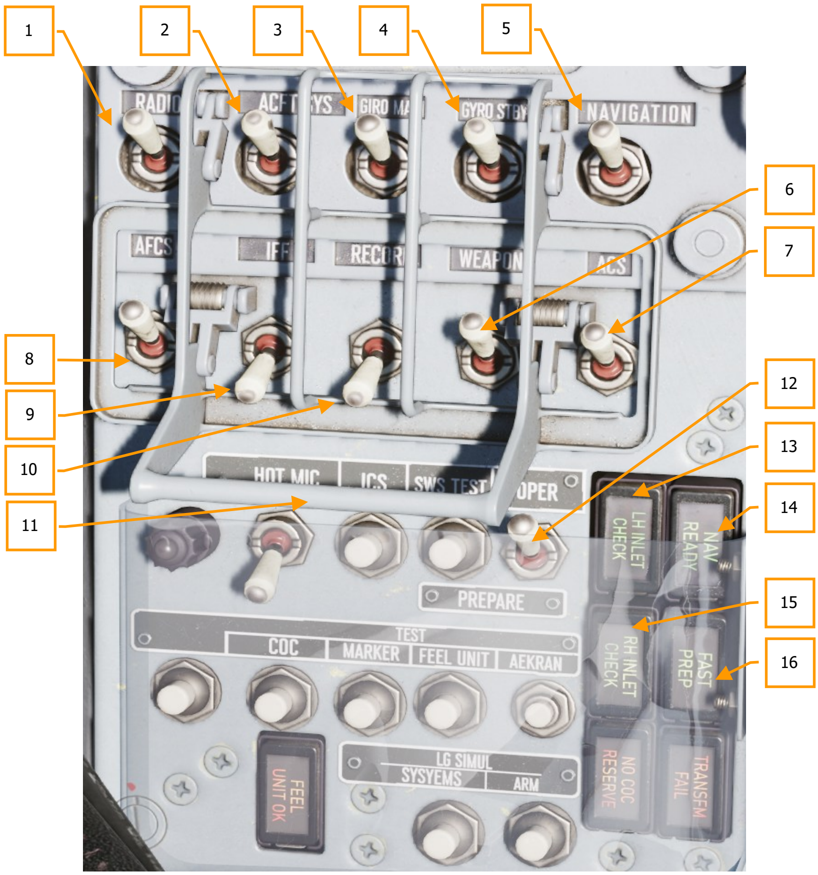


Figure 57: On-board systems power supply panel, test and check panel

The following switches, displays and buttons are located on the panel:

1. **"RADIO"** - to power-up the radio stations
2. **"ACFT SYST"** - for supplying power to onboard radio-electronic equipment (avionics)
3. **"GYRO MAIN"** - for supplying power to the main gyro (heading and vertical control system)
4. **"GYRO STBY"** - for supplying power to the standby gyro (heading and vertical control system)
5. **"NAVIGATION"** - for supplying power to the navigation system.
6. **"WEAPON"** - for supplying power through the weapon enabling circuits.
7. **"ACS"** - for supplying power to the weapons (armament) control system (WCS).
8. **"AFCS"** - for supplying power to the automatic flight control system
9. **"IFF"** - for power supply to IFF identification transponder
10. **"RECORD"** - for supplying power to aircraft state recording device

11. **"ALL ON" bracket**. To toggle on all above-mentioned switches
12. **INS navigation mode switch.** "OPER" - "PREPARE"
13. Light panel "LH INLET CHECK "
14. Light panel "NAV READY"
15. Light panel "RH INLET CHECK"
16. Light panel "FAST PREP"

Left console

Left console consists of vertical and horizontal panels designed to control the power plant parameters, fuel system, fire extinguishing, aircraft control automation, radio equipment and other equipment that the pilot most often has to work with in flight.

The engine control lever with buttons for turning on the SPU radio transmitter and the brake flaps release switch is located in the best reach area

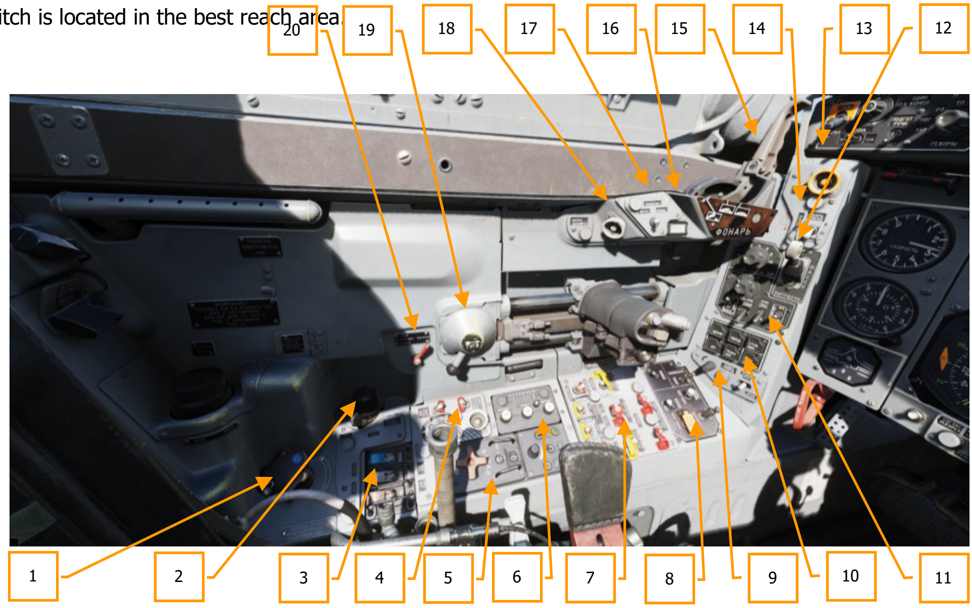


Figure 58: Left console

1. Oxygen supply valve
2. Suit ventilation control knob.
3. Oxygen system control panel
4. Control of the ARU, emergency pumping station and MRK. Drag parachute drop button
5. R-862 radio station control panel
6. Wing flap control panel
7. Emergency systems control panel
8. Radar control panel PU-S31
9. Chute release button
10. AFCS controls
11. Radar control panel

12. Landing gear control lever
13. Emergency missile launch button
14. Landing lights toggle switch
15. Canopy closing control handle
16. "CLOSE CANOPY" warning light
17. Weapon external stores selector switch
18. IR sound volume knob and the rudder trim switch
19. Throttle tightening handle
20. Cockpit emergency decompression lever

Oxygen supply valve

To turn on the supply of the pilot with breathing mixture during the flight, open the oxygen supply valve.

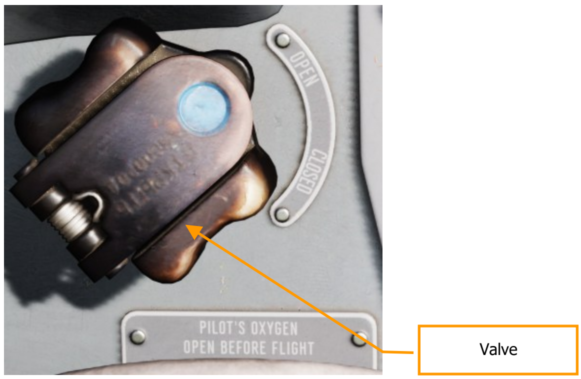
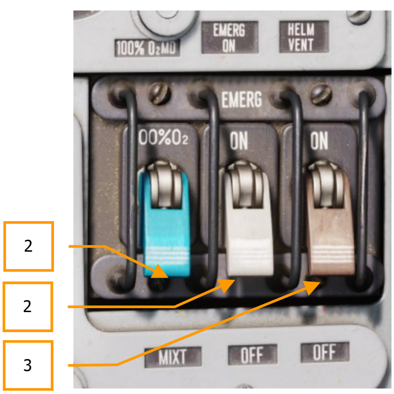


Figure 59: Oxygen supply valve

Oxygen system control panel



This panel contains three toggle switches equipped with protective covers:

1. 100% oxygen or "MIXT" selecting switch
2. Emergency oxygen supply system – on\off.
3. Ventilation of the pilot helmet

To use, open the cover first then move the toggle switch to the desired position.

Figure 60: Oxygen system control panel

Switching to 100% oxygen supply is mandatory during combat flights, regardless of altitude, and in the event of smoke in the cockpit. Emergency oxygen must be activated if the primary oxygen system malfunctions or if the pilot experiences any signs of physical distress. In such cases, oxygen consumption increases by a factor of 2 to 3, requiring heightened monitoring of supply levels. When flying at low altitudes, it is also recommended to activate the ventilation system to maintain cockpit air quality and comfort.

Cockpit emergency decompression control

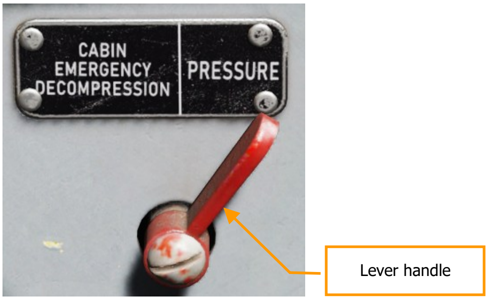


Figure 61: Cockpit emergency decompression valve lever

Pilot suit ventilation regulator

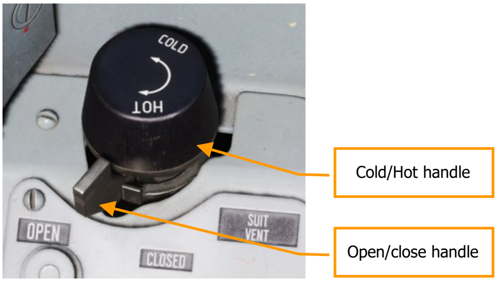
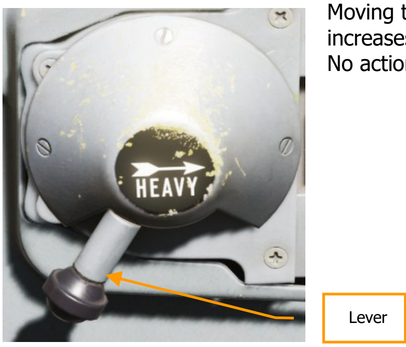


Figure 62: Pilot suit ventilation regulator

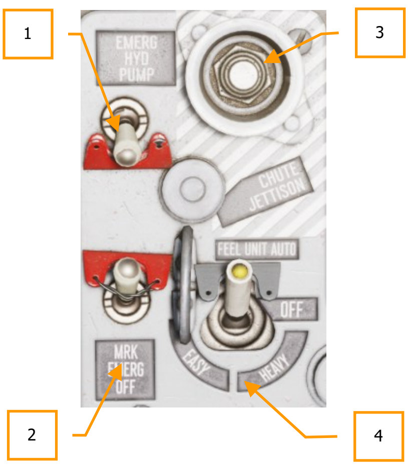
Throttle tightening handle



Moving the handle back reduces the force on the throttle, moving forward increases it.
No action.

Figure 63: Throttle tightening Handle

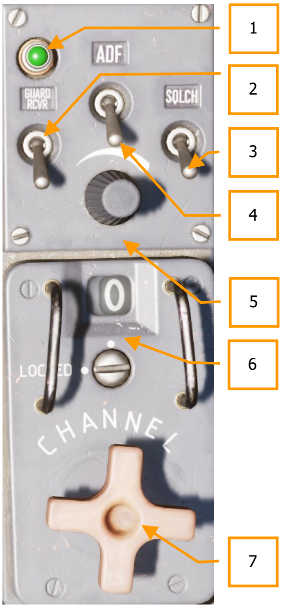
Feel unit control.



1. **Emergency pumping station switch**. Not implemented yet.
2. **Nose wheel strut control emergency shutdown**. Not implemented yet.
3. **Drag chute drop button**.
4. **FEEL UNIT** controls the authority of AFCS in flight handling. Not implemented yet.

Figure 64: Feel unit control panel

R-862 radio control panel



1. **Guard frequency signal receiving lamp indicator**.
2. **Guard frequency receiver switch**. Toggle to monitor the guard frequency.
3. **SQLCH switch**. Toggle for Noise suppression
4. **ADF switch**. Turn on to switch the audio circuits to ADF receiver outputs.
5. **Master volume control knob**
6. **Selected channel indicator**
7. **Preset channel selector**

Figure 65: R-862 radio control panel

The onboard radio transceiver (radio) provides radio communication within line of sight between own aircraft and air or ground correspondents on predefined channels, including the guard (emergency) frequency of 121.5 MHz

The radio station can operate 20 preset channels both in meter range: VHF – from 100 to 149.975 MHz; and decimeter range: UHF – from 220 to 399.975 MHz.

The range of radio communications between an aircraft and ground stations at a flight altitude of 3300ft is at least 65 nm, at an altitude of 16500 ft – at least 135 nm, and at least 189 nm on altitudes of 33000 ft.

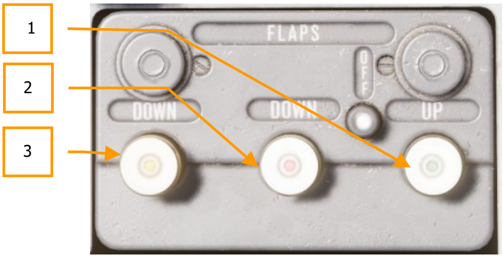
The time of transition from one to another channel is no more than 1.5 s.

The radio station is ready for operation immediately after power-up.

The radio antenna is installed in the tip of the right wing. When performing turns with a bank of more than 45°, the antenna may be shaded and radio communication may be lost in some attitude configurations.

The radio station support both modulation types for voice communication - frequency (FM) and amplitude (AM). The modulation mode is selected in accordance with the mission instructions by the AM-FM switch installed on the right console.

Wing flap control panel



Flap operation is controlled by three pushbuttons on the left console. Two are marked FLAPS DOWN, one FLAPS UP. Pushing either FLAPS DOWN button extends all flaps. Pushing the FLAPS UP button will retract the flaps and the slats, in a case of the gear is in up position:

1. In the "RETRACTED" position
2. In the "TAKEOFF" position
3. In the "LANDING" position

Figure 66: Wing flap control panel

The flaps and slats would extract both after either the "TAKEOFF" [2] or "LANDING" [3] button is pressed.

The slats are retracted manually by pressing the "UP" button [1] when WoW (weight on wheels) condition is active or automatically if the landing gear is retracted in the air.

In case of takeoff without flaps and slats – in a case "UP" button was previously pressed - the slats are extracted automatically right after the right landing gear loose contact with the ground – no WoW state .

After the front landing gear is retracted, the slats become fully automatic and operate depending on the angle of attack and the speed Mach number.

The speedbrake flaps are pilot-operated and provide effective aerodynamic drag to decelerate the aircraft during aerial maneuvers and landing. They are controlled via a spring-loaded switch located on the right-hand throttle, which automatically returns to the IN position when released. Full extension is achieved within approximately 3 seconds.

To protect the actuators and speedbrake surfaces at high speeds, a blow-back feature is incorporated. This mechanism automatically retracts the speedbrakes when airspeed exceeds 540 kts, preventing structural damage.

Speedbrake operation is not possible with the centerline tank installed, or gear down.
In case of general electrical failure, the speedbrakes retract automatically

Emergency control panel

Figure 67: Emergency control panel

The devices on the control panel are designed to respond to emergency situations.

1. Emergency ramp retraction switches, separate for left and right engines
2. Emergency fuel shut-off valve toggle switches
3. Protective covers for shut-off toggle switches
4. KSA fire extinguisher switch
5. Afterburner emergency shutdown switch
6. Generator Drive Emergency Shutdown Switch
7. Air-to-air engine start switches, separate for left and right engines

Not available.

Weapon control panel. PU-S31

Figure 68: Weapon control panel PU-S31

Designed for control weapon release modes

1. **"COOP" switch.** This switch has a dual function: 1. It switches on the radar and IR homing equipment in cooperative mode; 2. In a case of chute retarded bombing it commads should the bomb be released if high drag (retarded) or low drag (no retard) configutation.
2. **"A/A" – "A/G" mode switch** select deployment mode both for cannon or missiles. "AIR" – for air targets, "GROUND" – for ground targets.
3. **Explosion mode toggle switch** on jettisson. "ARMED" - explosion, "SAFE" – no explosion.
4. **Emergency bomb release button** with protective cover. To release, lift up the cover and press the button.
5. **Command Guidance mode switch**
   Position up – automatic guidance by a datalink, voice guidance from the command post. Currently not implemented.
6. **"LOCK" switch**. Defines if radar can lock on the targets being detected by IFF as friendly. Up – "FOE", down – "FRIEND".

