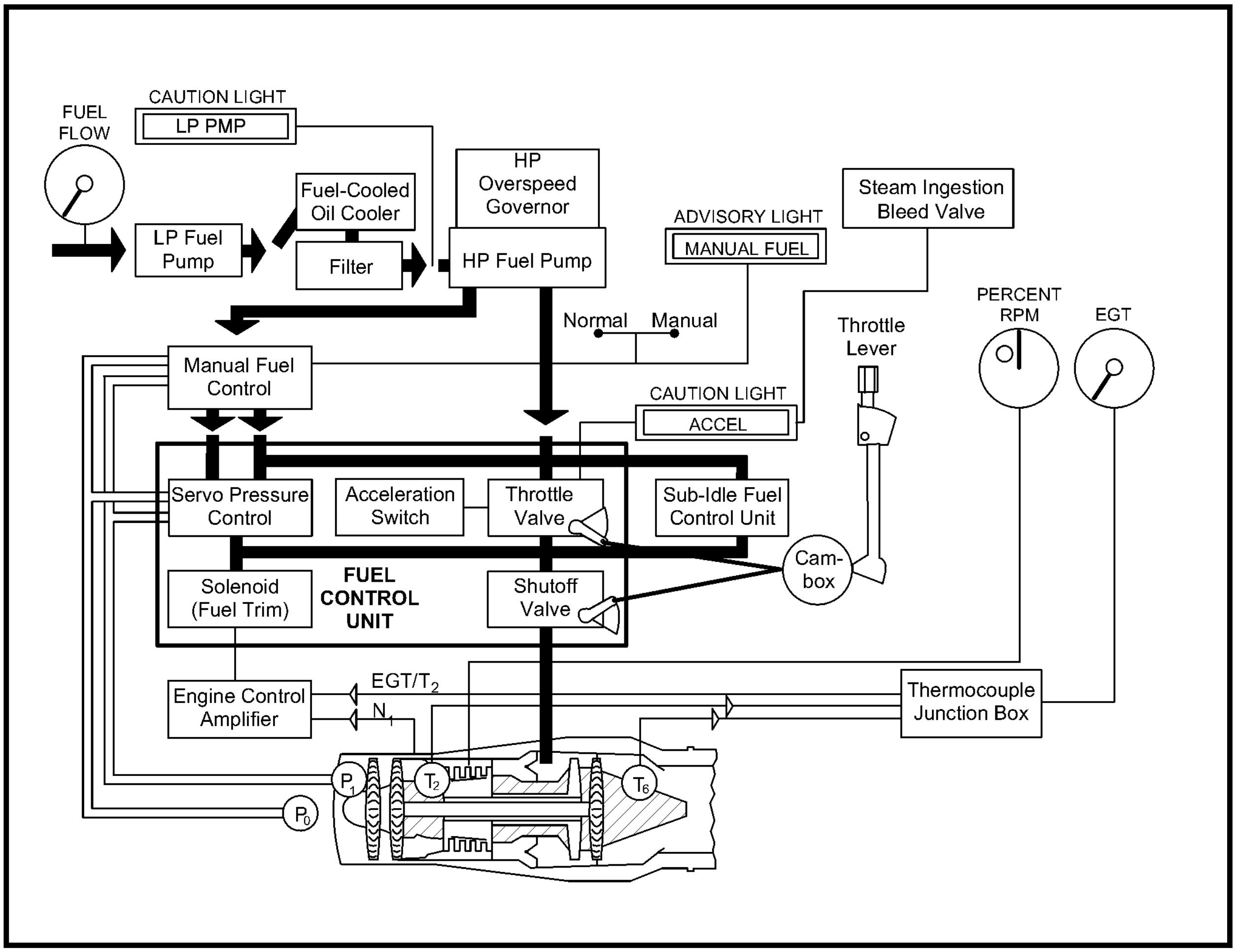
NAVAL AIR TRAINING COMMAND

NAS CORPUS CHRISTI, TEXAS CNATRA P-1278 (9-98) PAT

ENGINEERING



LECTURE GUIDE

BOOK 2

1998

T-45C LECTURE GUIDE

CHANGE SUMMARY PAGE

CHANGE NUMBER	DATE ENTERED	CHANGE DESCRIPTION	INITIALS
1	7/31/00	Incorporated	TSC
2	3/2/01	Incorporated	TSC
3	10/05/01	Incorporated	TSC
4	11/07/02	Incorporated	TSC
5	12/15/03	Incorporated	TSC
6	3/31/04	Incorporated	TSC
7	6/22/05	Incorporated	TSC

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LECTURE GUIDE
LIST OF EFFECTIVE PAGES

EFFECTIVE PAGES	PAGE NUMBERS
FRONT MATTER	
Change 7	i
Change 2	ii
Change 7	iii thru iv
Change 5	v
Change 3	vi
TS, ADV, & IUT ENG-01	
Change 1	Title page(s)
Original	1-1 thru 1-10
Change 1	1-11
Original	1-12 thru 1-40
TS, ADV, & IUT ENG-02	
Change 4	Title page(s)
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TS, ADV, & IUT ENG-03	
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TS, ADV, & IUT ENG-05	
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TS, ADV, & IUT ENG-05 (cont.)	
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TS, ADV, & IUT ENG-06	
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Change 4	Title page(s)
Original	9-1 thru 9-5
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TS, ADV, & IUT ENG-10	
Change 2	Title page(s)
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Change 2	10-3 thru 10-4
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Change 2	10-7
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Change 1	10-12
Original	10-13 thru 10-15
Change 1	10-16
TS, ADV, & IUT ENG-11	
Change 4	Title page(s)
Original	11-1 thru 11-3
Change 4	11-4
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Change 1	11-20
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Change 1	Title page(s)
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TS, ADV, & IUT ENG-14	
Original	Title page(s)
Original	14-1 thru 14-16
TS, ADV, & IUT ENG-15	
Change 4	Title page(s)
Original	15-1 thru 15-15
Change 4	15-16 thru 15-40
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Change 1	Title page(s)
Original	21-1 thru 21-33
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TS, ADV, & IUT ENG-22			
Original	Title page(s)		
Original	22-1 thru 22-16		
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Original	Title page(s)		
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Original	Title page(s)		
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Original	Title page(s)		
Original	25-1 thru 25-31		
TS, ADV, & IUT ENG-26			
Change 3	Title page(s)		
Original	26-1 thru 26-2		
Change 3	26-3 thru 26-4		
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Change 3	26-7		
Original	26-8 thru 26-9		
Change 3	26-10 thru 26-22		
TS, ADV, & IUT ENG-27/ENG-28			
Change 5	Title page(s)		
Original	27-1 thru 27-20		
Change 1	27-21		
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Original	27-24 thru 27-33		
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Change 1	27-158		
Original	27-159 thru 27-183		
Change 1	27-184		

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EXAMINATION:

The student is required to read On-Board Oxygen Generating System/Anti-G and Environmental Control System and related malfunction paragraphs in the NATOPS flight manual, receive classroom instruction, and complete assigned CAI lesson(s). The student shall demonstrate knowledge by completing, from memory with 80% accuracy, true/false and multiple choice block
examinations. The objectives in this lesson will be tested in either Engineering 29X or Engineering 30X.

LESSON GUIDE

COURSE/STAGE: TS, ADV & IUT / Engineering

LESSON TITLE: OBOGS & ECS/Pressurization System Malfunctions

LESSON IDENTIFIER: T-45C TS, ADV & IUT ENG-18

LEARNING ENVIRONMENT: CAI

ALLOTTED LESSON TIME: .5 hr

TRAINING AIDS:

Figures:
Fig 1: Cockpit Pressurization System

STUDY RESOURCES:

T-45C NATOPS Flight Manual, AI-T45AC-NFM-000

LESSON PREPARATION:

Read:
* Part I, Chapter 2, Section 2.18, "Environmental Control System," T-45C NATOPS Flight Manual, AI-T45AC-NFM-000
* Part I, Chapter 2, Section 2.19, "On-Board Oxygen Generating System," T-45C NATOPS Flight Manual, AI-T45AC-NFM-000

Review:
* Lecture Guide for Eng-17, "OBOGS & ECS/Pressurization System"

REINFORCEMENT: N/A

LESSON EXAMINATION:

The student is required to read On-Board Oxygen Generating System/Anti-G and Environmental Control System and related malfunctions paragraphs in the NATOPS flight manual, receive classroom instruction, and complete assigned CAI lesson(s). The student shall demonstrate knowledge by completing, from memory with 80% accuracy, true/false and multiple choice block examinations. The objectives in this lesson will be tested in either Engineering 29X or Engineering 30X.

LESSON OBJECTIVES

1.8.1.4.3.1
Identify indications of OBOGS malfunctions

1.8.1.4.1.1
Identify indications of loss of ECS temperature control

1.8.1.4.2.1
Identify indications of cabin pressurization failure

1.8.1.4.2.3
Identify indications of cabin altimeter failure

MOTIVATION

As a pilot of high flying jet aircraft, you must be aware of the importance of oxygen and pressurization systems.

This lesson teaches you how to identify several malfunctions that could occur in ECS and OBOGS. These systems are critical to your physical safety and the integrity of your avionics equipment.

OVERVIEW

LESSON GOAL
This lesson will help you recognize malfunctions in the OBOGS, ECS, and pressurization system.

This lesson presents indications of the following malfunctions:

* On-board oxygen generating system (OBOGS) failure
* Environmental control system (ECS) temperature control failure
* Cabin pressurization failure
* Cabin altimeter failure

REFRESHER

Recall the location and function of:

* Cockpit OBOGS/ECS controls and indicators
* Cabin pressurization indicators
* Warning panel lights associated with OBOGS/ECS

PRESENTATION

I. OBOGS failure **1.8.1.4.3.1**

A. Indications

1. OBOGS Pneumatic BIT failure

NOTE: The BIT should illuminate the OXYGEN warning light. After the test, the light should go out.

WARNING: Testing the OBOGS above 9000 ft MSL shuts down the OBOGS.

2. In flight

a. MASTER ALERT flashes

b. Warning tone sounds in headset

c. OXYGEN warning light illuminates

B. Verifications

1. Low concentration (OXYGEN light illuminated)

2. Overtemperature (OXYGEN light illuminated)

a. Temperature exceeds 250 degrees F

C. Effects on flight safety

1. Cabin altitude restricted to 10,000 ft MSL or below anytime supplemental oxygen is not available

2. Required decrease in altitude increases fuel consumption

3. Difficulty breathing with mask on

II. ECS temperature control failure **1.8.1.4.1.1**

A. Indications: cockpit too hot or too cold

B. Verifications

1. Cabin temperature too hot or cold in relation to temperature setting

2. No response to temperature control in AUTO or MANUAL

C. Effects on flight safety

1. Potential equipment failure if overheated (if occurred on ground)

2. Canopy fogging, especially during a penetration into hot and humid areas

3. May require turning off pressurization

Fig 1: Cockpit Pressurization Schedule

III. Cabin pressurization failure **1.8.1.4.2.1**

A. Indications

1. System failure above 24,500 +/- 500 ft: MSL

a. CABIN ALT warning light will illuminate

b. MASTER ALERT flashes

c. Warning tone sounds

2. System failure below 24,500 +/- 500 ft: MSL cabin altimeter increases to aircraft altitude, above 5000 ft MSL

B. Verifications

1. Cabin altitude gauge increases to aircraft altitude, above 5000 ft MSL

2. Confirm with aft cockpit, if possible

3. Possible discomfort in ears and sinuses if cabin altitude abruptly climbs

C. Effects on flight safety

1. Safest altitude below 25,000 ft MSL

2. At higher cockpit altitudes, pilot must closely monitor oxygen supply

3. Possible hypoxia if oxygen system lost

4. Lower altitude will increase fuel consumption

NOTE: Failure of OBOGS and pressurization may require an immediate descent and use of emergency oxygen.

IV. Cabin altimeter failure **1.8.1.4.2.3**

A. Indications: needle freezes or reads erroneous altitude

B. Verifications

1. As aircraft climbs and descends, cabin altimeter does not show true cabin altitude changes

2. Check with aft cockpit, if possible

C. Effects on flight safety: pilot unable to confirm cockpit altitude to check for proper pressurization

SUMMARY

This lesson has presented indications of these OBOGS/ECS malfunctions:

* On-board oxygen generating system (OBOGS) failure
* Environmental control system (ECS) temperature control failure
* Cabin pressurization failure
* Cabin altimeter failure

CONCLUSION

OBOGS and ECS are critical to your safety and comfort in the cockpit. In addition, ECS cools your avionics equipment.

If this lesson has raised any questions for you, be certain to contact your instructor.

REVIEW

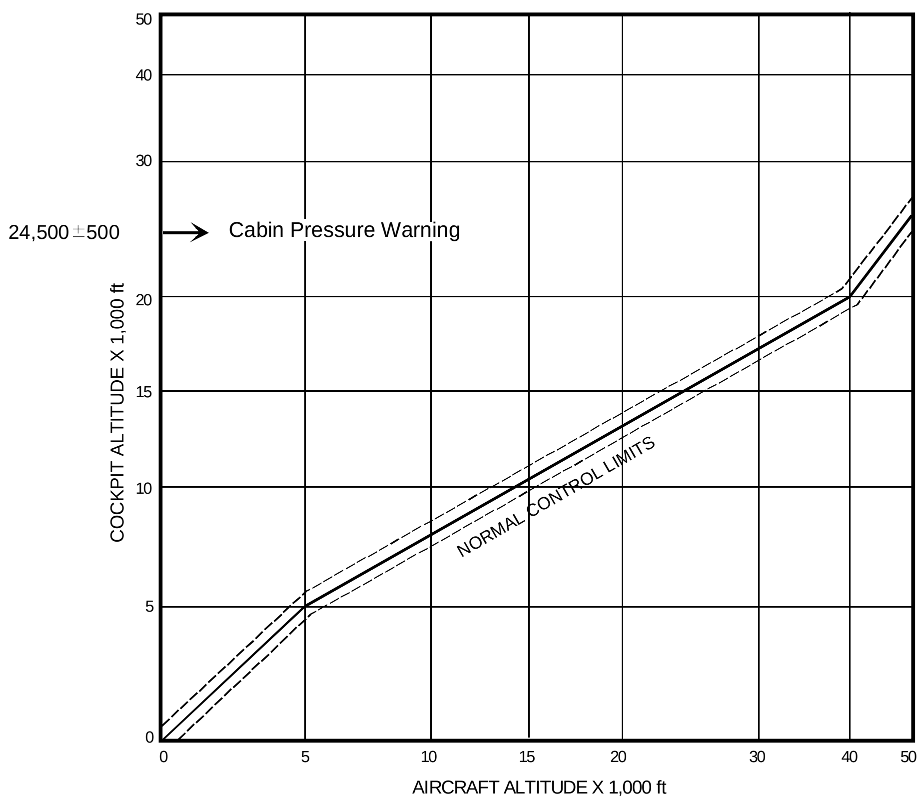


Figure 1: COCKPIT PRESSURIZATION SCHEDULE

LECTURE GUIDE

COURSE/STAGE: TS, ADV & IUT / Engineering

LESSON TITLE: Flight Instruments

LESSON IDENTIFIER: T-45C TS, ADV & IUT ENG-19

LEARNING ENVIRONMENT: Classroom

ALLOTTED LESSON TIME: 1.3 hr

TRAINING AIDS:

* Wall Charts
  T-45C Cockpit
* Figures:
  Fig 1: GINA Major Related Component Locations
  Fig 2: MFD with Attitude Director Indicator (ADI) Display
  Fig 3: MFD with Horizontal Situation Indicator (HSI) Display
  Fig 4: Standby Barometric Altimeter
  Fig 5: Standby Airspeed Indicator
  Fig 6: Standby Vertical Speed Indicator (VSI)
  Fig 7: Angle of Attack System
  Fig 8: Radar Altimeter Readout
  Fig 9: Standby Attitude Indicator
  Fig 10: Standby Turn and Slip Indicator
  Fig 11: Standby Compass
  Fig 12: Clock/Stopwatch
  Fig 13: HUD Indications

STUDY RESOURCES:

* T-45C NATOPS Flight Manual, A1-T45AC-NFM-000

LESSON PREPARATION:

Read:

* Part I, Chapter 2, Section 2.20, "Flight Instruments," in the T-45C NATOPS Flight Manual, A1-T45AC-NFM-000

REINFORCEMENT: N/A

EXAMINATION:

The student is required to read flight instruments and related flight instrument malfunction paragraphs in the NATOPS flight manual, receive classroom instruction, and complete assigned CAI lesson(s). The student shall demonstrate proficient knowledge by completing, from memory with 80% accuracy, two 40-question (true/false and multiple choice) block examinations. The objectives in this lesson will be tested in either Engineering 29X or Engineering 30X.

LESSON OBJECTIVES

1.4.5.3.1
Recall major components of the flight instrument system

1.4.5.2.1
Recall operating characteristics of the flight instrument system

1.4.5.3
Recall function, purpose, and location of flight instrument controls, switches, and indicators

1.4.5.2
Recall interfaces between the flight instruments and other a/c systems

MOTIVATION

From takeoff to landing, whether you're delivering weapons or engaging in ACM, much of the data that goes into decision making comes from your flight instruments.

OVERVIEW

This lesson covers the purpose, functional characteristics, and location of the major flight instruments, their operating limitations, and how they interface with other T-45C systems.

This lesson addresses the:

* Flight instrument system major components
* Pitot static system major components
* Angle of attack (AOA) major components
* Independent instruments
* Aircraft interfaces

REFRESHER

This lesson builds on information presented previously. In particular, review the:

* Primary inputs to the T-45C flight instruments -- i.e., electrical system, GPS/Inertial Navigation Assembly (GINA), and pitot static system

Sg 1, fr 2
Lesson Organization

FLIGHT INSTRUMENTS

* **Flight instrument system major components**
* Pitot static system major components
* Angle of attack (AOA) major components
* Independent instruments
* Aircraft interfaces

PRESENTATION

I. Flight instrument system major components **1.4.5.3.1, 1.4.5.2.1, 1.4.5.3, 1.4.5.2**

NOTE: Flight instrumentation provides heading, altitude, airspeed, attitude, vertical speed, and angle of attack information.

Wall Chart: *T-45C Cockpit*

A. Global Positioning System/Inertial Navigation Assembly (GINA)

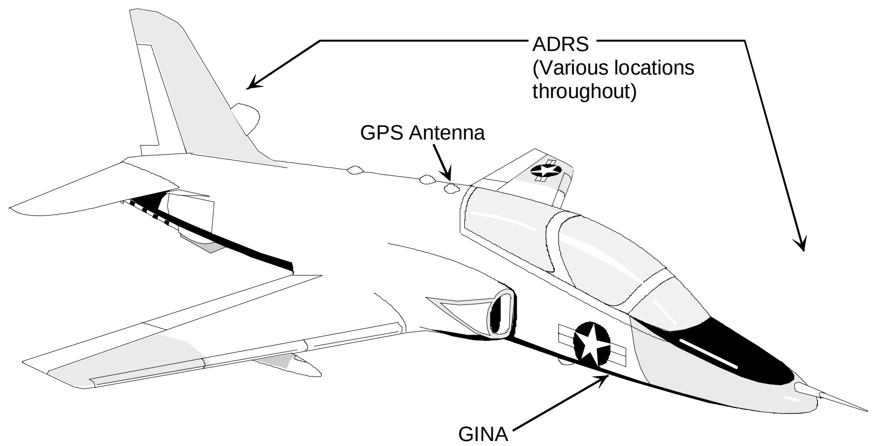
Sg 1, fr 3
Fig 1*: GINA Major Related Component Locations*

? **What does the GINA consist of and what inputs does it provide to its associated flight instruments?**

ANSWER:

1. The GINA consists of a self contained, all attitude, world wide, strapdown inertial system with an embedded GPS receiver and a GPS (FRPA-3) antenna.

2. The GINA provides vertical velocity, position, heading, digital and analog attitude (pitch and roll) and time to the DEU for the ADI, HSI and HUD displays, over the MIL-STD-1553B MUX BUS.



GINA RELATED COMPONENTS

* Fwd MFD & Aft MFD (not shown)
* DEU (not shown)
* GPS/Inertial Navigation Assembly
* Airborne Data Recording System (ADRS)
* Yaw Damper (not shown)
* VOR/ILS (not shown)
* Mission Data Loader (MDL) (not shown)

Figure 1: GINA MAJOR RELATED COMPONENT LOCATIONS

1. The GINA provides all attitude (digital and analog), acceleration, position heading and time information to the Display Electronics Unit (DEU) over the MIL-STD-1553B MUX BUS for ADI, HSI and HUD displays

2. GINA

   a. Location: lower electrical bay

   b. Function:

      (1) An inertial system using three (3) ring laser gyros and three accelerometers mounted on the three (3) aircraft axes

      (2) Provides acceleration and rotation

      (3) The embedded GPS receiver receives, tracks and processes GPS signals from the GPS antenna

(4) The GPS and inertial system navigation data is sent to the DEU, Yaw Damper Controller (YDC), Mission Data Loader (MDL) and the VOR/ILS/MB receiver over the MIL-STD-1553B MUX BUS

c. Controls/switches/indicators:

(1) GINA PWR controlled by push-button on MFD BIT display; GINA PWR initializes to on

(2) Four (4) operational modes

(a) HYBD (hybrid) mode, the most accurate mode. Attitude and position data provided by inertial system and GPS. Automatically selected on initial power-up and weight-on-wheels or manually from the ADI display

(b) GPS mode, position data provided solely by embedded GPS receiver, manually selected from the ADI display

(c) INS mode, navigational data provided solely by navigation assembly, automatically selected when in HYBD or GPS and GPS fails or manually when selected from ADI display

d) DGRO (directional gyro), an attitude heading backup mode, automatically commanded when insufficient initialization data and the parking brake is not set during ground alignment or manually when selected from ACFT DATA display

(3) GINA alignments

(a) Two stages of alignment, coarse and complete/fine

(b) Ground alignment, GINA align complete takes approximately 3 minutes after present position initialization

(c) In-flight alignment, GINA align complete takes between 5 and 15 minutes, 90-degree heading change 1 minute apart after altitude is valid will reduce alignment time

(d) Ship board alignment, altitudes available in approximately 20 seconds and position and heading are available in approximately 8 minutes

d. Subsystem interfaces: provides flight data information to the DEU readouts on ADI, HSI and HUD displays

(1) Power

(a) 28 VDC essential services bus

(b) 115 VAC essential services bus

NOTE: GINA is operational upon loss of the generator.

(2) Also exchanges information with YDC, ADRS, and VOR/ILS/MB

3. Summary:

The GINA three ring laser gyros and accelerometers provide stable and accurate information of acceleration, velocity, position, heading (true and magnetic), digital and analog attitude (roll, pitch, and heading), attitude rates and time. The GINA flexible initialization and alignments for ground, in-flight and on-board ship provide the best accuracy for flight profiles. The selection of modes for GINA operation are HYBD which incorporates inertial system and GPS data, INS that uses only inertial position data, GPS that uses embedded GPS position data only and DGRO as a backup attitude and heading mode

B. Multi-Function Display (MFD)

1. Location: Two (2) each cockpit, center of Main Instrument Panel (MIP)

2. Function: Provide electronic displays of the ADI, HSI, HUD, BIT menus, weapons menus and aircraft/ engine data pages

a. Attitude Director Indicator (ADI), an electronic display that replicates a standard electro-mechanical ADI with additional information

Sg 1, fr 4
***Fig 2**: Attitude Director Indicator (ADI)*

(1) Selected by actuating the ADI option

(2) Pitch ladder and horizon line

(3) Bank pointer and scale

(4) Aircraft heading reference and scale

Overlay

(5) Rate of turn indicator

(6) Slip indicator

(7) Vertical velocity

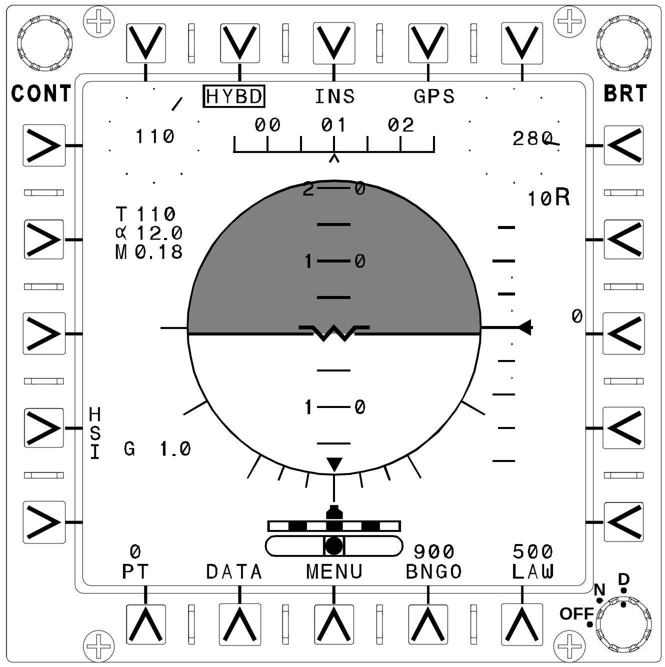
(8) Barometric and radar altitude

(9) Indicated and true airspeed

(10) Angle of attack

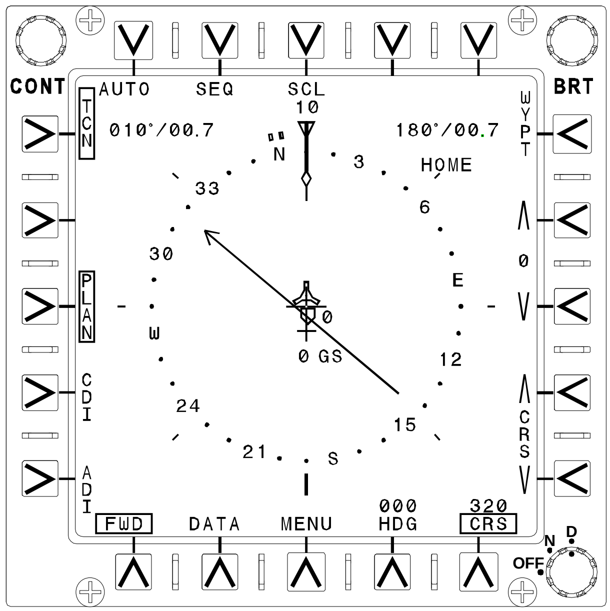
(11) G and peak G

(12) ILS Needles



(1) Pitch ladder and horizon line
(2) Bank pointer and scale
(3) Aircraft heading reference and scale
(4) Rate of turn indicator
(5) Slip indicator
(6) Vertical velocity
(7) Barometric and radar altitude
(8) Indicated and true airspeed
(9) Angle of attack
(10) G and peak G
(11) ILS needles

Figure 2: ADI DISPLAY



(1) Waypoint
(2) Waypoint symbol
(3) Waypoint offset symbol
(4) VOR bearing pointer/tail
(5) VOR bearing
(6) TACAN symbol
(7) Waypoint/waypoint offset bearing pointer/tail
(8) Lubber line
(9) Ground track pointer
(10) Command heading marker
(11) Sequential steering lines
(12) CDI course line
(13) Course deviation dots
(14) Planimetric course line
(15) Aircraft symbol
(16) Groundspeed and wind detection/speed
(17) TACAN data
(18) Waypoint/waypoint offset data
(19) Heading readout
(20) Course line readout

Figure 3: MFD WITH HORIZONTAL SITUATION INDICATOR (HSI) DISPLAY

Sg 1, fr 5, 7
***Fig 3**: Horizontal Situation Indicator (HSI)*

b. Horizontal Situation Indicator (HSI), an electronic display that replicates a standard electro-mechanical HSI with additional information

Overlay 1

(1) Selected by actuating the HSI option

(2) TACAN data

(3) Planimetric course line

(4) Groundspeed and wind direction/speed

(5) Sequential steering lines

(6) Command heading marker

(7) Waypoint/waypoint offset data

(8) Ground track pointer

Overlay 2

(9) TACAN symbol

(10) Waypoint zero

(11) Waypoint/waypoint offset bearing pointer

(12) Waypoint offset symbol

(13) Aircraft symbol

(14) Heading readout

(15) Course line readout

(16) Waypoint/waypoint offset bearing tail

(17) Lubber line

Overlay 3

(18) CDI course line

(19) VOR bearing

(20) Waypoint symbol

(21) CDI deviation dots

(22) VOR bearing pointer/tail

3. Controls/switches/indicators

   a. The Multi-Function Display (MFD) option push-buttons provide selection of the ADI and HSI displays and their modes, sub-modes and pilot inputs

4. Subsystem interfaces

   a. Display Electronics Unit (DEU) generates the ADI and HSI displays and provides the information for their readouts

C. Summary:

The MFD generates the ADI and HSI displays of GPS/Inertial system heading, pitch, roll, and navigation information

Sg 2, fr 2
Lesson Organization

FLIGHT INSTRUMENTS

* Flight instrument system major components
* **Pitot static system major components**
* Angle of attack (AOA) major components
* Independent instruments
* Aircraft interfaces

Sg 2, fr 3
Fig 4: *Standby Barometric Altimeter*

II. Pitot static system major components

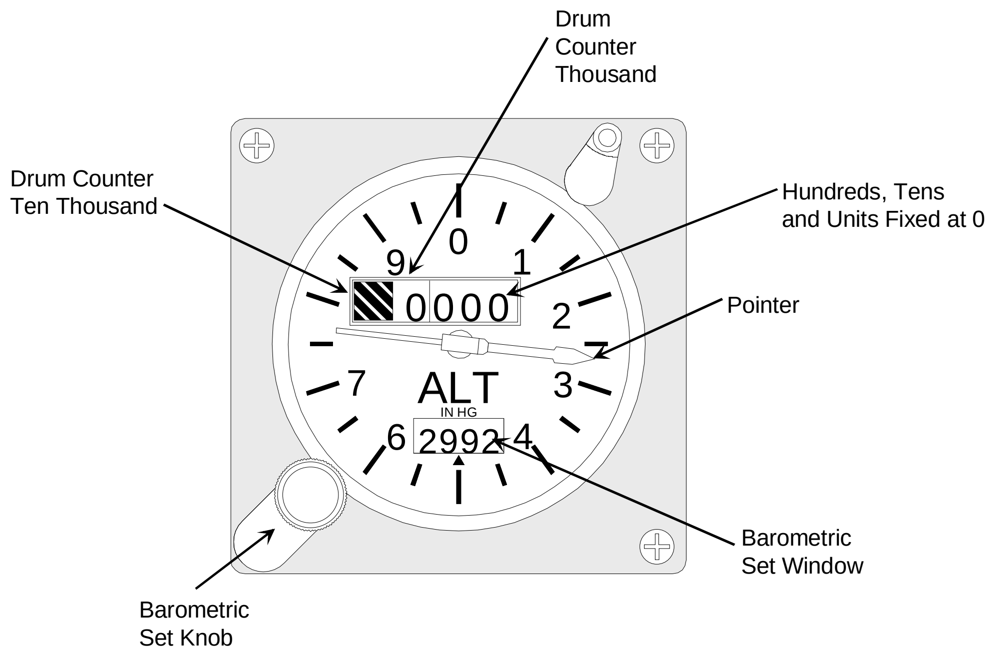


Figure 4: STANDBY BAROMETRIC ALTIMETER

A. Standby barometric altimeter

1. Location: left instrument panel, both cockpits

2. Function: provides standby altitude information from -1,000 to 50,000 ft MSL

   a. Information from aneroid capsule assembly drives needle and altitude drum counter

   b. Consists of gauge assembly containing:

      (1) Counter displays ten thousand and thousands of feet, hundreds of feet fixed at 000

      (2) Rotating pointer indicates hundreds of feet on circular scale with center graduations of 50 ft

(3) Barometric set window and knob

3. Controls/switches/indications: barometric set knob used to set local pressure in window (system has remote calibration screw for maintenance use)

4. Subsystem interfaces: both standby altimeters use same pitot static system inputs

   a. Power: 28 VDC generator bus vibrator power

   b. Forward standby altimeter provides barometric pressure for the entire system and Mode C altitude information to DEU then to IFF

B. Standby airspeed indicator

__Sg 2, fr 4__
***Fig 5**: Standby Airspeed Indicator*

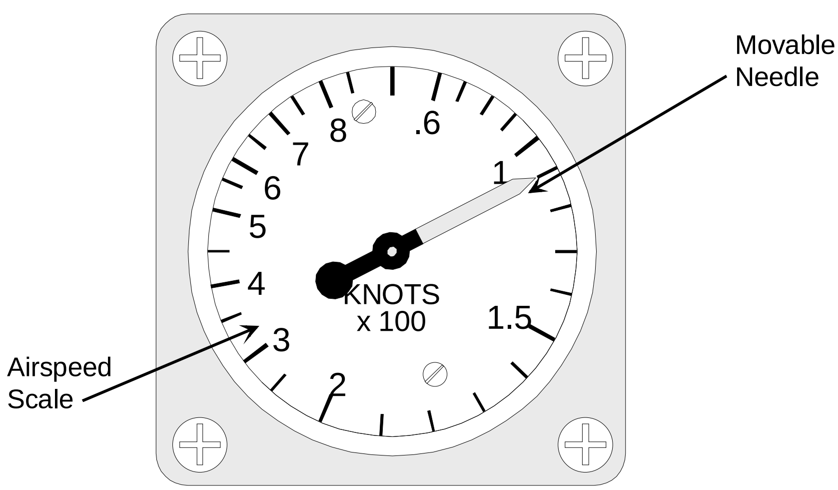


Figure 5: STANDBY AIRSPEED INDICATOR

1. Location: left instrument panel, both cockpits

2. Function: provides standby airspeed from 60 to 850 KIAS

   a. Airspeed measures relationship between pitot RAM pressure and static pressure

b. Needle indicates airspeed

3. Controls/switches/indicators: none in cockpit

4. Subsystem interfaces:

   a. Both indicators driven by same pitot static system

C. Standby vertical speed indicator (VSI)

Sg 2, fr 5
***Fig 6**: Standby Vertical Speed Indicator (VSI)*

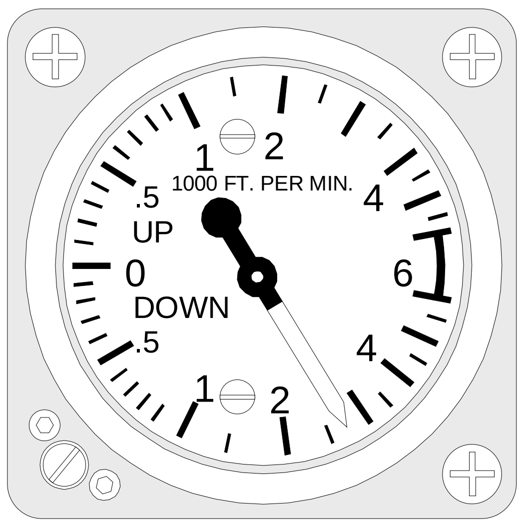


Figure 6: STANDBY VERTICAL SPEED INDICATOR (VSI)

1. Location: left instrument panel, both cockpits

2. Function: provides standby indication of rate of descent and rate of climb in feet per minute (ft/min)

   a. Measures rate of change of static pressure through conventional drum mechanism with mechanical needle

   b. Gauge with fixed dial calibrated from 0 to 6000 (ft/min) (both ascending and descending)

3. Controls/switches/indicators: none in cockpits

4. Subsystem interface: Both indicators use same pitot static system

D. Pitot tube

1. Location: nose of aircraft

2. Function: provides ram air pressure and static air pressure to pitot static system

3. Controls/switches/indicators: PITOT HEAT switch, on right instrument panel outboard in forward cockpit only, for ice protection

4. Subsystem interfaces:

   a. Power: 28 VDC essential services bus

   b. Standby barometric altimeter

   c. Standby airspeed indicator

   d. Standby vertical speed indicator

   e. Stability Augmentation Data Sensor (SADS)

   f. OBOGS

E. Summary:

The pitot static system measures the static air pressure, rate of change of static air pressure, and the difference between pitot air pressure to provide airspeed, altitude, and rate of climb information for the system. Standby flight instruments receiving pitot static input are the standby altimeter, standby airspeed indicator, and the standby VSI

Sg 7, fr 2
Lesson Organization

III. Angle of attack (AOA) major components

FLIGHT INSTRUMENTS

- Flight instrument system major components
- Pitot static system major components
- **Angle of attack (AOA) major components**
- Independent instruments
- Aircraft interfaces

Sg 7, fr 3
***Fig 7**: Angle of Attack System*

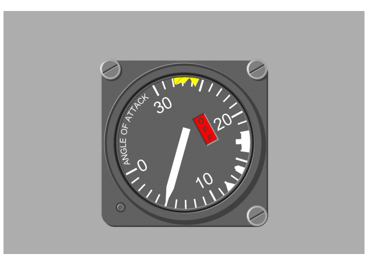
? What does the AOA system consist of and what is its primary function?