Chute release button

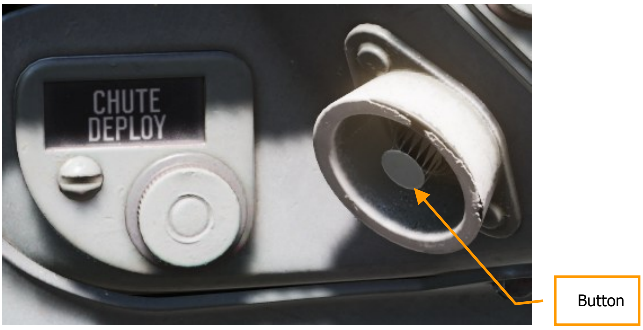


Figure 69: Drag chute release button

The landing drug chute enormously reduces the requred runway distance at landing. To use it or not is solely a pilot's decision. Chute is mandatory for:
– Landing immediately after takeoff
– Landing on a wet RWY
– Short field landings
– Landing without slats
– Aborted takeoff after nose wheel lift off
– AFCS Feel unit is in the position "Heavy".

The drag chute will separate from the aircraft if the aircraft exceeds 175 kts

External stores selector switch

Figure 70: External stores selector switch

The toggle switch is used to select the exact pair of stores (pylons) for the current attack.

When moving to the left position, the inner stores are selected; when in the right position, the outer stores are selected.

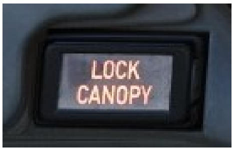
Canopy closing control handle

It is designed to bring the cockpit canopy into one of three provided positions.

Figure 71: Canopy closing control handle

The positions of the canopy closing control handle are, respectively:

1. The canopy is fully open
2. The canopy is partially open
3. The canopy is completely closed and locked.



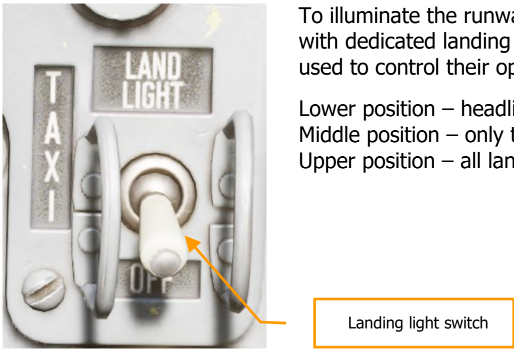
When the canopy is open, the red sign flashes "LOCK CANOPY" on the signal board located to the left of the handle.

Landing gear control lever

Moving the handle to the upper position retracts the gear and vice versa.

Figure 72: Landing gear control valve

Landing lights toggle switch



To illuminate the runway during landing and taxiing, the aircraft is equipped with dedicated landing headlights and taxi lights. A three-position switch is used to control their operation:

Lower position – headlights off
Middle position – only taxi light is operational
Upper position – all landing lights on.

Figure 73: Landing light control switch

Emergency missile launch button

The aircraft is equipped with a system that provides emergency launch of missile/rocket type ammunition.

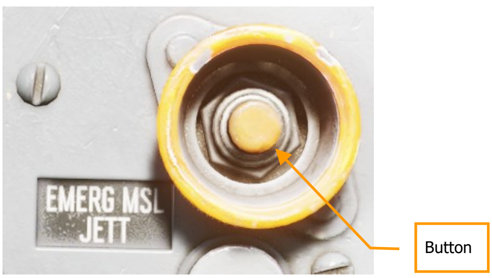


Figure 74: Emergency missile launch button

Hold the button down if you need to perform an emergency launch of missiles and ASP.

Radar control panel. PUR-31

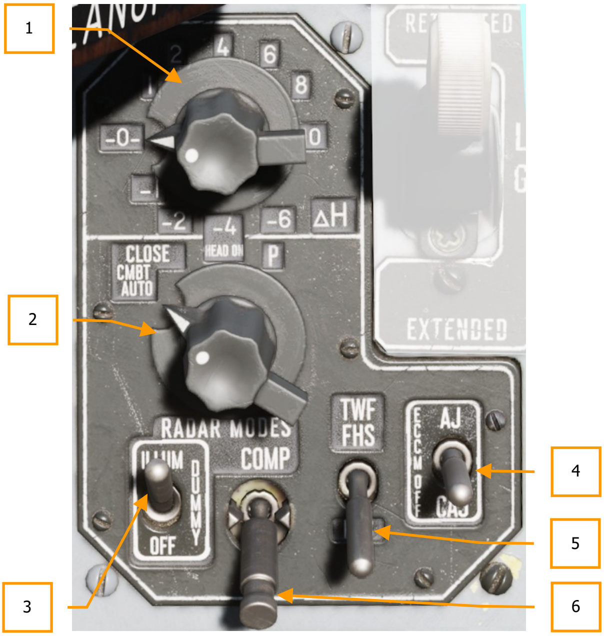


Figure 75: Radar control panel. PUR-31.

The control panel contains the radar controls:

1. **Radar antenna elevation selector**
2. **Radar modes switch**
   "AUTO" – Provides switching PFR frequency if target parameters are unknown.
   "CLOSE CMBT" – Optimized for close combat engagements
   "HEAD ON" – For intercepting approaching targets
   "P" – For chased or retreating targets
3. **Emission control switch**
   "ILLUM" – Combat mode. Radar fully operational.
   "DUMMY' – Antenna equivalent mode for testing
   "OFF" – Radar is powered down.
4. **ECCM counteraction three-position switch**. Selects HUD symbolic in the presence of jamming.
   "AJ" – indication of active interference
   "CAJ" – same as "AJ" in current implementation
   "OFF" – jamm indication without vertical notches, only index
5. **TWF Mode switch**
   – "FHS" front hemisphere
   – "RHS" rear hemisphere
6. **Radar interference compensation mode switch**. Not available

AFCS control panel

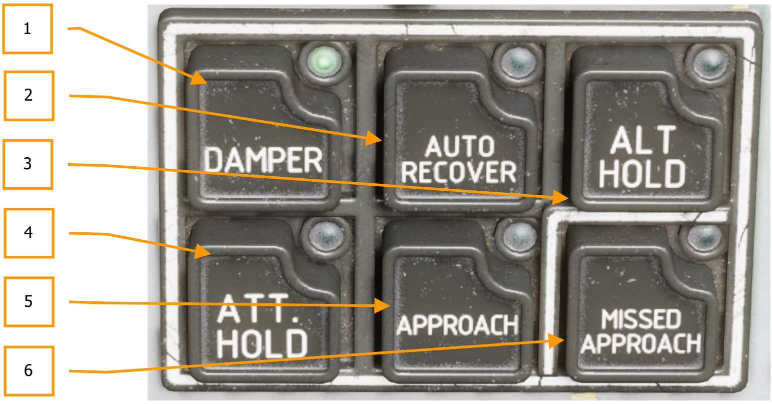


Figure 76: AFCS control

1. **DAMPER** – Enables the damping mode significantly improves the controllability and stability of the aircraft. In most cases of operations it must be enabled.
2. **AUTO RECOVER** – Automatic pull up from a dangerous altitude and restores horizontal flight
3. **ALT HOLD** – Maintains a given flight altitude
4. **ATT. HOLD** – Maintains the given attitude
5. **APPROACH** – Turns on director control following during the landing approach
6. **MISSED APPROACH** – Enables missed approach flight logic. Not implemented yet.

IR sound volume knob and the rudder trim switch

Figure 77: IR volume knob and rudder trim switch

1. **Volume adjustment knob** of the IR missile seeker LOCK sound
2. **Three-position rudder trimmer control**

Unified Indication System

The aircraft is equipped with a unified display system that integrates target acquisition, navigation, and other mission-critical data provided by the Weapon Control System (WCS). This system includes:

- Head-up display HUD
- HDD, also referred to as the direct vision indicator, currently works as HUD image repeater
- Power supply and image generation units.

The HUD projects symbolic and numeric data directly into the pilot’s front field of view, serving as the primary source of steering commands in navigation mode and becoming the main information interface during attack phases. The HUD image is focused to infinity using a collimator and combining glass, ensuring readability regardless of eye position.

The image generation unit receives inputs from:

- Navigation system
- Fire Control System (FCS)
- Automatic Flight Control System (AFCS)
- Angle of Attack (AOA) and sideslip vanes
- Radar altimeter

It generates symbology displayed on a cathode ray tube (CRT), which is then projected into the pilot’s line of sight.

The displayed information is directly controlled via the onboard computer and OEPrNK control signals.

Field of View:
Instantaneous FOV: 13° azimuth × 18° elevation at 600 mm from the lens axis
Total FOV: Circular 24°, accounting for pilot head movement
A light-limiting filter ensures readability against bright backgrounds.

HDD is used in a case of HUD failure or in direct sunlight conditions. Its CRT is specially optimized for these conditions.

Head-up display. HUD

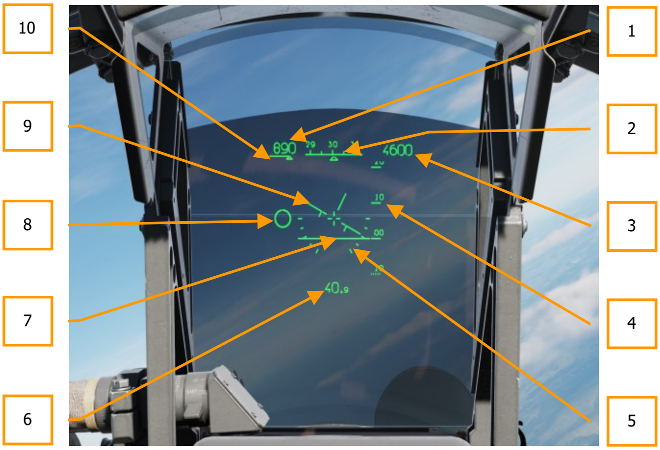


Figure 78: Head-up display. The view with the Light filter raised.

Base HUD indication symbols:

1. Indicated airspeed
2. Heading reference
3. Baro alt or Rad alt
4. Pitch angle
5. Bank angle
6. Nav range
7. Artificial horizon
8. Steering circle
9. Aircraft symbol
10. IAS trend indexer

HUD adjustment controls

Figure 79: HUD adjustment controls

Controls consist of:
– HUD filter on/off mechanical lever [1]
– HUD symbol brightness knob [2]
– "DAY"/"NIGHT"/"GRID" display mode switch [4] for changing the color of the symbol or turning on the fixed grid
– "TEST" button-lamp [3] for displaying a HUD test image

Head down display. HDD

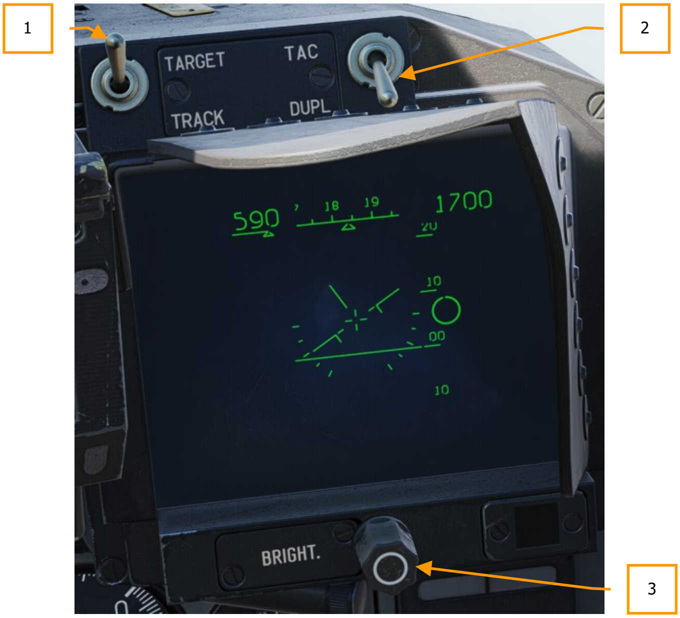


Figure 80: Head down display. HDD

The head down display duplicates and partially supplements the information displayed on the HUD, and is equipped with a shading cover. It is designed to continuously provide the pilot with data in cases where reading from the HUD is difficult due to environmental conditions, such as exposure to sunlight, and is equipped with a brightness control knob [3].

Over the screen placed "TARGET - TRACK" [1] and "TAC - DUPL" [2] switches. Not available.

Aircraft control stick

The handle is designed to control the aircraft roll and pitch, and is equipped with controls related to AFCS, weapon control system, trimmers, stores and brakes.

Figure 81: Airplane control stick

1. Four-position push-button trim control switch
2. ACFS MODES OFF button
3. Target acquisition symbol control button KU-31
4. Break-lock button
5. Brake lever
6. Levelling button
7. Gun trigger
8. Missile and armament launch trigger

9. Autopilot cut-off button
10. Movable arm rest
11. Adjustment screw for the movable arm rest
12. CL tank jettison button under the safety cap
13. Rudder pedal adjustment ring
14. Run-up brake lever

Throttle control grips

The throttle grips are designed to control the engine power and are equipped with radio, radar and other controls required in combat.

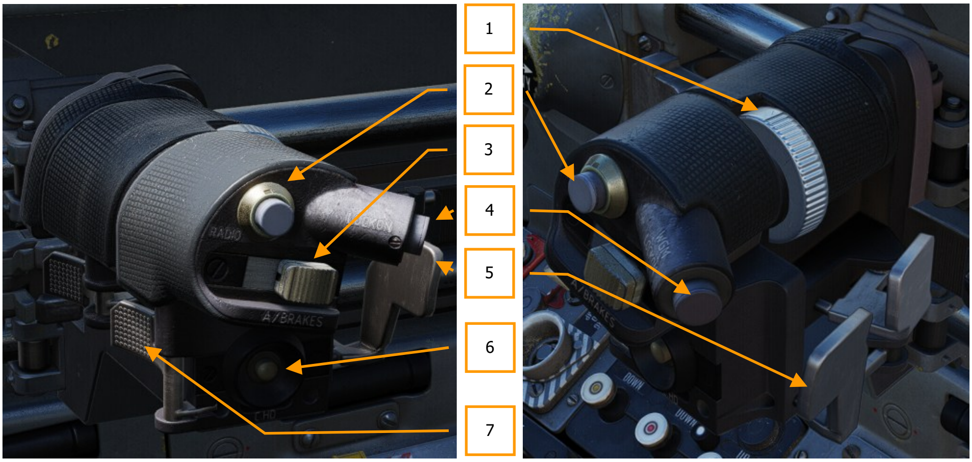
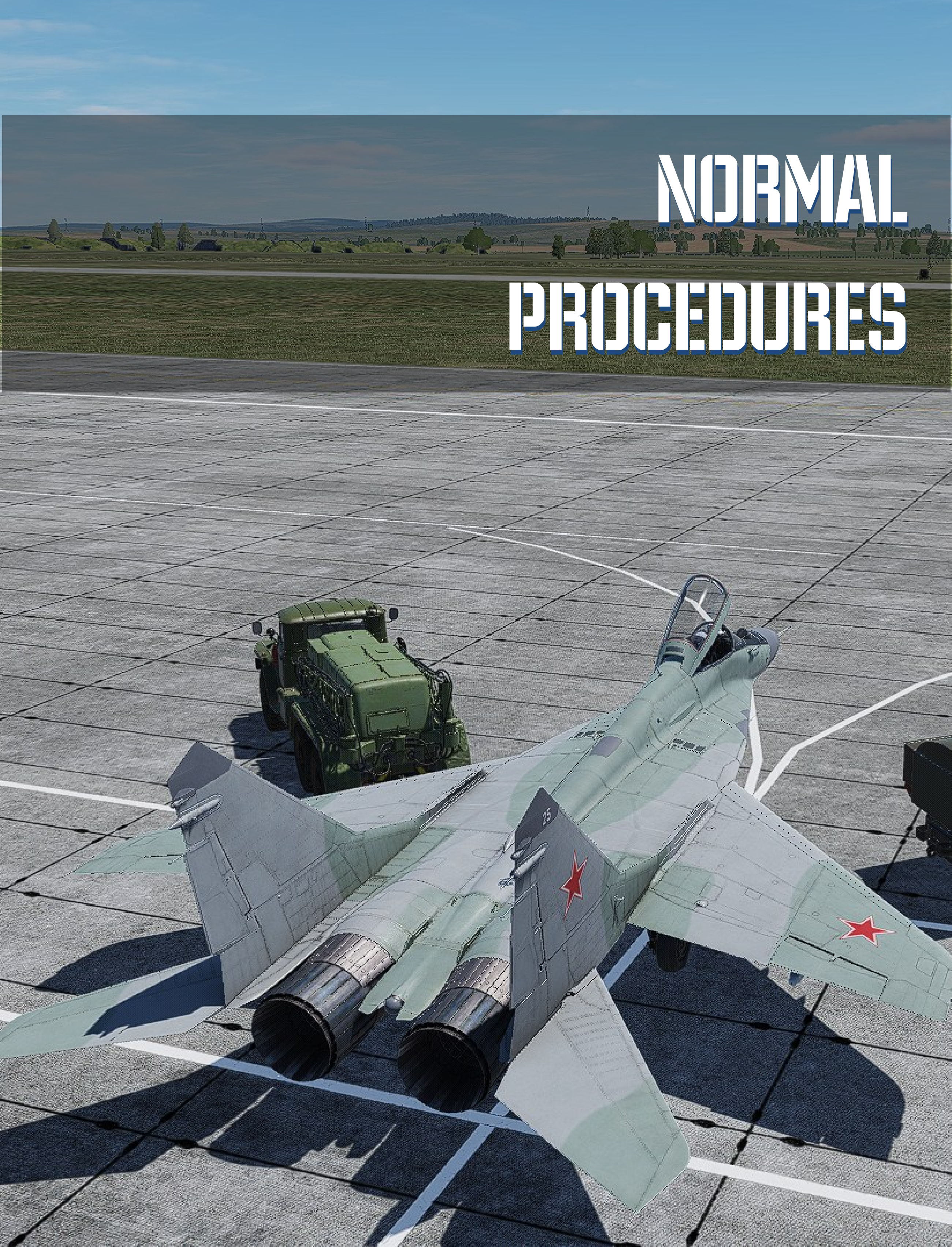


Figure 82: Throttle control handles

1. Target range wheel
2. Radio button
3. Airbrakes switch
4. Lock On (w/o WoW) / NWS High (w/ WoW and flaps up) / PF button
5. Afterburner lock latches
6. Countermeasures dispense button
7. Idle throttle lock latches

NORMAL PROCEDURES



NORMAL PROCEDURES

Preparation for Flight

Preflight interior check

Before any aircraft operation wheel chocks must be placed. Request the ground crew:

[\ ] – Communication Menu
[F8] – Ground Crew
[F5] – Wheel Chocks
[F1] – Place

All starting operations are performed using a ground power supply. Request the ground power.

[\ ] – Communication Menu
[F8] – Ground Crew
[F2] – Ground Electric Power
[F1] – On

Once the ground crew reports ground power on, do the following:

1. "BAT-GND SUPPLY" switch to the "UP" position.

Click the base of the control stick or **[Backspace]** key to hide it in order to get a clear view of the clock and other controls

2. Check the voltmeter indicates approximately 28 V ±0.5 V.
3. Turn all Electrical Power Panel switches to ON (UP) position – also you can use a special metal helper frame to move all "UP" at once.
4. On the "System Power Panel" turn on the switches "NAVIGATION", "GYRO STBY", "GYRO MAIN", "ACFT SYS".
5. Press the right-hand button on the clock to start the stopwatch needle.
6. After 30…40 seconds have elapsed since the gyros were powered, begin the heading alignment:
   - Simultaneously press the "MAG HDG SLAVE" and "COMP ZERO" lamp-buttons for 10…15 seconds.
     Use the keys **[J]** and **[9]** respectively to activate them. Confirm that the HSI needle aligns with the true heading of your stationary aircraft.
   - Turn your head to the right rear horizontal panel. Move the navigation "OPER / PREPARE" switch to "OPER" position.
7. Press the "LAMP TEST" button. Confirm that all warning lights are functional.
8. Press the "MASTER CAUTION" lamp-button to the left of the HUD to turn-off the cautions.
9. Check speed indicators:
   - M 0.2…0.29
   - TAS 110…190
10. Zeroize the altimeter reading by rotating the adjustment knob.
11. Adjust radio altimeter bug to 200 ft — minimum altitude for standard landing pattern.

12. Press the "TEST" button to check the radio altimeter functionality.
    Confirm the needle settles at 45 ft test mark.
13. Check hydraulic pressure readings on the Combined Pressure Indicator are settled within $P_{ак}$ region.
14. Press the "AEKRAN CALL" button – two messages should appear consequently: "SELFTEST", "AEKRAN READY".
15. Check fuel quantity — 3100…3700 kg.
16. Confirm that the navigation system is activated – the "WP-AD" #1 and "BEACONS" #1 lamp-buttons must be illuminated.
17. Temporarily switch to the standby gyro system by moving "GYRO" select switch to "STBY" position and check HSI needle reads the same heading.
18. Return "GYRO" selector switch to "MAIN".
19. Push the "SET COURSE" switch to "MAN" position.
20. Adjust HSI Course Selector Knob to set current airstrip landing course.
21. Push the SET COURSE switch back to AUTO.
22. Confirm Oxygen Flow valve is Open and Oxygen MIX-100% is in "MIX" position.
23. Check brake pressures:
    - 8.0 ± 0.5 kg/cm2 at Brake Lever press **[W]**
    - 11.0 ± 1.0 kg/cm2 when Run-Up Brake Lever is depressed **[LShift]+[W]**.
    - The gauges should read zero pressure if both levers are released.
24. Confirm the navigation system has finished the fast initialization phase by observing the "FAST PREP" lamp is lit.
25. Power Up the radio communication equipment by moving the "RADIO" switch, located on the System Power Panel, to ON position.

THE AIRCRAFT IS NOW READY FOR THE ENGINE START PROCEDURE

Starting engines

Request permission to start the engines:
[RAlt]+[\ ] – Communication menu
[F5] – ATC
[F3] – Request Start-Up
Upon positive response, hide the Communication menu by pressing **[F12].**

1. Turn on the onboard recording system by moving the "RECORD" switch to the "ON" position.
2. Close the canopy until fully locked. Check:
    - Pin — Recessed
    - AEKRAN — No signal
    - LOCK CANOPY light — Out
3. Set the "EJECTION HANDLE" between your knees to "ARMED" position by left clicking over the middle part of the arm.
4. Check whether the "Start-Up Mode Switch" is in the "START BOTH" position.
5. Pull Throttles to IDLE:
    - **[RAlt]+[Home]** to set left throttle grip to idle position
    - **[RShift]+[Home]** for right throttle respectively.

6. Press the "GND START" button.
7. Monitor:
   - RH/LH ENG START lamp go on in sequence (right engine leads)
   - Engine RPM rise
   - BOTH HYDRO FAILURE light extinguishes
   - Hydraulic pressure rise
   - Ramps closure at 35% RPM
   - RH/LH ENG START lamps extinguish
   - EGT within yellow sector limits
   - RPM settles between 58…72% at idle.
8. One by one both engines should go live and settle at idle
9. Once the engines come to life and aircraft self-powered, request disconnection of the Ground Power

   [\ ] – Intercom Communication menu
   [F11] – Parent Menu
   [F8] – Ground Crew
   [F2] – Ground Electric Power
   [F2] – Off

Post-engine-start-up procedures

> Turn back the view of the stick model by clicking on its base in the cockpit or press **[Backspace]**

1. Check the trim system:
   - Pitch trim full forward **[RCtrl]+[;]**, check for corresponding stick movement, trim aft **[RCtrl]+[.]** until "STAB TRIM NEUTRAL" light on the warning lights panel (TLP) illuminates
   - Aileron trim full right **[RCtrl]+[/]**, check for corresponding stick movement, then trim left **[RCtrl]+[,]** until "AIL TRIM NEUTRAL" light on the warning lights panel (TLP) illuminates
   - Rudder trim to the right **[RCtrl]+[X]** until "RUD TRIM NEUTRAL" light on the TLP extinguishes. Trim back to neutral **[RCtrl]+[Z]**
2. Power up the AFCS, moving the corresponding switch to "ON" position.
3. Monitor the AFCS self-test BIT in progress – the "DAMPER" light is blinking and stick moves automatically

> Do not move the flight stick until the end of BIT – it may cause fail of AFCS BIT!

> Players with FFB equipment should hold their hands on FFB stick during self-test, otherwise joystick may misalign with virtual stick - it may cause fail of AFCS BIT!

4. Check if COC – the flight envelope protection system – is functional by monitoring the "COC FAIL" and "NO COC RESERVE" light extinguishes on the annunciator warning panel (TLP)
5. Switch the PITOT HEAT "ON"
6. Check VOICE WARN SYSTEM — Press to test button. Answers "BINGO BINGO" if ok
7. Check the "ADF / Radio" compass system functionality:
   - Set "ADF / RSBN" switch to "ADF"

- Switch on the ADF mode on UHF/VHF radio panel
- Listen to the airdrome outer beacon Morse code in the earphones and check the direction of the needle on HSI showing the position of the beacon on plan
- Now look right above the radio altimeter. Find the "OUTER / INNER" switch and switch it to the "INNER" position
- Listen to the inner directional beacon signal and again, check the direction on the indicator.
- Set "OUTER / INNER" switch back to the "OUTER" position
- Switch off the ADF mode on the UHF/VHF radio panel
- Set "ADF / RSBN" switch back to "RSBN".

8. Switch "ON" the Radar Homing and Warning system RHAW.

Note that RHAW has the RWR indicator named "SPO"

Switch the corresponding SPO switch to "ON" and see the notch at the nose of the aircraft silhouette goes on.

9. Run a self-test RHAW aka SPO by first holding the "TEST" switch to the right in the "AUTO" position. Upon doing so, the function light, off the nose of the aircraft symbol, will extinguish but all the other lights will illuminate. After a 5…7 seconds, the function light will illuminate, and you can release the switch.
10. Set the desired brightness of the SPO indicator lamps by adjusting the BRIGHT knob.

11. Check If AFCS BIT ended up successfully:
    - TLP "DAMPER OFF" light is off
    - AFCS Panel "DAMPER" light is lit steadily

If the BIT failed – various lamps blinking on AFCS panel – procedure must be restarted manually:
Center the flight stick using the trim buttons until Pitch and Aileron neutral trim lights illuminate:
[RCtrl]+[.], [RCtrl]+[;], [RCtrl]+[,], [RCtrl]+[/]
Press AFCS MODES OFF control button on the stick shortly, key **[LAlt]+[9]**
AFCS BIT will restart

12. After AFCS BIT succeeded check the Flaps/Slats movement by pressing any of the "DOWN" buttons on the left flaps control panel, **[F]** key .
13. Confirm that the flaps and slats are deployed — both visually and via the corresponding indicator. Then press the "UP" button on the flaps panel to retract them.

Flaps extension caused reducing the maximum angle of rotation of the nose wheel strut

14. Check the variable duct Ramps functions correctly:
    - Push the LH / RH throttle to 80 - 90% RPM
    - Turn your head to the right rear horizontal panel and check if the "LH INLET CHECK" and "RH INLET CHECK" lights illuminate
    - Pull the throttles back to idle and confirm the lights go off.
15. Reset Trim system to Neutral – watch the green Rudder and Aileron neutral trim lights illuminate. Use the following keyboard combination for trimming **[LCtrl]+[T]** or as described in paragraph #1
16. Go to the aft side of the right console. Power UP the Armament Control System "ACS" and "WEAPON" circuits by moving corresponding switches to the forward position.

17. Verify that the "AEKRAN" queue is clear of active warnings — press the "AEKRAN CALL" button repeatedly until the "QUEUE" indicator turns off and the "MEMORY" indicator turns on.
18. Request ground crew to remove the wheel chocks:

    [\ ] – Communication menu
    [F8] – Ground Crew
    [F5] – Wheel Chocks
    [F2] – Remove

NOW YOU ARE READY TO TAXY

Taxi

Request permission to taxi:
- **[RAlt]+[\ ]** to communicate with the ATC, then navigate to:
- **[F1]** – Request Taxi to Runway

Verify:
- There are no obstacles ahead
- No aircraft on the left and right are taxiing out of the parking area
- Aircraft taxiing do not cross your taxiing path
- Aircraft taxiing towards the runway are at least 300 ft away.

Check the wheel brakes before taxiing:
- Press and hold the **[W]** button then gradually increase RPM to 80% **[Num+]**. The aircraft should remain stationary, but may crawl in the wet conditions.
- Release the wheel brakes.

During turn keep in mind that the nose wheel strut is placed well behind the pilot seat

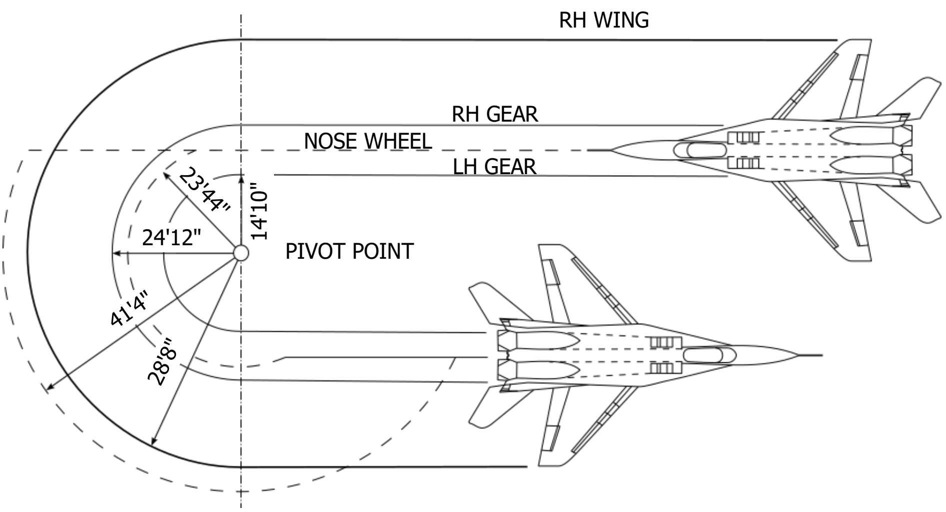


Figure 83: Turning radius and GND clearance

Once the aircraft pulls away, reduce throttles back to idle and allow the aircraft to keep the moment and roll slowly by itself.

Keep the aircraft slow in turns. Right before the sharp turn, press and hold the "Nose Wheel Steering" button **[LAlt]+[Q]** to increase wheel gain and gradually press the pedal to steer to the desired direction. Release the button.

Keep 72…75% RPM while taxiing to have a comfortable taxiing speed, requiring minimum brake inputs from the pilot.

The aircraft brakes with a slight delay, reducing the taxiing speed or stopping the aircraft must be done by smooth movements of the brake lever with a slight lead.

Hard braking of the wheels leads to a smooth but significant lowering of the nose of the aircraft.

During taxiing on straights and on turns, periodically check the operation of the navigation system and the HSI - indication of the current course, bank, pitch, and the presence of correction.

Look around and make sure that the runway is clear, before the final approach and on the descent after it there are no aircraft approaching for landing.

Make a stop at a runway threshold and request a take-off from ATC:
[RAlt]+[\ ] to call ATC
[F1] – Request take-off

Steer to the runway and stop when the aircraft is well aligned along the center line, after 10…15 meters.

Takeoff

Takeoff is typically performed at maximum throttle. The afterburner may also be used during training or when the aircraft is carrying external payloads.

The decision whether a MIL power or an AB takeoff s performed must be based on an assessment of the actual circumstances (A/C, mass, OAT, pressure altitude, winds, RWY, length, barrier available). More than anything else, maximum abort speed and minimum go speed will give an indication whether AB should be used. The use of AB will always lead to an increase in performance and therefore constitutes a favorable effect on safety reserves.

Pilots must be aware, however, that aircraft handling will be more difficult if an engine fails during an AB takeoff as opposed to a military power takeoff.