ANSWER:

1. The AOA system consists of the AOA indicator and AOA indexer (located on the instrument panel in both cockpits), the external approach lights (located on the nose landing gear), and the AOA transmitter probe (located on the forward left side of the aircraft fuselage).

2. The AOA system is primarily used during all approaches and landings to provide pilots with the necessary cues to maintain the precise airspeeds necessary for making carrier landings.

Sg 7, fr 4
AOA Indicator



A. AOA indicator

1. Location: top of instrument panel, left of HUD, front cockpit; left of gunsight, rear cockpit

2. Function: indicates AOA, using needle and scale graduated from 0 to 30 units. The pointer position is proportional to the local AOA signal provided by an AOA transmitter, via two DC potentiometers, to AOA indicator in each cockpit.

3. Controls/switches/indicators:

   a. OFF flag on each indicator to monitor power

   b. Stall warning index

   c. Optimum AOA for approach index

   d. Optimum rate of climb index

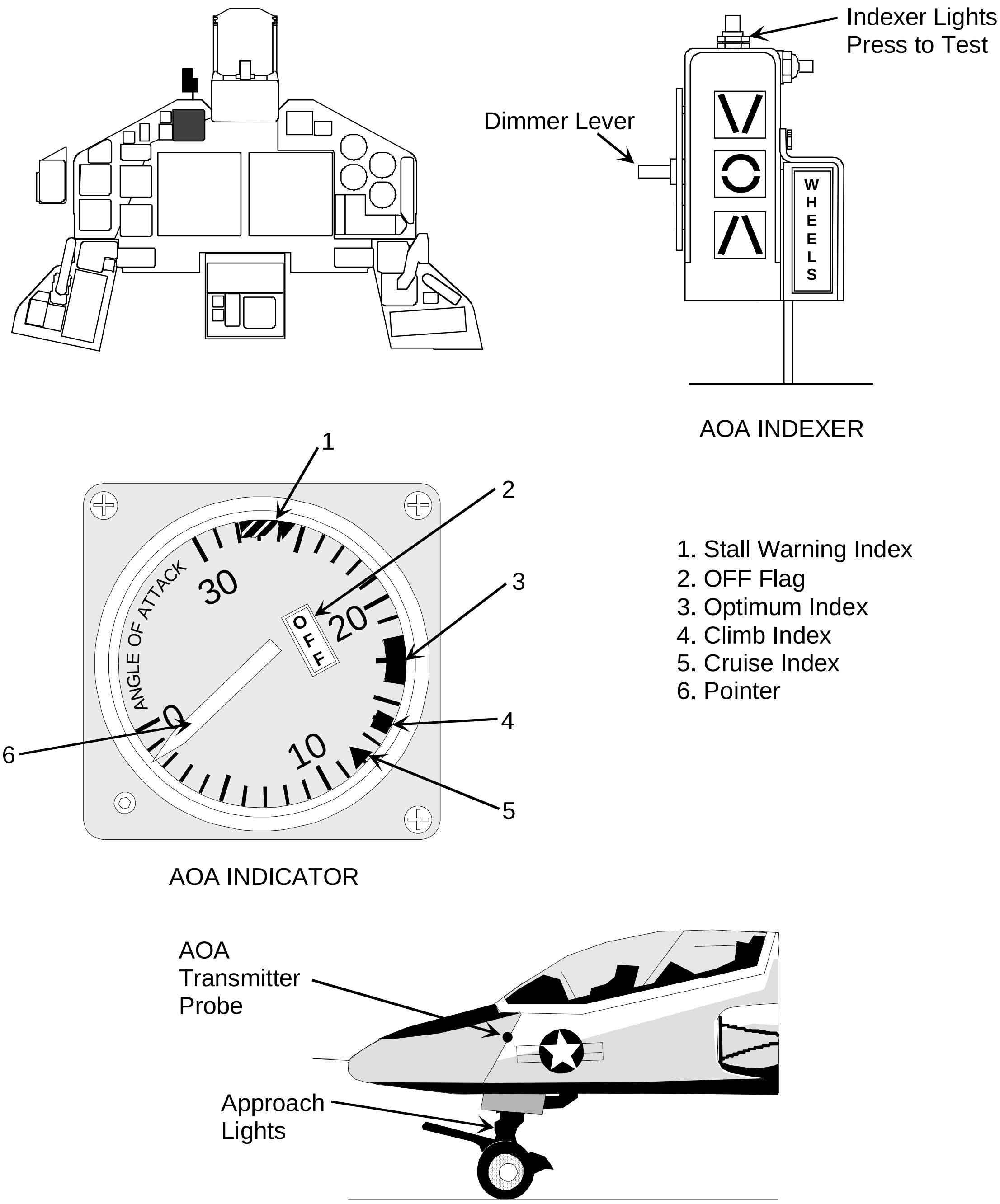


Figure 7: ANGLE OF ATTACK SYSTEM

e. Optimum AOA for cruise index

f. AOA pointer

4. Subsystem interfaces

a. The indicators require 28 VDC essential services bus power for indicator operation and 5 VAC non-essential bus power for indicator lighting

b. Front cockpit AOA indicator

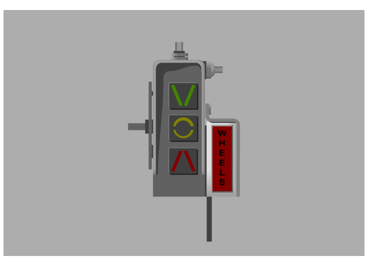
(1) Provides signals to illuminate external approach lights

(2) Provides signal to both cockpit approach indexers

(3) Provides signal to stall warning device

c. Rear cockpit indicator provides AOA display only

Sg 7, fr 5
AOA Indexer



B. AOA indexer

1. Location: top of each glare shield above AOA gauge

2. Function: provides second visual AOA display and warning when arresting hook is not extended during carrier operations

a. Indexer assembly contains three independent indexer lights

(1) Upper chevron green light indicates slow airspeed or high AOA

(2) Center donut amber light indicates on-speed or correct AOA

(3) Lower chevron red light indicates fast airspeed or low AOA

b. Displayed indexer flashes when hook is not down with landing gear down and the HOOK BYPASS switch in carrier position

3. Controls/switches/indicators

a. Dimming control mounted left of indexer light display, both cockpits

b. Press-to-test button located on top of indexer used for lamp test

4. Subsystem interfaces

a. Power: 28 VDC essential services bus through forward AOA indicator

b. The indexer flashes when the HOOK BYPASS switch is in CARRIER mode and hook is not down; controlled by AOA flasher unit in lower equipment compartment and HOOK BYPASS switch in fwd cockpit

C. External approach lights

1. Location: nose landing gear strut

2. Function: provides AOA information to LSO during carrier operations

NOTE: When the HOOK BYPASS switch in the forward cockpit is selected to CARRIER, the lights flash if the landing gear is down and locked and the arresting hook is not extended.

3. Controls/switches/indicators: none in cockpit

4. Subsystem interfaces

a. Power: 28 VDC essential services bus via AOA indicator in forward cockpit

b. Landing gear down switch activation

Sg 7, fr 6
Video: *AOA Transmitter Probe*

D. AOA transmitter probe

1. Location: forward left side of fuselage

2. Function: probe senses angle of relative airflow to longitudinal axis of aircraft when airspeed exceeds 90 KIAS

   a. Rotates over range of 50 degrees in response to air pressure entering slots in forward face of probe

   b. Two potentiometers regulate DC voltage signal in response to probe rotation

   c. Probe assembly contains body heater to prevent icing and condensation

3. Controls/switches/indicators: none in cockpit

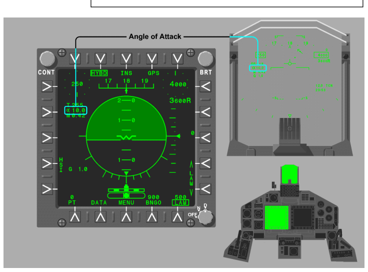
4. Subsystem interfaces

   a. Power: 28 VDC essential services bus (heater, 28 VDC generator bus)

   b. Weight-on-wheels switch controls probe heat (power applied when weight off wheels)

   c. Sends signal to AOA indicators

   Sg 7, fr 7
   Angle of Attack (Readout)

   d. Sends signal to DEU via ADR for AOA display on HUD and ADI display

   e. Sends signal to rudder pedal shakers at 21.5 units AOA

E. Summary:

The AOA system is used to maintain precise airspeed necessary for carrier and field operations by monitoring the airflow relative to the fuselage. Airflow direction is detected by a probe using an internal potentiometer to transmit DC voltage to the AOA indicators in each cockpit. The flight instruments receiving AOA outputs are the AOA indicator, the AOA indexer, ADI display and HUD. In addition to the cockpit indicators, the approach lights also receive AOA outputs.

IV. Independent instruments

A. Radar altimeter

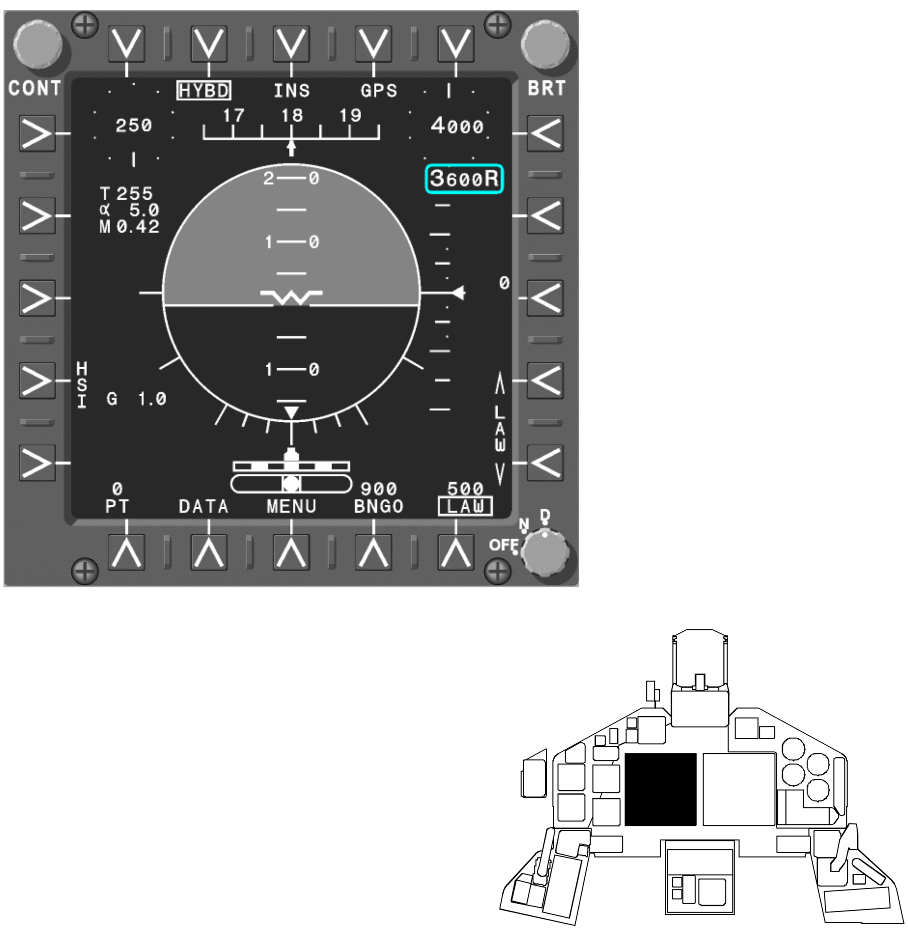


Figure 8: RADAR ALTIMETER READOUT

Sg 8, fr 2
Lesson Organization

FLIGHT INSTRUMENTS

* Flight instrument system major components
* Pitot static system major components
* Angle of attack (AOA) major components
* **Independent instruments**
* Aircraft interfaces

Sg 8, fr 3
Fig 8: *Radar Altimeter*

1. Location: any MFD (ADI) or HUD display

2. Function:

   a. Uses pulse radar to provide altitude information from 0 to 5000 ft AGL, in 10 foot increments

   b. Limits:

      (1) Pitch - 40 degrees nose up and 40 degrees nose down

      (2) Roll - 40 degrees left/right

   c. Uses transmitter/antenna and receiver/antenna to send signals to the ADR then to DEU for display readout on the MFD (ADI) and the HUD

3. Controls/switches/indicators

   a. RALT PWR, controlled by RALT PWR option on the BIT display page

   b. Low altitude warning (LAW), a LAW advisory will be displayed in the MFD advisory window and a HUD warning when below preset altitude

4. Subsystem interfaces

   a. Power

      (1) Transmitter/receiver; 115 VAC non-essential bus

   b. Audio alert system connected to low-level warning

B. Standby attitude indicator

Sg 8, fr 4
Fig 9: *Standby Attitude Indicator*

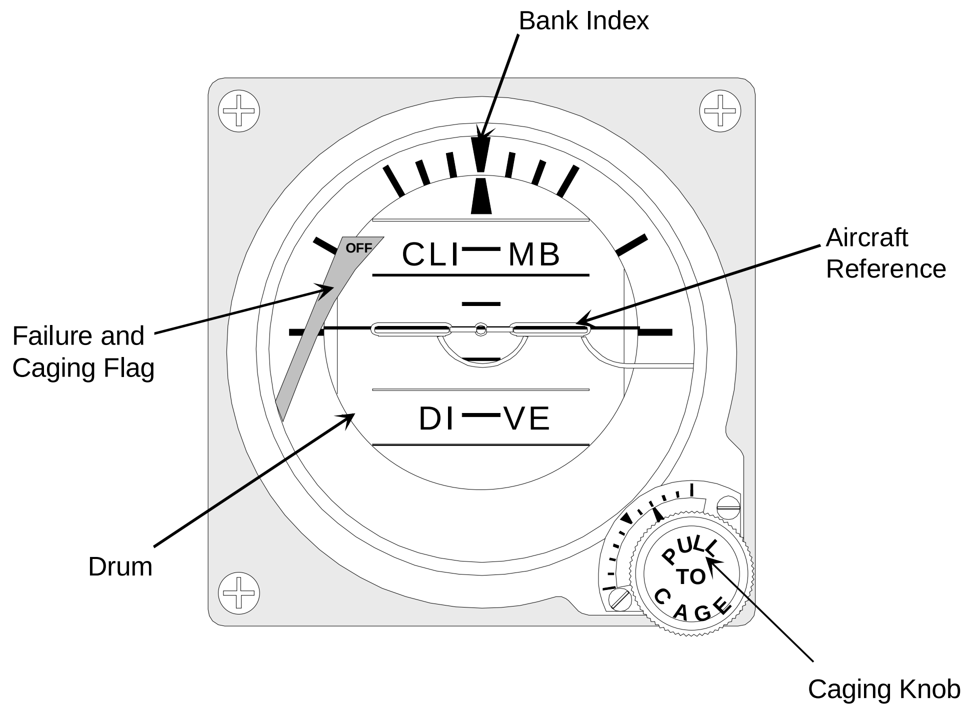


Figure 9: STANDBY ATTITUDE INDICATOR

1. Location: left instrument panel, both cockpits

2. Function: self-contained, two colored moving drum indicating aircraft attitude (accurate to 90 degrees nose up and 78 degrees nose down in pitch, and 360 degrees in roll) via an adjustable aircraft symbol

3. Controls/switches/indicators

   a. Caging and aircraft reference adjust knob

      (1) When pulled, cages the gyro to within 1^0 of datum (normal erection rate is a nominal 2.5^0 per minute)

(2) When pulled and turned clockwise into a detent position, cages and locks the gyro gimbals

(3) When pressed and rotated, adjusts the aircraft symbol up to 5^0 (up or down)

NOTE: Do not cage the standby attitude indicator within 30 seconds after power up or press with excessive force or repeated jabbing action.

NOTE: Do not cage and lock the standby gyro with electric power ON and aircraft in motion. The action will damage the gyro bearings and shorten the life of the gyro.

b. Solid color power OFF flag appears if power supply fails or faults develop within instrument

c. Bank index indicates roll in 10, 20, 30, 60, and 90 degree increments in both directions

4. Subsystem interface: requires/receives 28 VDC essential services bus power

NOTE: The two-inch standby AI provides a minimum of 9 minutes attitude information after total power failure.

Sg 8, fr 5
Fig 10: *Standby Turn and Slip Indicator*

C. Standby turn and slip indicator

1. Location: upper left instrument panel, both cockpits

2. Function: self-contained gyro driven rate of turn/slip indicator, with a power warning flag

3. Controls/switches/indicators

a. Power off flag appears when power to the instrument fails

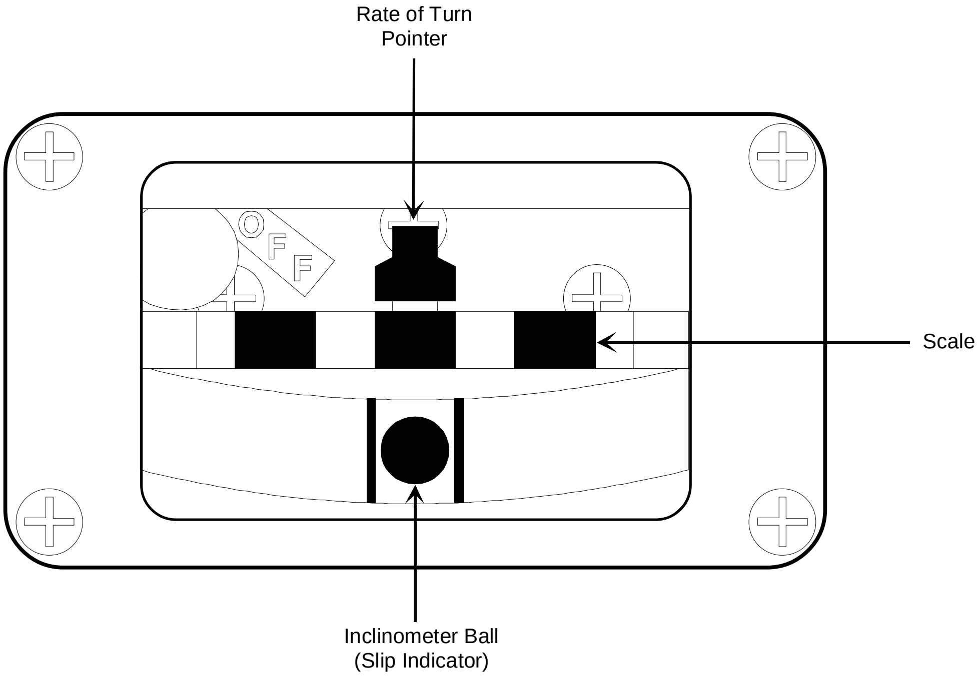


Figure 10: STANDBY TURN AND SLIP INDICATOR

b. Two minute turn indicated by the needle over the index left or right of center

c. Four minute turn indicated by the needle half way between the center and left or right of index

4. Subsystem interface: requires/receives 28 VDC essential services bus power

D. Standby compass

Sg 8, fr 6
***Fig 11:** Standby Compass*

1. Location: mounted at top of each canopy bow

2. Function: conventional wet compass suspended in damping fluid used as a backup for heading

a. Contains compass card graduated in 5 degree divisions with cardinal headings indicated as N, S, E, and W

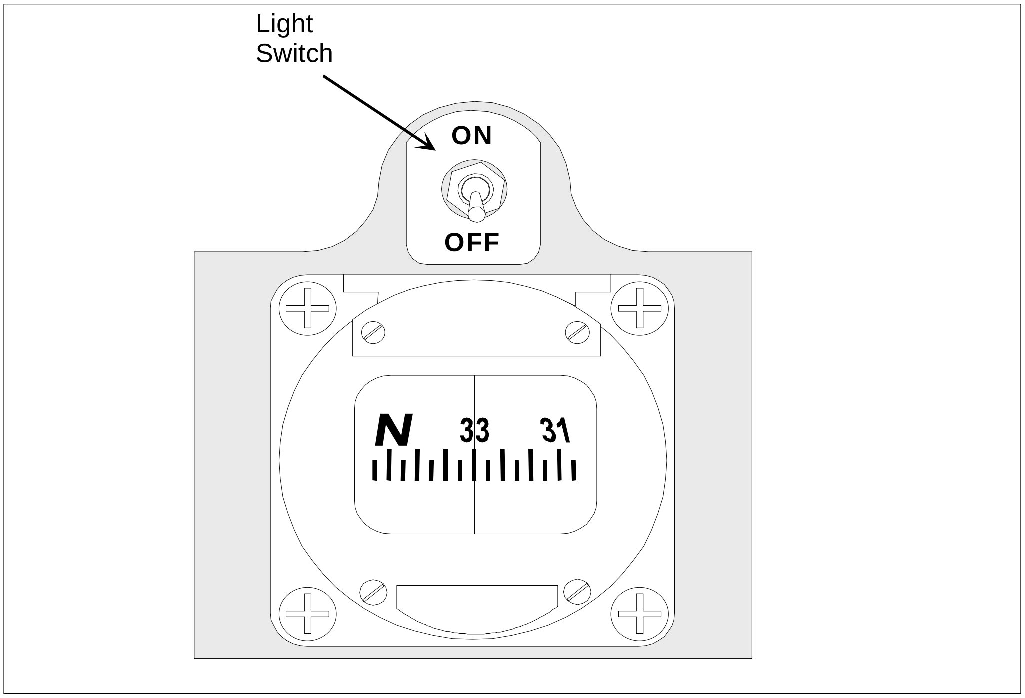


Figure 11: STANDBY COMPASS

b. Compass card floats horizontally within case to align itself with earth's magnetic field

c. Magnetic heading read off card under lubber line engraved upon lens

d. Two internal bar magnets compensate for deviation

e. Compass indication will lead or lag actual aircraft heading as shown by GINA on HSI, ADI, and HUD displays during turns

3. Controls/switches/indicators: light switch located above compass

4. Subsystem interfaces

   a. Power: 5 VAC non-essential bus

   b. Light switch and brightness control functional when interior lights MIP dimmer control is rotated out of OFF position

Sg 8, fr 8
Fig 12: *Clock/ Stopwatch*

E. Clock

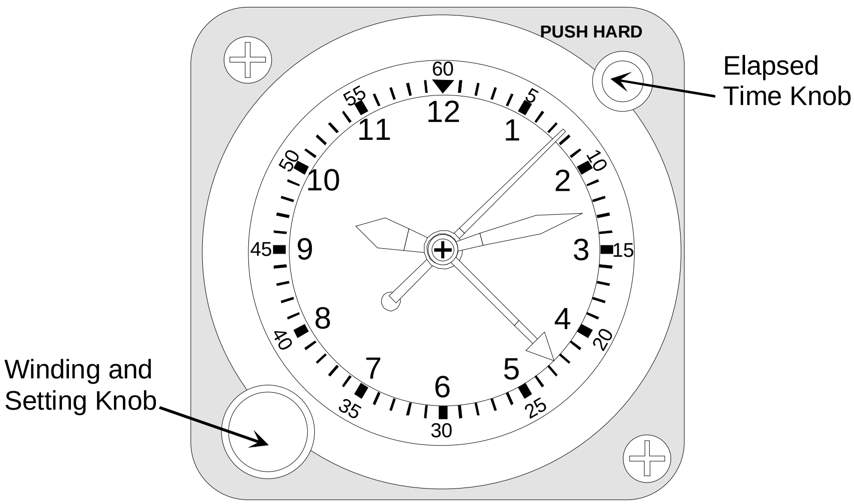


Figure 12: CLOCK/STOPWATCH

1. Location: right instrument panel, both cockpits

2. Function: combined mechanical clock/stopwatch with hands for hours, minutes, seconds, and time elapsed

3. Controls/switches/indicators

   a. Winding and setting knob: used to wind and set time on clock

   b. Elapsed time knob: used to start and zero stopwatch time elapse hand

4. Subsystem interfaces

   a. Power: 5 VAC non-essential bus

   b. Lighting brightness controlled by MIP dimmer control

F. Summary:

The independent flight instrument systems include the radar altimeter, the standby AI, the standby compass, and the clock/stopwatch.

The standby AI and standby compass are used primarily as backups in the event that the main flight instruments/ systems (ADI, HSI, HUD displays) have failed.

The radar altimeter is used primarily during low-level flight and landing operations. The clock/stopwatch is used as a timepiece and to identify elapsed mission time.

Sg 3, fr 2
Lesson Organization

FLIGHT INSTRUMENTS

* Flight instrument system major components
* Pitot static system major components
* Angle of attack (AOA) major components
* Independent instruments
* **Aircraft interfaces**

V. Aircraft interfaces **1.4.5.2**

Sg 3, fr 3
Electrical Power Inputs to Flight Instruments

28 VDC GENERATOR BUS
STANDBY BAROMETRIC ALTIMETER
COCKPIT FLOOD LIGHTS
VOR / ILS CONTROL
AOA PROBE HEATER
RH FWD / AFT MFDs

28 VDC ESSENTIAL SERVICES BUS
PITOT HEAT
AOA INDICATOR
GINA
TACAN
ADR
LH FWD / AFT MFDs

115 VAC NON-ESSENTIAL BUS
RADAR ALTIMETER
DEU COOLING FAN

115 VAC ESSENTIAL BUS
GINA

26 VAC NON-ESSENTIAL BUS
DEU
VOR / ILS / MB

26 VAC ESSENTIAL BUS
TACAN AZIMUTH COMPUTER
ADR

A. Inputs to flight instruments

1. Electrical power

a. 28 VDC essential services bus

(1) ADI, standby

(2) ADRS

(3) AOA indicator

(4) DEU (operates for 2 minutes after loss of generator bus)

(5) GINA

(6) MFD left hand

(7) TACAN

b. 115 VAC essential bus

(1) GINA (syncro signal)

c. 26 VAC essential bus

(1) ADRS

(2) TACAN - Azimith Computer

d. 28 VDC generator bus

(1) Standby barometric altimeter vibrator

(2) Cockpit flood lights

(3) VOR/ILS/control

(4) AOA probe heater

(5) RH FWD/AFT MFDs

e. 115 VAC non-essential bus

(1) DEU cooling fan

(2) Radar altimeter receiver

f. 26 VAC non-essential bus

(1) VOR/ILS/MB

(2) DEU

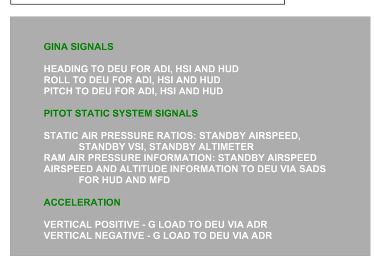
2. GINA signals

a. Heading to DEU for ADI, HSI, and HUD

b. Roll to DEU for ADI, HSI, and HUD

c. Pitch to DEU for ADI, HSI, and HUD

Sg 3, fr 4
System Interface Signals



3. Pitot static system signals

    a. Static air pressure ratios: standby airspeed, VSI, and altimeter

    b. Ram air pressure information: standby airspeed

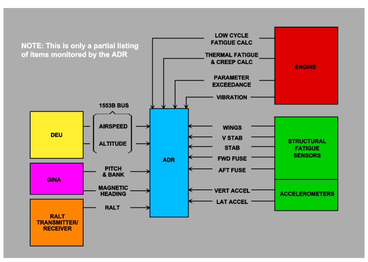
    c. Airspeed and altitude information to HUD, DEU, MFD

4. Acceleration from ADR

    a. Vertical positive-g load

    b. Vertical negative-g load

Sg 3, fr 5
ADR Inputs



B. Systems interface

1. Airborne data recorder (ADR): monitors structural fatigue of aircraft, engine parameters, and following flight instrument-related information

    a. Airspeed

    b. Mach number

    c. Altitude (barometric and radar)

    d. Pitch and bank

    e. Heading

    f. Acceleration

    NOTE: This is only a partial listing of items monitored by the ADR.

Sg 3, fr 6
HUD Indications

Fig 13: *HUD*

2. HUD system: presents the following information from various pertinent aircraft systems and instruments via the display electronic unit (DEU) to the pilot display unit (PDU) on the HUD

Figure 13: HUD INDICATIONS

NOTE: The HUD will be discussed in more detail in Eng-23.

LESSON NOTES

Identify the following items on the HUD.

a. Pitch

b. Roll

c. Heading

d. AOA

e. Altitude

(1) Barometric

(2) Radar

f. Airspeed

(1) KIAS

(2) TAS

(3) Mach

g. G load and Peak G

h. Vertical speed

3. Identification friend or foe (IFF) transponder: DEU provides altitude information to IFF system Mode C

4. Navigation system: provides inputs to flight instruments

a. TACAN provides range and bearing information

b. VOR provides bearing information

c. ILS provides glideslope and localizer information

d. Waypoint provides range and bearing information

e. GINA provides ground speed, wind direction and speed, and ground track marker

C. Summary:

The flight instrument system receives electrical, GINA, pitot static, NAV inputs.

The flight instrument system receives electrical inputs from the 28 VDC essential services bus, the 115 VAC essential and non-essential buses, the 26 VAC essential and non-essential buses, and the 28 VDC generator bus.

The GINA provides, vertical velocity, position, heading, digital and analog attitude (roll and pitch) and time to the DEU for the ADI, HSI and HUD displays, over the MIL-STD-1553B MUX BUS. The pitot static system provides static and ram air pressure for the standby attitude indicator, standby airspeed indicator, standby VSI and the DEU via the SADS.

The NAV system provides navigation inputs to the DEU for the ADI, HSI and HUD displays, in the form of TACAN, VOR, ILS glideslope and localizer, and waypoint information.

The flight instrument system provide outputs to the ADR and IFF systems.

PROGRESS CHECK

Question 1 — 1.4.5.2.1
How many operational modes does GINA have?

ANSWER: 4

Question 2 — 1.4.5.3
What is the approximate time for a GINA ship board alignment?

ANSWER: Attitude available in approximately 20 seconds and position and heading are available in approximately 8 minutes

Question 3 — 1.4.5.2
What electrical buses supply power to the DEU?

ANSWER: 115 VAC non-essential bus and 28 VDC essential bus

Question 4 — 1.4.5.2.1
What is the minimum time of operation of the standby ADI after a power failure?

ANSWER: 9 minutes

SUMMARY

GINA provides vertical velocity, position, heading, digital and analog attitude (roll and pitch) and time to the DEU for ADI, HSI and HUD displays, over the MIL-STD-1553B MUX BUS. The pitot static system provides input to the standby altimeter, standby airspeed indicator, standby VSI and the DEU. The AOA system is used to maintain precise airspeed necessary for carrier and field operations by constantly monitoring the airflow relative to the fuselage. The AOA system provides inputs to the AOA indicator, approach lights and the DEU via the ADR for the ADI and HUD displays.

The independent flight instrument systems include the radar altimeter display, the standby attitude indicator, standby altimeter, standby turn and slip indicator, standby compass and the clock/ stopwatch. The standby attitude indicator, the standby compass, standby altimeter and the standby turn and slip indicator are used as backups in the event that the main flight instruments/systems/ displays have failed.

The flight instrument system interfaces with the following aircraft systems: electrical, GINA, pitot static, NAV, ADRS, and IFF.

CONCLUSION

Correctly operating the flight instruments is essential to a successful flight completion, so you must thoroughly understand them.

Sg 6, fr 2
Review Menu

Wall Chart:
T-45C Cockpit

LESSON GUIDE

COURSE/STAGE: TS, ADV & IUT / Engineering

LESSON TITLE: Flight Instruments Malfunctions

LESSON IDENTIFIER: T-45C TS, ADV & IUT ENG-20

LEARNING ENVIRONMENT: CAI

ALLOTTED LESSON TIME: .8 hr

TRAINING AIDS:

* Figures
  - Fig 1: GINA and Related Components: Summary of Malfunction Indications and Verifications
  - Fig 2: Pitot Static System: Summary of Malfunction Indications and Verifications
  - Fig 3: AOA Instruments: Summary of Malfunction Indications and Verifications
  - Fig 4: Independent Instruments: Summary of Malfunction Indications and Verifications

STUDY RESOURCES:

* T-45C NATOPS Flight Manual, A1-T45AC-NFM-000
* T-45C NATOPS Pilot's Pocket Checklist, A1-T45AC-NFM-500

LESSON PREPARATION:

Read:

* Part I, Chapter 2, Section 2.19, “Flight Instruments,” Part VII, Chapter 21, Section 21.4.3,“Navigation Controls and Indicators,” and Part V concerning flight instrument malfunctions in the T-45C NATOPS Flight Manual, A1-T45AC-NFM-000

Review:

* Lecture Guide for Eng-19, “Flight Instruments”

REINFORCEMENT: N/A

LESSON EXAMINATION:

The student is required to read flight instruments and related flight instrument malfunction paragraphs in the NATOPS flight manual, receive classroom instruction, and complete assigned CAI lesson(s). The student shall demonstrate proficient knowledge by completing, from memory with 80% accuracy, two 40-question (true/false and multiple choice) block examinations. The objectives in this lesson will be tested in either Engineering 29X or Engineering 30X.

LESSON OBJECTIVES

2.8.1.1
Identify indications of GINA failure

1.8.1.7.1.1
Identify indications of ADI display failure

1.8.1.7.12.1
Identify indications of HSI display failure

1.8.1.7.10.1
Identify indications of turn and slip indicator display failure

1.8.1.7.11.1
Identify indications of radar altimeter display failure

1.8.1.7.3.1
Identify indications of pitot static malfunctions

1.8.1.7.2.1
Identify indications of standby ASI failure

1.8.1.7.9.1
Identify indications of standby altimeter failure

1.8.1.7.8.1
Identify indications of standby VSI failure

1.8.1.7.4.1
Identify indications of AOA indicator failure

1.8.1.7.5.1
Identify indications of AOA indexer failure

1.8.1.7.13
Identify indications of standby compass failure

1.8.1.7.6.1
Identify indications of standby attitude indicator failure

MOTIVATION

This lesson teaches you to identify and verify flight instrument malfunctions and to understand their ramifications on flight safety. In later lessons you will learn the procedures for dealing with these malfunctions.

OVERVIEW

The goal of this lesson is to familiarize you with the indications of flight instrument malfunctions and to explore some of the potential effects of these malfunctions.

This lesson covers the following instrument malfunctions:

* Global Positioning System/Inertial Navigation Assembly (GINA) and related components
  - Attitude director indicator (ADI) display failure
  - Horizontal situation indicator (HSI) display failure
  - Vertical speed indicator readout failure
  - General GINA failure
* Pitot static system
  - Standby airspeed indicator failure
  - Standby altimeter failure
  - Standby vertical speed indicator (VSI) failure
  - Pitot tube damage or icing
* Angle of attack (AOA) system
  - AOA indicator failure
  - AOA indexer failure
* Independent instruments
  - Radar altimeter display failure
  - Standby turn and slip indicator failure
  - Standby attitude indicator failure
  - Standby compass failure
  - Clock/stopwatch failure

PRESENTATION

Fig 1: GINA and Related Components: Summary of Malfunction Indications and Verifications

I. GINA and related flight components

A. Attitude director indicator (ADI) display failure

1. Indications

a. Blank pitch, roll, and/or heading information

b. Attitude advisory appear

c. Blank screen

2. Verifications

a. Standby AI reading differs from ADI

b. Cross-check outside references (e.g., horizon)

c. Cross-check with rear cockpit

d. Additionally verify by using BIT for equipment status

3. Effects on flight safety

a. Standby AI provides backup

b. Heading information not available, use standby compass

c. DEU failure must use standby instruments

B. Horizontal situation indicator (HSI) display failure

1. Indications

a. Blank heading and navigation information

b. Position advisory appear

c. Blank screen

2. Verifications

a. Known position (e.g., standby compass and outside reference) at variance with HSI

b. Cross-check HSI reading in other cockpit and if possible with other aircraft or ATC

c. Cross-check against ADI heading to ensure failure isolated to HSI

3. Effects on flight safety

a. Potential navigational errors with reduced accuracy

b. Downgraded IFR approach capabilities

C. Vertical speed indicator readout

1. Indication: blank digital readout missing pointer/scale/dots/dashes and tick marks

2. Verifications: cross-check with standby VSI an independent instrument

3. Effect on flight safety: if VSI display fails you must use standby VSI

D. General GINA failure

1. Indications

a. Input data source change from HYBD to INS to DRGO

b. Missing heading indications on HSI and ADI and HUD

c. Missing pitch and roll indications on ADI

2. Verifications

a. Look outside the cockpit, if VFR

b. Standby compass reading conflicts with compass indications on both the

(1) ADI

(2) HSI

c. Standby attitude indicator (STBY AI) reading differs from ADI reading

d. Rear cockpit indicators also fail

e. Cross-check with other aircraft attitude information or ATC

3. Effects on flight safety

a. Possible disorientation due to missing pitch and roll information

b. Transition to standby AI

c. Potential navigation problems due to heading errors

d. Instrument approach capabilities degraded due to heading errors

e. You must use standby compass

E. Incongruent GINA GPS-INS positon and/or velocity computations

1. Causes

a. INS-GPS position computation disparity

b. INS-GPS velocity computation disparity

c. Disparity persists for a 3-sigma period (three "sigmas" equates to three [3] times the nominal allowed deviation period; 24-30 seconds)

(1) Either GPS or INS may be in error

(2) Both GPS and INS may be in error (unlikely)

2. Indications to pilot

a. ADI

(1) Barometric altitude is no longer filtered, meaning indications may mildly fluctuate

(2) Vertical velocity is removed

(3) AV BIT advisory are displayed on all MFD's

(4) GINA status DEGD on the BIT display page

b. HSI

(1) Ground track marker is removed

(2) Groundspeed is removed

(3) Wind direction and speed are removed

(4) All time-to-go data is removed

(5) AV BIT advisory are displayed on all MFDs

(6) GINA status DEGD is indicated on the BIT display page

c. HUD

NOTE: AV BIT advisory is not presented on the HUD; only on MFD displays.

(1) Velocity vector is removed

(2) Waterline symbol is displayed

(3) Barometric altitude is no longer filtered

d. Check standby cockpit instrument indications

e. Cross-check navigation to assure proper orientation

(1) TACAN, VOR, ILS (as appropriate)

(2) ARTCC, TRACON, RAPCON, ARRIVAL/DEPARTURE controllers, etc. (request assistance, as appropriate)

(3) Visual landmarks (also use when possible)

f. ADI, HSI, and HUD displays will automatically revert to normal operation with full functionally, once fault is corrected

Fig 2: *Pitot Static System: Summary of Malfunction Indications and Verifications*

II. Pitot static system

A. Standby airspeed indicator failure

1. Indication: pointer drops to zero, fluctuates, or freezes in position

2. Verifications

a. Cross-check indicator in other cockpit

b. Airspeed/AOA cross-check

c. Cross-check with other aircraft information

3. Effect on flight safety: unreliable airspeed indications

NOTE: You can use AOA to compensate for loss of airspeed indications.

B. Standby altimeter failure

1. Indications

a. Pointer freezes in position

b. Erroneous readings

2. Verifications

   a. If below 5000 ft AGL, radar altimeter altitude plus known terrain elevation disagrees with standby altimeter

   b. Cross-check indicator in other cockpit or other aircraft

   c. Erroneous response to VSI

   d. Cabin pressure altitude disagrees below 5000 ft MSL or if cabin is unpressurized

3. Effects on flight safety

   a. Unreliable altitude readout

   b. Reduced approach capabilities

   WARNING: On all descents, it's good headwork to cross-check other instruments such as the radar and cabin altimeters.

C. Standby vertical speed indicator (VSI) failure

1. Indication: pointer freezes or fluctuates (appearing unreliable)

2. Verifications

   a. Cross-check with the following:

      (1) Standby attitude indicators

      (2) Standby airspeed indicator

      (3) Standby altimeter

   b. Cross-check indicator in other cockpit and/or with other aircraft

3. Effects on flight safety

   a. Loss of rate of climb/descent information

   b. Instrument approach capability downgraded

D. Pitot tube damage/icing

1. Indications: erroneous readings from all airflow and pressure instruments (standby airspeed indicator, standby VSI, standby altimeter, SADS and OBOGS)

2. Verifications

Fig 3: AOA Instruments: Summary of Malfunction Indications and Verifications

a. Instruments affected in both cockpits

b. Cross-check with other aircraft information

c. Cross-check airspeed with AOA indicator

3. Effect on flight safety: unreliable standby airspeed, standby altitude, and standby VSI

NOTE: In these circumstances, you would use AOA for airspeed and the radar altimeter (below 5000 ft AGL) and/or ATC for altitude. Further, with pressurization off, you could use the cabin altimeter for MSL altitude.

III. Angle of attack (AOA) system

A. AOA indicator failure

1. Indications

a. Needle freezes or is erratic and unreliable

b. OFF flag may appear

2. Verifications

a. Needle does not respond to noseup/down stick inputs

b. Cross-check with standby airspeed indicators in landing configuration

c. Cross-check with digital readouts on ADI display and HUD

d. Cross-check indicator in other cockpit and/or other aircraft

3. Effects on flight safety: loss of AOA indexer lights (both cockpits) and external approach lights. Also loss of rudder shaker and stall warning tone

B. AOA indexer failure

1. Indications

a. Fails to light with gear down

b. Light pattern erratic and unreliable

2. Verifications

a. Cross-check with AOA indicator

NOTE: The fwd AOA indicator drives the FWD and AFT cockpit indexer lights and the nose-gear mounted external approach lights.

b. Check bulbs and dimmer control

c. Cross-check with other aircraft or LSO

3. Effects on flight safety

a. Loss of secondary visual AOA indications

b. Loss of HOOK NOT DOWN warning signal

NOTE: The applicable indexer light in both cockpits and the applicable external approach light will flash if the hook is not extended and the HOOK BYPASS switch is in the CARRIER position.

IV. Independent instruments

Fig 4: **Independent Instruments: Summary of Malfunction Indications and Verifications**

A. Radar altimeter readout failure

1. Indications

a. Digital readout blank and R will remain

2. Verifications

a. Cross-check with other cockpit

b. Check BIT page for equipment status

c. Cross-check with standby altimeter (below 5000 ft AGL) and known terrain elevation

d. Cross-check with other aircraft information

e. An AV BIT will be displayed

NOTE: Both cockpit indicators will show blank indications if the receiver/transmitter is the source of the malfunction.

3. Effect on flight safety

a. Inability to determine exact AGL at or below 5000 ft

b. Low altitude warning lost

B. Standby turn and slip indicator failure

1. Indications

a. During taxi: turn needle does not deflect in direction of turn, or slip indicator fails to move opposite turn

b. Airborne: turn needle does not deflect with turn, or slip indicator does not respond to rudder movement

c. Power failure flag appears

2. Verifications

a. Perform a timed standard rate turn to see if you get proper turn needle deflection

b. Apply rudder pressure to confirm slip indicator failure

3. Effects on flight safety: Standby turn and slip indicator is an essential instrument during out-of-control flight recovery

C. Standby attitude indicator (Standby AI) failure

1. Indications

a. Indicator frozen, not erect, or unreliable

b. Red/orange flag appears

c. OFF flag may appear

2. Verifications

a. Cross-check ADI display

b. Cross-check Standby AI or ADI indications in other cockpit

c. Cross-check outside references

3. Effect on flight safety: loss of attitude reference backup

D. Standby compass failure

1. Indication/verification/effects on flight safety: The standby wet compass rarely fails unless physically damaged

E. Clock/stopwatch failure

1. Indication/verification/effects on flight safety: The clock/stopwatch rarely fails unless physically damaged. If the clock/stopwatch fails, back-up is GPS time readout on the HUD or MFD GPS page

SUMMARY

In this lesson, you have learned about malfunctions related to several important flight instruments:

* Global Positioning System/Inertial Navigation Assembly (GINA) and related components
  - Attitude director indicator (ADI) display failure
  - Horizontal situation indicator (HSI) display failure
  - Vertical speed indicator (VSI) display failure
  - General GINA failure
* Pitot static system
  - Standby airspeed indicator failure
  - Standby altimeter (ALT) failure
  - Standby vertical speed indicator (VSI) failure
  - Pitot tube damage or icing
* Angle of attack (AOA) system
  - AOA indicator failure
  - AOA indexer failure
* Independent instruments
  - Radar altimeter display failure
  - Standby turn and slip indicator failure
  - Standby attitude indicator failure
  - Standby compass failure
  - Clock/stopwatch failure

CONCLUSION

You depend on your flight instruments, especially during IMC conditions, to maintain your flight parameters and navigation procedures. This lesson has enabled you to recognize instrument malfunctions and to anticipate their effects on your flight.

The malfunctions described in this lesson might occur in conjunction with each other or with some malfunction related to another aircraft system.

If this lesson has raised any questions for you, be certain to contact your instructor.

FIGURES

GINA AND RELATED COMPONENTS		
	FAILURE INDICATIONS	FAILURE VERIFICATIONS
ADI Display	Missing heading, pitch & roll readings	STBY AI, HSI, outside reference
HSI Display	Missing heading & NAV info	ADI, wet compass
VSI Display	Missing digital readout, analog scale and pointer	STBY VSI
GINA	Blank ADI and HSI displays	STBY AI, wet compass, outside reference

Figure 1: GINA AND RELATED COMPONENTS: SUMMARY OF MALFUNCTION INDICATIONS AND VERIFICATIONS

PITOT STATIC SYSTEM INSTRUMENTS		
	FAILURE INDICATIONS	FAILURE VERIFICATIONS
Standby Airspeed	Needle freezes, drops, or fluctuates	AOA indicator, other cockpit
Standby Altimeter	Needle freezes or fluctuates, erroneous readings	Radar altimeter display, standby VSI, cabin altimeter, other cockpit
Standby VSI	Needle freezes or fluctuates, erroneous readings	Standby altimeter, HUD, standby attitude indicator, standby airspeed indicator, other cockpit
Pitot tube	Failure of all pitot static instruments	

Figure 2: PITOT STATIC SYSTEM: SUMMARY OF MALFUNCTION INDICATIONS AND VERIFICATIONS

	FAILURE INDICATIONS	FAILURE VERIFICATION
AOA INDICATOR	OFF flag, needle freezes or fluctuates	Airspeed, raise or lower nose
AOA INDEXER	No lights or erratic	AOA indicator, bulbs check OK

Figure 3: AOA INSTRUMENTS: SUMMARY OF MALFUNCTION INDICATIONS AND VERIFICATIONS

INDEPENDENT INSTRUMENTS		
	FAILURE INDICATIONS	FAILURE VERIFICATIONS
Radar altimeter display	Missing Value	Standby altimeter, ATC transponder, other cockpit
Standby turn and slip	No deflection or incorrect deflection	Std rate turn, kick rudder
Standby AI	Solid/striped Power OFF flag, freezes, doesn't erect, unreliable	ADI display, other cockpit
Wet compass	Freezes, fluctuates	HSI display, ADI display, fluid loss, other cockpit

Figure 4: INDEPENDENT INSTRUMENTS: SUMMARY OF MALFUNCTION INDICATIONS AND VERIFICATIONS

LECTURE GUIDE

COURSE/STAGE: TS, ADV, & IUT / Engineering

LESSON TITLE: CNI System

LESSON IDENTIFIER: T-45C TS, ADV, & IUT ENG-21

LEARNING ENVIRONMENT: Classroom

ALLOTTED LESSON TIME: 1.7 hr

TRAINING AIDS:

* Figures
  - Fig 1: Communication System--Major Components
  - Fig 2: Communication Control Panel
  - Fig 3: COMM Transfer Switch Panel
  - Fig 4: IFF System--Major Components
  - Fig 5: GINA--Major Components
  - Fig 6: VOR/ILS System--Major Components
  - Fig 7: TACAN System--Major Components
  - Fig 8: HUD and HSI Displays With TACAN Selected
  - Fig 9: Frequency Bands
  - Fig 10: CNI Input Power Sources
  - Fig 11: Communications Amplifier Block Diagram
  - Fig 12: VOR/ILS System--Marker Beacon Lights
  - Fig 13: VOR/ILS Outputs
  - Fig 14: TACAN Outputs
  - Fig 15: T-45C CNI Antenna Locations

STUDY RESOURCES:

* T-45C NATOPS Flight Manual, A1-T45AC-NFM-000

(9-98) CHANGE 1

LESSON PREPARATION:

Read:

* Part VII, Chapter 21, “Communications - Navigation Equipment and Procedures,” in the T-45C NATOPS Flight Manual, A1-T45AC-NFM-000

REINFORCEMENT: N/A

EXAMINATION:

The student is required to read CNI System and related CNI system malfunction paragraphs in the NATOPS flight manual, receive classroom instruction, and complete assigned CAI lesson(s). The student shall demonstrate knowledge by completing, from memory with 80% accuracy, true/false and multiple choice block examinations. The objectives in this lesson will be tested in either Engineering 29X or Engineering 30X.

LESSON OBJECTIVES

1.4.18.3.1
Recall major components of the CNI system

1.4.18.2.1
Recall operating characteristics of the CNI system

1.4.18.3
Recall function, purpose, and locations of CNI system controls, switches, and indicators

1.4.18.2
Recall interfaces between the CNI system and other a/c systems

1.4.18.1.1
Recall procedures for operational checks of the CNI system

2.1.10.1.2.1
Recall major components of the T-45 GINA

MOTIVATION

In the T-45C there are many possible combinations of CNI switch and control positions. If these are not set properly, navigation erodes or communication problems may arise.

OVERVIEW

In this lesson we will build on your basic understanding of CNI systems. For the T-45C, you will describe the purpose, functional characteristics, and location of controls used to operate the CNI system. You will also recall the interfaces between the CNI system and other T-45C systems.

In this lesson we will be covering the:

* Major CNI components
* Controls and operational characteristics--communication system
* Controls and operational characteristics--navigation system
* Antenna locations (CNI)

REFRESHER

Recall the basic COMM/NAV components and that:

* VOR/ILS and TACAN develop outputs to other systems
* Other systems may interface with COMM/NAV components
* The primary Navy navigation system is TACAN and the primary civil aviation system is VOR/ILS
* The primary military communication frequencies are in the UHF band and the primary civil communication frequencies are in the VHF band

PRESENTATION

I. Major CNI components **1.4.18.3.1**

Sg 1, fr 2
Lesson Organization

CNI SYSTEM

* **Major CNI components**
* Controls and operational characteristics--communication system
* Controls and operational characteristics--navigation system
* Antenna locations (CNI)

A. Communications system (AN/ARC-182)

1. COMM 1/COMM 2 radio system

a. UHF/VHF control panels

Sg 1, fr 3
Fig 1: *Communications System--Major Components*

NOTE: The T-45C is equipped with two independent comm radios, which should reduce incidents of lost comm and provide more efficient communication.

(1) Location

(a) COMM 1: center pedestal, both cockpits

(b) COMM 2: right console, forward of IFF control panel, both cockpits

b. UHF/VHF receiver/transmitters (RTs): fwd avionics bay (COMM 1 and COMM 2)

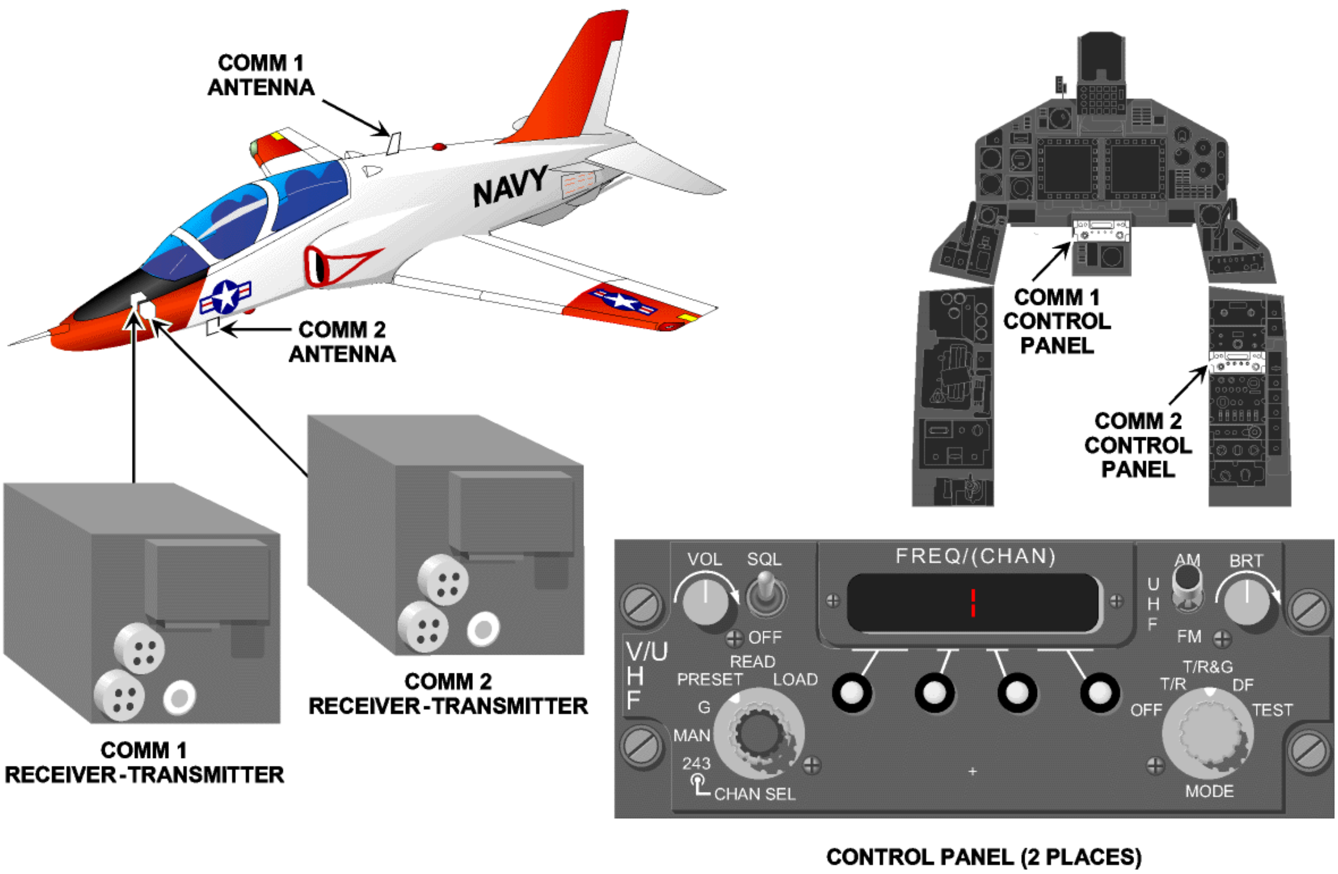


Figure 1: COMMUNICATIONS SYSTEM--MAJOR COMPONENTS

c. UHF/VHF antennas

(1) COMM 1 antenna: mounted on aircraft top centerline between anti-collision beacon and strobe

(2) COMM 2 antenna: mounted on fuselage under surface, aft of nose landing gear door

2. Communications control system/intercom system (ICS): COMM control panel, both cockpits

3. COMM/NAV control transfer panel: center pedestal, below COMM 1 control panel, both cockpits

4. Identification friend or foe (IFF) (AN/APX-100)

NOTE: The IFF system is commonly called the transponder.

a. IFF control panel: right console, aft of COMM 2 control panel, fwd cockpit only

b. IFF transponder: nose equipment compartment

c. IFF antennas

(1) Fwd antenna: upper surface of the nose

(2) Aft antenna: upper right-hand side of tail cone

Sg 1, fr 4
Fig. 2: *Communications Control Panel*

Sg 1, fr 5
Fig. 3: *COMM Transfer Switch Panel*

Sg 1, fr 6
Fig 4: *IFF System--Major Components*

B. Navigation

1. Global positioning system/inertial navigation assembly (GINA) LN-100G

a. T-45C GINA; forward equipment bay

b. GPS antenna: top fuselage, forward of UHF/ VHF No. 1 antenna

c. MFD displays

Sg 1, fr 7
Fig 5: *GINA System--Major Components*

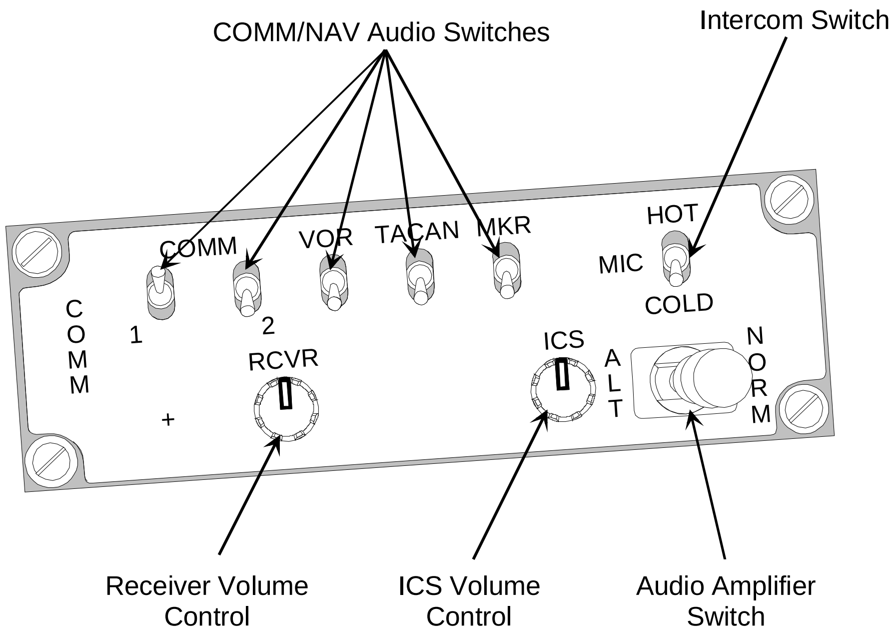


Figure 2: COMMUNICATIONS CONTROL PANEL

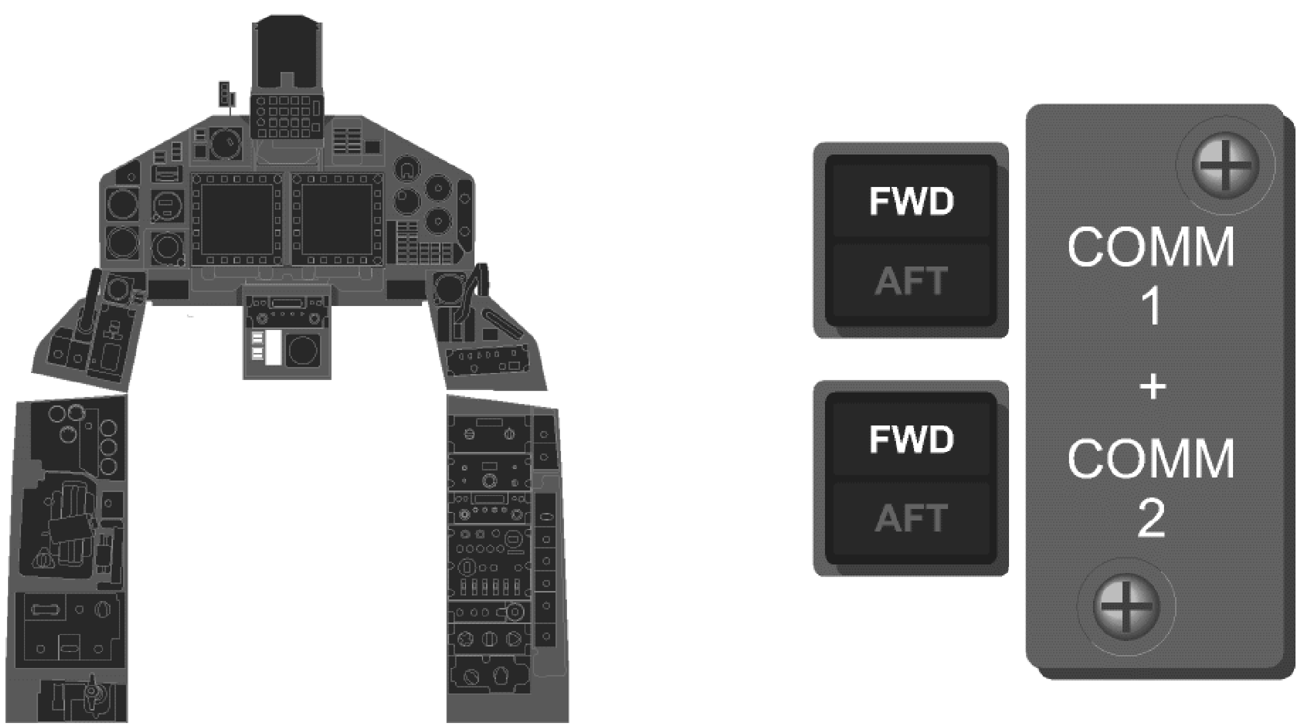


Figure 3: COMM TRANSFER SWITCH PANEL

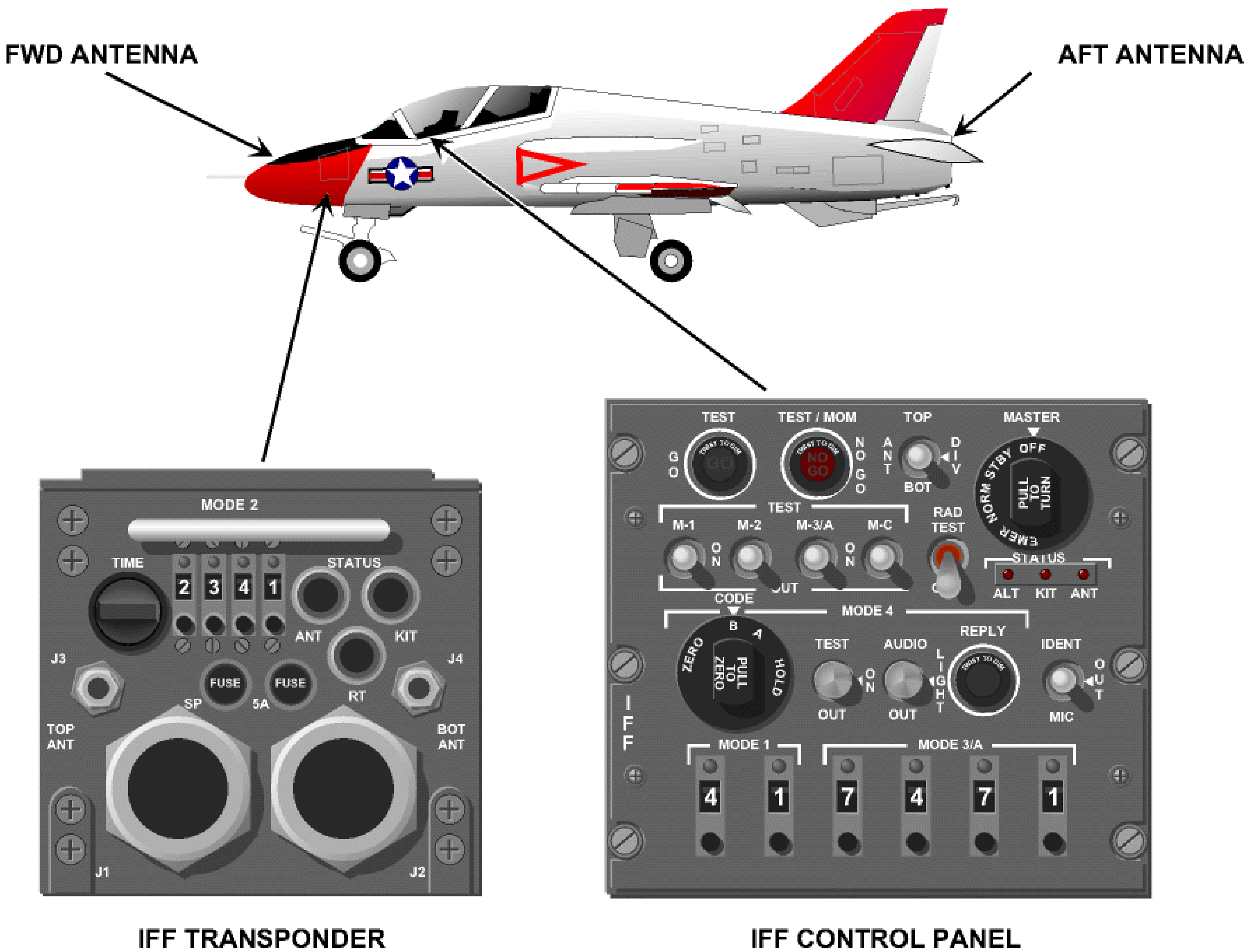


Figure 4: IFF SYSTEM--MAJOR COMPONENTS

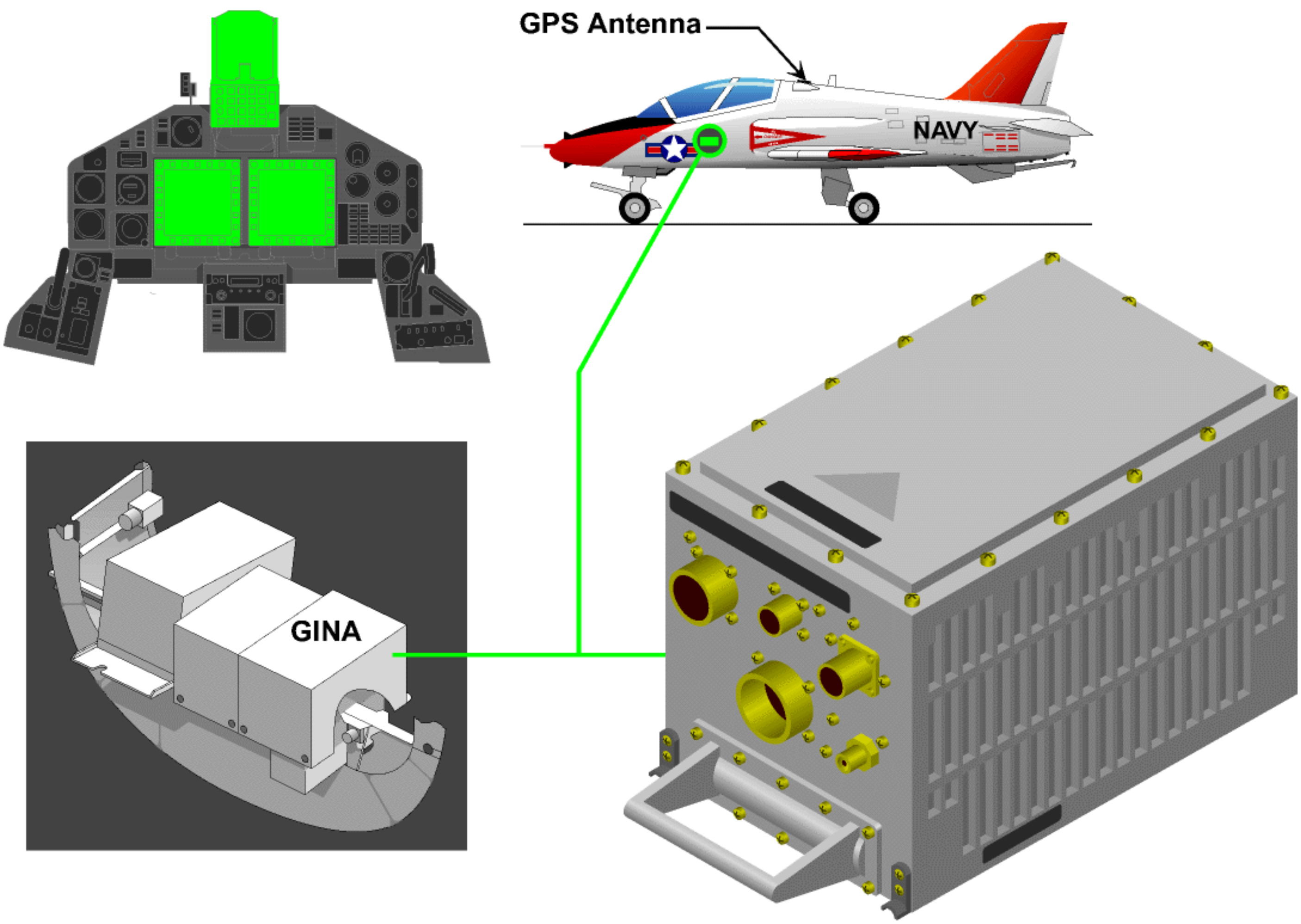


Figure 5: GINA SYSTEM--MAJOR COMPONENTS

(1) ADI display

(a) HYBD/INS/GPS operating modes

(b) Data page

(2) HSI display

(a) Data page

(b) Waypoint

(c) Waypoint increment/decrement

(3) Data page

(a) ACFT page

(b) GPS page

(4) HUD display

2. VOR/ILS system

Sg 1, fr 8
Fig 6: *VOR/ILS System--Major Components*

a. VOR/ILS control panel: right console, aft of COMM 2 control panel, both cockpits