Normal takeoff

1. Lower the FLAPS, by pressing **[F]** key, check their extension visually, in mirrors and by IP-52 combined gear flaps and slats indicator
2. Check the ROLL, PITCH, HEADING and COURSE indicators, confirm zero readings of the altimeter
3. Start the STOPWATCH and FLIGHT TIMER on the CLOCK

4. Check the lit state of the "FEEL UNIT TAKEOFF – LANDING" lamp and the state of three green neutral trimmer lights on the warning panel
5. Press the RUN-UP BRAKE TRIGGER **[LShift]+[W]** to apply the most possible pressure to the wheel's brakes
6. Gradually push the throttles to MAX position. Watch the aircraft lower the nose on the brakes complying with the thrust and brakes
7. Check the EGT readings are within the yellow sector and engine RPM difference is not bigger than 4%. Release the brakes. Keep the stick neutral on the run
8. Apply the necessary pressure to pull the stick back and raise the nose once the aircraft reaches the speed of 125…135 kts
9. Place the horizon right above the IR sensor on the nose keeping the pitch reading on the HUD within 8° to 10°

Liftoff occurs at 140 to 150 kts depending on aircraft gross weight

10. Once in the air keep the pitch and maintain it within 8…10°
11. Retract gear **[G]** at 32…50 ft of altitude

Figure 84: Aircraft takeoff position

12. Check the landing gear lamps go off and hydraulic pressure is normalized on combined pressure gauges.

In case of the landing gear is not fully retracted,
the red lamp on the IP-52 flashes
reduce engine RPM to 80%, set the speed to 220 kts
and check that the landing gear is fully retracted

13. Retract flaps **[F]** at altitude of 350 ft and check the corresponding lights extinguish on the indicator.
14. Once the airspeed reaches 270 kts adjust the engine RPM to 83-85% and maintain the climb rate at 985…1480 ft/m
15. Keep 270 kts until clear off the airbase's immediate control zone then continue your flight plan

Afterburner takeoff

Afterburner detents unlock by pressing **[0]** the on the throttles when needed

If an AB takeoff is desired, smoothly advance throttles to max AB after brake release. Maintain directional control with the rudder pedals. Wheel braking should not be used for directional control during takeoff roll.

Due to a nose-lowering tendency during intake duct opening delay rotation until it has occurred. When reaching safe altitude retract gear and thereafter the flaps.

Rapid full aft movement of the stick may result in the exhaust nozzles hitting the runway

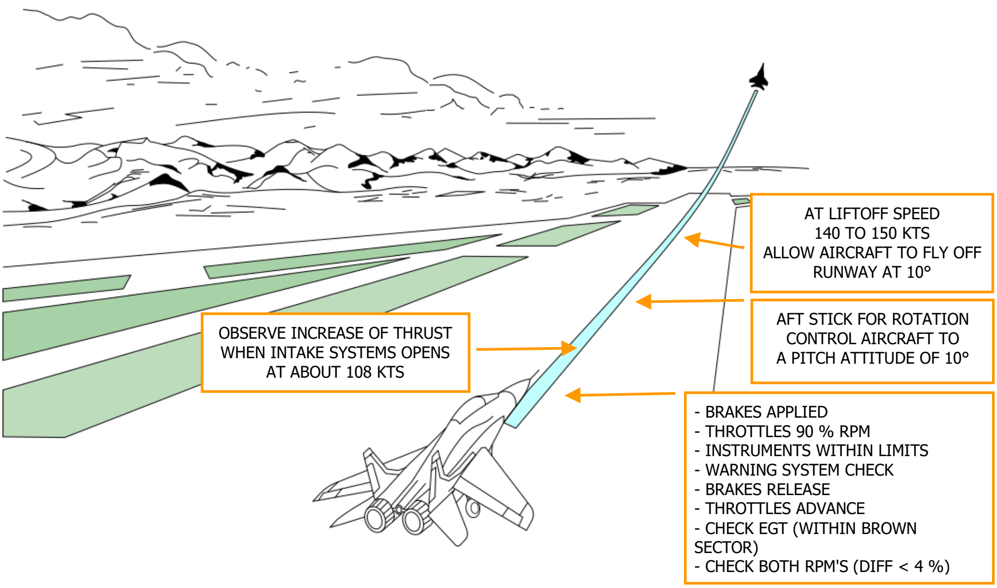


Figure 85: Military Takeoff

Crosswind takeoff

Under crosswind conditions, the aircraft tends to weather-vane into the wind.

This weather vanning tendency can easily be controlled with nose gear steering and rudder.

As speed increases, weather vaning tendency decreases.

Takeoff attitude should be slightly lower than normal to increase liftoff speed approximately 8 kts.

After liftoff the aircraft should be crabbed into the wind, wings level, to maintain runway alignment.

Landing

Normal landing

For a normal landing, fly the pattern as illustrated in figure 86.

1. Enter the pattern as local procedures dictate
2. Adjust power, as necessary, to attain allowable gear lowering airspeed
3. Extend landing gear **[G]** and flaps/LEF **[F]** on downwind leg
4. Ensure flaps/LEF down and out prior to initiating turn to base leg
5. Establish and maintain desired airspeed on the base leg or final approach, adjusting pitch attitude and power to maintain desired glide slope/rate of descent
6. When the aircraft reaches 20 to 30 ft altitude above ground, initiate flare
7. Round-out from descent to an acceptable touchdown sink rate requires nearly full aft stick application
8. Reduce power during late round-out or thereafter to touchdown at approximately 140 kts at 11° AOA During touchdown do not exceed 13 °AOA

> For landing with maximum landing weight add 5 to 10 kts to the touchdown speed

9. At touchdown, reduce power to idle, maintaining stick position and deploy chute **[P]**
10. After nosewheel touchdown maintain directional control with rudder and NWS

> At excessive touchdown speeds, the aircraft has a tendency to bounce.
> In this case, maintain/attain landing attitude and deploy chute immediately upon touchdown to prevent further bouncing

Crosswind landing

1. Carefully compensate for crosswind in the traffic pattern to guard against undershooting or overshooting the final turn
2. At crosswinds up to 15 kts compensate with a 5 to 10° low wing and crab
3. Above 15 kts, wings-level crab should be used
4. Approximately 1° of crab is required per 3 kts of crosswind. Since use of the chute intensifies the weather vane effect for any given deployment condition, consider a no chute landing at crosswinds near the limit. However, for landing on a wet runway, chute deployment is mandatory
5. Prior to touchdown assume wings level flight
6. Crab must be neutralized using rudder at touchdown
7. After nosewheel touchdown, deploy chute
8. Apply brakes upon reaching 115 kts. Counteract weather-vane effect by use of aileron into the wind, and rudder.

> If chute is used and excessive weather-vaning is encountered than jettison chute

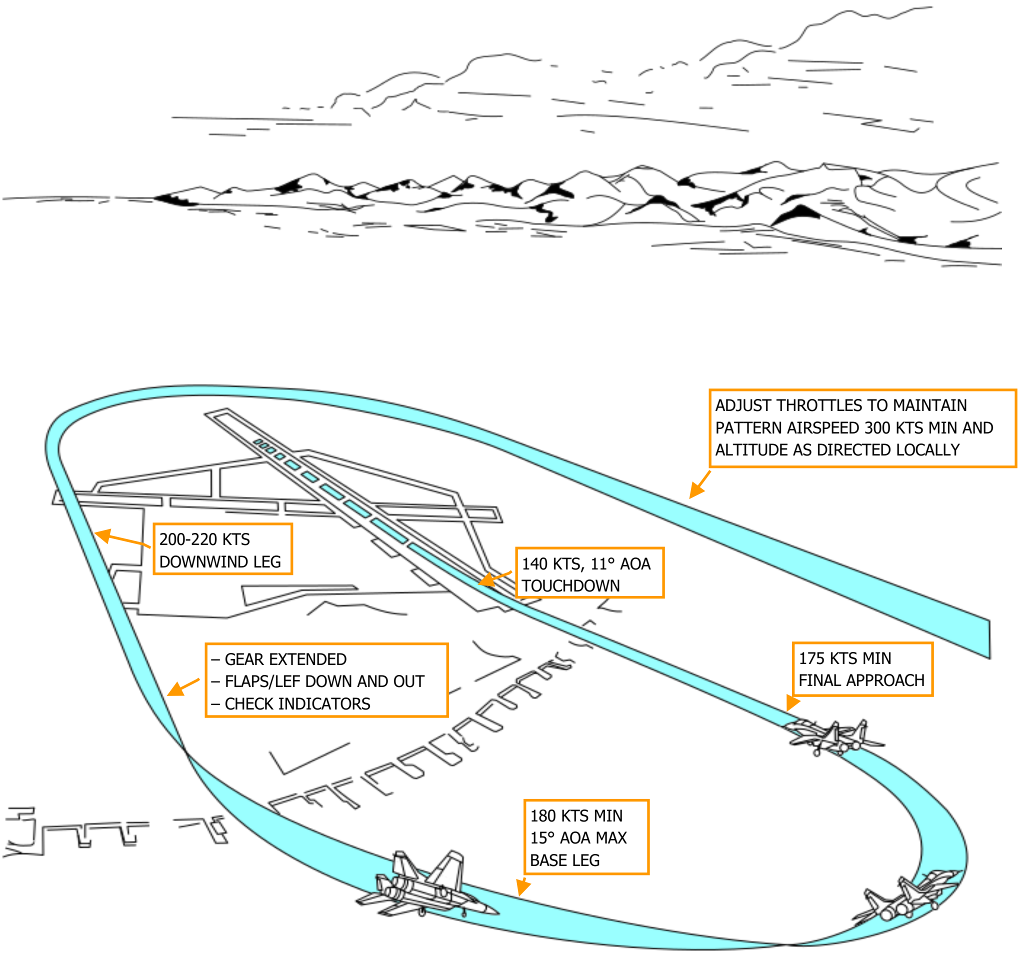


Figure 86: Normal landing pattern

Navigation

Navigation system

NAVIGATIONAL OPTIONS

Various navigational options are operated according to the setting on the navigation control panel:

- Point-to-point navigation
- Return
- Landing approach
- Traffic reentry (missed approach)
- Manual station selection

Navigation system provides programming up to nine navigation points - three waypoints, three airfields and three RSBN beacons.

All programming and data input operation for Navigation System performs by Data Transfer Cartridge manager

POINT-TO-POINT NAVIGATION

Six navigation points can be programmed and are selected by setting the "WP - A/D" switch and selection of one of the three "WP - A/D" illuminated pushbuttons.

The course to the selected coordinate is displayed by the course pointer and the course window, distance is displayed by the range indicator on the HSI and on the HUD. As the aircraft closes on the selected coordinate the "D<21" light illuminates. Passing the coordinate, the lost bearing indication will be shown until exceeding 3.2 nm distance outbound.

RETURN

Pressing the "RETURN" illuminated pushbutton provides bearing information to a lead point for the nearest 9.2 nm final intercept to the selected airfield, provided the correct landing direction is selected with the COURSE switch and the update function is operating. Slant range is indicated to the selected A/D coordinates.

If automatic navigation computer update is inoperative, course and distance to the aerodrome reference point are provided.

During the approach, glide path information is displayed on the ADI for a 7° glide slope to the final intercept point at 3 700 ft AGL or QFE.

TRAFFIC RE-ENTRY (MISSED APPROACH)

If the MISSED APPROACH button is pressed, the navigation computer supplies steering information for a traffic pattern, provided the landing select switch is off.

Steering is provided for a 5.4 nm downwind leg and final intercept.

Pattern direction left or right hand is selected by placing the circle left-right switch to the corresponding direction. Glidepath information is displayed for a pattern altitude of 2000 ft AGL or QFE.

MANUAL STATION SELECT

With the channels "MAN / AUTO" switch in "MAN", bearing and distance to a selected beacon is displayed. Navigation computer update is not provided.

> With the "CHANNELS" switch in manual, the final course must be dialed in on the HSI to receive steering commands

Flight along a pre-programmed route in calm winds at altitude

1. Select "NAV" mode with "WCS MODES" selector knob
2. After takeoff and landing gear retraction observe the circular flight direction marker and distance indication to the waypoint on the HUD
3. Align fixed crosshair and direction marker

> Flight direction marker indicates azimuth, not altitude reference

4. Climb to the specified altitude and proceed to the waypoint
5. Monitor the distance
6. When the distance to the waypoint less than 21 nm turns on "D<21" signal on the NS panel
7. When the distance to the waypoint less 3 nm direction marker will stabilize.
8. When the distance to the waypoint is zero, press next waypoint button and proceed
9. Repeat sequence for another waypoint's

RETURN mode

The RETURN mode can only be used when landing at a programmed airfield and with correction from a programmed RSBN beacon, located less than 43.2 nm from the landing airfield.

The RETURN mode may be switched on at any distance from the landing airfield within the working area of one of the programmed RSBN radio beacons. Before switching on the RETURN mode, it is necessary to:

1. Set the obtained barometric pressure value on the altimeter indicator
2. Set the dangerous altitude indicator of the radio altimeter to an altitude of 2000 ft
3. Make sure that the KORR lamp is lit on the SN control panel
4. Set the "ADF RSBN" switch to the "RSBN"
5. COURSE switch - in accordance with the landing course of the airfield
6. CIRCLE switch - in accordance with the direction of the flight circle
7. On the "NAVIGATION" and "LANDING" scales, set (check the setting) the beacon type and the operating channels of the RSBN and ILS of the landing airfield, in case of computer failure.

> The "WP A/D" switch can be in any position - in the "RETURN" mode it performs the function of the "A/D" position

To enable the "RETURN" mode, do the following:

1. Press the "RETURN" lamp-button on the NS control panel
2. Press the lamp-button of the landing airfield in the "WP A/D" row
3. Press the lamp-button of the RSBN beacon, selected for correction in the "BEACONS" row
4. Check the activation of the mode by the lighting of the pressed lamp-buttons.

Follow the direction marker, maintain descending speed to set 2000 ft altitude in 8…16 nm radius near the selected airfield and speed 270 kts, altitude and distance to airfield according the following table

H, ft	15000	12000	9000	6000	3000
D, nm	30	25	20	15	10

Check direction marker - if altitude deviates more than ±560 from glideslope, marker drops up or down, same as glideslope director bar on the ADI.

LANDING mode

The automatic landing mode will engage if the aircraft meets all of the following conditions:
- It is within ±0.8 nm of the runway centerline (the glidepath groove).
- The difference between the aircraft heading and the landing course is less than 60°.
- Flight altitude is below 3700 ft.
- Distance to the runway center point is between 4.5 and 19 nm.

At this moment:
- Both GS and LOC failure flags on the HSI disappear; the HUD displays GS and L markers.
- The HSI course arrow aligns with the true landing course.
- The HSI small needle switches from RSBN to indicate the outer NDB bearing.
- The vertical director bar on the HSI and the flight direction circle on the HUD indicate steering commands to maintain alignment and centerline tracking.
- The ADI horizontal position pointer mirrors the HSI course director bar. The ADI vertical position pointer shows deviation from the 2000 ft plateau altitude prior to glideslope entry, and then mirrors the HSI glideslope indicator once established.
- The "CORR" display extinguishes after automatic landing mode was engaged, but the "RETURN" lamp-button stays lit, indicating that the system is still ready to fulfill the "MISSED APPROACH" command if needed.

Manual engaging of LANDING mode by turning the "LANDING" switch "UP" is also allowed, but requires correct ILS beacon channel set

Follow the HUD direction marker, and ADI directors and perform landing procedures, as described earlier.

MISSED APPROACH mode

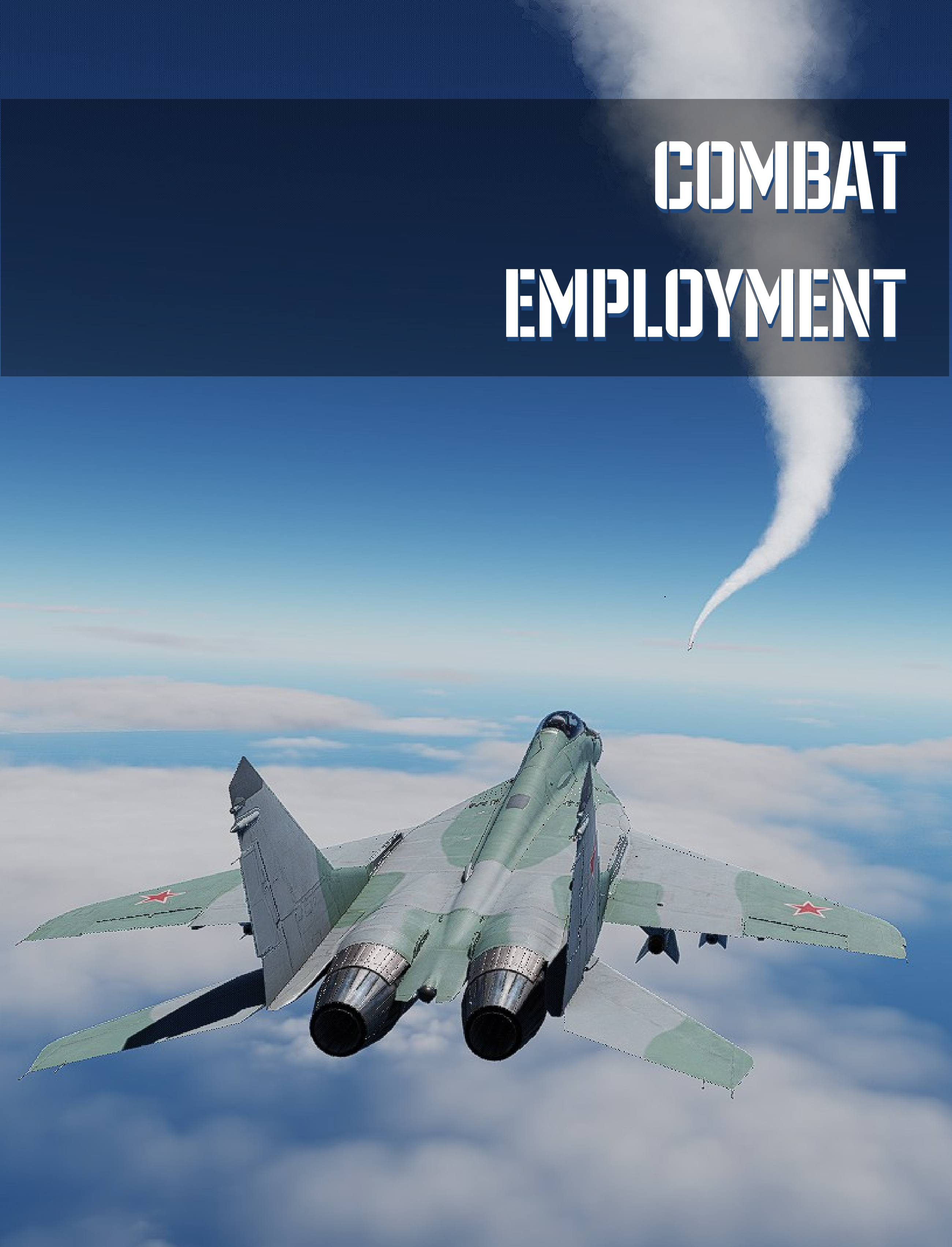
This mode is used if for some reason the landing on the move was not performed.

1. Put the aircraft into a climb
2. Remove the frame and covers
3. Press the "REPEAT APPROACH" button on the ACS PU
4. Check the activation of the mode by turning on the indicator lamp with this button.
   In this case:
   - The "LANDING" mode deactivated.
   - The "RETURN" button-lamp remains lit
   - The HSI course pointer and the ring HUD direction marker appear at the set point in the direction of the first turn.
5. Select an altitude of 600 ft and a speed of 270 kts.
6. The turn is performed with a bank of 30° with an altitude gain of up to 2000 ft
7. On the KTA mountain pass, check the outer route – 5,4 nm
8. Start the stopwatch
9. Estimated time to the second turn is 2 minutes
10. When the estimated point of the second turn is completed:
    - Distance from the KTA according to the range counter is 10-12 nm
    - The "REPEAT APPROACH" mode is activated, the lamp on the ACS panel goes out.
    - The "RETURN" mode is activated
    - The HSI course pointer and the ring HUD direction marker show the course to the set point in the direction of the turn to the landing course.

The subsequent actions of the pilot are similar
to the use of the "RETURN" mode.

FLY SAFE!

COMBAT EMPLOYMENT



COMBAT EMPLOYMENT

Based on its flight characteristics and capabilities of the aircraft weapons system, the aircraft can perform various combat missions:

- Interception and attacks of air targets in free space and with earth background, day and night, in simple and complex weather conditions at medium and short ranges
- Close air combat
- Destruction of visually visible ground or sea targets.

Targets are hit by the aircraft's missile, gun and bomber weapons, used in various combinations.

Air-to-air targets could be engaged by:

- Guided missiles with SARH (RGS) in any weather conditions, day and night
- Guided missiles with IR (TGS) and fire from a cannon during the day and at night in conditions of optical visibility of the target.

The weapons complex consists of:

- Weapons Control System – WCS
- Aircraft weapons
- Devices for suspension of weapons.

The WCS includes:

- Radar sighting system RLPK-29 – NO-19 "Sapphire-29"
- Optical-electronic sighting and navigation system OEPrNK-29.

Air-to-Air operations

To destroy air targets, air-to-air guided missiles and a 30 mm GSh-301 (9A-4071K) aircraft cannon with 150 rounds of ammunition are used.

The MiG-29's missile armament includes the R-27R and R-27ER medium-range air-to-air missiles with semi-active radar homing (SARH), the medium-range air-to-air missiles R-27T, R-27ET and short-range missiles R-60, R-60M, R-73 with thermal homing heads (IR).

Guided missiles are carried on six wing hardpoints.

The aircraft cannon is built into the aircraft body on the left side of the cockpit.

RAD mode

In the RAD mode, detection and tracking of targets within the range of the onboard radar station and moving at approach/lag speeds is carried out:

- – Above 81 kts at ranges greater than 8 nm
- – Above 27 kts at ranges less than 8 nm.

Detection of targets at approach/lag speeds
less than 32.4 kts and at ranges less than 5.4 nm in "HEAD ON" mode is not guaranteed

At lower speeds of approach/removal from the target, automatic tracking may be disrupted.

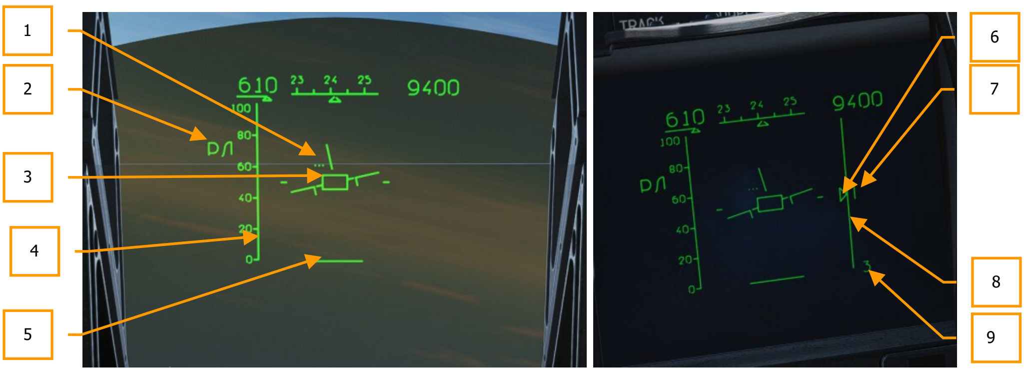


Figure 87: Radar SCAN mode "Obzor" with voice guidance and independent search

1. Target mark
2. The operating mode of the WCS is "RAD"
3. Radar capture strobe
4. Range scale
5. Radar search area by azimuth – in center position
6. Horizon mark on HDD
7. Radar viewing area by elevation angle on HDD
8. Radar visibility zone by elevation angle on HDD
9. Current line number on HDD

Before starting combat, move the switch "ILLUM - DUMMY - OFF"
to the "ILLUM " position

Stores INBD/OUTBD selection – **[RAlt]+[P]** key

SCAN mode

1. Set the "WCS MODE" switch to the "RAD" position
2. Detect the target, changing the elevation angle and antenna zones by azimuth, using the switches "∆H" and "ZONE", if necessary. The antenna position displayed by the search zone marks by elevation angle and azimuth on the HUD and HDD
3. After the target enters the capture range, put the capture strobe at it, keys are **[,]** – left, **[;]** – forward, **[.]** – back, **[/]** – right, and capture the target by pressing the "LOCKON" button, key **[Enter]**
4. Enable the TWS mode – Track-While-Scan – for automatic target strobing:
   – "TWS FHS - RHS" in the "FHS" position
   – "AJ - OFF - CAJ" to the "OFF" position
5. If retargeting to another target, press the control button, key **[L]**, aim the strobe at the mark of the selected target and capture by pressing the "LOCKON" button.

To return to automatic selection of a most dangerous target, press the "RESET" button on the aircraft control stick

LOCK mode

After capture, the symbol "A" is displayed on the HUD and the scan mode changes to a lock mode indication.

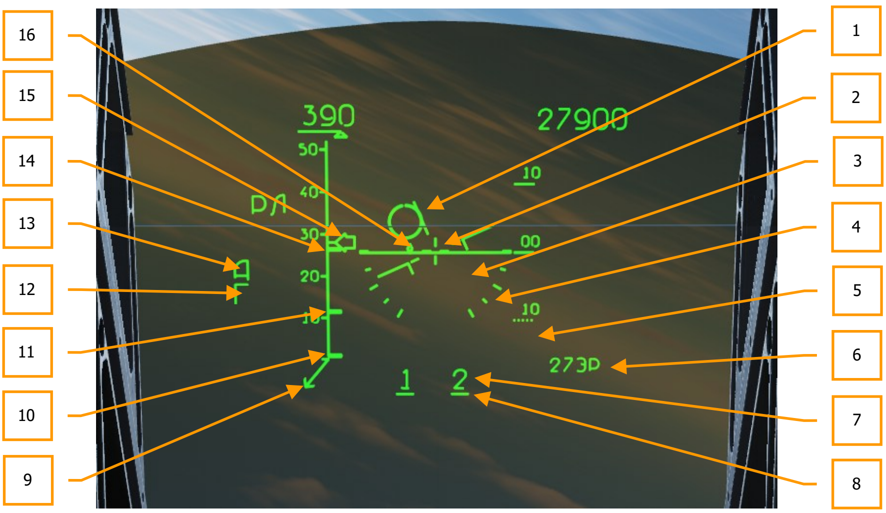


Figure 88: Radar LOCK mode. Target indication

1. Aiming ring
2. Fixed crosshair
3. Artificial horizon
4. Roll scale
5. Pitch scale
6. Selected missile type indicator

7. Readiness or capture of the missile's seeker mark
8. Availability indication
9. Target aspect
10. Label $D_{r\ min}$
11. Label $D_{r\ max2}$
12. "Gorka" order
13. "Attack" order
14. Label $D_{r\ max1}$
15. Current target range mark
16. RLPK antenna position mark

To destroy a captured air target:

1. Align the aiming ring with the electronic crosshair
2. Set $\Delta H_{targ} = 0$ for smooth exit to the target height, before issuing the "Gorka" command
   At the moment of issuing the "Gorka" command, the "Г" symbol is displayed on the display and the aiming ring moves up or down in a jump
3. Close to the target, maintaining sufficient closing speed
4. Reach the range of use of the selected type of weapon
5. Launch a missile or fire a shot
6. Exit from the attack is carried out on the command "OTB" on the HUD.

The range scale during the approach switches from 54 nm to 27 nm, 13.5 nm and 5.40 nm when the range decreases to the corresponding value

RAD Close Combat mode

The mode is used in conditions of direct visibility of the target and ensures the capture of a target located in the vertical search zone at ranges from 5.4 nm to 1500 ft.

In the "CLOSE CMBT" mode, stable automatic tracking is provided at equal speeds and at a lag, which allows for the launch of missiles and the conduct of maneuverable air combat.

To enable the mode:

1. Set the "WCS MODE" switch to the "RAD" position
2. Set the "RADAR MODES" switch to the "CLOSE CMBT" position
3. Switch "ILLUM - DUMMY - OFF", set to the "ILLUM" position
4. Use the "SPAN" handle to set the target size.

Two vertical lines and the "РЛ" symbol will appear on the screen (Fig. 89)

For weapon employ:

1. Align the vertical zone with the target being attacked
2. Capture the target by pressing "LOCKON" button, key **[Enter]**, for no more than 2 seconds - the HUD will display targeting information similar to the "HEAD ON" and "P" modes with a range scale of 5.4 nm
3. Align the aiming ring with the electronic crosshair to improve aiming
4. Launch the missiles after "ПР" is displayed,
5. On command "OTB" exit the attack in the direction of the aiming ring.

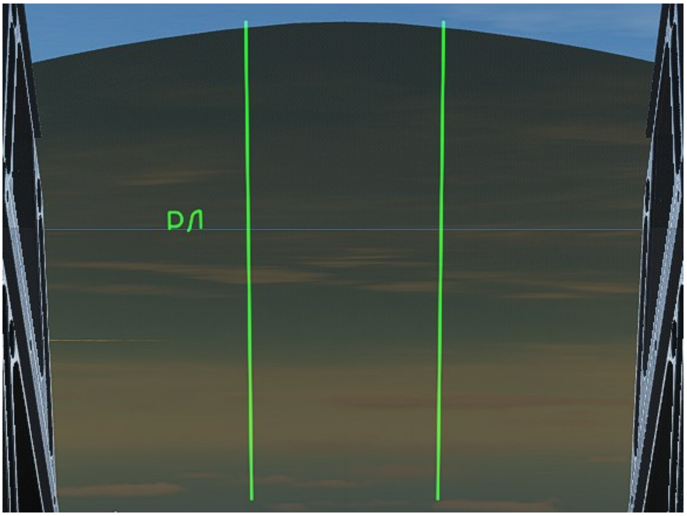


Figure 89: RAD close combat mode. Scanning

IR mode

IR mode – thermal direction finding – is used in simple weather conditions, when the radar operation is complicated or impossible due to jamm interference, equipment failure or to increase the stealth of approaching the target. Turn on IR mode after takeoff.

The appearance of the information on the HUD when working in the IR scan mode is shown in Fig. 90.

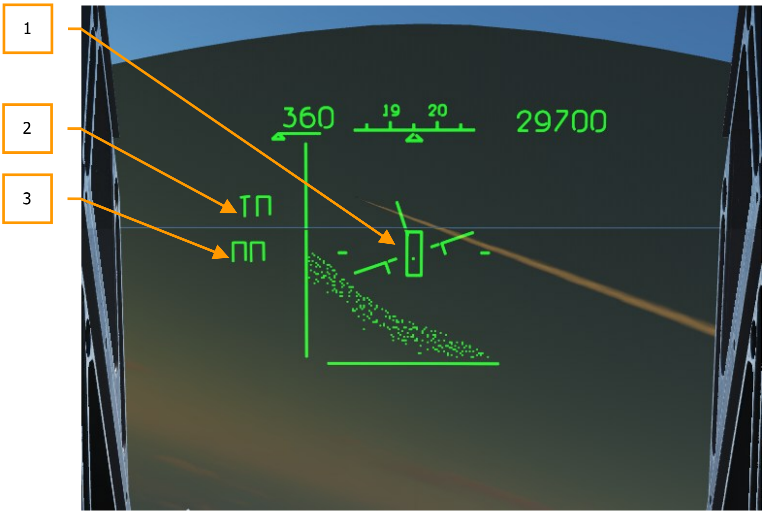


Figure 90: IR mode. SCAN

1. KOLS capture strobe with target mark in it
2. The sign of the operation of the WCS is the leading channel of the "ТП"
3. Sign of introduced passive interference "ПП"

The target detection range in the IR mode is 13.5...5.4 nm. The target detection range in the presence of thermal interference is reduced, depends on the interference level and is 5.4...1.6 nm.

To enable the mode:
1. Set the "WCS MODES" switch to the "IR" position
2. Set the attack hemisphere with the "FHS-RHS" switch to "RHS"
3. Set the target size with the "SPAN" handle

For weapon use:
1. Detect the target mark on the HUD
2. If there is interference and it is difficult to select a target, remove some of the marks on the HUD by reducing the sensitivity of the KOLS using the "IR GAIN / HELM BRIGHT" knob.
   In this case, the "ПП" symbol appears on the HUD - passive interference
3. Place the strobe on the target mark using the control button
4. Press the "LOCKON" button, key **[Enter]**, and hold it down until the target is captured – 2…3 seconds. Target designation by the missile IRH and missile preparation occurs automatically after the KOLS switches to automatic tracking. The appearance of the information picture of the mode, the aiming performance are similar to the mode of operation with the radar (Fig. 91)
5. When the command "ПР" appears, launch the missiles by pressing the trigger missile launch
6. Disengage after the missiles are launched or upon the command "ОТВ" in the direction of the ring movement.