b. VOR/ILS receiver: fwd equipment bay

c. Antennas

(1) Glideslope: starboard wing tip

(2) VOR/localizer: port wing tip

(3) Marker beacon: fuselage aft of nose gear

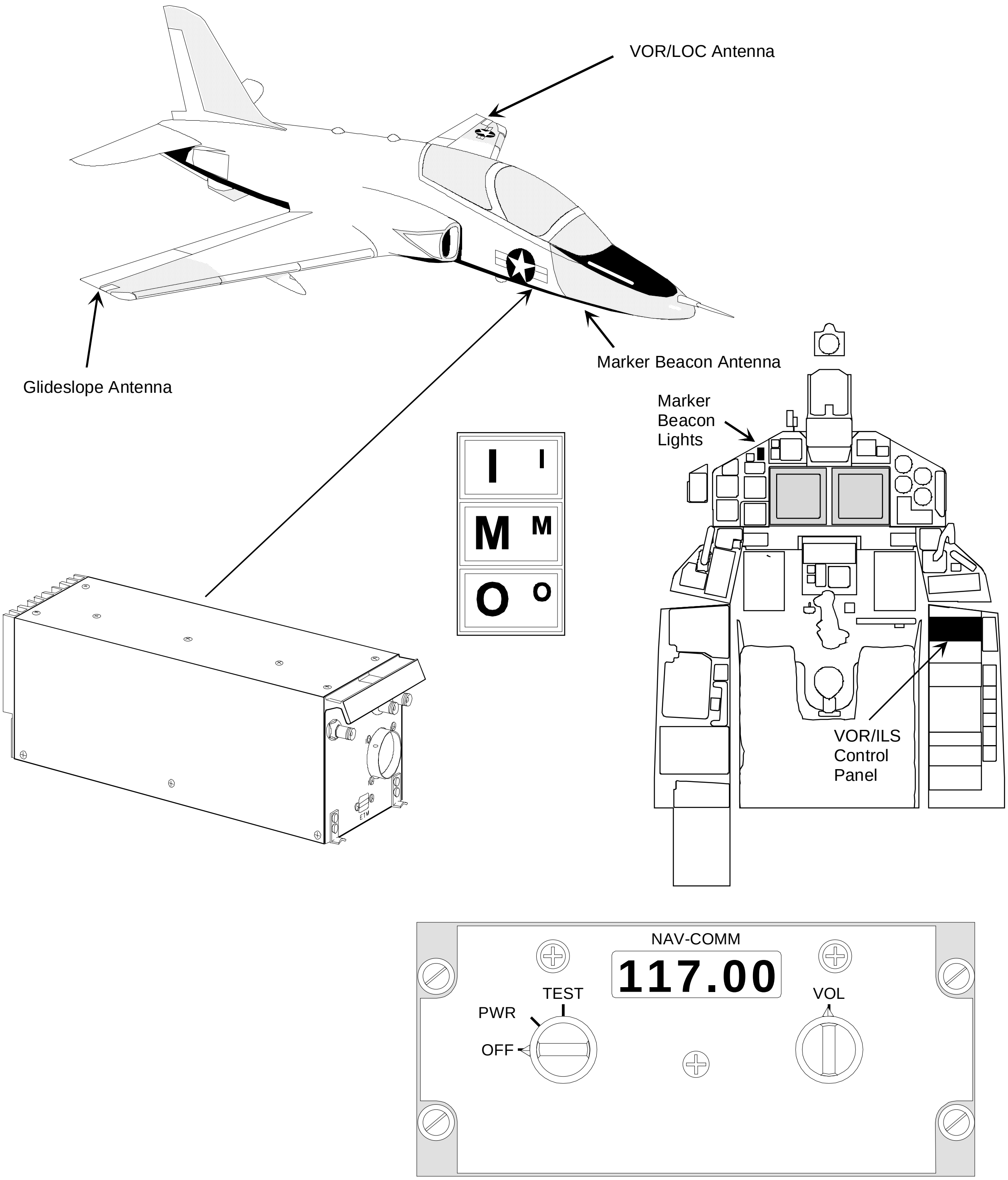


Figure 6: VOR/ILS SYSTEM--MAJOR COMPONENTS

d. Marker beacon lights: left of MASTER ALERT on instrument panel, both cockpits

e. MFD display

(1) ADI display

(2) HSI display

Sg 1, fr 9, pg 1
Fig 7: *TACAN System--Major Components*

3. TACAN

a. TACAN control panel: right console, aft of VOR/ILS control panel

b. TACAN receiver transmitter (RT): nose equipment compartment

Sg 1, fr 9, pg 2
Fig 8: *HUD and HSI Displays With TACAN Selected*

c. TACAN azimuth computer: nose equipment compartment

d. Antenna: forward external under surface of nose cone

e MFD display

(1) HSI display

f. HUD display

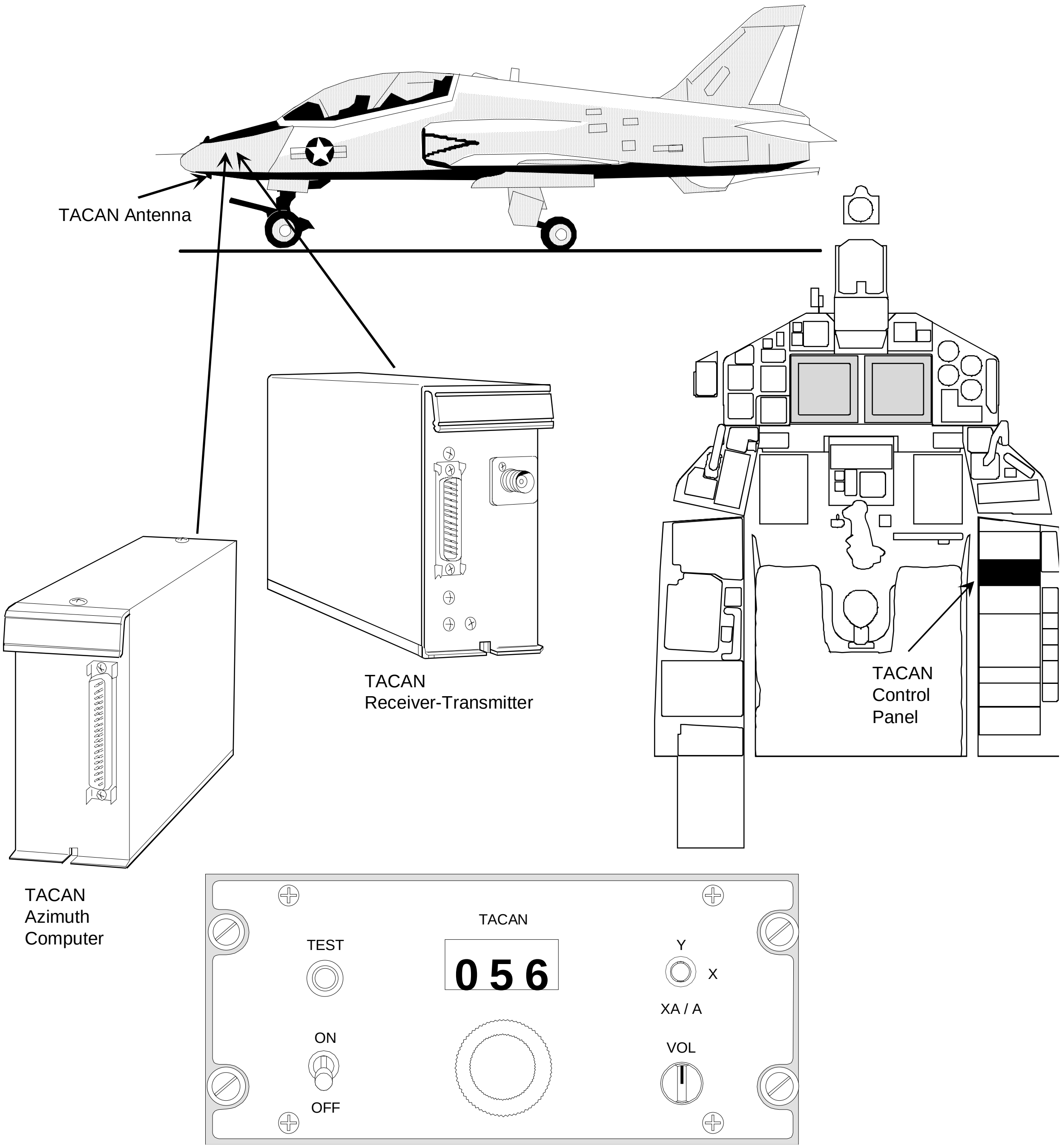


Figure 7: TACAN SYSTEM--MAJOR COMPONENTS

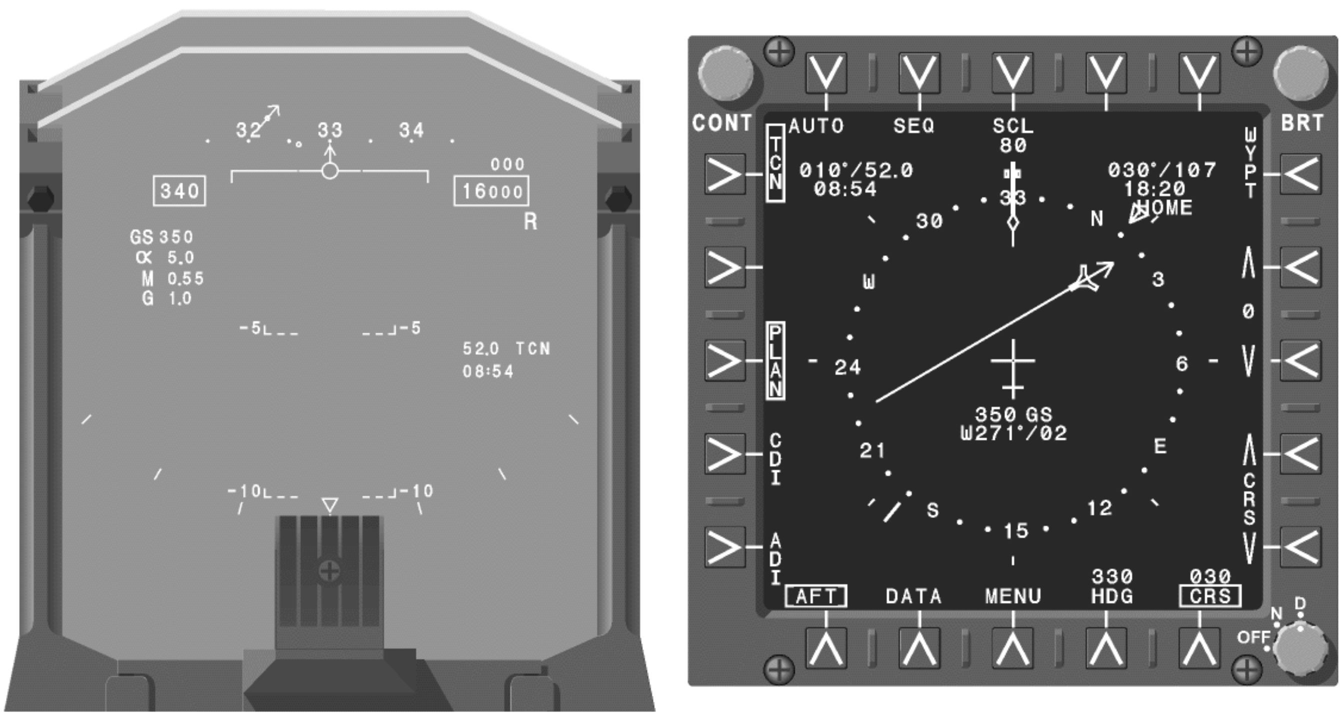


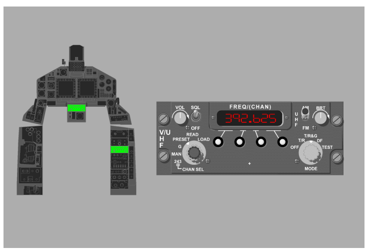
Figure 8: HUD AND HSI DISPLAYS WITH TACAN SELECTED

Sg 2, fr 2
Lesson Organization

CNI SYSTEM

* Major CNI components
* **Controls and operational characteristics--communication system**
* Controls and operational characteristics--navigation system
* Antenna locations (CNI)

Sg 2, fr 3
UHF/VHF Control Panel



Sg 2, fr 4
Fig 9: *Frequency Bands*

II. Controls and operational characteristics--communication system **1.4.18.2.1**

A. COMM 1/COMM 2 radio system: The UHF/VHF comm radio system provides air-to-air and air-to-ground communications. The system consists of two remote receiver transmitters (RT) (COMM 1, COMM 2), four radio control panels (two in each cockpit) and two UHF/ VHF antennas.

1. UHF/VHF control panels

a. Controls operation of remote RT

b. Allows pilots to select operational frequencies of AM and FM signals in UHF and VHF bands

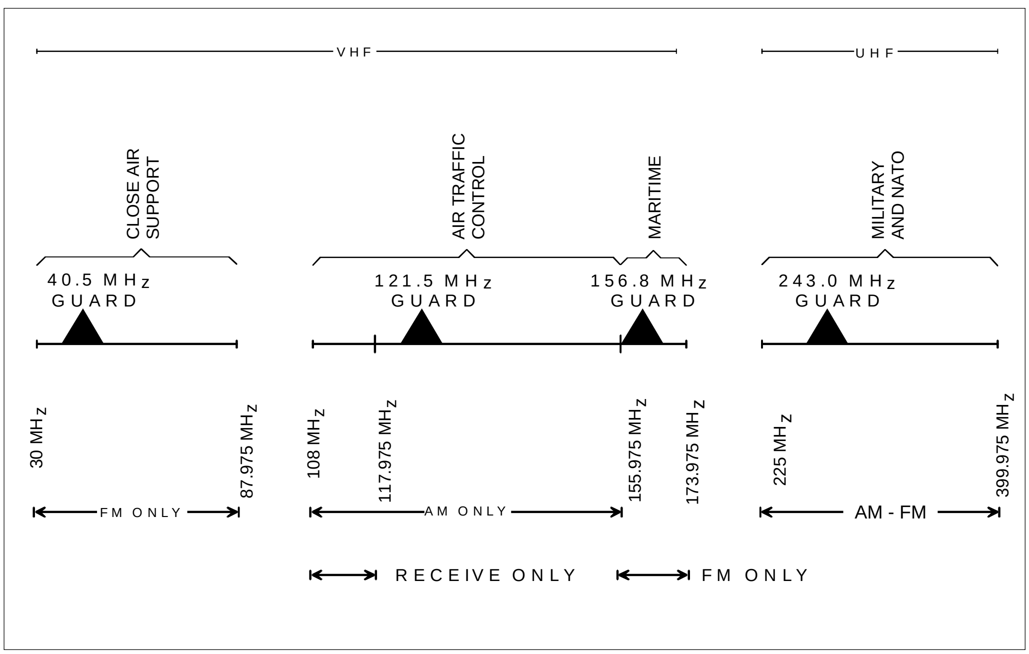


Figure 9: FREQUENCY BANDS

(1) UHF frequency range: 225.0 to 399.975 MHz; commonly used in military aviation for communications

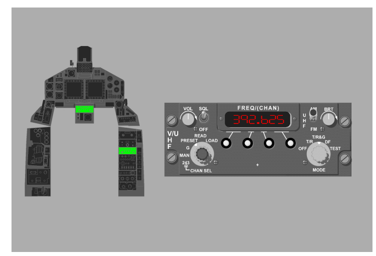
(2) VHF frequency range: 30.0 to 173.975 MHz; commonly used in civil aviation for communications and navigation

c. Enables preset of up to 30 operating frequencies, which allows for ease of frequency selection while flying formation or other demanding maneuvers

NOTE: The LED readouts will display the frequency or channel of the cockpit that has control.

2. UHF/VHF functionality

Sg 2, fr 5
UHF/VHF Control Panel



a. MODE control selector

(1) OFF: power is removed from the set

(2) T/R: set is energized to receive and transmit on selected channel or frequency

(3) T/R & G: same as for T/R position except Guard receiver is energized to receive on guard frequency applicable to frequency band selected on main receiver

(4) DF: not functional

(5) TEST: initiates built-in-test (BIT) for the RT. Test results are displayed on the frequency/channel display.

(a) 888.888 indicates system readiness

(b) Other number combinations indicate system problem and require service by maintenance personnel

b. Frequency selector (outer knob)

(1) 243: RT is automatically tuned to 243.0 MHz (UHF Guard frequency) and overrides mode control selector function, independent of which cockpit currently has control. All other control functions except volume, brightness, and squelch are disabled

(2) MAN: permits manual selection of operating frequency using frequency select switches; RT is disabled during frequency change

(3) G: RT is tuned to Guard frequency in band in which set was last tuned (243.0 MHz UHF or 121.5 MHz VHF)

(4) PRESET: enables selection of any one of 30 preset channels with channel selector (inner knob). Selected channel displayed by two center digit readouts on frequency/ channel display

(5) READ: enables selection of any one of 30 preset frequencies with the channel selector (inner knob). Displays frequency (rather than channel number) of the preset channel on frequency/channel display

(6) LOAD: automatically loads into system memory manual frequency displayed by selected preset channel

c. Frequency select switches: used to manually select desired frequency when frequency selector in MAN position

d. FREQ (CHAN) display window: displays digital readout of selected frequency or channel and BIT results

e. UHF AM/FM mode switch

(1) Selects either AM or FM mode when RT is tuned to frequencies in 225.0 to 399.975 MHz band

(2) Mode selection automatic in all other bands

NOTE: This switch is normally left in the AM position.

f. Squelch switch

(1) SQL: eliminates receiver background noise when no signal is being received (decreases reception sensitivity)

(2) OFF: disables main receiver automatic squelch to increase reception range/ sensitivity

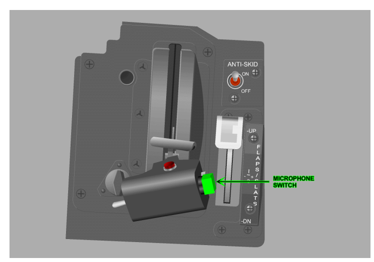
g. Brightness (BRT) control knob: adjusts light intensity of frequency/channel display

h. Receiver volume (VOL) control knob: adjusts level of UHF/VHF audio signals delivered to the communications amplifier

NOTE: With exception of the marker signals volume, volume of the COMM, VOR/ILS, and TACAN are adjustable from each cockpit through the individual system control unit.

3. Throttle/stick

Sg 2, fr 6
Microphone Switch



a. Microphone switch

(1) Location: above speed brake switch on throttle handle in both cockpits

(2) Function: three-position slider-type switch, spring loaded to center (off) position

(a) Up (XMIT-1): allows transmission on frequency/channel selected on COMM radio 1

(b) Down (XMIT-2): allows transmission on frequency/channel selected on COMM radio 2

(c) Depress (ICS): allows intercommunication between cockpits and/or between cockpits and ground crew when MIC switch is in COLD position

Sg 2, fr 8
Fig 10: *CNI Input Power Sources*

4. Aircraft interfaces--communication system **1.4.18.2**

28 VDC ESSENTIAL SERVICES	28 VDC GENERATOR
COMM AMPLIFIER A UHF/VHF #1 DEU TACAN TURN/SLIP CWS IFF GINA MFD, LEFT	COMM AMPLIFIER B VOR/ILS/MB UHF/VHF #2 ALTIMETER ENCODER MFD, RIGHT
115 VAC ESSENTIAL	**115 VAC NON-ESSENTIAL**
GINA	
26 VAC ESSENTIAL	**26 VAC NON-ESSENTIAL**
TACAN	VOR/ILS/MB

Figure 10: CNI INPUT POWER SOURCES

a. COMM 1 power

(1) 28 VDC essential bus: operating

(2) 28 VDC generator bus or 5 VAC non-essential bus: lighting via INTERIOR LIGHT DIMMING panel switch and MIP dimmer

b. COMM 2 power

(1) 28 VDC generator bus: operating

(2) 28 VDC generator bus or 28 VAC non-essential bus: lighting via INTERIOR LIGHT DIMMING lights panel switch and MIP CONSOLE dimmer

c. Receives RF through the COMM 1/COMM 2 antennas

d. Logic that enables and controls selection and display of remote RT frequencies to both cockpits

e. COMM control panel selects audio inputs to headset

f. Transmits UHF/VHF radio signals

B. COMM control panel/intercom system (ICS): The ICS provides communications between cockpits and, when on deck, with the ground crew. It also generates the warning and caution tones initiated by the centralized warning system (CWS) when a malfunction or aircraft configuration problem occurs

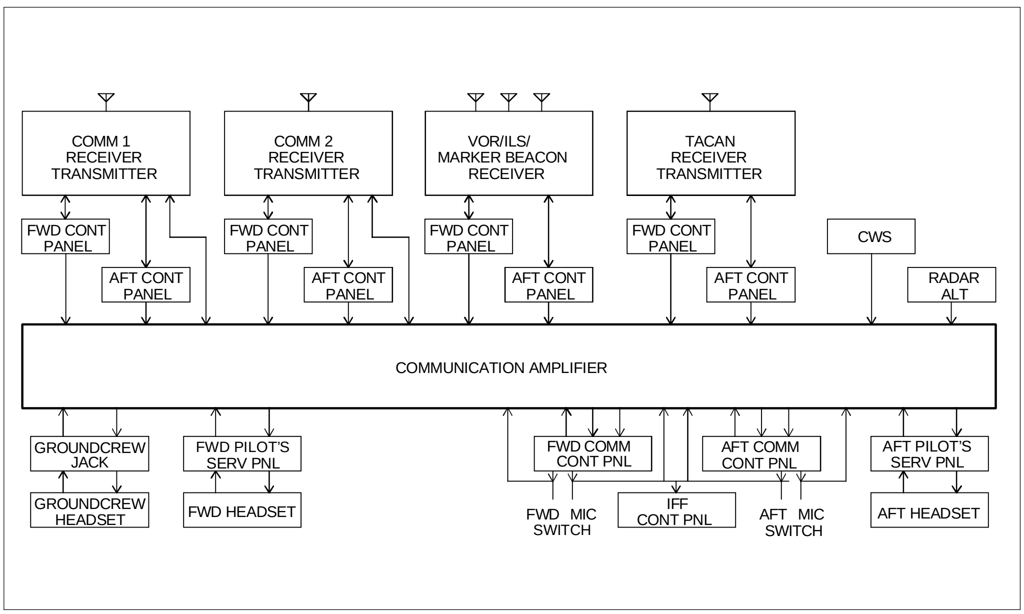


Figure 11: COMMUNICATIONS AMPLIFIER BLOCK DIAGRAM

1. Intercom system

a. Allows communication between cockpits and between cockpits and ground-handling via intercom receptacle in nose wheelwell

b. Generates seven different tones in response to inputs from various systems, including the TONE TEST switch

Sg 2, fr 10
Fig 11: *Communications Amplifier Block Diagram*

(1) Warning tone: in conjunction with illumination of warning (red) light on warning/caution/advisory light panel, the FIRE warning light, or L BAR warning (red) light

(2) Caution tone: in conjunction with illumination of caution (amber) light on caution advisory panel

(3) Wheels warning tone in conjunction with a red wheels warning light on the right side of the AOA indexer in both cockpits: indicates LDG GEAR handle is not set to DN, the throttle is below 95% N_2 rpm position and either of the following conditions exists:

(a) Altitude is less than 7,700 feet MSL and the airspeed is less than 170 KIAS, or

(b) The FLAPS/SLATS levers are not in the UP position

(4) Low altitude tone: indicates aircraft has descended below altitude index set on radar altimeter

(5) Weapon release tone: sounds when weapon pickle button is depressed

(6) Simulated gunfire tone: generated when trigger is depressed and armament control system (ACS) is armed for guns

(7) Stall warning tone: indicates impending aircraft stall, associated with rudder pedal shaker

Sg 2, fr 10
Fig 2: *Communications Control Panel*

2. COMM control panel

a. Provides selection of comm amplifier (normal or alternate)

b. Provides master volume control for COMM radios, the ICS, and VOR/ILS, TACAN, and MKR audio and identification signals

c. Allows selection of COMM 1, COMM 2, VOR, TACAN, or MKR audio

   (1) Switch Up turns on audio of selected COMM/NAV

   (2) Switch Down turns off audio of selected COMM/NAV

d. Provides HOT/COLD MIC selection

e. MIC switch: two-position toggle switch

   (1) HOT: permits intercom between cockpits/ ground crew without depressing microphone switch

   (2) COLD: permits intercom between cockpits/ ground crew only when microphone switch is depressed

f. ALT-NORM switch: two-position toggle switch

   (1) ALT: selects alternate audio amplifier for use when normal amplifier fails. Amplifies all inputs at fixed audio level, i.e. receiver volume inoperative

   (2) NORM: selects normal audio amplifier

g. ICS volume control knob: When ALT-NORM switch in NORM, adjusts intercom reception volume independent of individual equipment volume settings

h. RCVR volume control knob: adjusts volume of all receiver audio signals delivered to headsets. With exception of marker beacon audio, volume of all COMM/NAV signals is adjustable on individual control panels

Sg 2, fr 11
Fig 11: *Communications Amplifier Block Diagram*

3. Aircraft interfaces--COMM control panel/Intercom System (ICS)

   a. ICS (COMM Amplifier)

      (1) Power

         (a) 28 VDC generator bus and 28 VDC essential services bus (wired in parallel): operating

         (b) 28 VDC generator bus: lighting via INTERIOR LIGHTS DIMMING panel switch and CONSOLE dimmer

         (c) 28 VDC essential bus: lighting via emergency flood lights

      (2) Receives audio from radio receivers

      (3) Receives audio from ICS

      (4) Receives VOR/ILS, TACAN, and marker beacon identification audio from respective receivers

      (5) Receives sidetone from either cockpit microphone and integrates it with radio RTs as selected

      (6) Receives inputs from the CWS to generate warning/caution tones

   b. Outputs selected audio to headset and allows for volume control

Sg 2, fr 12
Fig 4: *IFF System--Major Components*

C. IFF system (transponder): The IFF transponder provides for aircraft identification and air traffic control functions. It is controlled remotely by the IFF control panel located in the fwd cockpit

   1. IFF control panel: controls operation of IFF transponder

2. IFF transponder

   a. Receives series of multiple-pulse interrogation signals from ground-based, shipboard, or airborne interrogator (encoded radar signal)

   b. Decodes interrogation signals

   c. Checks validity of signals

   d. Transmits reply to provide

      (1) Aircraft identification

      (2) Altitude from barometric altimeter (Mode C)

   e. Both antennas receive transmissions, but only antenna receiving the strongest signal transmits reply

3. IFF control panel functionality

   a. Master control selector (MASTER)

      (1) OFF: disconnects power to system

      (2) STBY: places receiver-transmitter in warm-up (standby condition)

      NOTE: Allow a minimum of 2 minutes for warm-up when system is first turned on.

      (3) NORM: applies power to receiver-transmitter at normal receiver sensitivity for full range operation

      (4) EMER: transmits emergency reply signals to Modes 1, 2, or 3/A interrogations regardless of Mode control settings. In addition, 7700 Mode 3/A is transmitted automatically

   b. STATUS lights

      (1) ALT: not functional

Sg 2, fr 13
IFF Control Panel
Fig 4: *IFF System--Major Components*

(2) KIT: not functional

(3) ANT: illuminates during self test to indicate antenna function failure

c. Identification of position (I/P) switch

(1) IDENT: initiates identification reply for approximately 20 seconds

(2) OUT (spring loaded from IDENT): prevents triggering of reply

(3) MIC: permits identification reply to be transmitted by pressing microphone switch

d. Mode 4 controls and lights: not functional

e. Mode 3/A code selectors: selects and displays Mode 3/A four-digit reply code number for air traffic control

f. Mode 1 code selectors: selects and displays Mode 1 two-digit reply number for security identification (not normally used)

g. Mode 2: displays a preset four-digit code with 4096 combinations for security identification (not normally used)

h. Mode select/test switches (4)

(1) TEST (spring loaded to ON): BIT function in receiver-transmitter self interrogates Modes 1, 2, 3/A, or C

(2) ON: permits receiver-transmitter reply to Modes 1, 2, 3/A, or C interrogations

(3) OUT: disables the receiver-transmitter for the mode selected

i. RAD TEST switch: permits reply to test mode interrogations from test equipment (for maintenance use only)

j. Test lights (2): functional when RAD TEST switch is set to RAD TEST or when mode select/test switch(es) set to TEST

(1) GO (green): illuminates if system BIT successful

(2) NO GO (red): illuminates if system BIT fails

k. Antenna (ANT) switch

(1) TOP: selects forward antenna

(2) DIV: diverse setting, antenna is automatically selected

(3) BOT: selects aft antenna

4. Aircraft interfaces--IFF System (Transponder)

a. Power: 28 VDC essential services bus

b. Logic that enables and controls selection of the various RT operating modes including BIT

c. Receives digitally encoded altitude supplied by the fwd cockpit barometric altimeter

d. Transmits signals on fwd or aft antenna

e. Interfaces with ground-based, shipboard, and airborne stations for identification and air traffic control purposes

f. When activated, ejection seat initiates transmission of emergency code 7700

Fig 10: *CNI Input Power Sources*

PROGRESS CHECK

Question 1 — 1.4.18.2.1
What buses provide electrical operating power to the communication system (COMM 1, COMM 2, ICS, and IFF)?

ANSWER: 28 VDC essential services bus; COMM 2: 28 VDC generator bus

Question 2 — 1.4.18.3.1
What is the function of the COMM control panel?

ANSWER: It provides selection of COMM amplifier (normal or alternate); provides master volume controls for COMM radios, ICS, VOR/ILS, and TACAN; allows selection of audio that you're going to hear; and provides HOT/COLD MIC selection.

Sg 3, fr 2
Lesson Organization

CNI SYSTEM

* Major CNI components
* Controls and operational characteristics--communication system
* **Controls and operational characteristics--navigation system**
* Antenna locations (CNI)

III. Controls and operational characteristics--navigation system **1.4.18.2.1, 2.1.10.1.21**

A. GINA: The T-45C GINA is a self-contained, all attitude, world wide, strap-down inertial system and embeded GPS receiver. GINA provides all attitude (digital and analog), acceleration, position heading and time to the Display Electronic Unit (DEU) over the MUX Bus for processing ADI and HSI display and the MFDs

Sg 3, fr 3
Fig 5: *GINA System--Major Components*

1. Inertial system

a. Three gyros detect rotation in their respective axis for output to DEU

b. Three accelerometers detect acceleration in their respective axis for output to DEU

2. GPS receiver/antenna

a. Receiver RF ranging codes and navigation data broadcast from GPS satellites orbiting the earth

b. Provides range and time data to DEU

Sg 3, fr 4
Fig 6: *VOR/ILS System--Major Components*

B. VOR/ILS system: The VOR/ILS system receives and processes signals from NAVAID ground stations to produce standard VOR/ILS navigation displays. The receiving unit can be set to receive either VOR or ILS transmissions. Additionally, a marker beacon receiver is also available for reception of marker beacon transmissions. Data received by the VOR/ILS system (other than marker beacon transmissions) are displayed on the MFD (HSI and ADI) displays and the HUD

1. Function: Receives and processes signals from NAVAID ground stations to produce standard VOR/ILS displays

a. VOR operation

(1) Provides navigation information using nationwide VOR system

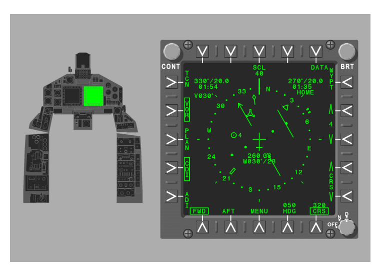
(2) Remote receiver controlled via separate panels in fwd and aft cockpits

(a) Power/frequency selector on VOR/ILS control panel set to PWR

(b) VOR/ILS control panel: frequency tuned (112.00 to 117.95)

(c) Navigation selection control on HSI display: allows either pilot to give or take control of the navigation system and HSI display modes

Sg 3, fr 5
VOR Displays



(3) Transmitted ground signals routed through the VOR/LOC antenna, processed and displayed

(a) Reference and variable phase signal

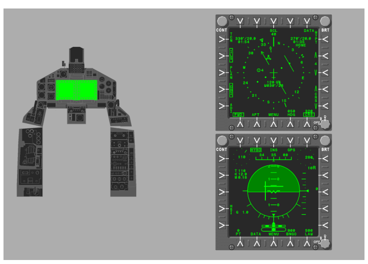
(b) Differences being directly related to the bearing of the ground station from or to the aircraft

(c) Receiver processes ground station signals and the heading input signal from DEU to provide output (magnetic bearing)

(d) Displays course deviation and the VOR radial on the VOR bearing pointer and digital VOR bearing

(4) Station identity processed to provide audio to pilot's headset when VOR switch on COMM control panel is set to VOR

Sg 3, fr 6
ILS Displays



b. ILS Operation

(1) Provides instrument landing system (ILS) information (localizer, glideslope, and marker beacon)

(2) Power/frequency selector on VOR/ILS control panel set to PWR

(3) ILS frequency is tuned (108.10 to 111.95) and automatically displays ILS steering options on HSI display

(4) Signals from the localizer and glideslope transmitter are routed through the VOR/ LOC and glideslope antennas to receiver

(5) Receiver detects, filters and compares the 90 Hz and 150 Hz signals to provide outputs

(6) Displays localizer and glideslope on localizer and glideslope needles on ADI display and HUD

(7) Displays course deviation from an ILS localizer (CDI), on the HSI when ILS is only selected steering

(8) Advisory window displays ILS, localizer or glideslope failure

c. Marker beacon: provides beacon passage by flashing marker beacon lights and audio tone

Sg 3, fr 8
Fig 12: *VOR/ILS System--Marker Beacon Lights*

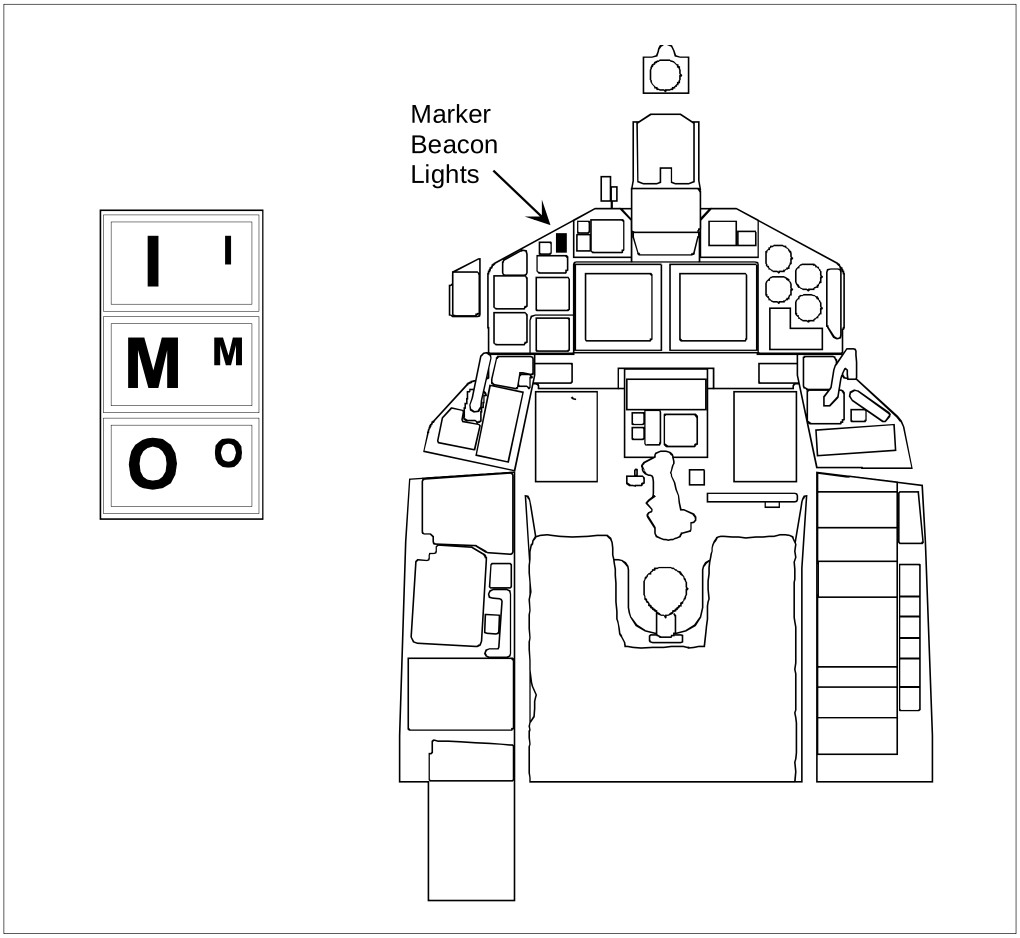


Figure 12: VOR/ILS SYSTEM--MARKER BEACON LIGHTS

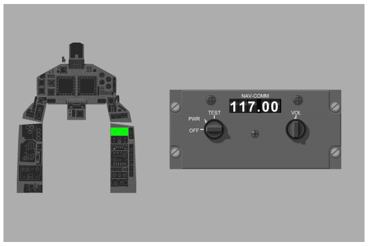
(1) I (White) illuminated indicates aircraft passing over inner marker beacon

(2) M (Amber) illuminated indicates aircraft passing over middle marker beacon

(3) O (Blue) illuminated indicates aircraft passing over the outer marker beacon

(4) MKR switch selected up on the communications control panel permits delivery of marker beacon audio signal to pilot's headset

Sg 3, fr 9
VOR/ILS Control Panel



2. Controls and indicators--VOR/ILS System **1.4.18.3**

   a. Power/frequency selector

      (1) Outer knob (three-position switch)

         (a) OFF: disconnects power to system

         (b) PWR: connects power to system

         (c) TEST: initiates system BIT--A warmup period of 5 seconds is required before system operation. A built-in-test of the VOR/ILS system is performed as follows:

            (i) Select VOR steering and CDI on HSI display

            (ii) Select and set 000 on HSI display

            (iii) Set and hold the Power/Frequency selector in the Test position

            The following occurs:

            (iv) NAV and GS flags and glideslope pointer should not be visible. Range flag should be in view

            (v) The VOR bearing pointer and digital bearing will indicate 315 ± 3.0 degrees

            (vi) The CDI bar will move to the left, maximum 2 dots

            (vii) The marker beacon lights will illuminate

NOTE: The indications of a valid VOR BIT test are: VOR bearing pointer and digital bearing 315 ± 3.0 degrees - CDI will move left, maximum 2 dots. Marker lights illuminate. If a valid VOR signal is not received, only the marker lights will illuminate.

(2) Inner knob: when rotated, changes frequency of operation in 1-MHz increments

b. Frequency display window: displays frequency in use

c. Volume/frequency knob

(1) Outer knob: when rotated, adjusts volume of audio signal

(2) Inner knob: when rotated, changes frequency of operation in 50-KHz increments

3. Aircraft interfaces--VOR/ILS system **1.4.18.2**

Sg 3, fr 10
Fig 10: *CNI Input Power Sources*

a. Power

(1) 28 VDC generator bus: VOR/ILS receiver, control panels

(2) 28 VDC essential services bus: COMM control panels

b. Inputs

(1) ILS glideslope and localizer signals

(2) VOR magnetic bearing signals from station

(3) Marker beacon signals

__Sg 3, fr 11__
__Fig 13:__ VOR/ILS Outputs

c. Outputs

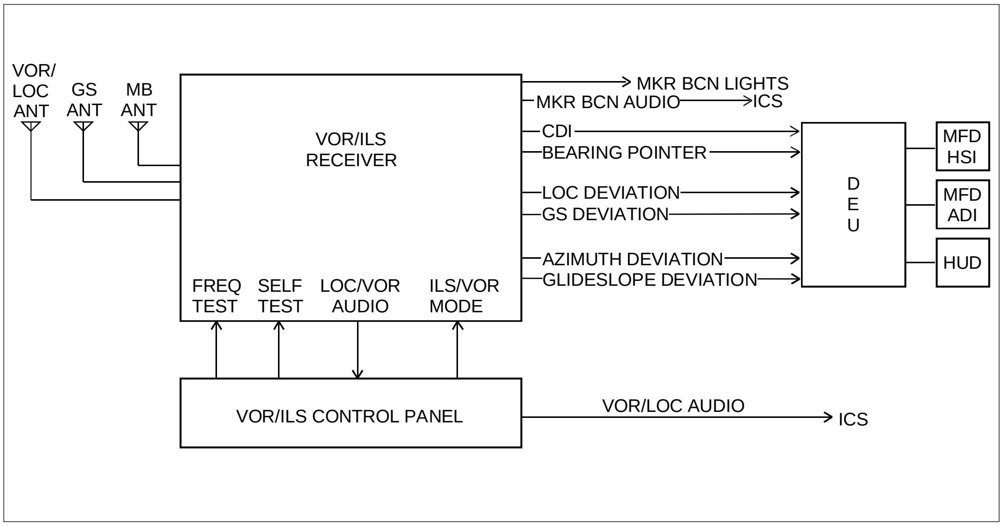


Figure 13: VOR/ILS OUTPUTS

(1) Signal appropriate marker beacon lights to illuminate on approach

(2) Provide marker beacon audio to headsets

NOTE: To display VOR or ILS information on the HSI, ADI, VOR and HUD or ILS steering and course must be selected (boxed) and a VOR or ILS signal received

(3) Course deviation bar on HSI display

(4) Magnetic course/radial information to HSI VOR bearing pointer and digital bearing

(5) ILS localizer deviation (CDI) when ILS frequencies selected and ILS only selected steering

(6) ADI and HUD glideslope and localizer deviation needles when ILS frequencies selected

(7) VOR and ILS idents and marker beacon tones to ICS for amplification if selected

Sg 3, fr 12
Fig 7: *TACAN System--Major Components*

C. TACAN system: TACAN provides magnetic bearing to/from the selected station. It also provides a distance measurement capability. It consists of a single TACAN RT that is controlled remotely by the TACAN control panel in either cockpit. TACAN navigational data are displayed on the HSI display and HUD

1. TACAN Receiver/Transmitter

   a. Receives, transmits, and processes radial and range signals from TACAN ground stations and range information from other aircraft in air-to-air mode

   b. Sends signals to TACAN azimuth computer for display on HSIs

2. TACAN azimuth computer

   a. Derives and produces signals to display bearing received from TACAN RT

   b. Displays, course deviation (CDI), DME data, and TACAN radial on the TACAN bearing pointer on the HSI

3. TACAN control panel

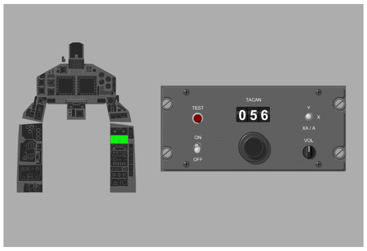
   a. Controls operation of remote RT

   b. Controls operation of azimuth computer

   c. Provides magnetic bearing

   d. Provides Distance Measuring Equipment (DME): slant range distance to suitably equipped ground stations/aircraft

Sg 3, fr 13
TACAN Control Panel



e. Controls and indicators

(1) Power switch (two-position switch)

(a) ON: connects power to system

(b) OFF: disconnects power to system

(2) Option select switch (three-position switch)

(a) Y: selects Y channel for TACAN operation. (There are 126 preset operating channels)

(b) X: selects X channel for TACAN operation. (There are 126 preset operating channels)

(c) XA/A: selects TACAN air-to-air mode. Participating aircraft must have 63-channel separation. Distance information to suitably equipped aircraft is displayed on HSI

(3) Channel selector: when rotated, selects desired channel for TACAN operations and displays selection on channel window

(4) Channel display window: displays selected TACAN channel

(5) Volume control knob (VOL): when rotated, adjusts volume of TACAN station identification signals

(6) TEST button: initiates system built-in test (BIT) if pushed and held for a minimum of 5 seconds and the following conditions exist:

(a) TACAN steering selected on HSI display

(b) 180 course set on HSI

The following should occur:

(c) The TACAN bearing pointer and digital bearing will indicate 180 ± 2.5 degrees

(d) Range will read 0 ± 1 NM

(e) The CDI bar will be centered

NOTE: The indications of a valid TACAN BIT test are: TACAN bearing pointer and digital bearing - 180 ± 2.5 degrees - Range reads 0 ± 1 NM - CDI centered.

NOTE: The system initiates an auto-test when lock-on is broken.

4. Aircraft Interfaces - TACAN System

a. Power

Fig 10: *CNI Input Power Sources*

(1) 28 VDC essential services bus: TACAN RT, control panels, COMM control panels

(2) 115 VAC essential services bus: TACAN

(3) 26 VAC essential bus: TACAN RT, control panels

b. Inputs

(1) RF TACAN magnetic bearing and distance measurement signals

(2) COMM/NAV control transfer panel signals RT as to which cockpit has control

Sg 3, fr 14
Fig 14: *TACAN Outputs*

c. Outputs

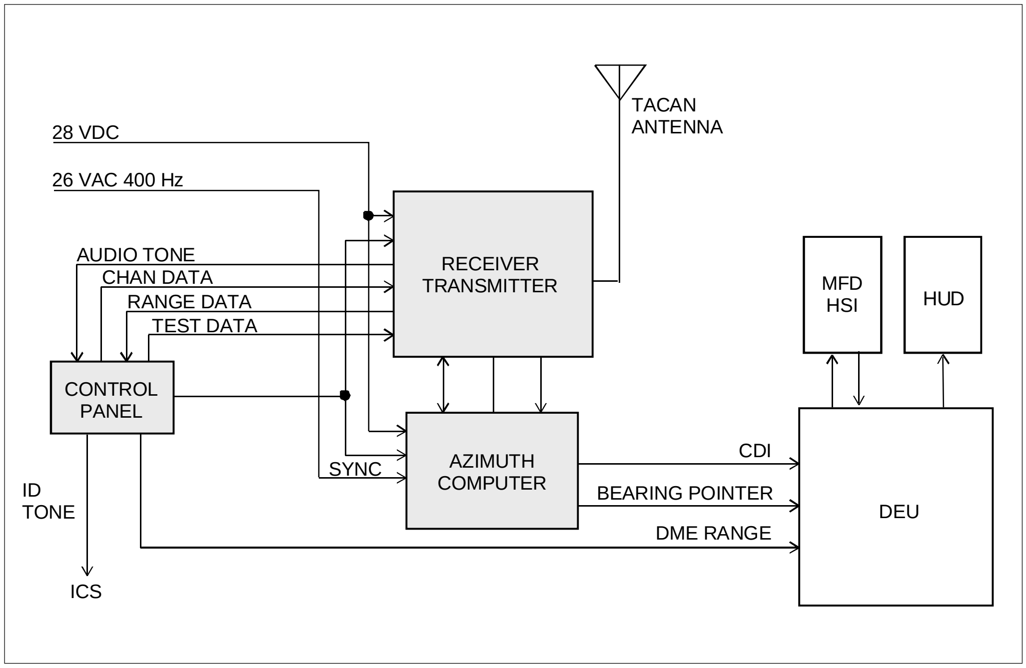


Figure 14: TACAN OUTPUTS

(1) TACAN course deviation information (CDI) to HSI and HUD

(2) TACAN magnetic course/radial information to HSI TACAN bearing pointer and digital bearing

(3) DME data to HSI and HUD

(a) Distance to ground station

(b) Distance to other aircraft

(4) TACAN idents to ICS for amplification if selected

PROGRESS CHECK

Question 3 — 2.4.7.1.1

What instrument displays TACAN information and, more specifically, what indicators on the instrument are affected by TACAN outputs?

ANSWER: TACAN outputs are displayed on the HSI and HUD Indicators affected by TACAN include the TACAN bearing pointer and digital bearing, the TACAN range indicator, and the CDI.

D. Navigation Control

1. On HSI display FWD or AFT

2. Default to FWD on start

3. Indicates which cockpit controls

   a. HSI display mode

   b. VOR/ILS control panel

   c. TACAN control panel

   d. Command heading

   e. Command course

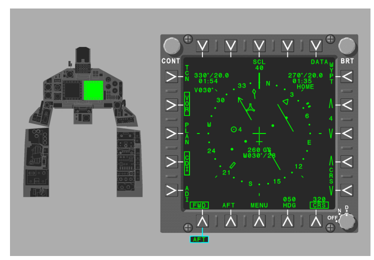
   f. Waypoint selection

   g. Steering reference

   h. Sequence steering

   i. Compass rose scale

Sg 3, fr 15
Navigation Control



Sg 3, fr 16
Fig. 2: *Communications Control Panel*

E. COMM control panel

1. VOR switch: when positioned to the up position, VOR audio signals are delivered to headsets

2. TACAN switch: when positioned to the up position, TACAN audio signals are delivered to headsets

3. MKR switch: when positioned to the up position, marker beacon audio signals are delivered to headsets

Sg 3, fr 17
Fig. 3: *COMM Transfer Switch Panel*

F. COMM control transfer switch panel

1. FWD or AFT illuminated indicates cockpit with control of the COMM 1 or COMM 2 radio

2. Depressing the switch transfers control between the forward and aft cockpit

PROGRESS CHECK

Question 4 — 1.4.18.2
Which indicators on the ADI are controlled by the VOR/ILS receiver when in the ILS operating mode?

ANSWER: The ADI azimuth deviation bar and glideslope deviation bar

Sg 4, fr 2
Lesson Organization

CNI SYSTEM

* Major CNI components
* Controls and operational characteristics--communication system
* Controls and operational characteristics--navigation system
* **Antenna locations (CNI)**

Sg 4, fr 3 (8 Overlays)
Fig 15: *T-45C CNI Antenna Locations*

IV. Antenna locations (CNI)

A. Nose section

1. IFF antenna

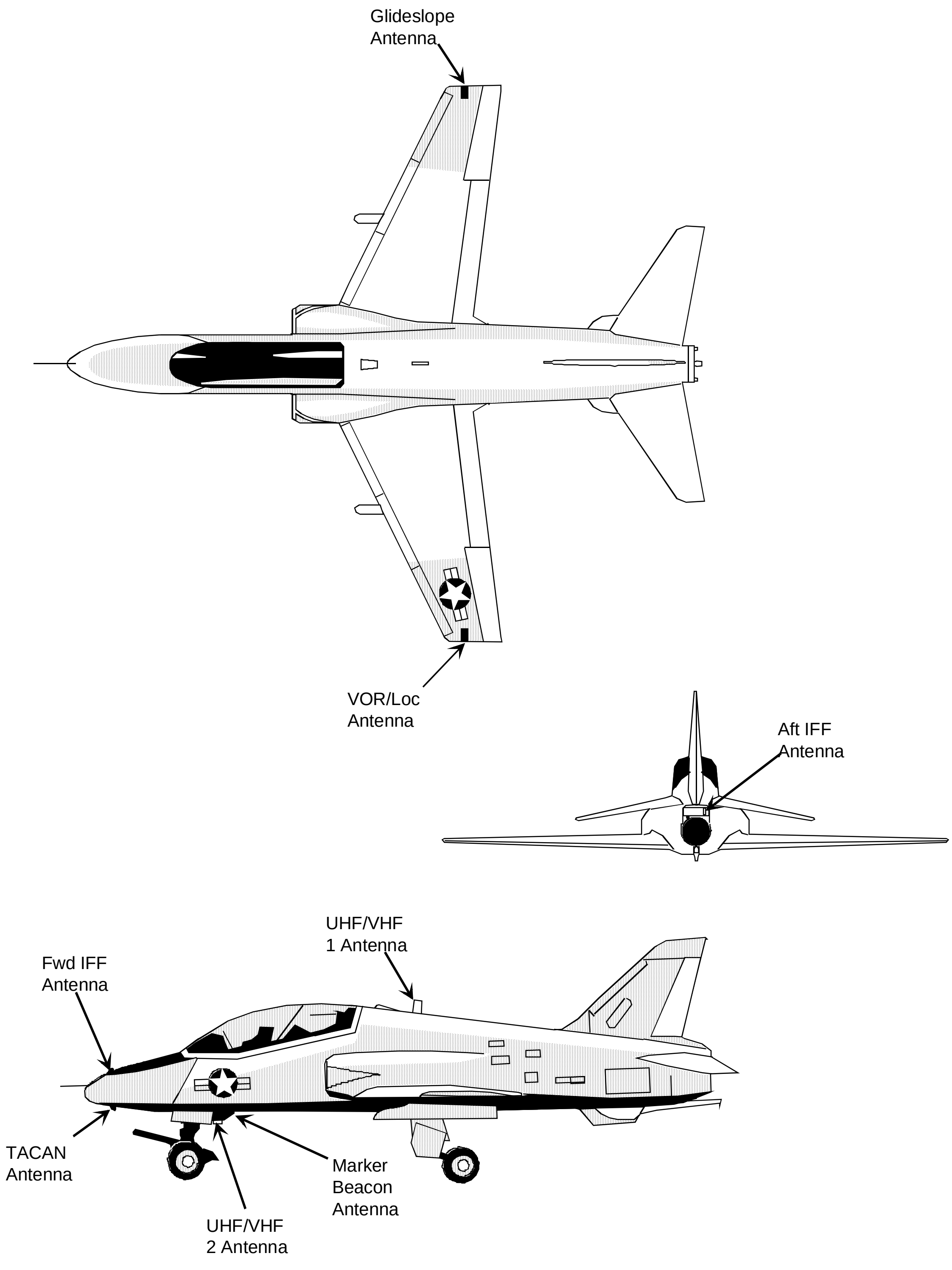


Figure 15: T-45C CNI ANTENNA LOCATIONS

Overlay 1
TACAN Antenna

Overlay 2
UHF/VHF 2 Antenna

Overlay 3
Marker Beacon Antenna

Overlay 4
Glideslope Antenna

Overlay 5
UHF/VHF 1 Antenna

Overlay 6
AFT IFF Antenna

Overlay 7
VOR/LOC Antenna

2. TACAN antenna

B. Forward fuselage (underside)

1. UHF/VHF 2 antenna

2. Marker beacon antenna

C. Right wing

1. Glideslope antenna

D. Top fuselage (right side)

1. UHF/VHF 1 antenna

E. Tail section (right side)

1. IFF antenna

F. Left wing

1. VOR/LOC antenna

PROGRESS CHECK

Question 5 — 1.4.18.3
What is the function of the Navigation control FWD/AFT on the HSI display?

ANSWER: It allows pilots to transfer control of the navigation systems.

Question 6 — 1.4.18.2.1
What electrical buses supply power to the CNI system?

ANSWER: 28 VDC essential services bus, 28 VDC generator bus, 115 VAC essential bus, 26 VAC essential bus, and 26 VAC non-essential bus

SUMMARY

Sg 5, fr 1
Review Menu

In this lesson we have covered the:

* Major CNI components
* Control and Operational characteristics--communication system
* Control and Operational characteristics--navigation system
* Antenna Locations (CNI)

CONCLUSION

Knowing the operation of the CNI system and recognizing the significance of cockpit indications are critical to completing your flight in a safe and professional manner.

NOTES

LESSON GUIDE

COURSE/STAGE: TS, ADV & IUT / Engineering

LESSON TITLE: CNI System Malfunctions

LESSON IDENTIFIER: T-45C TS, ADV & IUT   ENG-22

LEARNING ENVIRONMENT: CAI

ALLOTTED LESSON TIME: 1.0 hr

FIGURES: N/A

STUDY RESOURCES:

T-45C NATOPS Flight Manual, A1-T45C-NFM-000

LESSON PREPARATION:

Read:
* Part VII, Chapter 21, "Communications-Navigation Equipment and Procedures," in the T-45C NATOPS Flight Manual, Al-T45C-NFM-000

Review:
* Lesson Guide for Eng-21, "CNI System"

REINFORCEMENT: N/A

LESSON EXAMINATION:

The student is required to read CNI System and related CNI system malfunction paragraphs in the NATOPS flight manual, receive classroom instruction, and complete assigned CAI lesson(s). The student shall demonstrate knowledge by completing, from memory with 80% accuracy, true/false and multiple choice block written examinations. The objectives in this lesson will be tested in either Engineering 29X or Engineering 30X.

LESSON OBJECTIVES

1.8.1.9.1.1
Identify indications of COMM 1 failure

1.8.1.9.2.1
Identify indications of COMM 2 failure

1.8.1.9.3.1
Identify indications of ICS failure

1.8.1.8.1.1
Identify indications of CWS audio failure - on

1.8.1.9.6.1
Identify indications of IFF failure

2.8.1.1
Identify indications of INS failure

1.8.1.9.4.1
Identify indications of TACAN azimuth failure

1.8.1.9.5.1
Identify indications of TACAN DME failure

1.8.1.9.8.1
Identify indications of VOR failure

1.8.1.9.9.1
Identify indications of ILS glideslope failure

1.8.1.9.10.1
Identify indications of ILS localizer failure

1.8.1.9.11.1
Identify indications of ILS marker beacon failure

MOTIVATION

A critical component of the aircraft system, the Communications/ Navigation Instruments (CNI) system acts as your eyes and ears to the outside world and has a direct impact on your ability to successfully complete the flight. If a problem occurs in the CNI system, you must immediately identify the malfunction and assess its impact on flight operations and safety.

OVERVIEW

This lesson will enable you to recognize and verify CNI system malfunctions and to assess their impact on aircraft operations and flight safety.

This lesson presents cockpit malfunctions related to the following CNI systems:

* COMM system
    - COMM 1 and COMM 2
    - ICS
    - CWS audio
    - IFF
* NAV system
    - GINA
    - TACAN azimuth
    - TACAN DME
    - VHF Omni Range (VOR)
    - ILS glideslope
    - (ILS) localizer
    - ILS marker beacon

REFRESHER

* Recall the location of CNI major components:

    - COMM/NAV Components—Right Console
        - -- COMM 2 control panel
        - -- VOR/ILS (NAV) control panel
        - -- TACAN control panel
        - -- IFF (FWD cockpit only)

    - COMM/NAV Components—Main Instrument Panel
        - -- COMM 1 control panel
        - -- COMM control panel
        - -- COMM transfer switches
        - -- Outer/Middle/Inner marker beacon light
        - -- ADI
        - -- HSI

* Recall the location and function of the controls and indicators related to the CNI system

* Recall that the CNI system consists of integrated, interrelated components-the output of one is the input of another and vice versa.

PRESENTATION

I. Communication system malfunctions **1.8.1.9.1.1, 1.8.1.9.2.1**

A. COMM 1 and COMM 2 failure

1. Indications: unable to receive and/or transmit

NOTE: Because of the redundant design of the COMM system, the possibility of a total COMM failure is minimal.

2. Verifications

a. Check Communications transfer switch settings

b. Check COMM control panel switch settings

c. Check UHF/VHF radio control panel switch settings

d. Check helmet/mask connections

e. Verify other cockpit experiences same problem

f. Still receiving navigation audio

g. Check with other aircraft

h. Perform BIT

NOTE: If a malfunctioning UHF/VHF radio control panel is causing the problem, communications can be transferred to the other cockpit, if occupied. If a faulty receiver/transmitter is causing the problem, select the other COMM system. If both COMM amplifiers have failed, the communication system is lost.

3. Effects on flight safety: normal air-to-air and air-to-ground communications will be lost

Examples of hazards:

* Lost comm procedures will apply
* Possible traffic conflict
* ASR/PAR approach will be impossible
* Must rely on visual communications
* Must maintain VFR conditions if possible

B. Intercom system (ICS) failure **1.8.1.9.3.1**

1. Indications

   a. Loss of communications between cockpits, and cockpits and plane captain

   b. Loss of all communications, navigation, and intercom audio indicate an ICS malfunction

   NOTE: Each cockpit has one COMM Control Panel with normal and alternate circuitry. If the normal amp fails, switching to ALT should resolve the problem. However, the alternate amplifier operates at a fixed volume level.

2. Verifications

   a. Check switch setting on COMM control panel to ALT

   b. Check helmet/mask connection

   c. Check that BATT switches on the power management panel are on

   d. No side tone when keyed in COLD mic

   e. No side tone in HOT mic

   f. Other cockpit experiences same problem

3. Effects on flight safety: normal air-to-air and air-to-ground communications will be impossible

Examples of hazards:

* Lost COMM procedures will apply if both normal and alternate COMM amplifier circuitry fails
* Complicates the handling of emergencies if dual
* Requires use of deck ground handling signals
* You are responsible for all traffic separation

C. Centralized warning system (CWS) audio failure **1.8.1.8.1.1**

1. Indications

   a. Warning/caution tone without corresponding light

   b. No warning/caution tone with warning or caution lights

2. Verifications

   a. Verify with associated instruments, indicators, and gauges

   b. Tone test with MASTER TEST switch

   c. WCP light test with MASTER TEST switch

   d. Other cockpit experiences same problem

3. Effects on flight safety

   a. An uncommanded tone can distract you from performing normal cockpit duties

   b. The absence of a tone coincident with a warning/caution light may delay application of emergency procedures

Examples of hazards:

* Uncommanded tone may interfere with UHF/VHF and ICS communications
* Loss of continuous warning tone with warning lights
* Loss of one second caution tone with caution lights
* Loss of wheels-up and stall warning tones and weapons release tones

D. Identification Friend or Foe (IFF) transponder failure **1.8.1.9.6.1**

1. Indications

    a. ATC reports unable to read squawk

    b. ATC reports unable to read Mode-C altitude

2. Verifications

    a. IFF control panel configured properly

    b. STATUS ANT light illuminated

    c. BIT fails

3. Effects on flight safety

    a. Loss of IFF ATC radar identification

    b. ATC flight restrictions or special handling required

II. Navigation system malfunctions **1.8.1.9.4.1, 2.8.1.1**

A. GINA failure — GPS or INS

1. GPS failure (not just a loss of satellite lock-on)

    a. HYBD legend goes blank

    b. GPS legend goes blank

c. INS legend automatically selects (boxes)

d. AV BIT advisory appears on all MFDs in lower right-hand corner

e. BIT page shows DEGD for GINA

NOTE: GINA will still provide accurate aircraft attitude information for the pilot, providing INS mode is functioning properly.

2. INS failure

a. HYBD and INS legends go blank

NOTE: GPS legend may also go blank. Selecting (boxing) GPS — if able — allows GPS derived LAT/LONG to be read on the Aircraft Data Sublevel page.

b. AV BIT advisory appears on all MFDs in lower right-hand corner

c. BIT page shows DEGD for GINA

d. ATTITUDE advisory window appears, first

e. POSITION advisory replaces ATTITUDE advisory after (if) attitude is resolved

NOTE: All aircraft attitude information is lost with a failed INS. GPS — alone — cannot provide any attitude data.

f. GINA may automatically realign and completely recover; GINA may not

(1) Cross-check Standby instruments
NOTE: If possible, remain VMC until attitude and position problems are safely resolved.

(2) Do not maneuver aircraft during coarse-alignment phase (attitude), if system automatically (or manually) enters a realignment process

B. GINA GPS-INS mismatch

1. Causes

a. INS-GPS position computation disparity

b. INS-GPS velocity computation disparity

c. Disparity persists for a 3-sigma period

(1) Three “sigmas” equates to three (3) times the nominal allowed deviation: a total of 24-30 seconds until cockpit displays are affected

(2) Either GPS or INS may be in error

(3) Both GPS and INS may be in error (unlikely)

2. Indications to pilot

a. ADI

(1) Barometric altitude is no longer filtered; indications may mildly fluctuate

(2) Vertical velocity is removed from displays

(3) AV BIT advisory displayed on all MFDs in lower right-hand corner

NOTE: AV BIT advisory may be removed from view by selecting the BIT display.

(4) GINA DEGD is indicated on the BIT display sub-menu

b. HSI

(1) Ground track marker is removed

(2) Groundspeed is removed

(3) Wind direction and speed are removed

(4) All time-to-go data is removed

(5) AV BIT advisory displayed on all MFDs in lower right-hand corner

(6) DEGD is indicated on the BIT display sub-menu

c. HUD

NOTE: An AV BIT advisory is never shown on the HUD; only on MFD displays.

(1) Velocity vector is removed

(2) Waterline symbol is displayed

(3) Barometric altitude is no longer filtered

d. Check Standby instrument indications

e. Cross-check navigation to assure proper orientation

(1) TACAN, VOR, ILS (as appropriate)

(2) ARTCC, TRACON, RAPCON, Arrival/ Departure controllers, etc. (request assistance, as appropriate)

(3) Cross-check navigation with visual landmarks when possible

f. ADI, HSI, and HUD displays will automatically revert to normal operation with full functionality, once fault is corrected

C. TACAN azimuth failure

1. Indications

a. Bearing and time-to-go blanked in TACAN data block, bearing pointer, course line, TACAN symbol, blanked on HSI display

NOTE: Counterclockwise rotation of the TACAN bearing pointer is normal during periods of "break lock"

b. Course steering arrow and time-to-go blanked on HUD

2. Verifications

   a. Verify TACAN receiver control panel switch settings

   b. Verify TCN and CRS are Selected on HSI

   c. Verify navigation control is set for crewstation you are occupying

   d. Verify same indications present in other cockpit, if possible

   e. Verify position with other waypoint navigation source or other aircraft, if possible

   f. BIT fails

   g. Check more than one TACAN station

   h. Loss of aural ident

   i. Verify the Morse identifier for your station

3. Effects on flight safety

   a. If undetected, a TACAN azimuth failure could cause you to leave assigned airspace, with ensuing risk of midair collision

   b. Possible navigation errors

   c. Loss of TACAN navigation and approach capabilities

   d. May require alternate approach

D. TACAN distance measurement equipment (DME) failure **1.8.1.9.5.1**

1. Indications

    a. TACAN DME and time-to-go blanked in TACAN data block

    b. TACAN symbol blanked from HSI

    c. Distance and time-to-go on HUD blanked

2. Verifications

    a. Verify TACAN receiver control panel settings

    b. Verify navigation control is set for crewstation you are occupying

    c. Verify same indications present in other cockpit

    d. Verify with other aircraft, if available

    e. Verify range from waypoint data or ATC

    f. No TACAN ident

    g. BIT fails

3. Effects on flight safety

    a. Possible navigation errors

    b. Reduced approach capabilities

E. VHF omni range (VOR) failure **1.8.1.9.8.1**

1. Indications

    a. VOR bearing, bearing pointer and center course line are blanked

2. Verifications

    a. Verify VOR/ILS receiver control panel settings

b. Verify VOR and CRS are selected on HSI

c. Verify navigation control is set for crewstation you are occupying

d. Verify same indications present in other cockpit

e. Verify with other aircraft, if available

f. Verify station operation with ATC

g. Loss of aural ident

h. BIT fails

3. Effects on flight safety

a. If undetected, VOR failure could cause you to leave assigned airspace, with ensuing risk of midair collision

b. Possible navigation errors

c. Reduced approach capabilities

F. Instrument landing system (ILS) glideslope failure **1.8.1.9.9.1**

1. Indications

a. GLIDESLOPE advisory shown on all MFDs

b. GLIDESLOPE needle blanked on ADI and HUD

2. Verifications

a. Verify VOR/ILS receiver control panel settings

b. Verify ILS selected on HSI

c. Verify navigation control is set for crewstation you are occupying.

d. Verify same indications present in other cockpit, if possible

e. Verify with other aircraft, if available

f. Verify with ATC

g. Verify condition of ILS glideslope with approach control or tower

3. Effects on flight safety

a. May require missed approach procedure

b. Reduced approach capabilities (LOC only)

G. Instrument landing system (ILS) localizer failure **1.8.1.9.10.1**

1. Indications

a. LOCALIZER advisory shown on all MFDs

b. Center portion of CDI blanked if ILS is the only selected steering.

c. Localizer azimuth and glidesolpe deviation bars blanked on ADI and HUD

2. Verifications

a. Verify VOR/ILS receiver control panel settings

b. Verify ILS selected on HSI

c. Verify navigation control is set for crewstation you are occupying

d. Verify same indications present in other cockpit

e. Verify with other aircraft, if available

f. Verify status of facility with approach control or tower

g. BIT fails

h. Loss of aural identification

3. Effects on flight safety

    a. If undetected, an ILS localizer failure can lead to serious navigation errors during approach

    b. May require missed approach procedure

    c. ILS and localizer approach capability lost

H. Marker beacon failure **1.8.1.9.11.1**

1. Indications: no associated lights or aural tones

2. Verifications

    a. Verify with aft seat, if available

    b. Verify with other aircraft, if available

    c. Check status of beacon with ATC

    d. Check marker beacon light bulbs with MASTER TEST switch

3. Effects on flight safety

    a. A failed marker beacon will degrade most ILS and LOC approaches

    b. A failed marker beacon may preclude an ILS or LOC approach

    c. Possible position disorientation during approach

SUMMARY

This lesson has presented indications of the following CNI system malfunctions:

* COMM system
  - COMM 1 and COMM 2
  - ICS
  - CWS audio
  - IFF
* NAV system
  - GINA
  - TACAN azimuth
  - TACAN DME
  - VHF Omni Range (VOR)
  - ILS glideslope
  - (ILS) localizer
  - ILS marker beacon

CONCLUSION

This lesson has given you the information needed to recognize CNI system malfunctions and to assess their impact on aircraft operations and flight safety. This background information will be of critical importance to you when you enter the simulator and aircraft cockpits and encounter simulated or actual CNI system malfunctions. Your safety depends on your ability to recognize and react properly to any malfunction that may occur.