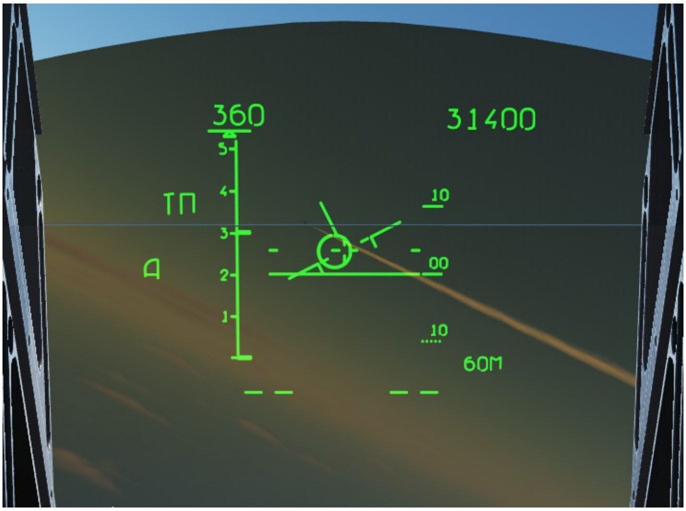


Figure 91: IR mode. LOCK

IR Close Combat mode

This mode is used in visibility conditions when attacking in the RHS at an target aspect ratio of up to 3/4. The aiming method and indication are identical to the "CC" radar mode. To use the mode, it is necessary to set the "WCS MODES" switch to the "ТП" position and act as in the "CC" radar mode (see the information picture in Fig. 89).

HELM mode

The "HELM" mode is used in conditions of target visibility in the range of angles of ± 60° in azimuth and +60...-14° in a shortage of time for attack.

The helmet-mounted system provides target designation based on the elevation angle to the radar, KOLS and IR of guided missiles, and outputs aiming and signal information to the helmet-mounted sighting device (HMD) (Fig. 92).

To work in the "HELM" mode:

1. Switch "WCS MODES" to "HELM" position
2. Set the radar mode rotary switch to the "CLOSE CMBT" position.
3. Set the HMD monocle to the working position
4. Adjust the brightness of the aiming mark with the rheostat "IR GAIN / HELM BRIGHT."
5. Align the center of the aiming mark of the HMD on the target by turning your head
6. Set the attack hemisphere with the "FHS - RHS" switch according to the situation
7. Set the target wing span with the "SPAN" handle
8. Press and hold the "LOCKON" button, key **[Enter]**, until the radar, KOLS or IR missile target is captured. When the IR target is captured, a sound signal appears and the HMD displays a flashing "ПР" command.
9. Release the button "LOCKON"
10. When the command "ПР" appears, launch the missiles by pressing the missile launch

When the "HELM" mode turning on

Target acquisition indicator

Blinks 2 times per second

You can switch to HUD, release the "LOCKON"

Command "ПР" when $D_{tech} < D_{r\,max}$

You can launch missile

Command "ПР" when capturing a target only by IR

Blinks 2 times per second

You can launch missile when target in range

Figure 92: HELM mode, indication on HMD

When the "LOCKON" button is pressed, the target designation of the missile's IR is carried out directly from the HMD, regardless of whether the target is captured by the KOLS or radar

In the event of target capture by a radar or KOLS, the command "ТП capture" is displayed on the HMD and the information picture of the radar or KOLS capture mode is displayed on the HUD and target designation on the missile IR when the "LOCKON" button is released comes from the RLPK or KOLS

Provided that the target is in the launch zone:

1. For R-73 missiles:
   1.1. Release the "LOCKON" button
   1.2. Launch missiles, determining the range by eye. The target is no longer tracked via the HMD

The R-73 missiles can be launched without releasing the "LOCKON" button, but the target must be tracked via the HMD

2. For R-60(M) missiles
   1.1. Hold the button "LOCKON", **key [Enter]**
   1.2. Launch missiles, determining the range by eye. Track the target via HMD

OPT mode

The "OPT" mode - optical - is intended for aiming at visible targets. Targets are issued to the radar, KOLS and IR of missiles manually, using the aiming mark, from the control button - manual target designation

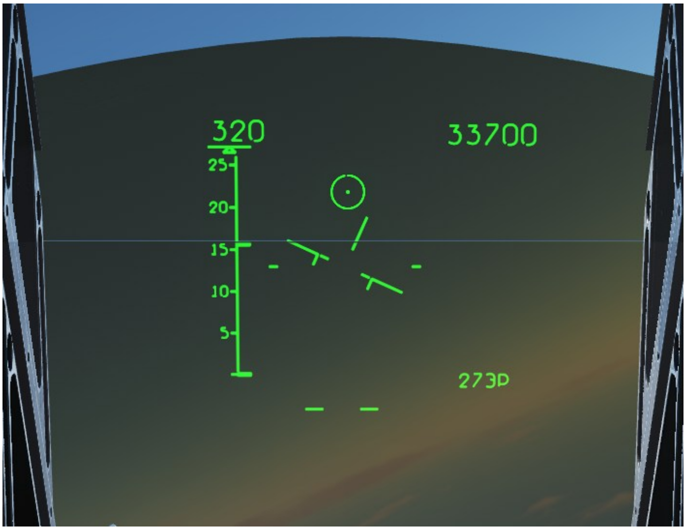


Figure 93: "OPT" mode. Manual targeting

For operation in the "OPT" mode using missiles with IR:

1. Set the "WCS MODES" switch to the "OPT" position
2. Visually detect the target
3. Set the attack hemisphere with the "FHS – RHS" switch
4. Set the target size with the "SPAN" handle
5. Bring the target into the HUD field of view by maneuvering the aircraft
6. Align the aiming mark with the target using the control button
7. Press and hold the "LOCKON" button, key **[Enter]**, until the radar, KOLS or IR missiles capture the target. When a radar or KOLS captures a target before the missile's IR, the HUD displays the command "A" (attack) and an indication of the mode of the system that captured it first.
8. Release the "LOCKON" button and continue working as in the radar or IR mode.
9. When the IR missile target is captured with the "LOCKON" button pressed, a flashing "ПР" command will appear. The missile can be launched by defining the permitted launch range.

BS mode

Boresight – BS – mode is intended for aiming and launching IR and SARH missiles when the WCS modes fail. For aiming in this mode, a fixed electronic crosshair is displayed on the HUD.

To operate in BS mode , it is necessary:

1. Set the "WCS MODE" switch to position "BS"
2. Set the attack hemisphere with the "FHS – RHS" switch
3. Set the target size with the "SPAN" handle
4. Align the fixed electronic crosshair of the HUD - the aiming point of the fixed grid - with the target, controlling the aircraft according to the commands of the control panel or visually
5. The capture of the target by the IR is determined by the appearance of the launch readiness index on the HUD.
6. Launch missiles upon reaching range.

If there is no electronic crosshair on the HUD when switching on the "BS" , set the "DAY - NIGHT - RETICLE" switch to the "RETICLE" position

When aiming at a fixed grid, the capture indication on the HUD is not issued, only the voice message "Launch permitted", additionally for R-60(M) and R-73 missiles, an audible signal

RETICLE mode

The RETICLE mode is used when it is impossible to use other aiming modes.

When firing from a cannon using a fixed net for conducting escort and barrage shooting, it is necessary after visual detection and identification of the target

1. Set the "DAY - NIGHT - RETICLE" switch to the "RETICLE" position and move the trigger to the intermediate position. The appearance of the grid is shown in Fig. 94.
2. Take the starting position for the attack
3. When reaching a range of about 0.22 nm, estimate the true speed of the target, its resource, and select the firing zone in accordance with them (determine the maximum x minimum lead),

4. Refine your aim, reduce your aircraft's turn rate
5. Open fire at the moment the target enters the firing zone, at the point corresponding to the maximum lead
6. Stop firing when the target leaves the firing zone, after passing the point on the sight grid corresponding to the minimum lead.

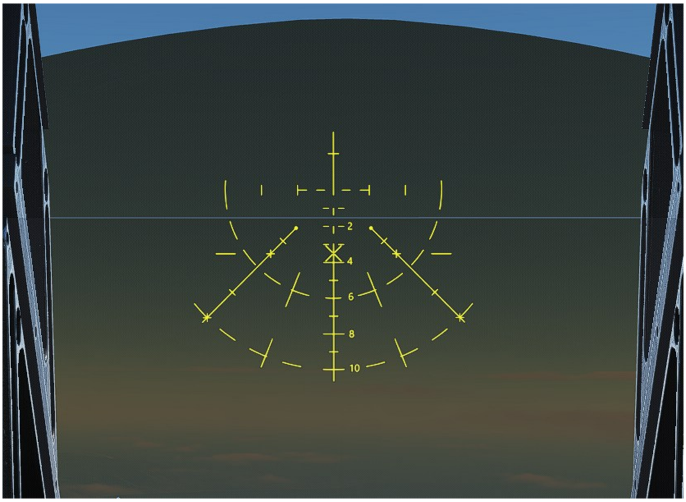


Figure 94: RETICLE mode

Gun employment

The mode is switched on by moving the gun trigger to an intermediate position with the "WCS MODE" switch set to the "RAD", "IR", "CC", "HELM" or "OPT" position.

The cannon can be fired in one of two modes:
- "Automatic" mode - switch to "ALL" position
- "Cutoff" mode - switch in the "SINGLE 0.5 ALL" position.

The cannon can be used using the "Asynchronous shooting" or "Gun funnel" methods.

"Asynchronous shooting"

The method is implemented when the target is captured by automatic tracking radar or radar.

Before the attack, the target base in meters should be established to ensure continuation of the attack using the "Forecast-track" method in the event of a failure to capture the radar or KOLS.

When attacking a visible target:
1. Set the target base with the "SPAN" handle
2. At a distance of ≤ 0.65 nm (after changing the indication to HUD, see Fig. 95, 96) align the moving cross with the target, and then with the ring

At a distance of about one kilometer to the target,
the range scale changes

3. Fire by pressing the gun trigger
4. Disengage on command "OTB".

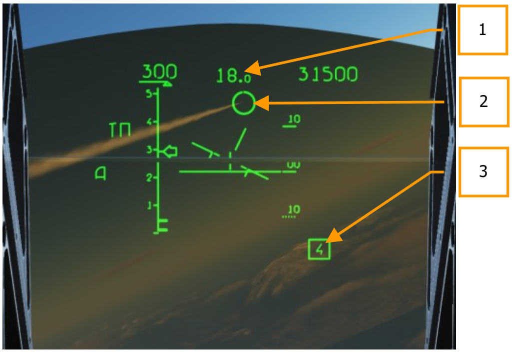


Figure 95: Gun employment, "Asynchronous shooting", D>0.65 nm

1. Target base
2. Sighting ring
3. Remaining ammunition in quarters

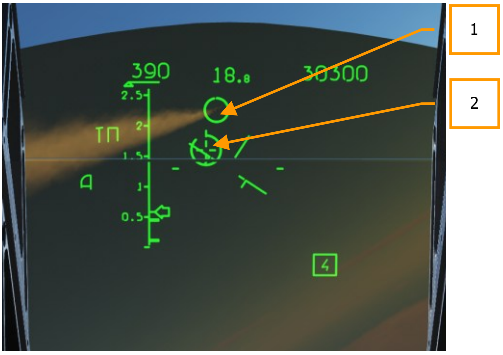


Figure 96: Gun employment, "Asynchronous shooting", D<0.65 nm

1. Target position mark
2. Movable crosshair with current range scale

When attacking an invisible target, in the clouds or at night:

1. Change the information picture on the HUD by briefly pressing the control button, key **[L]**. The HUD screen view at D<0.65 nm is shown in Fig. 97
2. Approach the target at a distance of < 0.65 nm
3. Perform a rough aim - align the aiming ring with the fixed central crosshair by maneuvering the aircraft
4. Perform a precise aiming - align the precision aiming mark with the aiming ring
5. Fire by pressing the gun trigger
6. The aircraft exits the attack on command "OTB".

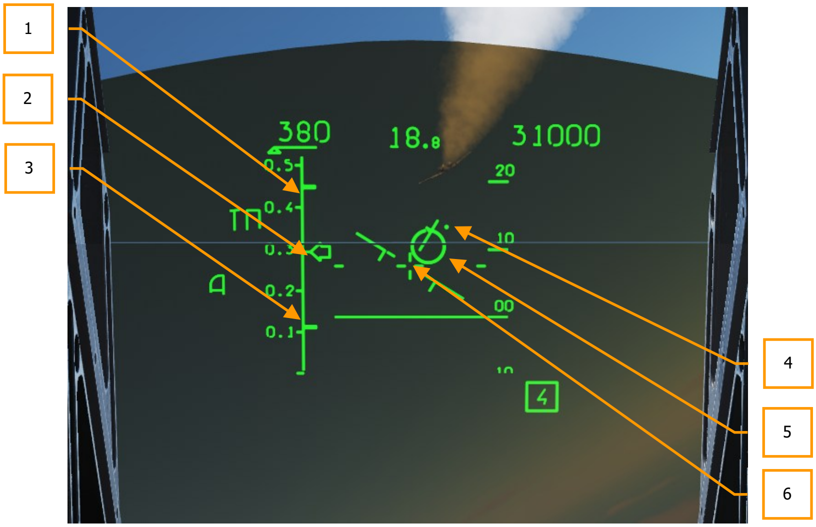


Figure 97: Gun employment, "Asynchronous shooting", "invisible" target at D<1200m

1. Label $D_{r\ max}$
2. Current range mark within the permitted firing range
3. Label $D_{r\ min}$
4. Precision aiming mark - dot
5. Rough aiming mark - ring
6. Fixed crosshair

Aimed shooting is provided at ranges of 4000...660 ft
Effective firing range 2600…660 ft

When holding the ring on the electronic crosshair, the precise aiming point should enter the ring

"Gun funnel"

The method is applied to a visible target in the absence of radar or radar lock-on.

The screen view is shown in Fig. 98.

Before attacking, set the target base in meters.

Attacking a target:

1. Enter the target by maneuvering the aircraft into the contour lines of the "path"
2. Fire by pressing the gun trigger
3. Disengage at a safe distance.

The best shooting accuracy is achieved by reducing the speed of the target's movement on the HUD screen at the moment it fits into the "track" contour - due to the angular speed of the turn of your aircraft and equalizing the speed of the fighter with the speed of the target

Figure 98: Gun employment, "Gun funnel"

Air-to-Ground operations

Operating against ground or surface targets, the weapons control system uses in the "OPT", "TOSS" or "RETICLE" modes.

Unguided rockets and Gun

Unguided rockets are C-24, C-8, C-5 type and a gun can be used the WCS is operating in the "OPT" and "BS" modes.

"OPT" mode

In the "OPT" mode, aiming can be done with or without pre-designate. Pre-designate is done when there is sufficient time to attack the target.

To use the "OPT" method with pre-designation:

1. Check the switch settings
   – "WCS MODE" to the "OPT" position
   – "AIR – GROUND" to "GROUND" position - for gun
   – "ALL – SINGLE 0.5 ALL" in accordance with the assignment - for unguided missiles
2. Turn the "MASTER ARM" switch ON, key **[M]**
3. Put the plane into a dive
4. Move the gun or missile launch trigger to the preliminary position
5. Press and hold the "LOCKON" button**,** key **[Enter]**, the PM will take the target detection position
6. Make sure that the laser rangefinder is automatically activated by the "A" symbol when it lights up at dive angles greater than 10° and the current range to the target is less than $D_{r\ max}$ + 1640 ft
7. If the "A" symbol is not displayed, start it manually by pressing the control button, key **[L]**
8. Align the aiming mark with the target and release the "LOCKON" button. At the moment of releasing the button, a preliminary target acquisition occurs
9. Re-align the aiming mark with the target and at the permitted firing ranges press the missile launch trigger - the index is in the effective firing zone, a sound signal is received - the appearance of the HUD screen is shown in Fig. 99
10. After finishing shooting, withdraw the aircraft from the attack.

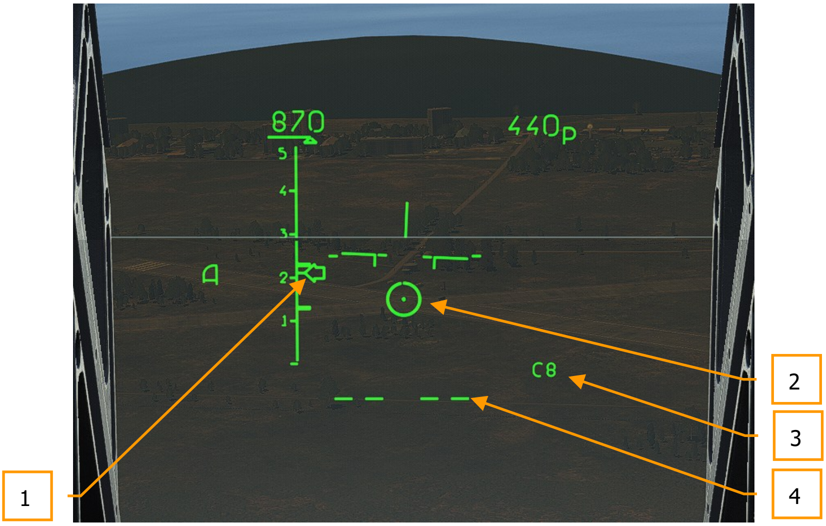


Figure 99: OPT mode, Pre-Aquisistion, Unguided rockets and Gun

1. Moving index
2. Target mark
3. Weapon type
4. Availability mark

When attacking ground targets, between releasing the "LOCKON" and by pressing the gun or missile launch trigger, the minimum time should be more than 1 second, the maximum time - less than 10 seconds.
The highest shooting accuracy is achieved in the range of 1.5...4 seconds.