If this lesson has raised any questions for you, be certain to contact your instructor.

LECTURE GUIDE

COURSE/STAGE: TS, ADV & IUT / Engineering

LESSON TITLE: Other T-45 Systems

LESSON IDENTIFIER: T-45C TS, ADV & IUT ENG-23

LEARNING ENVIRONMENT: Classroom

ALLOTTED LESSON TIME: 0.5 hr

TRAINING AIDS:

* Figures
  - Fig 1: Airborne Data Recorder (ADR) Event Button
  - Fig 2: MFD - Maintenance (MANT) Display
  - Fig 3: Total Air Temperature (TAT)
  - Fig 4: ADR Monitoring
  - Fig 5: ACS Controls/Indicators
  - Fig 6: Gunsight
  - Fig 7: Wing Stations
  - Fig 8: Armament Controls/Indicators
  - Fig 9: HUD Controls/Indicators
  - Fig 10: HUD Integrated Avionics System

STUDY RESOURCES:

* <u>T-45C NATOPS Flight Manual</u>, A1-T45AC-NFM-000

LESSON PREPARATION:

Read:

* Part I, Chapter 2, Section 2.25, “Miscellaneous Equipment”; Part VIII, Chapter 22, “Armament System”; and Part VIII, Chapter 23, “Avionics,” T-45C NATOPS Flight Manual, A1-T45AC-NFM-000

REINFORCEMENT: N/A

EXAMINATION:

The student is required to read airborne data recorder (ADR) system and armament control system (ACS) and related malfunction paragraphs in the NATOPS flight manual, receive classroom instruction, and complete assigned CAI lesson(s). The student shall demonstrate knowledge by completing, from memory with 80% accuracy, true/false and multiple choice block examinations. The objectives in this lesson will be tested in either Engineering 29X or Engineering 30X.

LESSON OBJECTIVES

1.4.19.5
Receive overview of the airborne data recorder (ADR) system

1.4.19.5.1
Recall major components of the airborne data recorder (ADR) system

1.4.19.5.2
Recall operating characteristics of the airborne data recorder (ADR) system

1.4.19.5.3
Recall aircraft interfaces of the airborne data recorder (ADR) system

1.4.17.3.1.1
Receive overview of the armament control system (ACS)

1.4.17.3.1
Recall major components of the ACS

1.4.17.2.1
Recall operating characteristics of the ACS

1.4.17.3
Recall function, purpose, and location of ACS controls, switches, and indicators

4.4.5.1.1
Recall major components of HUD system

1.4.17.2
Recall interfaces between the ACS, HUD, and other aircraft systems

MOTIVATION

This lesson will provide essential information on other systems which will be beneficial in your training.

OVERVIEW

In this lesson we will discuss the:

* Major components and operating characteristics and functions of the airborne data recorder (ADR) system
* Interface between ADR and other T-45C systems
* Armament control system (ACS) major components and operating characteristics
* Head-up display system (HUD) major components and operating characteristics
* Interfaces between ACS, HUD, and other T-45C systems

REFRESHER

* Recall the T-45C aircraft systems you have studied

PRESENTATION

I. Airborne data recorder (ADR) system

A. Airborne data recorder (ADR) system overview **1.4.19.5**

1. Function: provides the combined functions of a flight incident recorder, engine monitor, and structural fatigue monitor

2. Components: airborne data recorder (ADR), incident record push-button, and associated aircraft system sensors

B. System interface

1. Electrical: power is provided by 28 VDC essential services bus and 26 VAC essential bus

2. The ADR provides N_2 speed switching signals as follows:

a. $N_2 < 42\%$ - dump HYD 2 pump pressure to return to assist engine starting

b. $N_2 > 42\%$ - disconnect external electrical power

c. $N_2 < 70\%$ - disable the steam ingestion bleed valve

Sg 1, fr 2
Lesson Organization

OTHER T-45 SYSTEMS

* **Airborne data recorder (ADR)**
* ADR major components, operating characteristics, and interfaces
* Armament control system (ACS) overview
* Armament control system (ACS) major component identification
* ACS operational characteristics
* HUD system
* ACS and HUD aircraft interfaces

Sg 2, fr 2
Lesson Organization

OTHER T-45 SYSTEMS
* Airborne data recorder (ADR)
* **ADR major components, operating characteristics, and interfaces**
* Armament control system (ACS) overview
* Armament control system (ACS) major component identification
* ACS operational characteristics
* HUD system
* ACS and HUD aircraft interfaces

Sg 2, fr 3
Fig 1: *ADR Event Button*

Sg 2, fr 4
Fig 2: *MFD MANT (Maintenance) Display*

II. Airborne data recorder (ADR) system major components, operating characteristics, and interfaces

A. Major components **1.4.19.5.1**

1. Airborne data recorder (ADR) located in electronics bay

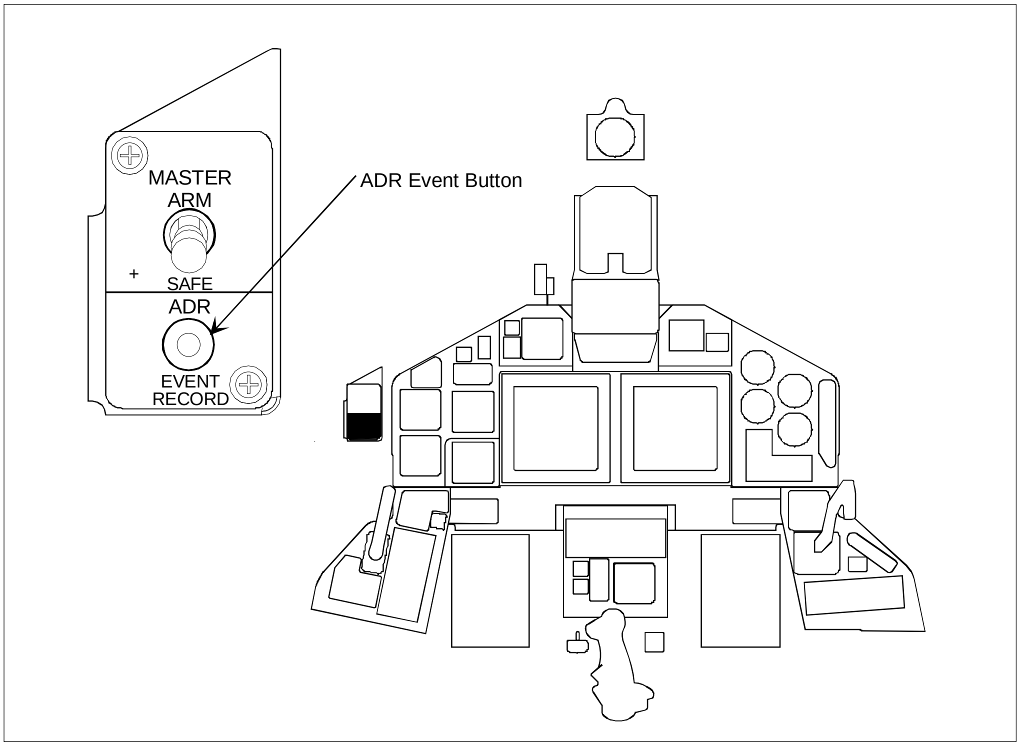


Figure 1: AIRBORNE DATA RECORDER (ADR) EVENT BUTTON

2. Incident record switch in each cockpit labeled ADR EVENT BUTTON located on left instrument panel, both cockpits

3. ADR BIT and exceedance values on MFD maintenance page

a. An exceedance signal on the MFD MANT page if vertical acceleration limits are exceeded

b. Stress monitoring on both wings, vertical stabilizer, stabilator, forward and aft fuselage, and vertical and roll accelerations

Figure 2: MFD - MAINTENANCE (MANT) DISPLAY

Sg 2, fr 5
Fig 3: Total Air Temperature (TAT)

c. Record stress data when parameters reach a predetermined value

4. Sensors

a. GINA

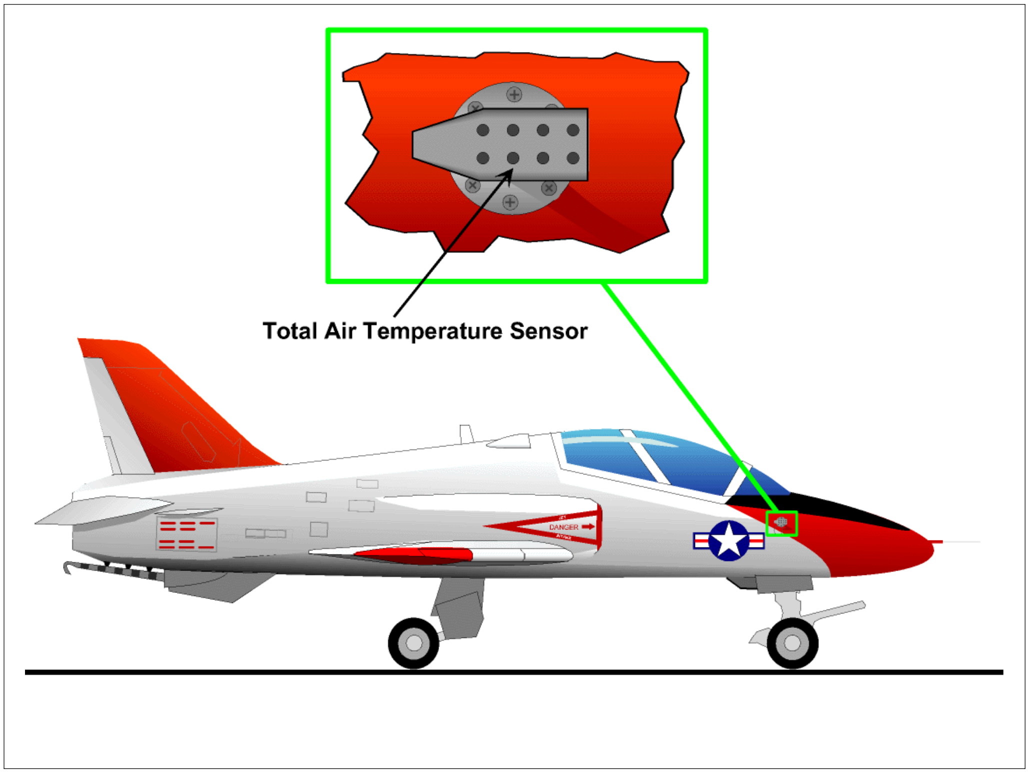


Figure 3: TOTAL AIR TEMPERATURE (TAT)

b. Total air temperature (TAT)

c. Indicated airspeed transducer

d. Radar Altimeter R/T

e. Strain gauges

f. Aileron, rudder, stabilator, flaps, and throttle position potentiometers

g. Engine pressure and vibration transducer

B. Operating characteristics **1.4.19.5.2**

1. Functionality

   a. ADR activates on engine start

   b. Built-in test initiated with power application

   c. Capable of recording 6-8 hours of flight data with emphasis on last 15 minutes

   d. Pressing either cockpit ADR event button initiates a 10-second ADR function. The ADR saves in memory (until downloaded by maintenance personnel) both the 5-second period *prior to* and the 5-second period *after* pressing the ADR event button

Sg 2, fr 6
ADR Functions

ADR FUNCTIONS

* ADR activates when 28 VDC essential services bus is powered
* Built-in test initiated
* Records 6-8 hrs of data
* Either ADR button initiates 10-second ADR function

2. Flight incident function records

   a. ADR records incident data continuously so that the last 15 minutes is always retained. Data prior to 15 minutes is also retained at a lower sampling rate

   b. Trend detection can be obtained from recorded data

   c. Records generated by flight incident functions are stored in a dedicated section of memory separate from engine and structural monitoring

   d. Engine monitoring functions provide engine component life usage tracking capability. Four categories of monitoring are provided:

Sg 2, fr 8
Fig 4: *ADR Monitoring*

      (1) Low cycle fatigue calculations

      (2) Thermal fatigue and creep calculations

      (3) Incidents involving engine parameter exceedance

      (4) Engine vibrations

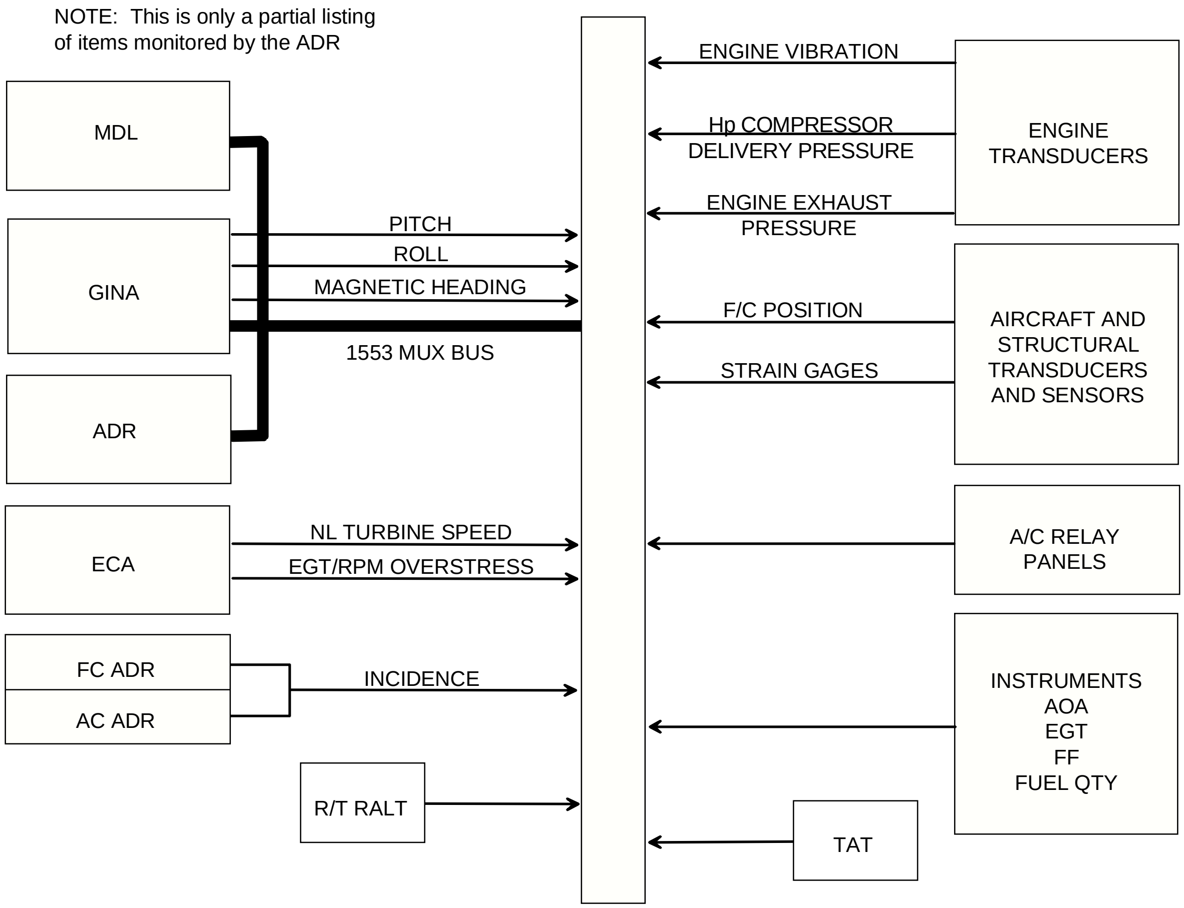


Figure 4: ADR MONITORING

e. Structural fatigue monitoring function provides aircraft performance data for tracking of fatigue life consumption and periodically summarizing the condition of the aircraft. In addition, the function provides:

f. General: The ADR also records many other aircraft conditions. Such things as weight-on-wheels, weight-off-wheels, fuel quantity, flap/ slat position, gear position, and lapse time are among the other aircraft conditions monitored.

C. Aircraft interfaces **1.4.19.5.3**

1. 28 VDC essential services bus powers ADR

2. 26 VAC essential bus

III. Armament control system (ACS) overview **1.4.17.3.1.1**

Sg 3, fr 2
Lesson Organization

OTHER T-45 SYSTEMS

* Airborne data recorder (ADR)
* ADR major components, operating characteristics, and interfaces
* **Armament control system (ACS) overview**
* Armament control system (ACS) major component identification
* ACS operational characteristics
* HUD system
* ACS and HUD aircraft interfaces

A. Function: T-45C armament system consists of equipment and components which provide for carriage, jettison, sitting, gun firing simulation, and controlled release of external stores

B. Cockpit controls and switches

1. Master arm switch

2. Weapons release button

3. Gun trigger

4. Master armament override switch/master arm light

5. Emergency jettison button - both cockpits

6. Weight on wheels bypass switch

7. Gunsight (aft cockpit only)

8. HUD

9. MFD: (2)

10. DEP

C. Wing stores

1. Pylons

2. Practice multiple bomb racks (PMBR)

3. LAU-68 rocket launcher

D. System interfaces

1. Electrical system

a. 28 VDC essential services bus

b. 28 VDC generator bus

2. Centralized warning system (CWS)

Sg 4, fr 2
Lesson Organization

OTHER T-45 SYSTEMS

* Airborne data recorder (ADR)
* ADR major components, operating characteristics, and interfaces
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* **Armament control system (ACS) major component identification**
* ACS operational characteristics
* HUD system
* ACS and HUD aircraft interfaces

IV. Armament control system (ACS) major component identification **1.4.17.3.1**

NOTE: The ACS is composed of circuits, components, and controls used to select and deliver weapons.

Sg 4, fr 3
Fig 5: *ACS Controls/ Indicators*

A. Switches and indicators

1. MASTER armament switch

a. Location: upper left portion of instrument panel, fwd cockpit only

b. Description: controls all armament circuits, with the exception of the emergency jettison of stores

2. Weapons release button

a. Location: stick grip in each cockpit

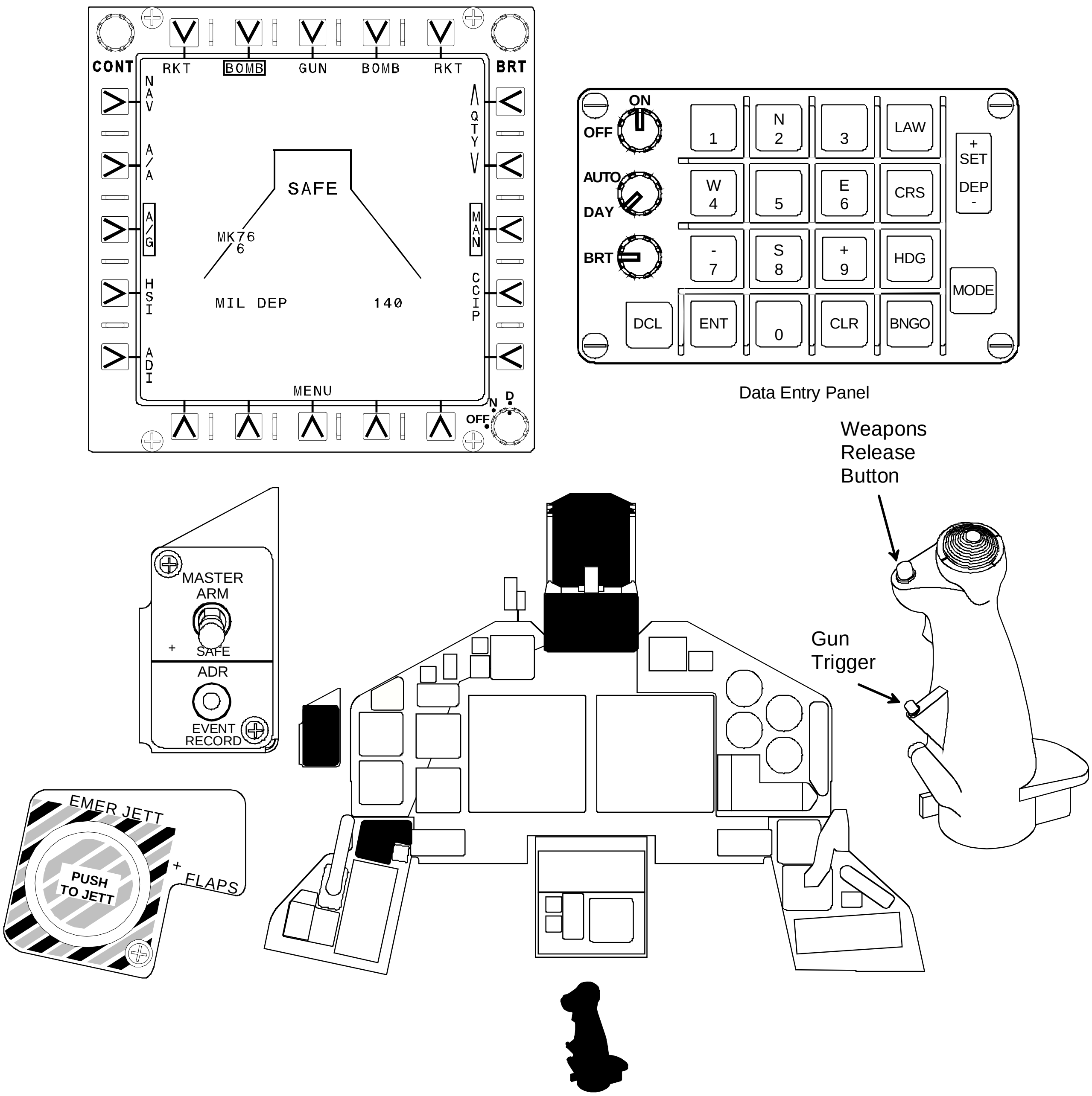
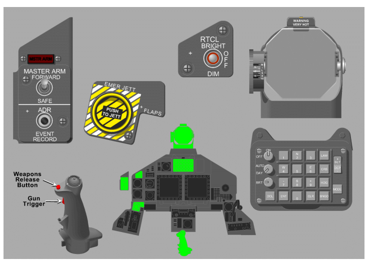


Figure 5: ACS CONTROLS/INDICATORS

Sg 4, fr 4
Aft Cockpit ACS



b. Description: The weapons release button "pickle" initiates release of bombs or rockets from either cockpit

3. Gun trigger

   a. Location: stick grip in each cockpit

   b. Description: initiates gun simulator tone in headset

4. Master armament override switch

   a. Location: middle left center of instrument panel, aft cockpit only

   b. Description: two-position switch (FORWARD SAFE), used to override and disarm weapon system

5. Master arm light

   a. Location: above master override switch

   b. Description: indicates master arm switch in fwd cockpit is in MASTER ARM position

6. Emergency jettison button

? What is the function of the PUSH TO JETT guarded button?

ANSWER: It is used to jettison stores carried on pylons.

   a. Location: left-hand instrument panel, both cockpits

b. Description: labeled PUSH TO JETT, the guarded momentary push-button switch is used to jettison stores carried on pylons

7. Weight on wheels bypass switch

   a. Location: nose wheel well, port side

   b. Description: two-position switch, weight on wheels and bypass armament; the switch is lever-locked at the weight on wheels position and spring-loaded to return to weight on wheels position when released from the bypass position. With aircraft weight on wheels and power connected to the aircraft, holding the weight on wheels bypass switch at bypass armament enables testing of armament/jettison power supplies or verification of weapon selection and arming capability

8. HUD and MFD's

   a. Location:

      (1) HUD, upper center MIP forward cockpit

      (2) MFD, MIP both cockpits

   b. Description: displays symbologes of selected master modes and selected weapons/mode

9. Data entry panel (DEP)

   a. Location:

      (1) Directly below HUD forward cockpit MIP

      (2) Directly below gunsight aft cockpit MIP

   b. Description: consists of push-buttons and switches for selecting modes and setting MIL setting for manual delivery

Sg 4, fr 5
Fig 6: *Gunsight*

B. Gunsight

1. Location: top center instrument panel, aft cockpit only

2. Description: combining glass displayed reticle with conventional or manually depressible pipper

Sg 4, fr 6
Fig 7: *Wing Stations*

C. Wing stations

Sg 4, fr 7
Practice Bombs

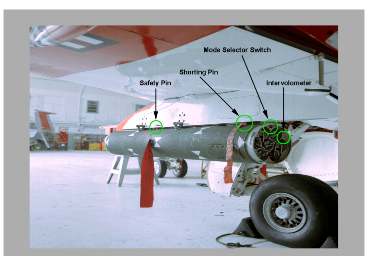
1. Pylons: left and right underwing pylons may be installed on the aircraft, providing carriage and release of armament stores

   NOTE: Both wing pylons incorporate an ejection release unit (ERU) for emergency jettison. The ERU shall always be considered armed.

2. Practice multiple bomb racks (PMBR)

   a. Attached to each pylon station by ejector release unit that provides PMBR emergency jettison capability

Sg 4, fr 8
Rocket Launcher



   b. Capable of carrying six MK 76 (25 lb) practice bombs on each rack

3. LAU-68 rocket launcher

   a. Attached to each pylon station by ejector release unit that provides launcher emergency jettison capability

Sg 5, fr 2
Lesson Organization

OTHER T-45 SYSTEMS

* Airborne data recorder (ADR)
* ADR major components, operating characteristics, and interfaces
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* Armament control system (ACS) major component identification
* **ACS operational characteristics**
* HUD system
* ACS and HUD aircraft interfaces

   b. Capable of carrying seven 2.75-inch FFAR rockets on each station

V. ACS operational characteristics **1.4.17.2.1, 1.4.17.3**

Sg 5, fr 3
Fig 8: *Armament Controls/Indicators*

A. Master armament (MASTER) switch: two-position toggle switch controls power to all armament circuits

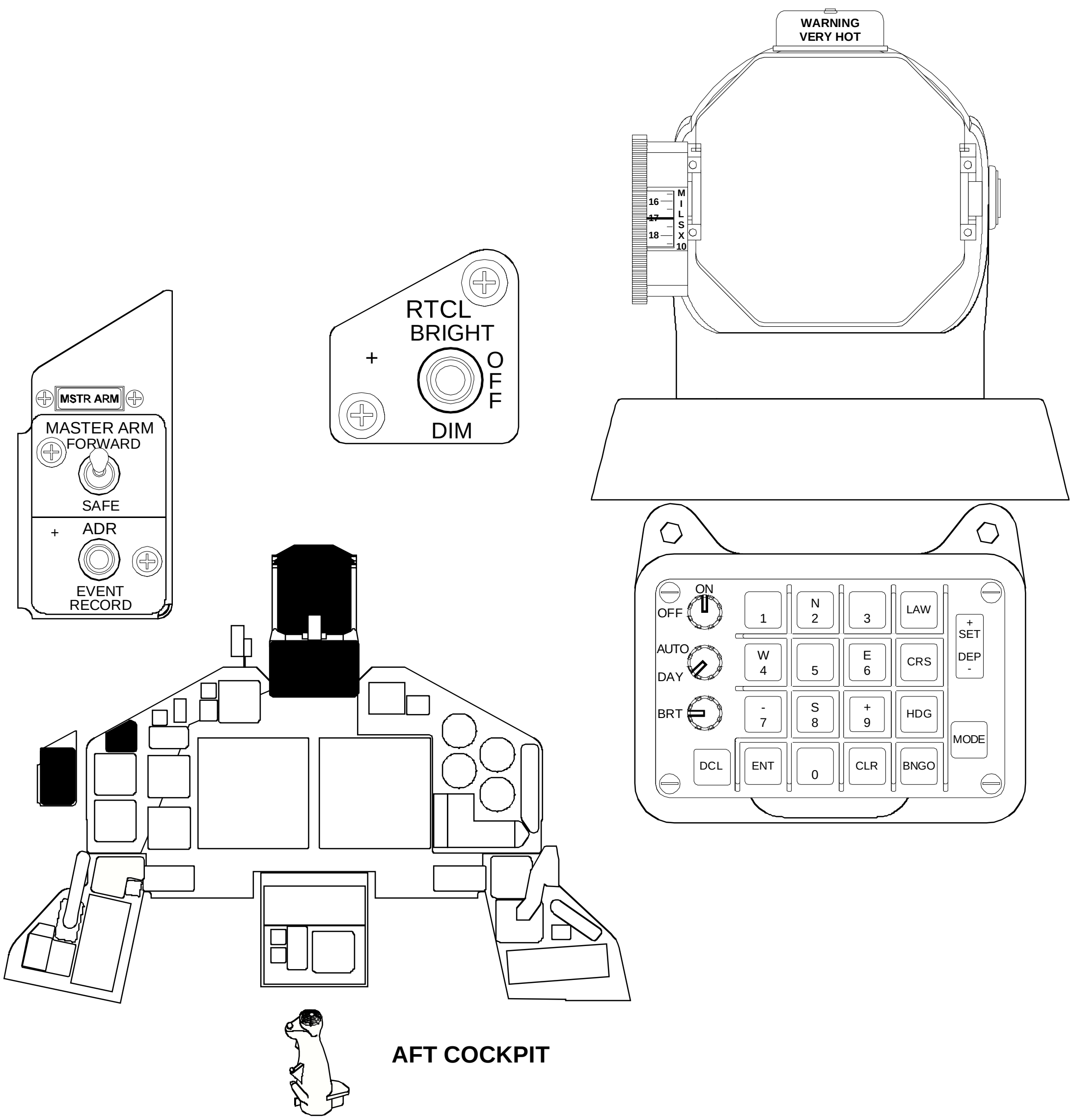


Figure 6: GUNSIGHT

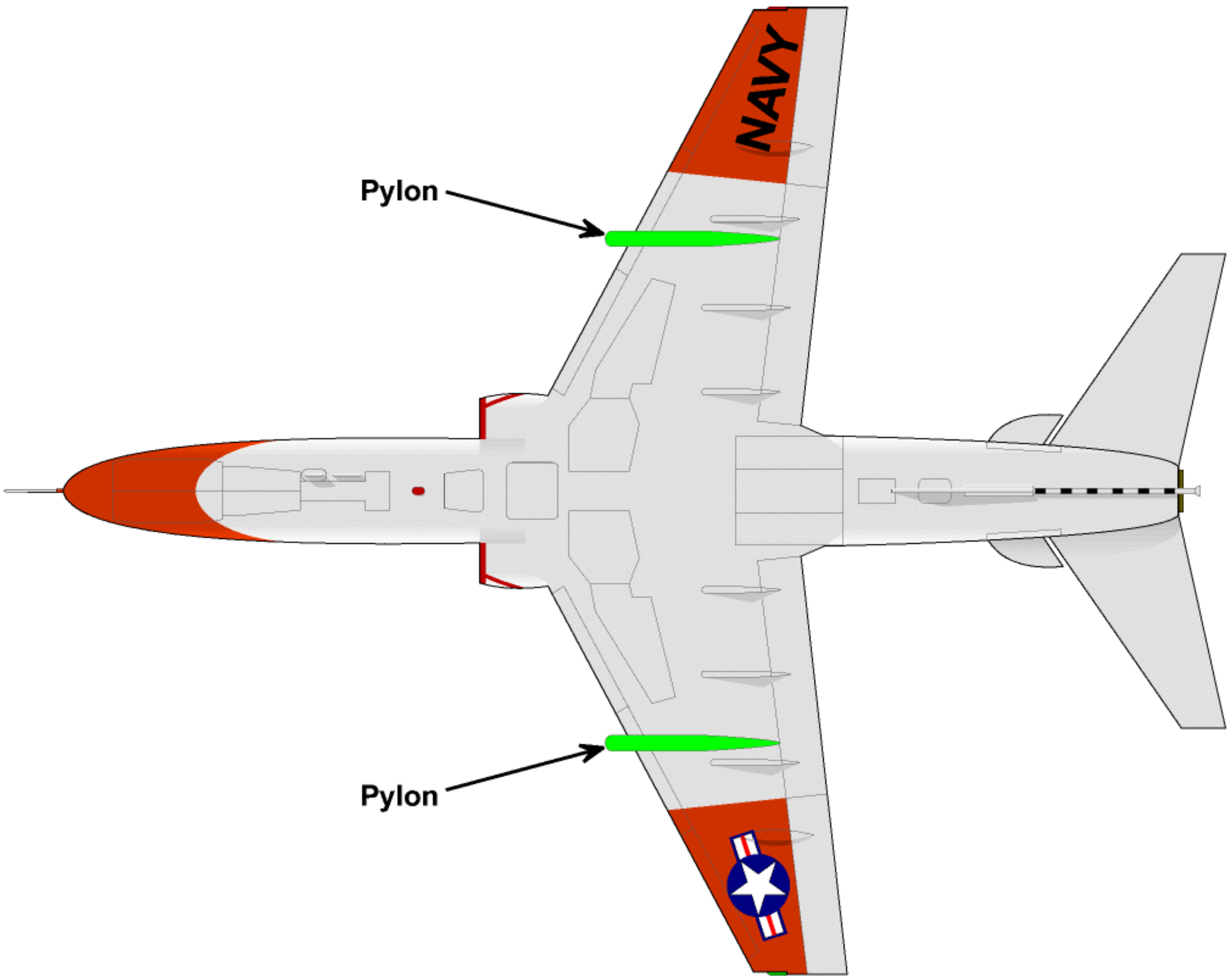


Figure 7: WING STATIONS

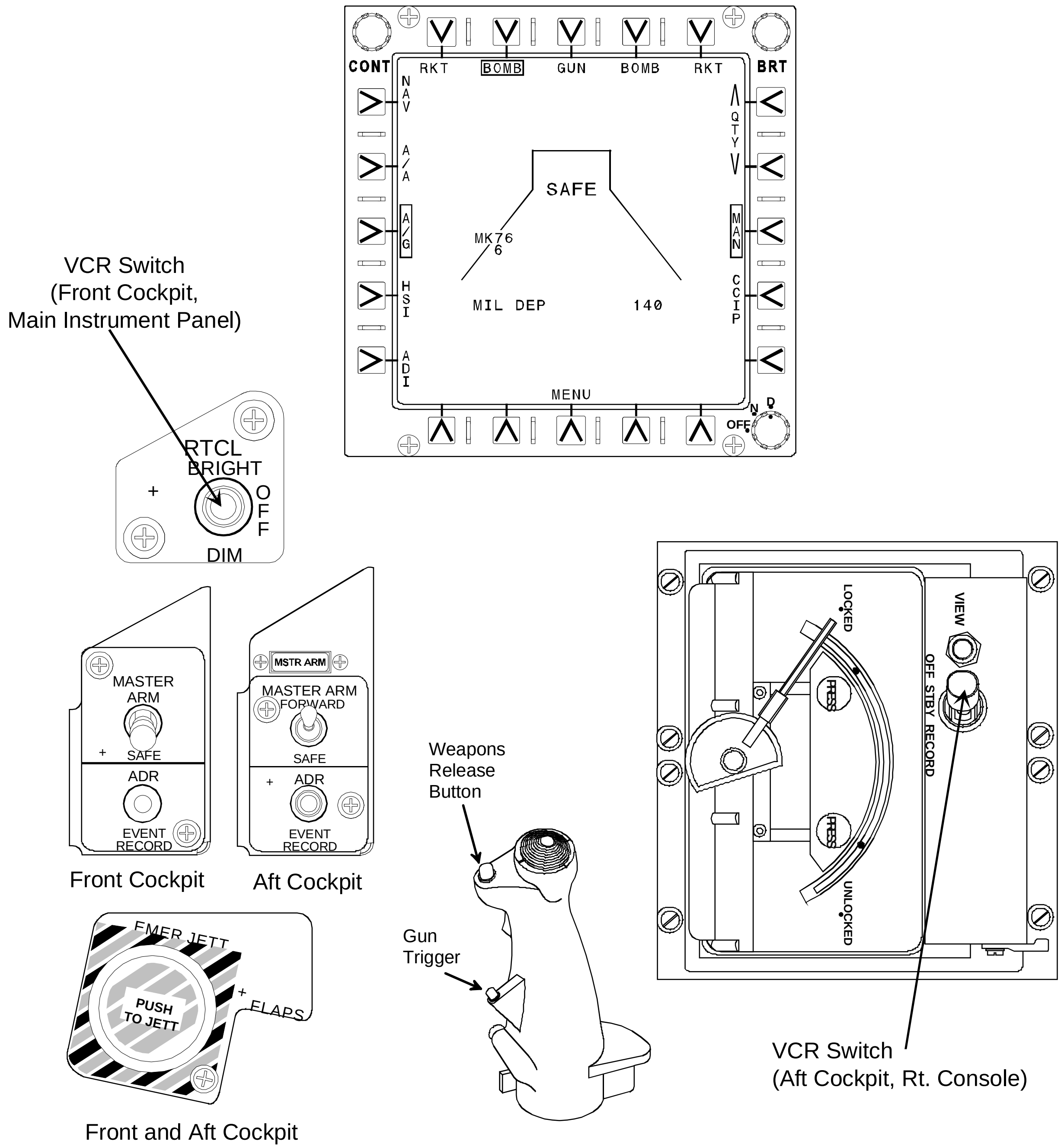


Figure 8: ARMAMENT CONTROLS/INDICATORS

NOTE: To prevent inadvertent release of weapons on the ground, 28 VDC to the master armament switch is removed by the nose and main landing gear WOW relays.