It is possible to re-intersect the target by pressing the "LOCKON" button again during the attack

If the "A" symbol does not appear after pressing the control button,
the attack can be continued anyway.
In this case, the range to the target is measured in a less accurate way

When the minimum permitted firing range is reached,
the HUD displays a flashing "OTB" symbol.

Aiming in the "OPT" mode without pre-designate is performed if there is little time or altitude to attack the target.

To aim without pre-designate mark, after entering the dive and starting the laser rangefinder:
1. Determine corrections for wind speed and target movement
2. Move the aiming mark relative to the target by the amount of corrections
3. Press the gun or missile launch trigger at permitted firing ranges - the moving index in the effective firing zone and an audio signal is sent to the phones
4. After finishing shooting, withdraw the aircraft from the attack.

"BS" mode

The "BS" – boresight – mode is used when the "OPT" mode fails.

To work in this mode:
1. Set the "DAY – NIGHT – RETICLE" switch to the "RETICLE" position
2. Switch "ALL – SINGLE 0.5 ALL" in accordance with the assignment - for NRS
3. Switch "AIR – GROUND" to the "GROUND" position - for the gun
4. Turn on the "MASTER ARM" switch, key **[M]**
5. Put the plane into a dive
6. Move the gun or missile launch trigger to the preliminary position
7. Determine the range to the target, corrections for wind speed and target movement, taking into account the ballistic characteristics of the weapon used, see the table
8. Move the crosshair center relative to the target by the correction value and at the recommended firing ranges press the gun or missile trigger .
9. After finishing shooting, withdraw the aircraft from the attack.

Type of weapons	Firing range, nm	Shooting speed, kts	Dive angle, °	Angular corrections in the plane of symmetry of the aircraft, thousand.
C-24	0.97	432	20	60
C-8	0.86	432	20	43
C-5	0.81	432	20	54
Gun	0.81	432	20	14

Bomb weapons employment

Aviation bombing weapons (ABSP) can be used with the WCS is operating in the "OPT", "KBR", and "BS" modes.

"OPT" mode

In the "OPT" mode, aiming is performed by Pre-Designation, or without it.
Pre-Designation is performed when there is sufficient time to attack the target.

Aiming with Pre-Designation during dive bombing at angles up to 40° is performed in the following sequence:

1. Switch "WCS MODES" to the "OPT" position
2. "ALL – SINGLE 0.5 ALL" - in accordance with the task
3. Turn on the "MASTER ARM" switch, key **[M]**
4. Put the aircraft into a dive with a combat course and a dive angle of up to 40°
5. Move the missile launch trigger to the preliminary position
6. Press and hold the "LOCKON" button, key **[Enter]**, and the aiming mark will take the position for target acquisition
7. When the signal "A" is displayed, make sure that at dive angles greater than 10° and the current range to the target is about 11500 ft, the laser rangefinder (LRF) has automatically started.
8. If there is no "A" symbol, turn the LRF on manually by pressing the control button, key **[L]**
9. Align the aiming mark with the target and release the "LOCKON" button.
   At the moment of releasing the button, a preliminary target acquisition occurs
10. After the aiming mark stops moving downwards, align the aiming mark with the target again and press the missile launch trigger.

> Before missile trigger pressed, at $D_{min} < D_{cur} < 1.62$ nm,
> an audible signal is sent to the pilot's telephones

> The minimum time between releasing the "LOCKON" button and pressing
> the missile launch trigger should be ≥ 1 sec, the maximum time ≤ 10 sec.
> The highest bombing accuracy is achieved in the time interval of 1.5-4 sec.

Aiming without pre-designation is used for bombing from horizontal flight and dive bombing at angles of up to 40° when there is a shortage of time or altitude for attack.

To aim using this method:

1. Check the setting of the "WCS MODES" switch to the "OPT" position
2. Enter a combat course in level flight or dive with a combat course and dive angle of up to 40°
3. Move the missile trigger to the preliminary position
4. Launch the laser rangefinder - when bombing with a level flight – 3…5 seconds before it hits the target - check for the presence of the "A" symbol on the HUD (Fig. 100)
5. Determine the lead for the longitudinal and lateral drift of an aerial bomb by the wind during its fall and the speed of the target
6. Move the center of the aiming mark relative to the target on the lead amount
7. Press the missile launch trigger and hold it until the ABSP is released. The ABSP is released at the moment the missile launch trigger is pressed, provided that the sighting angle and the ABSP release angle are equal. If the release angle is greater than the target sighting angle, then when the missile launch trigger is pressed, the indication changes - the vector of the current overload and the ring of the specified overload appear, the range scale is replaced by the scale of the time remaining until the ABSP is released (Fig. 101)
8. Continue horizontal flight or dive until separation of the ABSP, aligning the end of the current vector with the center of the ring of the specified overload. 1.5…3 seconds before the remaining time $t_{ост}$

is out, an audio signal is sent to the phones and after its expiration, ABSP launch occurs. After the ABSP is out, the symbols for the presence of weapons on the suspension go out on the HUD.

9. After dropping the bombs, use an energetic maneuver to exit the attack.

> When using the KMGU, the aiming mark indicates the location of the first block's fall. After the KMGU unloading begins, it is necessary to maintain the flight parameters constant until it is completely unloaded - the presence symbols disappear

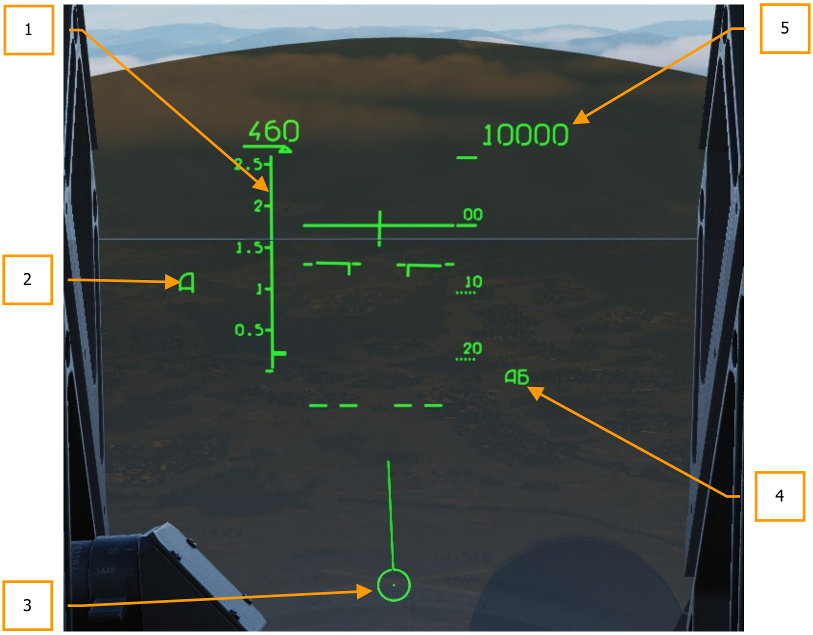


Figure 100: OPT mode, level flight and dive

1. Scale of slant range to target
2. "A" - indicator of laser rangefinder activation
3. "Spade" - line of ABSP impacts
4. Indicator of ABSP type selected
5. Altitude

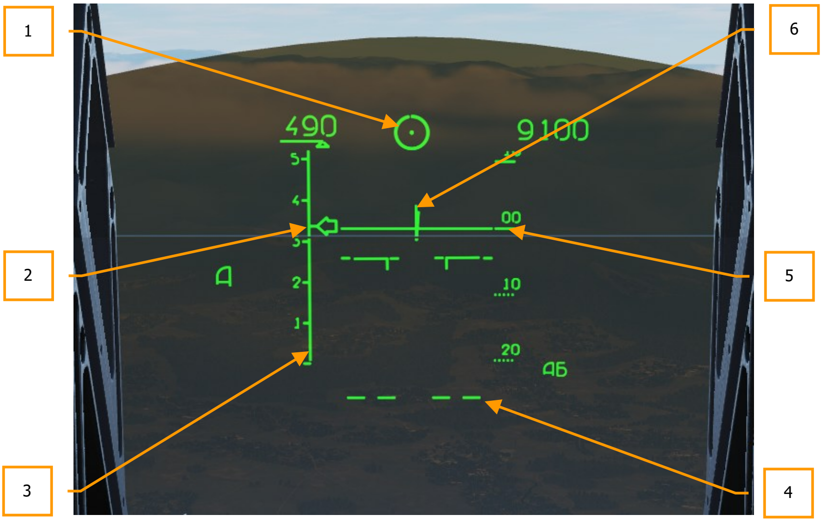


Figure 101: OPT mode, level flight and dive, trigger pressed

1. Director control ring
2. Time index to the ABSP launch
3. Time scale to the ABSP launch
4. ABSP availability indicator
5. Zero roll mark
6. Current overload vector

"TOSS" mode

The mode provides bombing from a pitching angle of 110…130°.

Aiming in this mode is performed in the following sequence:

1. Check the setting of the WCS MODES switch to the "TOSS" position
2. Go on a bombing course
3. 3…5 seconds before the aiming mark is placed on the target, start the laser rangefinder by pressing the control button, key **[L]**
4. When aligning the aiming mark with the aim of pressing the missile launch trigger, hold it until the ABSP is launched. At the moment the trigger is pressed, the range scale is replaced by the time scale, remaining until the start of entering the half-loop
5. Continue horizontal flight, aligning the director ring of the given overload with the end of the current overload vector. When flying over the target, the aiming mark may jump to the left or right. Do not track the jump of the aiming mark (Fig. 102).
6. An audible signal appears 1.5...3 seconds before the start of pitching.
   At the moment of zeroing the remaining time, the audible signal disappears, the symbol "Г" appears,
   the director ring of the specified overload jumps upward.
   The time remaining until reset is indicated on the scale

7. Enter the aircraft into a half-loop, aligning the end of the current overload vector with the center of the ring.
   In this case, the overload will be within 4…5 at pitch angles of 90…95°, the ring of the given overload vector may oscillate to the right, then to the left, followed by a return to the original position. The oscillations of the ring should not be monitored by piloting the aircraft.
8. 1.5...3 seconds before reset, a sound signal appears
9. The descent of the bomb is monitored by the disappearance of symbols on the HUD indicating the presence of pendants.

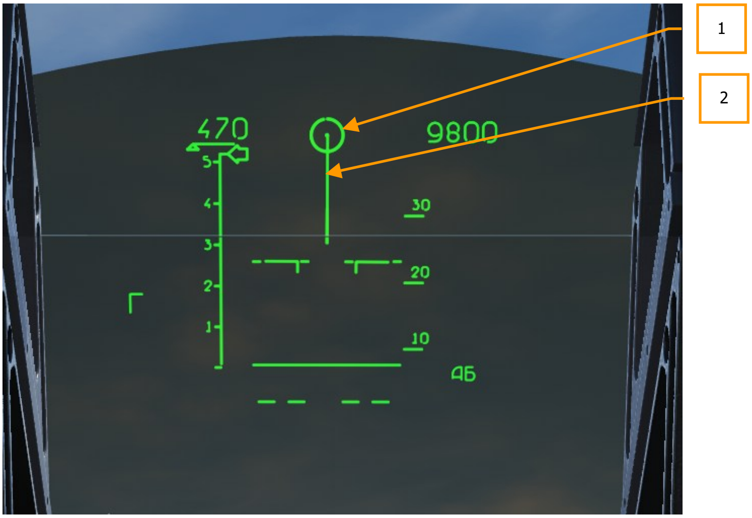


Figure 102: TOSS mode, trigger pressed, half-loop enter

1. Director ring of a given overload
2. Vector of current overloads

When operating against ground targets, in the event of failure of the ABSP, C-24, the presence of empty NRS and KMGU blocks, a presence signal is indicated, and the weapon type is removed

It is allowed to release the missile trigger after binding to the target and then pressing it during the execution of the half-loop

"RETICLE" mode

If the "OPT" mode fails, bombing from horizontal flight and diving is possible by aiming using a fixed grid at the calculated angle, maintaining the specified flight conditions during the aiming process.

To perform bombing using a fixed grid, it is necessary to set the "DAY - NIGHT - RETICLE" switch to the "RETICLE" position and turn on "PREPARE MAN."

When bombing in conditions where the calculated correction value is within the vertical grid line, it is necessary to align the calculated point with the target in the given conditions and press the missile launch trigger.

When bombing in conditions where the calculated correction value is outside the vertical grid line, it is necessary, having aligned the point of intersection of the outer warning ring with the vertical line with the target, to count the time according to the calculated data and press the missile launch trigger.

DEFENSIVE SYSTEMS

RHAW. SPO-15LM

Information display

The SPO-15LM radar warning receiver is designed to warn the pilot about radio-frequency emissions in centimeter band, for the purpose of defense against hostile fire control radars.

The device records, analyzes and displays the following information:

- Azimuth to illumination event
- Mode of the illuminating radar (search or track)
- Type of the threat
- Determination of the main threat
- Closing dynamics of the main threat
- For SAM batteries, estimated border of the weapon engagement zone in terms of equivalent signal power
- Main threat elevation relative to own aircraft.

The information is presented on the display unit, located on the right side of the central instrument panel.

In addition to the controls present directly on the indicator, a control panel on the right console allows the pilot to turn the device on or off, filter out radars operating in search mode and adjust the warning tone volume.

The SPO-15LM detects incoming radiation within 360° around the aircraft, and ±30° in elevation using dedicated receiving channels. Each azimuth and elevation channel works individually and each detection event is displayed on the green azimuth scale with at least 125 ms flash in the corresponding channel, accompanied by a low audio tone.

The LM variant of SPO-15 features 10 azimuth channels total and 8 logical azimuth channels for processing. Each front hemisphere antenna uses an array of 4 separate feeds with a common Luneburg lens; the half power beamwidth is 20° in azimuth and 60° in elevation for each channel, with 20° separation in azimuth between peaks. The 70° and 50° channel feeds are merged into a single logical channel in the LM variant. The rear hemisphere is covered by standard spiral antennas with a 40% power beamwidth of at least 60°. The device is set up for a 10° overlap between sectors in forward hemisphere at average frequency and signal power level, allowing signals incoming from in-between two sectors to be indicated as a double detection. As a result, the azimuthal resolution is 10° in ±50° sector in forward hemisphere, ±20° beyond that sector, and ±45° in the rear hemisphere. Note that in the LM variant, **the 90° sector on the indicator is virtual** - it corresponds to a simultaneous detection in the rear hemisphere and the 50° sector on the same side.

Figure 103: RHAW. SPO-15LM display unit

1. Device ready light
2. Main threat azimuth light
3. Threat azimuth light
4. Tracking Warning Light - RED
5. Emitter power level indicator
6. Own aircraft silhouette
7. Threat azimuth indicator (rear channels)
8. Primary threat azimuth indicator (rear channels)
9. Main threat type light
10. Threat type light
11. Brightness control knob
12. BIT switch "MANUAL" - "AUTO" - starts manual or automatic SPO check.
13. Main threat position light (N/I)
14. Elevation angle indicators. "B" is the upper hemisphere, "H" is the lower hemisphere.

The RHAW system is powered up by the "SPO" switch on the control unit panel – Figure 104.