1. SAFE position removes all power from 28 VDC armament control bus

    a. Provides an X over weapons type on HUD

2. ARM position

    a. Applies power from 28 VDC generator bus to 28 VDC armament control bus

    b. Illuminates red MASTER ARM light in aft cockpit

    c. Activates VCR when VCR switch in the AUTO position

        NOTE: Assumes VCR switch in the aft cockpit is not set to off.

B. Multi-Function display (MFD): provides switch logic, control and stores inventory display of the weapon system

1. MFD - Stores display: provides symbology of stores type, station selection, stores quantity and master arm status

    a. Bombs, rockets or guns

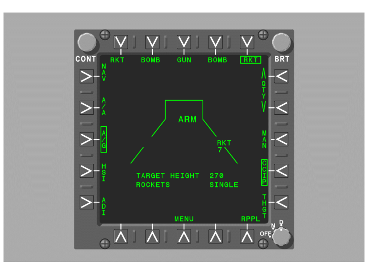
    b. Option selection is boxed

    c. Type and quantity displayed

    d. MASTER ARM and SAFE

2. MFD - option push-buttons; provides selection of station, stores type, and quantity of stores

Sg 5, fr 4
MFD With Stores Display



a. Weapon and station option selections: used in conjunction with station option selection and MASTER ARM switch to set release logic and arm appropriate weapon and station

b. Station weapon option selection;

(1) L STA RKT, L STA BOMB

(2) R STA RKT, R STA BOMB

(3) Simulated GUN (center but no station)

c. Bombs/Rocket quantity select option: used to adjust (increment/decrement) the number of bombs or rockets on the stores display

d. BOMBS, ROCKETS, GUNS A/A or GUNS A/G selection will provide appropriate HUD display of weapon selection and delivery mode

NOTE: There is no interface between the weapon station and the stores display making it important that the selected bomb/rocket quantity on the stores display match the actual bomb/rocket load on the aircraft.

C. Weapons release button

1. When pressed, routes 28 VDC from armament bus through relay logic set by weapons selector and station selector switches, releasing respective weapon

2. With BOMBS or ROCKETS selected, the CWS generates weapon release tone upon weapon release

D. Gun trigger: operates in conjunction with weapons selector and station select GUN mode; when pressed, sounds the simulated gun tone

E. Master armament override switch: safety measure, allows aft cockpit pilot armament override capability

1. FORWARD allows armament system to function normally

2. SAFE removes 28 VDC power from armament control bus, disabling any trigger or release signals

   a. When initiated, switch is solenoid-held in SAFE position, preventing further functioning of armament system

   b. Automatically resets to FORWARD when electrical power removed

   c. Can be manually reset to FORWARD or by setting master armament switch to MASTER ARM or with weight on wheels

F. Emergency jettison (PUSH TO JETT) button: guarded momentary push-button switch, used to jettison stores carried on pylons

NOTE: Pressing PUSH TO JETT jettisons the entire bomb rack or rocket pod, not individual bombs or rockets.

1. When PUSH TO JETT is pressed in either cockpit, 28 VDC from essential services bus electrically fires twin pyrotechnic cartridges in each pylon, ejecting the store carried on that station

2. When aircraft is on ground, nose and main gear WOW relays break the 28 VDC path, preventing inadvertent jettisoning of stores

   NOTE: The T-45C has provisions for carrying a baggage container on a center pylon which is not electrically connected; therefore, the baggage container cannot be jettisoned.

PROGRESS CHECK

Question 1 — 1.4.17.2.1, 1.4.17.3
What prevents inadvertent release of weapons on the ground?

ANSWER: The nose and main landing gear WOW relays remove 28 VDC from the master armament switch.

VI. HUD system: basic head-up display (HUD), similar to those used by fleet aircraft, provides sighting capability for air-to-air and air-to-ground and displays flight instrument navigation information **4.4.5.1.1**

Sg 6, fr 2
Lesson Organization

OTHER T-45 SYSTEMS
* Airborne data recorder (ADR)
* ADR major components, operating characteristics, and interfaces
* Armament control system (ACS) overview
* Armament control system (ACS) major component identification
* ACS operational characteristics
* **HUD system**
* ACS and HUD aircraft interfaces

WARNING: The HUD should not be used as a primary flight instrument.

A. Pilot display unit (PDU)

Sg 6, fr 3
Fig 9: *HUD Controls/Indicators*

1. Location: top center of instrument panel, fwd cockpit only

2. Description: displays flight information and weapon delivery symbology on transparent optical assembly

B. Data entry panel (DEP)

1. Location: lower part of and mounted on PDU

2. Description: consists of numeric keyboard, ON/OFF switch, and other controls used for mode selection, declutter of visual display, and HUD lighting

C. Display electronics unit (DEU)

1. Location: aft lower equipment bay

2. Description: processes aircraft flight information and weapons-selector logic and sends appropriate display signals to PDU

Figure 9: HUD CONTROLS/INDICATORS

PROGRESS CHECK

Question 2 —1.4.17.3.1
What information is displayed on the HUD PDU?

ANSWER: Flight information and weapons delivery data on transparent optical assembly

D. Video camera system (VCS)

1. Camera sensor head (CSH)

    a. Location: mounted on HUD, just above and forward of DEP

    b. Description: consists of periscope-mounted video sensor (lens assembly) providing visual images of view through HUD combining glass

2. Camera electronics unit (CEU)

    a. Location: forward electronics bay

    b. Description: receives video from CSH, processes video for recorder, and provides electronic control of camera system

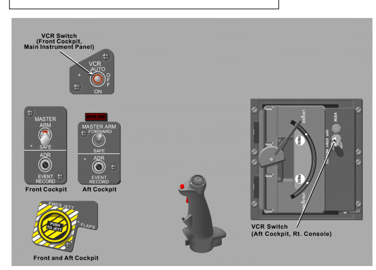
3. Videocassette recorder (VCR)

    a. Location: right console, aft cockpit

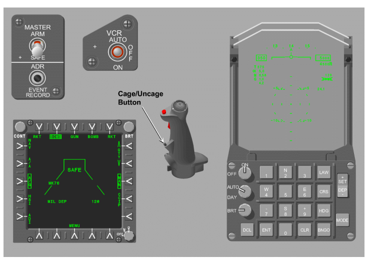
    b. Description: similar to home VCR recording system, provides visual record of flight information displayed on PDU and pilot's forward view for debriefing and analysis

    c. Radio transmissions and ICS conversations are recorded on the HUD video tape any time the VCR system is recording

Sg 6, fr 4
Video Camera System



Sg 6, fr 5
HUD Controls/ Indicators



4. VCR switch

   a. Location: upper left instrument panel, fwd cockpit only

   b. Description: operates VCR system either full time (ON) or when master armament switch is in ARM (AUTO)

E. HUD BIT

1. Momentarily press MODE push-button on DEP

   NOTE: The aircraft must be on the ground and the system must be in the navigation master mode for the BIT circuits to function properly.

2. All detectable failures will be logged in memory and displayed on far right side of PDU

3. System will return to navigation master mode when CLR push-button on DEP is pressed

Sg 7, fr 2
Lesson Organization

OTHER T-45 SYSTEMS
- * Airborne data recorder (ADR)
- * ADR major components, operating characteristics, and interfaces
- * Armament control system (ACS) overview
- * Armament control system (ACS) major component identification
- * ACS operational characteristics
- * HUD system
- * **ACS and HUD aircraft interfaces**

VII. ACS and HUD aircraft interfaces **1.4.17.2**

A. Electrical system

1. 28 VDC essential services bus supplies power for emergency jettison of pylon stores

2. 28 VDC generator bus: supplies power to 28 VDC armament control bus when

   a. Generator bus ARMAMENT circuit breaker: IN

   b. Nose and main landing gear WOW relays are energized (aircraft airborne)

   c. Master armament (MASTER) switch (fwd cockpit): ARM

   d. Master armament override switch (aft cockpit): NORMAL

B. Flight data inputs to HUD DEU

1. Radar altimeter and barometric altimeter

2. AOA system

3. Accelerometer

4. GINA (pitch, heading, and roll)

C. CWS

1. Inputs to HUD DEU

a. Master caution

b. Master warning

2. Output from ACS: weapons release (tone generation)

Fig 10: *HUD Integrated Avionics System*

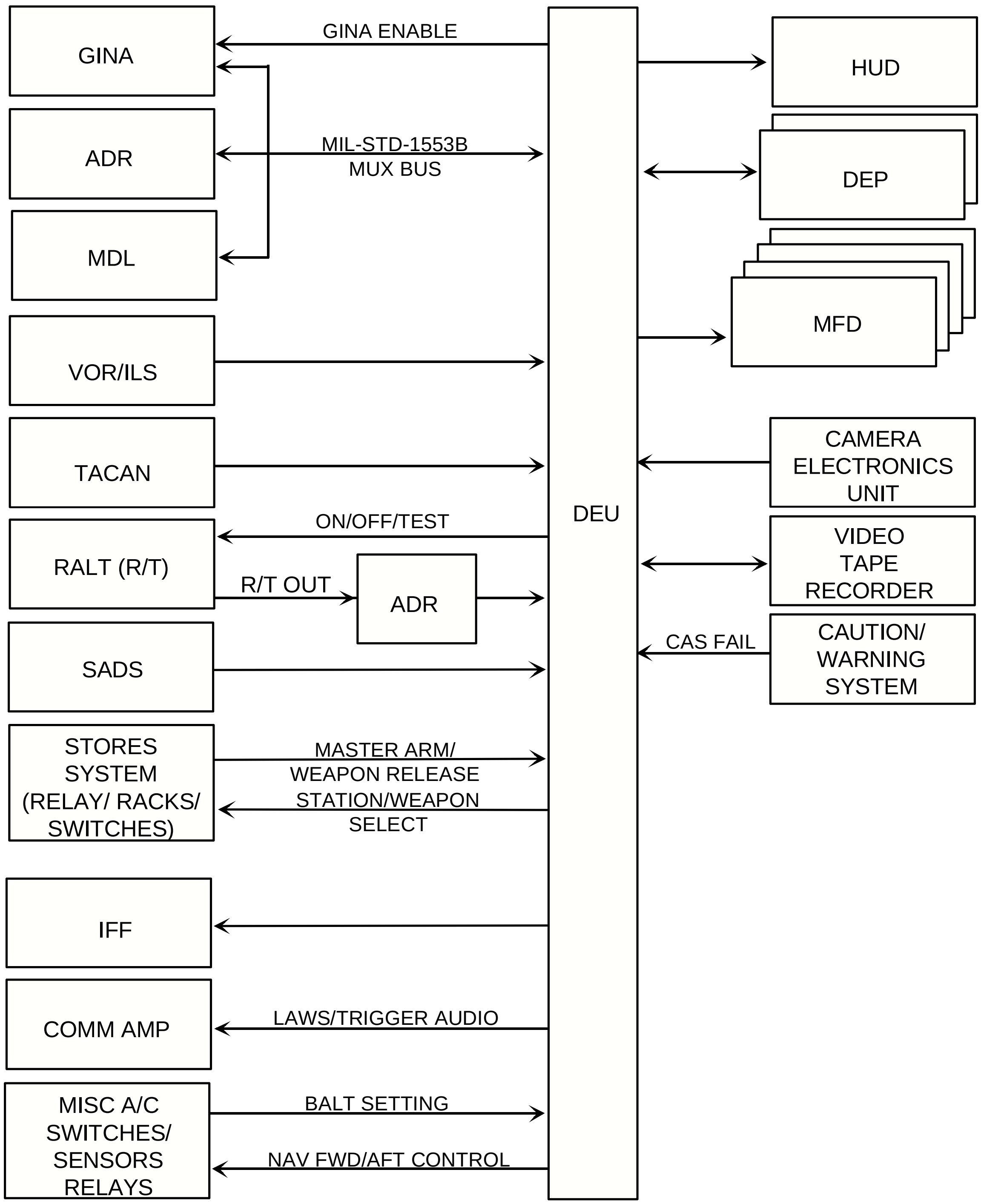


Figure 10: HUD INTEGRATED AVIONICS SYSTEM

SUMMARY

Sg 8, fr 2
Review Menu

This lesson focused on the following topics:

* Major components and operating characteristics and functions of the airborne data recorder (ADR) system
* Interface between ADR and other T-45C systems
* Armament control system (ACS) major components and operating characteristics
* Head-up display system (HUD) major components and operating characteristics
* Interfaces between ACS, HUD, and other T-45C systems

CONCLUSION

The ADR provides vital aircraft engine and structural information for analytical purposes. Knowing how the system operates and how to input data could have a profound effect on incident investigation. Possessing knowledge of the ACS will ensure that you select and fire the desired weapon and will help you analyze malfunctions should they occur.

LECTURE GUIDE

COURSE/STAGE: TS, ADV & IUT / Engineering

LESSON TITLE: GINA Operating Characteristics

LESSON IDENTIFIER: T-45C TS, ADV & IUT ENG-24

LEARNING ENVIRONMENT: Classroom

ALLOTTED LESSON TIME: 1.0 hr

TRAINING AIDS:

* Figure

Fig 1: Gyroscope
Fig 2: Earth-Rotation Apparent Precession (Aircraft Stationary)
Fig 3: Transport Apparent Precession
Fig 4: XYZ Axis Mechanical Gyroscope
Fig 5: LITTON Ring Laser Gyro Assembly
Fig 6: GPS Satellite Array
Fig 7: Optimum Satellite Array
Fig 8: GINA Installed-Location (Outside View)
Fig 9: GINA Installed-Location (Inside View)
Fig 10: GPS Antenna
Fig 11: GINA Components
Fig 12: SHIP Alignment
Fig 13: ACFT DATA Page
Fig 14: GPS DATA Page
Fig 15: BIT Display Page (Weight-on-Wheels)
Fig 16: BIT Display Page (Weight-off-Wheels)
Fig 17: GINA WRA
Fig 18: Got a Problem

STUDY RESOURCES:

* T-45C NATOPS Flight Manual, A1-T45AC-NFM-000
* Aeronautical Information Manual (AIM), Chapter 1 - Navigation Aids, Section 1 - Air Navigation Radios, 1-1-22-Global Postioning System

LESSON PREPARATION:

Read:

* Part VII, Chapter 21, “Communications - Navigation Equipment and Procedures,” 21.3 Navigaton in the T-45C NATOPS Flight Manual, A1-T45AC-NFM-000

REINFORCEMENT: N/A

EXAMINATION: N/A

LESSON OBJECTIVES

1.7.7.6.1
Recall design and operating characteristics of the T-45C GINA

1.7.7.6.3
Recall design and operating characteristics of an Inertial Navigation System

1.7.7.6.4
Recall design and operating characteristics of a Global Positioning System

MOTIVATION

The T-45C GINA, which includes INS and GPS components, is fundamental to aircraft primary navigation and flight performance indicating systems. Normally, the GINA requires no management or intervention by the pilot. System malfunctions are not common; however, should one occur, it is imperative that you fully comprehend its impact on your flight. To effectively manage non-standard situations, you must understand basic INS and GPS system design and operating characteristics. This course is aimed to aid your understanding of the information, functions, and options that the GINA provides the pilot.

OVERVIEW

In this lesson we will discuss:

* Gyroscope characteristics
* LITTON GINA INS design
* Global Positioning System characteristics
* LITTON GINA Global Positioning System design
* GINA components
* GINA functions

REFRESHER

Recall the design fundamentals of a gyroscopic attitude indicating system that you learned in T-34 Primary flight training.

PRESENTATION

I. Gyroscope characteristics **1.7.7.6.1 1.7.7.6.3**

Sg 1, fr 1
Lesson Organization

A. General properties

1. Definition of mechanical gyroscope from The American Heritage

Sg 1, fr 2
Fig 1: *Gyroscope*

"A device consisting of a spinning mass, typically a disk or wheel, spin axis of which turns between two low-friction supports and maintains its angular orientation with respect to inertial coordinates when not subject to external torques."

2. Rigidity in space

a. Each axis maintains its orientation barring outside force application

GYROSCOPE

- WHAT IS A GYROSCOPE?
- WHAT ARE ITS PROPERTIES?
- WHY USE ONE?
- WHAT KINDS ARE THERE?

Figure 1: GYROSCOPE

b. 3-axis (XYZ) gyro maintains a precise inertial coordinate orientation during all movement

INSTRUCTOR NOTES

"Inertial coordinate orientation" means that a gyroscope maintains an orientation towards a point in space rather than towards a point on earth. That stability attribute makes gyros suitable for use anywhere on earth; polar regions, as well as mid-lattitudes. Additionally, that attribute allows gyros to be used for navigation in space.

3. Provides a stable platform for an attitude reference system

4. Real precession

   a. Caused by friction

      (1) Due to extreme G-forces

      (2) Due to lack of effective lubricant

      (3) Due to wear

   b. Changes a stabilized gyro's inertial coordinate orientation

   c. Can be caused by intentional force applications

      (1) To compensate for apparent precession

      (2) To keep the gyro platform "level" with earth's surface

Sg 1, fr 3
Fig 2: *Earth-Rotation Apparent Precession (Aircraft Stationary)*

5. Apparent precession

   a. Two types

      (1) Earth-rotation (earth rate): transport of the gyro by the earth's rotation causes the spin axis to appear to shift

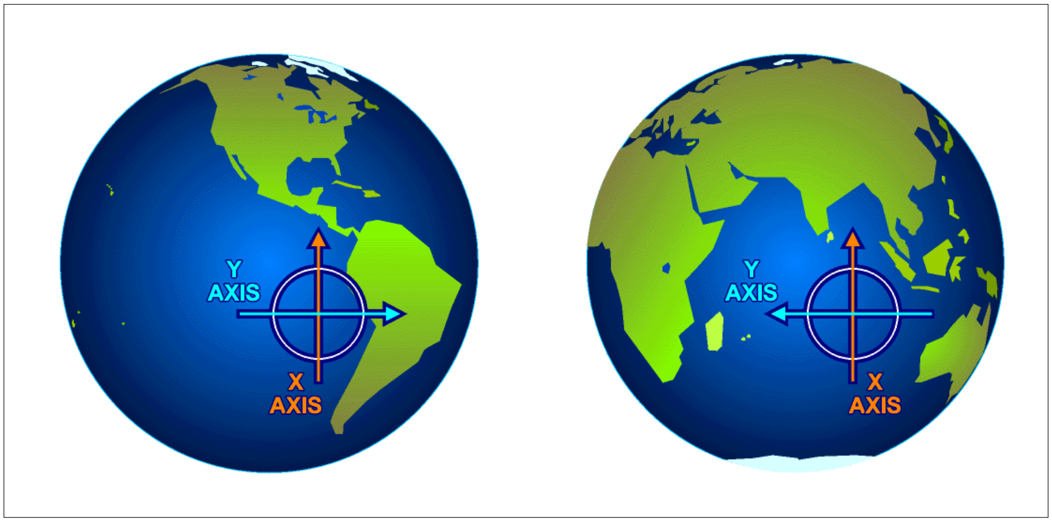


Figure 2: EARTH-ROTATION APPARENT PRECESSION (AIRCRAFT STATIONARY)

(2) Transport: actual movement of a gyro to a new earth location causes the spin axis to appear to shift

Sg 1, fr 4
Fig 3: *Transport Apparent Precession*

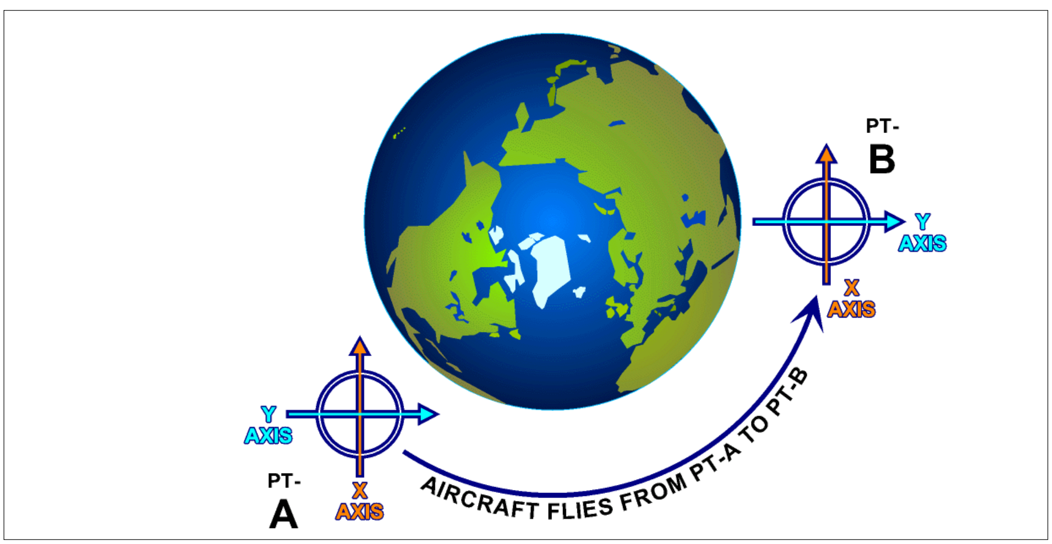


Figure 3: TRANSPORT APPARENT PRECESSION

(a) Apparent precession is not a physical movement of the gyro's inertial orientation, which remains fixed

(b) Apparent precession is a precession "perceived" in relationship to the earth and its coordinate system

(c) Apparent precession is a major factor that must be accounted for mechanically or mathematically when using a gyro as an attitude reference platform

INSTRUCTOR NOTES

Apparent Earth-Rotation precession can be exemplified by mentally visualizing yourself on the equator viewing a fully stabilized 3-axes gyroscope at 0600 hours in the morning. Its primary spin axis is pointing due east. Due to the earth's rotation, half way through the day at 1800 hours, the gyro's spin axis "appears" to have precessed through the vertical so as to, then, point due west. In another 12 hours, once again 0600 hours, the gyro will again appear to point due east. In fact through the entire 24 hours, the gyro has maintained its inertial orientation towards the same point in space, but due to the earth's rotation has "appeared" to precess; hence, the name Apparent precession.

Apparent Transport precession occurs, when a gyro is transported across the earth's surface, either physically or apparently due to earth rotation. By further example, a rapid movement (transport) of a gyro from Chicago to Paris will result in the same apparent precession as though the earth had rotated an equal number of degrees longitude.

B. Mechanical INS gyroscopes – generic

Sg 1, fr 5
Fig 4: *XYZ Axis Mechanical Gyroscope*

Figure 4: XYZ AXIS MECHANICAL GYROSCOPE

1. Gimbaled: XYZ axes

   a. Allow full 360 degrees freedom of motion

   b. Used in earlier aircraft inertial navigation systems (INS)

   c. Subject to friction/wear

2. Prone to drift

   a. Drift is an undesired shift of a spin axis from original inertial coordinate orientation

   b. Drift causes a more significant effect on heading and position than on attitude reference indicators

   c. Can be compensated for mechanically and/or mathematically

3. Stabilized platform

   a. Mechanical gyros are initially aligned in a caged mode

   b. An initial true vertical is sensed by accelerometers; then, the gyro is torque-precessed to the true vertical

   c. Earth-rotation (earth-rate) and transport apparent precession are compensated for using call-up tables

   d. Gyro is torque-precessed to compensate for apparent precession

C. Ring laser INS gyroscopes – generic

1. Not <u>really</u> gyroscopes, as per the dictionary definition

   a. No spinning masses

b. No physical “rigidity” in space

INSTRUCTOR NOTES

Ring laser “gyroscopes” are so-termed, because they provide the same type information as mechanical gyros, with respect to a stable attitude reference platform. The physics involved is totally different, but practical results are the same.

2. XYZ axes within laser assemblies are firmly mounted to their container

   a. No gimbal mountings for six-degrees freedom of movement

   b. Some ring laser assembly manufacturers incorporate moving mirrors to perform laser beam “dithering”

   c. Other manufacturers eliminate all moving parts in the laser assembly, accomplishing dithering by other means

      NOTE: There are no moving parts in the LITTON ring laser used in the T-45C GINA.

3. Measures angular motions

4. Stabilized platform

   a. The true vertical is sensed by accelerometers during alignment, and the platform is mathematically leveled

   b. Earth-rate precession is compensated for using call-up tables and mathematical corrections, rather than mechanical corrections

   c. Transport precession is compensated for mathematically

PROGRESS CHECK

Question 1 -- 1.7.7.6.1, 1.7.7.6.3
As relating to an INS, what is the primary usage of a ring laser gyro assembly, versus, the accelerometer assembly?

ANSWER: The laser assembly is used primarily to detect angular motions: pitch, roll, and heading changes. The accelerometers are used to detect linear motions: velocities derived from accelerations.

Question 2 -- 1.7.7.6.4
What type(s) of precession affect ring laser gyros?

ANSWER: Only apparent precession: earth-rate and transport. Real precession is not a factor relevant to ring laser gyros.

Sg 2, fr 1
Lesson Organization

II. LITTON GINA INS design **1.7.7.6.3**

INSTRUCTOR NOTES

A LITTON inertial navigation system is an integral part of the GINA. It is a second generation LITTON ring laser gyro, which that company terms the Zero-Lock™ Laser Gyro (ZLG™). Its design is unique, because unlike competitor designs, it contains no moving parts. LITTON accomplished that by using optical laser beam biasing, thus, eliminating the need for mechanical dithering of the beams. This ring laser gyro system is from the LITTON LN-100 product family. Other military applications include the Apache Longbow and Comanche helicopters, F-18E/F, and the F-22 fighter.

A. Three triangular laser assemblies – X, Y, Z axes

1. Each sealed gyro assembly contains its own laser generator

2. The laser beam generated in each assembly is split into four beams; two firing in each directon

Sg 2, fr 2
Fig 5: *LITTON Ring Laser Gyro Assembly*

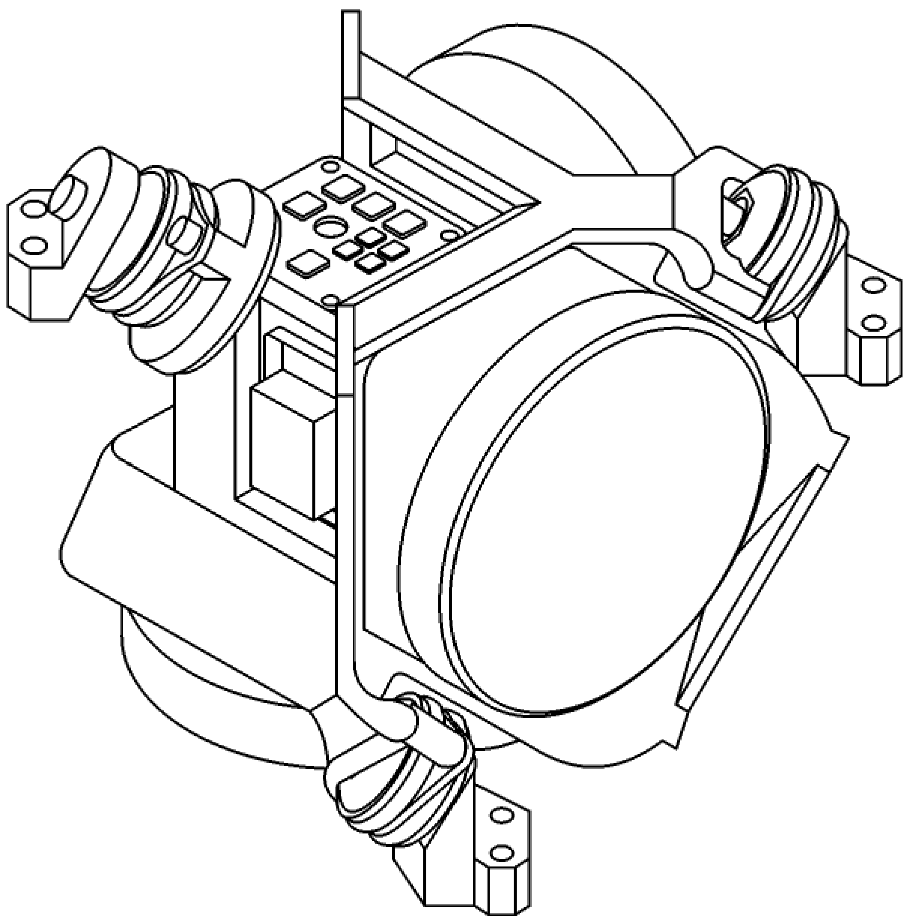


Figure 5: LITTON RING LASER GYRO ASSEMBLY

3. Laser beam cavities are orthogonally [at right angles] aligned to X, Y, and Z axes

4. Laser beam optical cavities are drilled into special glass

    a. Low-expansion ceramic glass: Zerodur

    b. Bore holes are gas filled (helium and neon mixture)

    c. Bore holes contain the helium-neon plasma discharge

    d. Plasma is a gas: electrically neutral, composed of ions, electrons, and neutral particles

5. Optical cavity mirrors – four (4)

    a. Two (2) flat mirrors; one for each 120 degree turn

    b. Two (2) curved mirrors that are automatically adjusted using piezoelectric transducers to keep the laser beam lengths constant

       NOTE: Laser cavity length varies mostly due to temperature changes.

6. Photo diode frequency discriminators

    a. Two in each optical cavity

    b. Measure laser beam Doppler shift patterns resulting from apparent earth-rotation precession and transport precession over earth's surface

       NOTE: Apparent precession is mathematically cancelled out.

INSTRUCTOR NOTES

Light Amplification by Stimulated Emission of Radiation (LASER) beam generation is used for many applications. Some products are very high-energy beams employed in manufacturing to cut metals. Others, like those in ring laser gyros, are used for applications that require less power.