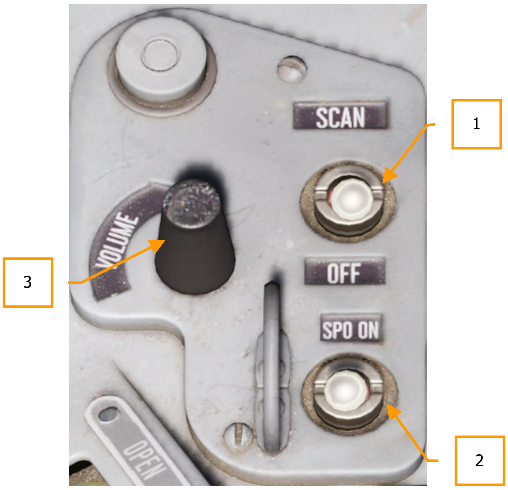


Figure 104: SPO-15LM control unit panel in the cockpit of Mig-29

1. Allow search on/off
2. Power on/off
3. Audio volume

Type letter	Typical threats	Description
П	F-4, Aegis ships	LPRF fire control radar equipped with a continuous wave illuminator operating in SA guidance mode (colocated pulsed and a continuous wave signal) - **this should be treated as a launch warning in most cases**
3	Vulcan	AAA/Short/Medium range SAM fire control radar
X	Hawk CWAR/HiPIR	Continuous wave radar, HPRF radars at low power levels
H	Nike-Hercules	Strategic SAM search and fire control radar
F	F-14, F-15, F-16	4th generation (F-type) HPRF fighter radar
C	F-4, F-5, Mirage-F1, Naval radars	LPRF fire control radar equipped with a continuous wave illuminator operating with the CWI channel disabled Other known threat radar types including LPRF fighter FCR and surveillance radars

Table 1: SPO-15LM threat type description

Threat recognition

The device attempts to identify each detected signal based on its pulse width and pulse repetition frequency. The threats are divided into 6 types - these types, by design, cover specific high threat emitters, but in practice they cover a range of emitters of similar type. The general rules according to which the threats are divided are shown in Table 1

If the incoming signal is recognized, one of the 6 green letters (corresponding to type letters in Table 1) turns on simultaneously with the first azimuth lamp flash. If the signal is unknown (the parameters don't match any of those in the threat program), no type lamps turn on. By convention, friendly radars are not included in the threat program - however due to limited ability to distinguish between signal parameters (especially at medium to high PRF), friendly radars might be mistakenly recognized as one of the known threat types. These kinds of collisions might also occur between enemy radars - generally if the parameters of two threat radars overlap (within the resolving ability of the device), the higher priority threat is included in the threat program, and the lower priority threat will be mistakenly identified as a higher priority threat. If unsure please refer to the kneeboard for the description of the installed threat program.

The device distinguishes between search and track modes of the threat radars based on the length of the detection event: detections longer than 125-250 ms are designated as track mode, giving them a higher priority and switching the device into track warning mode, denoted by a red light in the middle of the indicator and a continuous high audio tone. The logic of the search switch is tied to this property - when the switch is set to off, emitters are filtered out if they are not classified as operating in track mode.

Threat priority

The current highest priority threat is designated with additional yellow lights above the respective threat type and azimuth light. The main threat is remembered for 8-12 s in search mode and 2-4 s in track mode. In addition to azimuth and type, the device displays the signal power over threshold (in 2 dB increments) on the circular signal power level scale and the output of the elevation channels in form of 2 elevation lights (B - higher/H - lower). The elevation channels are mutually exclusive, however the exact border between them changes with the signal power. Both signal power and elevation should be treated as estimates. Additionally, if the type covers surface-to-air threats, the weapon engagement zone of the main threat type (in terms of signal power corresponding to that range) is indicated by a flashing light on the signal power scale - this indication is conservative and corresponds to the lowest power emitter designated under given type, however it should also be treated as a rough estimate, since the actual signal power and weapon engagement zone vary with radar mode, conditions, and angle off-boresight of the emitting antenna.

The device can display Nike-Hercules missile launch by modulating the track light and its corresponding audio tone at 2 Hz. This is triggered by detection of missile command pulse packets from the Missile Tracking Radar using a dedicated circuit (not implemented).

The threat priority logic in the MiG-29 is shown in Table 2.

Priority	Description
1	Nike-Hercules launch (N/I)
2	Emitter in track mode
3	Emitter is within azimuth-altitude priority range and closest to the front of type priority row
4	Emitter is outside of azimuth-altitude priority range and closest to the front of type priority row
5	Emitter PRF is above 781 Hz
6	Emitter signal power is the highest

Table 2: SPO-15LM threat priority logic

Type	Threats
П	F-4, F-104, Talos, Terrier, Tartar, SM-1
З	Vulcan, Sea Wolf, Mk 35, AN/SPG-48, AN/SPG-53
X	Hawk CWAR/HiPIR
H	Nike-Hercules TTR/MTR
F	F-14, F-15, F-16, F/A-18, M-2000
C	F-4, F-5, F-104, Mirage-F1, Jaguar, Talos, Terrier, Tartar, SM-1

Table 3: Stock threat program

Remark	Explanation
CW	Continuous wave radar - will always be listed under type X, as the device is not able to differentiate between different CW emitters.
CWI	The radar system contains a continuous wave illuminator (that does not necessarily mean it will be displayed as type П - this is limited to type C threats by hardwired logic, other types will report an additional type X if they are not HPRF)
QCW	Quasi-continuous wave i.e. HPRF - this means the threat might be mis-identified as type X at low power levels, and will block detection of further CW signals once recognized, see Device limitations
P/Z/H/N/F/S occl	The parameters of this emitter are close to a higher priority emitter of a different type, so it might be falsely recognized as that type
Launch	Launch can be detected by the device (this is limited to Nike-Hercules and not applicable in DCS)
Jitter/ Stagger/ Rand. PRF	The emitter PRF is unstable which might interfere with ID process, see Device limitations

Table 4: Kneeboard remarks

The type priority "rows" described in Table 2 are П > З > X > H > F > C for high priority threats and X > H > F > П > З > C for low priority threats. The row to use is determined based on an azimuth-altitude criterion. In the MiG-29, the altitude is permanently assumed to be 26000-55000 ft, and threats with WEZ ceiling below 26000 ft are always considered low priority. The azimuth criterion depends on type:

for types П and F only abeam targets are considered low priority, for types 3 and X the forward hemisphere targets are considered high priority, for type H head on and abeam targets are considered high priority, for type C head on and non-abeam targets are high priority.

Threat program

The SPO-15LM was designed to be modular, with different circuits of the computational block separated into plug-in cartridges that can be quickly replaced by the ground crew. This allowed easier servicing, and in principle allowed the device to be upgraded. In particular, the threat program, which was limited only to 6 distinct types (4 in practice, as 2 of them - П and X - are special purpose and cannot be freely assigned) could be upgraded by replacing the cartridges containing the threat recognition circuits. This ability was limited in practice, due to the analog nature of the device - the threat program is implemented in hardware, and changing it requires resoldering of jumper wires on the board. In practice, the threat program cartridges were not frequently upgraded and the threat programs were assigned per theatre to match local threats.

For this reason, the threat program isn't freely modifiable by the pilot, and instead is generated automatically. Two types of threat programs are available: stock and automatic. The threat program is selected per aircraft slot in Mission Editor.

- Stock - this program is intended to be used with former Warsaw Pact aircraft in air forces which do not have access to manufacturer servicing. Historically the devices were usually not upgraded after dissolution of Warsaw Pact, causing the threat program to be disconnected from the real threat environment. This does not mean the threats cannot be detected, but they will not be recognized accurately in manner consistent with Table 1 requiring additional pilot training to use it effectively. The simulated threat program is presented in Table 3 - note that some of the radar systems in this program are not present in DCS, however other radars with similar signal parameters will be recognized as them by the device.
- Automatic (default) - this program is generated automatically based on the known threat list in the mission. The threats are assigned to types according to logic presented in Table 1. Radars which are unlikely to be detected (typically due to lying outside of operational frequency range of the device) are not included in the program. In case of parameter overlap between *different* types, the higher priority threat is used. The precedence here is aircraft > air defense > navy > surveillance, with more capable threat taking precedence within the same group. The program is overwritten on top of the stock program, so the threats in that program are still in memory and might be falsely identified e.g. when illuminated by a friendly radar with similar properties (including other fighters)

The threat program is listed in the pilot's kneeboard. The list includes abbreviated remarks relating to threat properties the pilot needs to be aware, which are described in Table 4.

Device limitations

- Due to the principle of operation (entirely analog using application-specific circuits), the SPO-15 has several limitations that need to be taken into account (some of which were described above). One important limitation to take into consideration relates to how the azimuth signals are processed. The only interaction between azimuth channels in the SPO-15 is for the measurement of signal power level. Outside of that, each channel is processed separately, one at a time, in a clockwise direction. As a result, the azimuth indication is not only limited in resolution by the number of antennas used to cover a sector, but is subject to physical properties of the antennas. The directivity of the front facing antennas varies significantly with frequency, which causes multiple sectors to activate when illuminated by low frequency radars. The methods used to reduce this effect are also tuned for specific power level, therefore the effect gets worse at high power levels. In worst case scenario, the device can be "blinded" resulting in all azimuth channels being triggered at once. High power search signals can also be falsely identified as track signals due to detection of side lobes of the emitter's directivity pattern, resulting in longer illumination events.
- Another limitation of the device relates to its ability to distinguish between multiple signals in the same azimuth sector. If two pulse radars are present on the same azimuth, the device may only identify them if the signals differ in power by at least 6 dB (3 levels on the indicator). If there are more pulse radars on the same azimuth, only the most powerful radar signal will be recognized (provided it is at least 6 dB above the rest). Otherwise, *none* of the signals will be recognized, as the device will not be able to measure the PRF.
- Radars which rapidly modulate the PRF (jitter/stagger etc.) might not always be recognized effectively, either in track mode or in all operational modes, even if they're present in threat program, due to inability of the device to measure the PRF of such emitters consistently.
- If two pulsed radars are present in the same sector and both are recognized, but one of them operates in track mode, the other radar might be mistaken as operating in track mode too, and its signal parameters might overwrite the actual tracking radar if the resulting emission is higher priority. This is because the track property is determined **per entire azimuth channel** rather than per event - any time a track is detected, the corresponding sector is marked as tracking for the next 2-4s.
- If a continuous wave radar is detected on the same azimuth as a type C radar, and both operate in the same mode (search or track), they might be falsely identified as a single type П radar - the pilot must exercise their judgement to determine if the type П warning is legitimate or a false positive. If the type П is selected as priority, it prevents types X and C from being displayed at all if present. If the two radars operate in different modes, the device has provisions to filter out false type П indication, so in practice this will only happen when both radars are tracking (as simultaneous illumination by both radars in search mode is unlikely).
- The continuous wave detection circuit can falsely detect HPRF signals as low power continuous wave signals. Due to a higher sensitivity of the continuous wave circuit, HPRF emitters will usually be detected as type X long before they are detected as pulsed radars - the difference can be anywhere between 6 and 14 dB depending on the emitter frequency. To denote the identification as ambiguous, low power type X detections are indicated by a flashing X on the threat type scale as opposed to a solid one. Additionally, when an HPRF type is positively identified, the continuous wave detection circuit is **shut down** preventing detection of actual continuous wave threats - this needs to be taken into account when operating in an environment with both 4th gen fighters and Hawk batteries present.

- The elevation is measured with separate channels, with their own antennas. Because these antennas have relatively low efficiency, the elevation channels usually won't activate until relatively high power levels, often well within the weapon engagement zone.
- Although the sensitivity of the azimuth channels is much higher than the sum channel used for power level measurement, only continuous wave signals can be detected at power level 0 - pulsed signals are deliberately filtered out until power level 1, in order to avoid chaotic behavior due to inconsistent detection of pulsed signals at low power levels.
- **When the onboard FCR is radiating, the forward hemisphere of the device is completely disabled.** This is necessary because the device is not capable of effectively filtering out HPRF signals of the MiG-29 FCR.

Built-in test system

The device features a built-in test system, controlled by the test switch on the indicator panel. Depressing the switch to the right enables an automatic system test, together with a light test. When the device is enabled and under test, the "device ready" light turns off. If the light turns back on within no more than 5-7 s, it means the test has passed successfully, and the device returns to normal operating mode. While the switch is held, all lights except for the "device ready" light and the "sound disabled" light should turn on (the "sound disabled" is connected directly to the control panel, and turns on when the volume potentiometer is turned all the way down into off position - it is not controlled by the computation block of the device). When in test mode, the brightness is halved to reduce load on the power supply.

Pushing the BIT switch to the left enables manual test mode. In manual test mode, one of the azimuth channels is fed a continuous wave test signal allowing the receiver and all the elements downstream of it to be tested. Pressing the switch to the left repeatedly cycles channels. The first 16 presses test the higher frequency sub-band of the device, the next 16 presses test the lower sub-band (in the 9-12 this is the only time when the device operates the two receivers separately, as binning by carrier frequency is disabled permanently in this aircraft). In each sub-band the test system cycles through channels twice, with the exception of the two merged channels in forward hemisphere antennas (50° and 70°), allowing individual receivers to be tested. The elevation channels are tested together with the rear hemisphere channels on first pass. While going through the higher sub-band, the device should report main type X in track mode. In order to exit manual test mode, the switch must be depressed to the right. After running a test, the device may display a false main type, this false contact should expire normally after 2-12 seconds.

Countermeasures dispensers

In order to defense against missiles, aircraft equipped with two flare/chaff dispensers, mounted in front of vertical stabilizers.

Release button placed on right throttle grip, and mode select switch – on the frontal instrument panel, under emergency chaff/flare jettison button.

Abbreviations

A2A – Air-to-Air

A2G – Air-to-Ground

AAA – Anti-Aircraft Artillery

AAM – Air-to-Air Missile

ACS – Automated Control System

ADI – Attitude Direction Indicator

AFCS – Automatic Flight Control System

AFF – Advanced Frontline Fighter

AGM – Air-to-Ground Missile

AIM – Airborne Intercept Missile

AOA – Angle of attack

AOJ – Angle of Jam

ARH – Active Radar homing head/missile

ARU – Automatic control regulation

ASM – Air-to-Surface Missile

AWACS – Airborne Warning and Control System

BCVM – On-board digital computer

BIT – Built-in Test

BVR – Beyond Visual Range

CEP – Circular Error Probable

ECM – Electronic Countermeasures

EGT – Exhaust Gas Temperature

EOS – Electro-optical system

EW – Early Warning

FCS – Flight Control System

FHS – Frontal hemisphere

GCI – Ground-controlled Intercept

HAFF – Heavy Advanced Frontline Fighter

HDD – Head Down Display

HSI – Horizontal Situation Indicator

HMD – Helmet mounted display

HMS – Helmet-mounted sighting device

HOJ – Home on Jam

HUD – Head-up Display

IAS – Indicated Air Speed

IFF – Identification Friend or Foe

ILS – Instrumental landing system

IR – Infra Red

IRH – Infra-Red Homing Head/Missile

IRST – Infra Red Seek and Track System

KMGU – Universal small cargo container

KOLS – Quantum Optical-Laser Station

KSA – Aircraft Accessories Box

KSC – Master caution button-lamp

LA – Launch Authorized

LAFF – Light-weight Advanced Frontline Fighter

LCOS – Lead Computed Optical Sight

LD – Laser rangefinder

LEF – Leading Edge Flaps

LEX – Leading Edge Extension

LTRD – Laser Track/Ranging Designator

MED – Medium

MEZ – Missile Employment Zone

MLWS – Missile Launch Warning System

NAV – Navigation

NWS – Nose wheel steering (MRK)

NRS – Unguided rocket

OEPrNK – Opto-Electronic Sighting/Navigation System based on KOLS data

PM – Aiming mark

PMU – Simple meteorological conditions

PRF – Pulse Repetition Frequency

PRI – Pulse Repetition Rates

QFE – Q-code Field Elevation

RCS – Radar cross-section

RGS – Radar homing head

RHS – Rear hemisphere

RKT – Rockets

RLPK – Radar sighting complex

RPM – Rounds per minute

RWR – Radar Warning Receiver

RWS – Radar Warning System

SAM – Surface-to-Air Missile

SARH – Semi-active Radar Homing head/missile

SLAR – Side-Looking Airborne Radar

SPU – Intercom

STT – Single Target Track

SUVP – Passive Jamming Emission Control System

TAS – True Air Speed

TDC – Target Designation Controller, also refers to the corresponding designator (mark)

TGS – Thermal homing head

TLP – Telelight panel

TWS – Track While Search

UIE – Unified indication system

VS – Vertical Scaning

VSD – Vertical Situation Display

VVI – Vertical Velocity Indicator

WCS – Weapon Control System

WoffW – Weight-off-Wheels

WonW – Weight-on-Wheels

WoW – Weight on Wheels status