The process of creating a gas laser beam, such as is used in a ring laser gyro, is begun by the application of electrical power to a gas that forms a plasma. The process entails ionization of a contained gas. That is accomplished by energizing an electrical current between an anode (+) and cathode (-) that are immersed in the contained gas. Ionization is the effect of creating a charge on the gas's molecules by causing some electrons to occupy a higher energy state [different orbits]. Large numbers of electrons are moved to higher, but unstable, energy states in a plasma.

The actual laser beam forms, when free electrons in a plasma return to a stable position/condition in molecular orbit. At that moment, energy is released in the form of light; photons are generated. The photon emission rate is linked to the degree of power applied to the laser tube and contained gas; more power/more laser light from more photons.

The emitted laser light is all in the same frequency, which is related to the type molecules/atoms being lased. Hence, it is termed a "coherent light." Next, that coherent light is polarized and redirected with mirrors.

In high-energy lasers, a great deal more power is applied to the laser and the light beam is amplified by repeated reverse reflections. Actual designs of lasers vary, considerably. Some use gas, others like ruby lasers, use crystals.

B. Accelerometers

1. GINA contains the LITTON A-4 inertial grade model

2. Triad design: XYZ axes orthogonally mounted on the laser assembly

3. Measure linear accelerations

4. Acceleration data used to calculate aircraft speeds

5. Nuclear hardened

INSTRUCTOR NOTES

Accelerometers are fundamental INS devices that very accurately detect when the aircraft is moving, how fast, and in what axis/axes (direction). That acceleration data, combined with time to determine speeds and distances, is used to build a continuously calculated present position plotted from the original position of the aircraft in the chocks, when the system was first aligned. A pure INS present position is the result of those sensed accelerations and the resulting computations. Keep in mind that when the GINA is operating in HYBD mode, present position is not a pure INS solution. It is derived from a blending of INS data with GPS position information, appropriately weighted by the Kalman filter.

PROGRESS CHECK

Question 3 -- 1.7.7.6.3
How is aircraft movement detected by the laser assembly?

ANSWER: Laser beam Dopple frequency shift patterns, developed due to motion, are measured on the photo diodes. That data is then manipulated mathematically to derive movement values.

III. Global Positioning System (GPS) characteristics **1.7.7.6.1 1.7.7.6.4**

Sg 3, fr 1
Lesson Organization

A. 24 earth orbit geo-synchronous satellites are available

NOTE: More GPS satellites are being added by the U.S. Government and upgrades are being incorporated.

1. Minimum of five (5) GPS satellites are always observable; frequently, more

2. Four (4) GPS satellites are required for optimal GPS operation

Sg 3, fr 2
Fig 6: *GPS Satellite Array*

Figure 6: GPS SATELLITE ARRAY

Sg 3, fr 3
Fig 7: *Optimum Satellite Array*

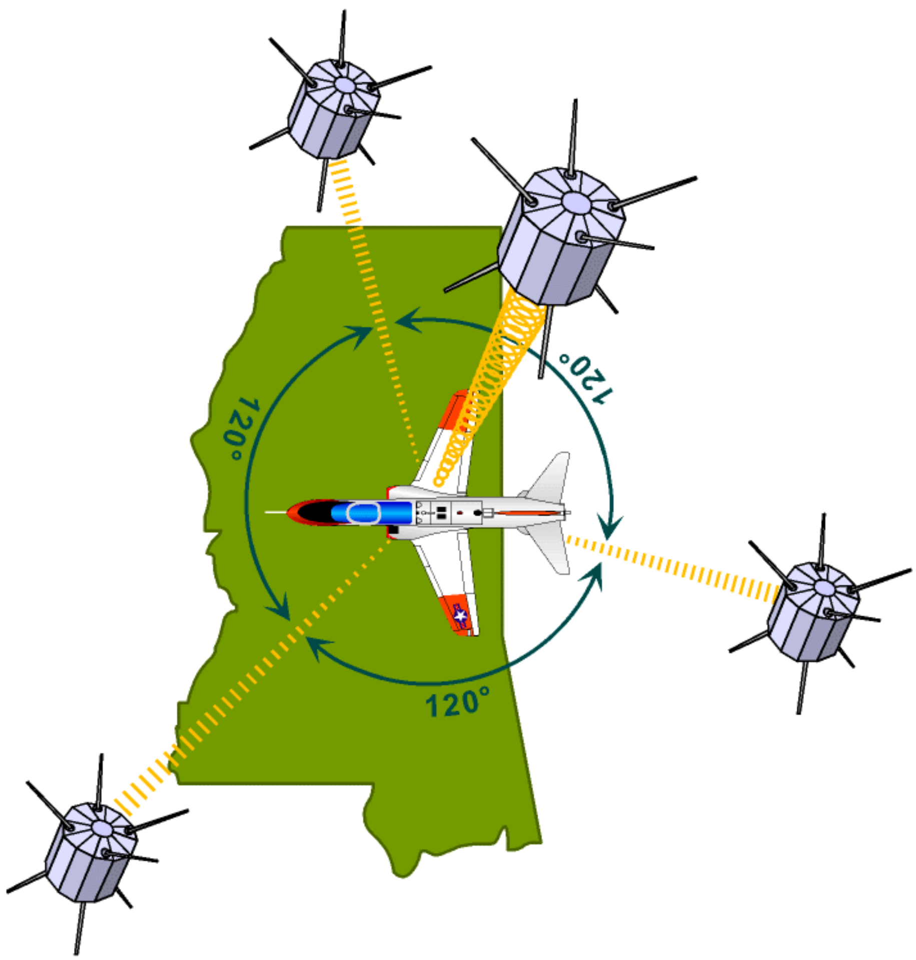


Figure 7: OPTIMUM SATELLITE ARRAY

B. Ranging and triangulation

1. Distance from satellites is determined using pseudo-ranging

   NOTE: Pseudo-ranging is a measurement of the time a satellite signal takes to arrive at a receiver

2. An optimum satellite array (technically termed a constellation) for triangulation is one (1) satellite directly above receiver; three (3) to the sides, each separated by 120 degrees spacing

C. Standard Positioning Service (SPS)

1. Provided to all users

2. Horizontal positioning accuracy of 100 meters with 95% probability; to 300 meters with a 99.99% probability

3. Signal is unencrypted

4. Modulated error signal is purposely induced

INSTRUCTOR NOTES

At the time of this writing, it was recently announced that the U.S. government will be taking steps over the next 8-10 years to up-grade the accuracy of GPS signals provided to civilian users. Additionally, new satellites will be launched that contain more available frequencies and other improvements for both military and civilian use. The modulated error signal will be removed. Government intent is to equate the increased SPS accuracy with what is now available to the U.S. military and other approved users.

D. Precise Positioning Service (PPS)

1. Currently, only provided to government authorized users

2. Horizontal positioning accuracy to 16 meters; it may be even more accurate

3. Applicable signals are encrypted; receiver must have a government supplied crypto-key for decoding

E. Timing pulse

1. Both satellites and receivers contain highly accurate clocks

2. Using the known speed of radio transmission signals, adjusted for atmospheric effects, distance from each satellite is mathematically derived

F. Satellite position and other information

1. Satellites transmit ephemeris data (satellite's exact position in space)

2. Satellites transmit GPS system time

3. Satellites transmit their known clock error

4. Satellites transmit known health and accuracy of their data

5. Satellites transmit ionosphereic data

G. GPS can operate in stand-alone capacity

1. GPS present position displayed on ACFT DATA page

2. GPS normally operates in conjunction with INS: HYBD mode

NOTE: Even in DGRO mode, INS and GPS operate together.

INSTRUCTOR NOTES

If the INS is inoperative, the only navigational GPS data displayed will be GPS coordinates on the ACFT DATA page. Depending upon exact nature of the INS failure, that data may/may not be accessible.

H. Receiver Autonomous Integrity Monitoring (RAIM) GPS feature

1. Not available in the current version T-45C GPS system configuration, but may be included in future system upgrades

2. RAIM's purpose is to determine if a satellite is providing corrupt information; intentionally or otherwise

3. RAIM requires 5 satellites in view (or 4 and baro-aiding)

4. To discriminate and remove a "corrupt" satellite from solution process, RAIM requires 6 satellites in view (or 5 and baro-aiding)

I. Differential-GPS for aviation

1. A type GPS system that produces extremely precise GPS data to support exact navigation for precision instrument approaches (PAR)

2. Differential-GPS is still being developed by competing manufacturers; FAA has not, yet, approved/certified any design (as of this writing)

3. FAA envisions differential-GPS becoming the primary precision approach navigation aid, replacing ILS (Instrument Landing System) and MLS (Microwave Landing System)

4. Each regional differential-GPS site will include a ground transmitter that transmits a "differential" signal to differential-GPS equipped aircraft

5. Differential-GPS signals are used by receiving aircraft to "correct" standard GPS satellite signals to the required degree of precision

INSTRUCTOR NOTES

A differential-GPS type of process is used by surveyors and others, who require extremely accurate data. That process employs a locally known benchmark coordinate to correlate and correct the received GPS signals. Some systems accomplish the correlation in "the field," whereas others correlate the data later in an office (post-processing). The in-the-field type GPS signal correlation is similar to aviation GPS systems being developed for use by aircraft. However, regional differential-GPS transmission sites will be necessary, because the error factor will vary geographically. For instance, a differential correction signal valid for St. Louis will not be valid in Memphis. Design-wise, most aviation systems being tested at this time employ a GPS correction signal that is transmitted to receiving aircraft, which then applies that "correction" to the GPS data being received from satellites.

PROGRESS CHECK

Question 4 -- 1.7.7.6.4
What is the certified accuracy of the T-45C GPS system?

ANSWER: Since the T-45C is not a "keyed" GPS system, it is certified to 100 meters. A new government policy affecting the allowed accuracy of SPS (Standard Positioning Service) GPS systems will likely enable the T-45C GPS to become much more accurate, even without crypto-keying. And, a form of differential-GPS will probably be approved by the FAA in the near future. Then, GPS precision approaches will be possible for properly equipped aircraft.

IV. LITTON GINA Global Positioning System (GPS) design **1.7.7.6.4**

Sg 4, fr 1
Lesson Organization

Sg 4, fr 3
Fig 8: *GINA Installed-Location (Outside View)*

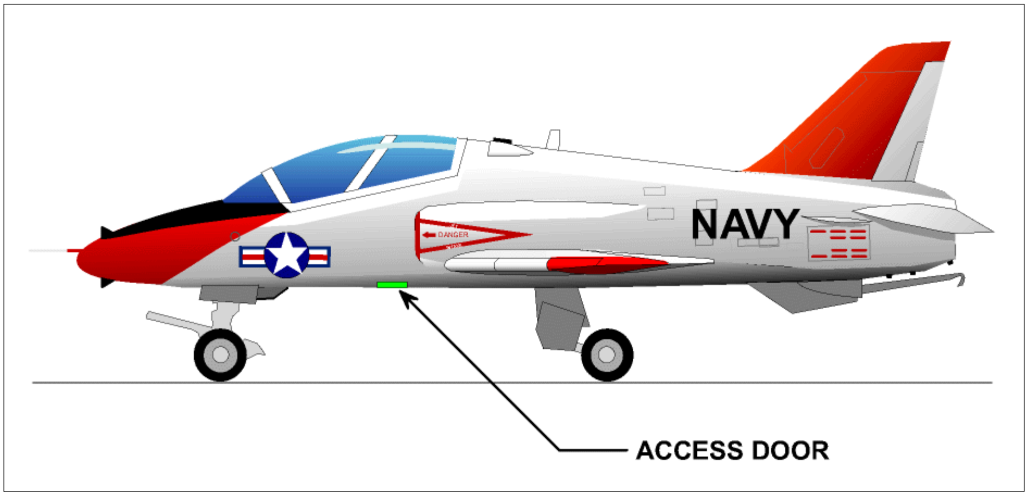


Figure 8: GINA INSTALLED-LOCATION (OUTSIDE VIEW)

Sg 4, fr 3
Fig 9: *GINA Installed-Location (Inside View)*

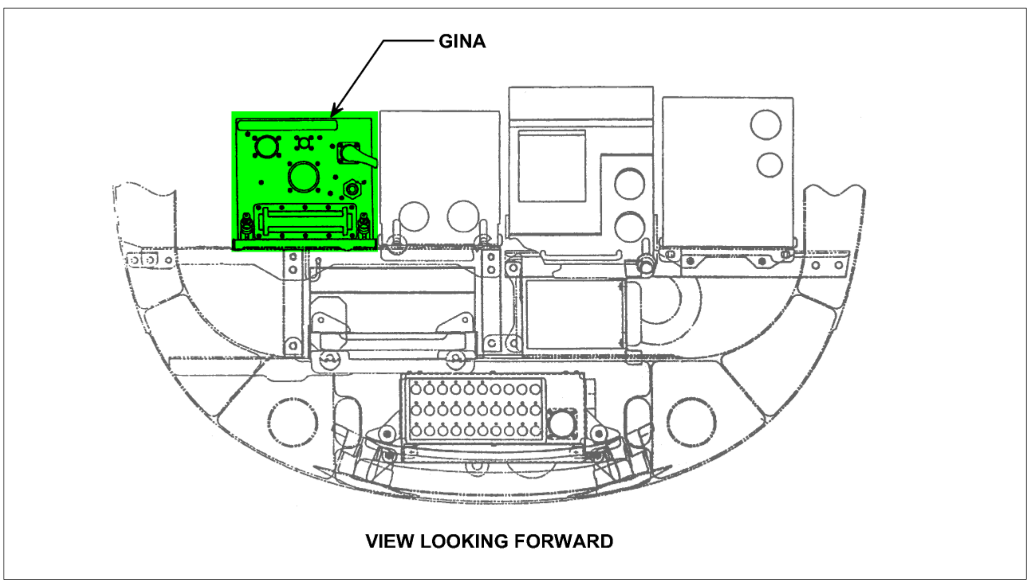


Figure 9: GINA INSTALLED-LOCATION (INSIDE VIEW)

A. GPS component card is designed and built by ROCKWELL-COLLINS (division of ROCKWELL not owned by BOEING)

B. Single electronic slot card

1. ROCKWELL-COLLINS model: GPS Embedded Module-3 (GEM-3)

INSTRUCTOR NOTES

At time of this writing three (3) companies are in competition to produce the next generation embedded GPS system for Government Furnished Equipment (GFE), already designated GEM-4. The winning product will likely contain 8-12 satellite channels and RAIM capability. It is expected that additional GPS satellites will be launched to capitalize on enhanced GEM-4 capabilities.

2. Dimensions: 5.88 x 5.85 x 0.57 inches

3. Weight: 1.5 pounds (approximate)

C. Five (5) satellite communication channel capability

1. Four (4) channels used to receive data from four (4) GPS navigation satellites

2. Fifth GPS channel used to repeatedly interrogate all satellites in view so GPS processor can chose the best four (4) GPS satellites to use for the navigation solution

D. Satellites used for navigation

1. Requires lock-on to four (4) satellites for optimum operation

2. System will continue to function with less than a four (4) satellite lock-on (can decrease to just one [1] satellite lock-on), but only after a full GINA alignment has been completed

   NOTE: GPS (only) accuracy degrades as satellites are lost.

3. ACFT display page continually indicates the number of GPS satellites locked-on by the aircraft

4. When less than four (4) satellites are locked-on, the INS automatically updates GPS data; no time limit

INSTRUCTOR NOTES

The GPS may lose contact with one or more navigation satellites for a variety of reasons. That is most likely to occur when the aircraft is banked, inverted, or another aircraft blocks the signal, and when a new satellite array is being selected. During those moments, the INS feeds velocity data to the GPS, so that the GPS can continue to accurately calculate present position. If satellite contact is completely lost for more than 65 seconds, the GINA will automatically switch to INS mode. When that occurs, the HYBD and GPS legends on the ADI display, may or may not disappear: If GPS data passes an internal accuracy criteria check, those legends will remain; if GPS data fails that accuracy test, those legends will be removed.

E. GPS antenna

Sg 4, fr 4
Fig 10: *GPS Antenna*

1. Located atop aircraft behind canopy

2. Installed on door 312CT

3. Fixed radiation pattern, omni-directional

4. Receives GPS satellite signals 360 degrees above 10 degree elevation from mount perspective

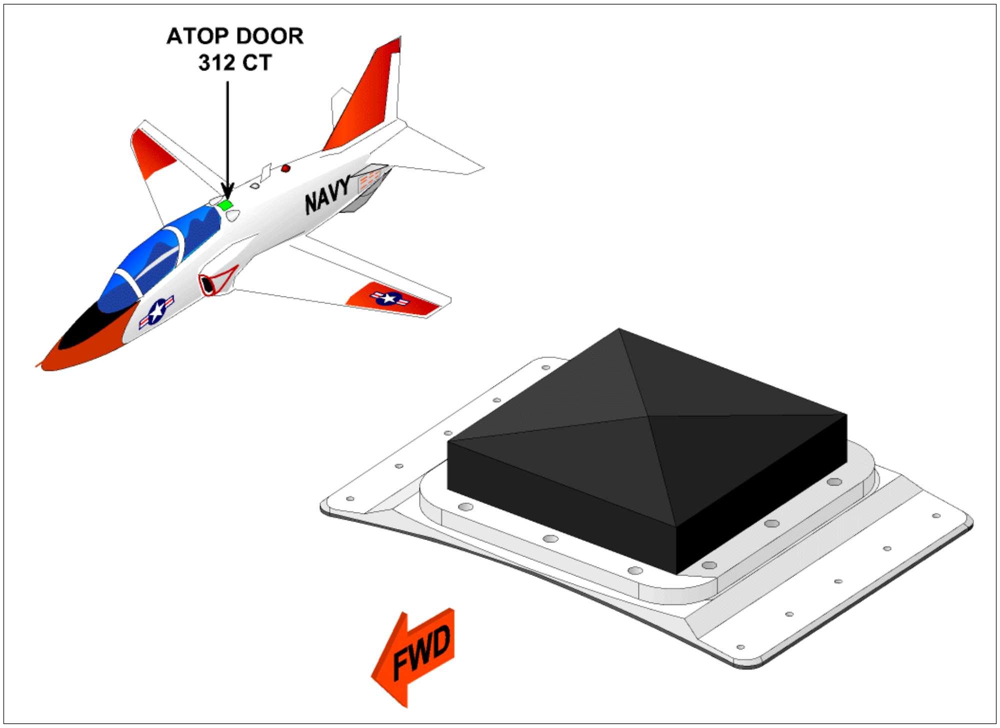


Figure 10: GPS ANTENNA

F. T-45C system crypto-capable status

1. PPS capable (not currently used)

2. NSA crypto-certified

3. Requires a KYK-13 crypto interface device for code setting

G. Computes GPS data

1. Aircraft position

a. Calculated using GPS satellite pseudo-range

b. Receives GPS satellite delta (change) pseudo-range values

c. Computes aircraft geographic coordinate position using pseudo-range from satellites

2. Aircraft altitude

a. GPS computed altitude is input to Kalman filter

b. GPS altitude is <u>not</u>, otherwise, used by GINA

INSTRUCTOR NOTES

Cockpit altitude read-outs are exclusively Air Data Computer (ADR) computational products. GINA altitude is internally processed, but not used for display purposes.

PROGRESS CHECK

Question 5 -- 1.7.7.6.4
How does GPS system determine aircraft position from GPS satellite signals?

ANSWER: Pseudo-ranges from the satellites are calculated by measuring the time it takes the various GPS signals to travel from GPS satellites to the aircraft. Then, since the GPS satellite positions are known values, a relatively simple trigonometric solution determines aircraft coordinate position (3-dimensional).

V. GINA Components **1.7.7.6.1**

Sg 5, fr 1
Lesson Organization

Sg 5, fr 2
Fig 11: *GINA Components*

A. LITTON nomenclature: LN-100G

B. GINA is Government Furnished Equipment (GFE)

C. Contains three (3) Litton ZLG™ sealed laser gyro units combined with three (3) accelerometers (LITTON A-4 assembly) to form the INS sensor assembly

D. Contains one (1) ROCKWELL-COLLINS GPS receiver card

E. BACKGROUND:

1. T-45C GINA development began in 1990; derived from the LITTON LN-100 product family and

ROCKWELL-COLLINS GPS receiver

2. ZLG™ gyro is a second generation ring laser design

3. GINA is first US military INS production unit to combine embedded GPS with INS

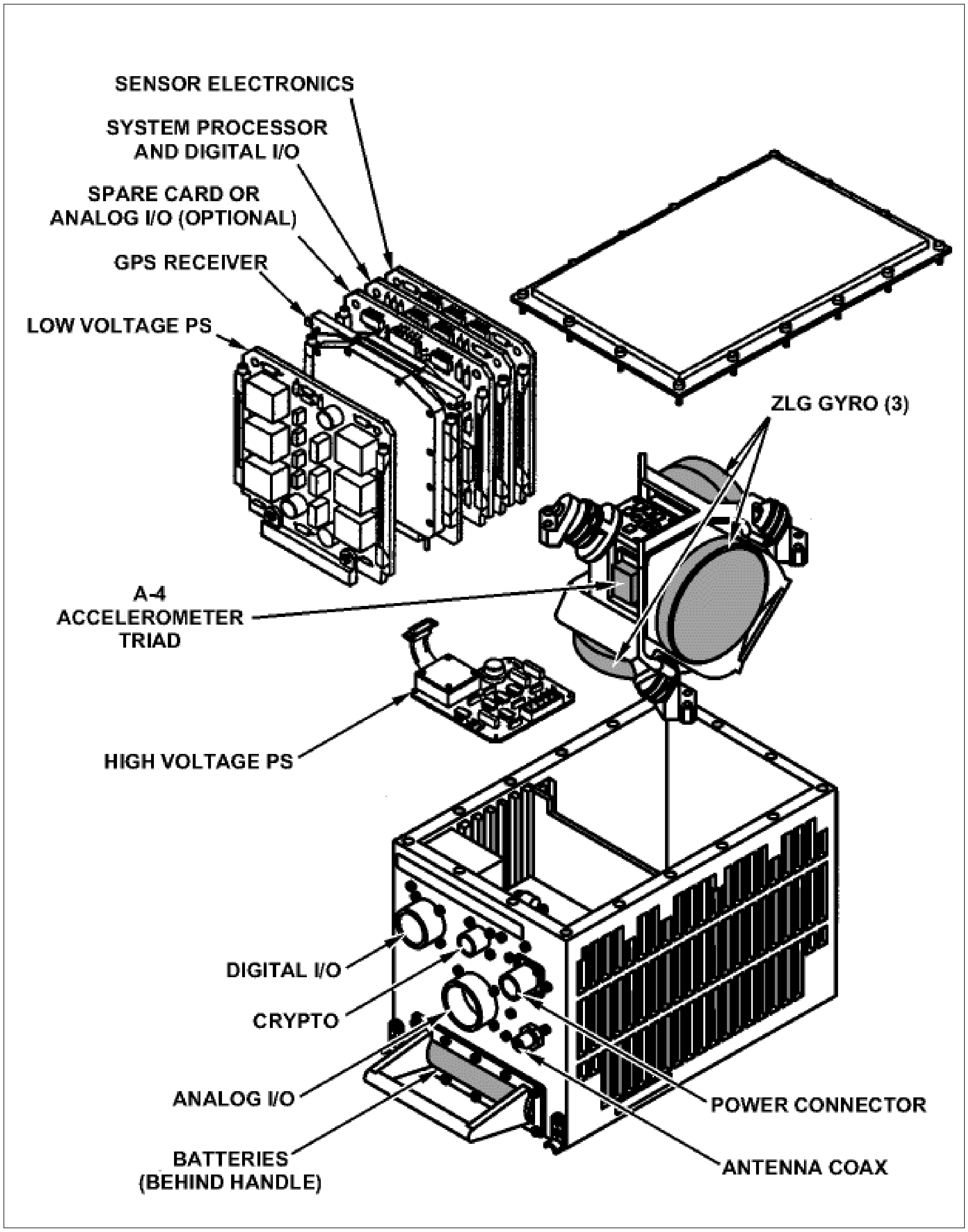


Figure 11: GINA COMPONENTS

F. Power supplies

1. Low voltage power: +28 Vdc

2. High voltage power

   a. +3500 Vdc ZLG™ start voltage

   b. +697 Vdc ZLG™ run voltage

   c. +120 Vdc CLC (laser Cavity Length Control)

3. Lithium battery back-up

   a. Two (2) C-size cells

   b. +3.6 Vdc

   c. For GPS receiver cold-load requirement

   d. Used for non-volatile data storage retention

   e. Each battery can be removed separately; thus, maintaining voltage for non-volatile memory retention

4. GINA consumes approximately 60 watts power

G. 1553B data bus (two-way)

1. Links GINA to Display Electronic Unit (DEU)

2. Links GINA to Airborne Data Recorder (ADR)

H. GINA system processor

1. High-speed INTEL 8096XA microprocessor

2. 256 word x 32 bit

   a. Static RAM memory

   b. I/O control

c. For communication with other circuitry

d. Performs BIT processing

e. Programmed in ADA software language

3. Kalman filter

a. 32 state (path) computation logic filter

b. Contains sophisticated algorithms that determine exact weight to apply to various like-type inputs in order to arrive at most accurate and consistent GINA "solutions"

INSTRUCTOR NOTES

Kalman filtering techniques are employed to most accurately integrate GPS up-dates of INS accelerometer measurements. This type of "filtering" employs a sophisticated set of mathematical weights assigned to numerous data processed within the GINA. Particular forms of data are assigned more/ less weight at different times as conditions vary. By example, GPS position is generally weighted very heavily because it is usually highly accurate; however, as GPS satellite lock-on decreases to less than four (4) satellites, the Kalman weighting of GPS position, likewise, decreases. Over many years, LITTON has continually refined their Kalman formulas. The company has in the past (and continues today) to accrue a great deal of empirical data and uses it to improve the GINA Kalman algorithms.

PROGRESS CHECK

Question 6 -- 1.7.7.6.1
To what other aircraft systems does the GINA Link using the 1553 data bus?

ANSWER: The DEU and ADR

PROGRESS CHECK

Question 7 -- 1.7.7.6.1
Does BOEING supply the GINA for the T-45C?

ANSWER: Yes, to extent that it builds the aircraft; however, the GINA is built by LITTON for the government, and the government supplies GINA to BOEING for inclusion in the T-45C, as well as in other aircraft.

VI. GINA functions **1.7.7.6.1**

Sg 6, fr 1
Lesson Organization

INSTRUCTOR NOTES

It should be noted that the GINA is an extremely reliable piece of equipment, as are each of its internal components. Furthermore, the GINA is designed to function in a very automated, hands-off manner. Normally, a T-45C pilot need only be concerned about routine operational choices. However, if a GINA problem is suspected – or does in fact develop – the pilot should crosscheck and continue to monitor standby instruments. In any way reasonably possible, he should confirm that only reliable data is being used for navigation and aircraft control. Depending upon the nature and degree of the problem, the pilot should remain (or attain) VMC flight conditions, land a soon as practical (as soon as possible in critical circumstances), and declare an in-flight emergency.

A. Calculate aircraft attitude using the ring laser/ accelerometer assembly

B. Process GPS data

C. Kalman filtering is used to compute outputs of highest accuracy

D. Calculate an integrated GPS/INS position data for HYBD mode

E. Calculate GPS/INS velocities and derive position coordinates

F. Send/receive data to DEU and ADR

1. ETA's are computed by DEU

2. Data formatted for display by DEU

3. GINA receives pressure altitude computed by Stability Augmentation Data Sensors (SADS)

4. GINA sends flight parameters sent to ADR for recording

G. Modes of GINA operation

1. HYBD

a. Normal GINA operating mode

b. Integrates GPS and INS, using most reliable data inputs, as per the Kalman filter algorithms

c. On ACFT DATA page displays a Lat/Long position derived from a combination of GPS and INS data

2. INS

a. An alternate GINA operating mode

b. Generates pure INS data for position and velocity related information and cockpit display

c. Halts GPS inputs to the INS unit's navigational solution

d. Displays INS Lat/Long position on ACFT DATA page

INSTRUCTOR NOTES

For purposes of this note, presume the navigation system is aligned in normal fashion and operated in HYBD mode one (1) hour. Then, INS mode is selected. Under this scenario two points should be kept in mind: (1) When INS is selected, GPS data stops being used. (2) When in INS mode, the Lat/Long shown on the ACFT display page does not reflect a "pure" INS solution for position computations. INS, alone, starts affecting the Lat/Long only from the precise moment INS mode is selected. Selecting INS does not remove accrued HYBD (INS and GPS) position errors. In this example, the GPS and INS both affected present position computations from the time the GINA completed its ground alignment and entered HYBD mode, one hour earlier.

3. GPS

   a. Not a GINA operating "mode"

   b. Selecting GPS on the ADI display does not change the internal GINA mode of operation

      NOTE: GPS is boxed, when selected. That boxing is accomplished by the DEU. By contrast, when HYBD or INS are boxed, the GINA operating mode is actually changed, accordingly.

   c. Pilot reads a pure GPS Lat/Long position on ACFT DATA page when GPS is boxed

INSTRUCTOR NOTES

The statement "Not a GINA operating mode" requires clarification. At no time can INS be entirely deselected from the GINA navigation process. It is integral to the GINA system, whatever is selected: HYBD, INS, DGRO or GPS. From a pilot's perspective, selecting GPS results in just one significant effect: i.e., the Lat/Long coordinates shown on the ACFT DATA page reflect GPS positional information, only.

H. DGRO

1. Main uses

a. When having to take-off from an aircraft carrier with a less-than 8 minute alignment

NOTE: Course-alignment complete: heading and altitude are resolved. Will occur very quickly. Later (5-8 minutes) position will resolve. No velocity vector generated. Can take-off before position is determined, and resolve in flight.

b. In-flight following loss of attitude information

(1) Establish straight and level and unaccelerated flight

(2) Cycle GINA PWR on the BIT display page

(3) If attitude is not reestablished in 45-60 seconds, pilot may select DGRO

(4) GINA may auto-select DGRO

(5) May not be able to select DGRO, depending upon INS failure

(6) If GPS is available GINA will use it

(7) Pilot cannot easily confirm he has lost all GPS

2. DGRO mode is a back-up to HYBD mode that provides attitude and heading

3. Do not have following items when operation in DGRO mode

(1) Velocity vectors

(2) HYBD mode option legend

(3) INS mode option legend

4. Heading in DGRO

   a. Pilot can enter a magnetic heading using the DEP, unless heading is already resolved by GINA

   b. Heading may noticeably drift if neither GPS or pilot-entered position is available

5. Once DGRO mode is entered, can only exit following three ways

   a. Select RST on ACFT DATA page

   b. Cycle GINA PWR on BIT page

   c. Initiate an IBIT test (on ground)

6. GINA defaults to DGRO mode during initial alignment under following conditions

   a. Parking brake not set

   b. GPS (4-satellite lock-on) not available within 65 seconds

   NOTE: When GPS becomes available, GINA will automatically continue alignment using GPS

I. Alignment (land)

1. GINA determines heading using the ring laser assembly; GPS not needed

2. Must have weight-on-wheels

   NOTE: If parking brake is not set, GINA will default to the DGRO mode, when GPS is not available.

3. Must have GPS tracking four (4) satellites for a full alignment to begin, or a manual present position initialization using WYPT-0

INSTRUCTOR NOTES

When the parking brake is set, if the system does not attain a locked-on with four (4) satellites, the GINA will not complete its alignment. There will be no cockpit indication, except that ALIGN (alignment time) on the ACFT DATA page will remain at zero, and GPS SAT (number of GPS satellites locked-on) will be a number less than four (4). DGRO will not be boxed. The pilot should send WYPT-0 information from the DEU to the GINA, so an alignment can progress.

4. Determines aircraft position

   a. GPS is the primary data source for position determination during land alignments

   b. WYPT-0 is secondary position data source

   c. WYPT-0 is automatically used for land alignment only if one (1) of the following four (4) conditions are met

      (1) GINA power is cycled; using PWR on the BIT display page is easiest method

      (2) RST (restart) is selected on the ACFT DATA display page

      (3) WYPT-0 coordinates are changed

      (4) GINA IBIT is initiated; takes approximately two (2) minutes

5. A full alignment is complete, when a velocity vector replaces the waterline symbol on the HUD and the INS legend appears on the ADI

Sg 6, fr 2
***Fig 12:** SHIP Alignment*

J. Alignment (SHIP)

1. Ship's movement must be cancelled out during the alignment; GPS required to determine heading and attitude and ship movement "null" factor

Figure 12: SHIP ALIGNMENT

2. GPS <u>must</u> be tracking four (4) satellites to perform a SHIP alignment; cannot use WYPT-0 method

3. SHIP <u>must</u> be selected on the ACFT DATA display page, then, RST (restart) cycled

4. Attitudes should appear after approximately twenty (20) seconds

5. Position and heading should appear after approximately five to eight (5-8) minutes

6. A full alignment takes approximately 16-24 minutes

   NOTE: If a launch is to occur before a full alignment is complete (position and heading displayed), alignment will <u>automatically</u> complete within three to five (3-5) minutes <u>after</u> launch.

7. SHIP option only displayed with weight-on-wheels and when alignment is <u>not</u> complete

8. SHIP DGRO alignment – an option

a. SHIP option is displayed in DGRO mode with weight-on-wheels and true heading invalid

b. To be used when less than eight (8) minutes until launch from ship

c. Must box DGRO on ACFT DATA display page and enter magnetic heading in EHDG using the DEP

d. Following takeoff an In-Flight Alignment (IFA) should be performed (automatically or manually commanded)

K. In-Flight Alignment (IFA)

INSTRUCTOR NOTES

An in-flight alignment requires a four (4) GPS satellite lock-on. Also, in-flight alignments are automatically initiated and require no additional action, unless GINA is not responding. Whenever an IFA is commenced, the aircraft should be in straight and level and unaccelerated flight.

1. IFA should be initiated following takeoff in DGRO mode by selecting RST on the ACFT DATA page, one (1) minute after a position appears on ACFT display page

   NOTE: Waiting one (1) minute after position information appears, prevents losing attitude information when RST is selected.

2. IFA should be automatically initiated following an interruption of GINA power, etc., causing a platform or heading problem or lost/incorrect symbology

INSTRUCTOR NOTES

It is very possible that the IFA will have commenced before the aircraft has been stabilized in straight/level/unaccelerated flight. Therefore, the pilot is advised to cycle GINA PWR on the BIT display page, after he is certain that a straight/level/ unaccelerated condition is attained.

3. IFA should not be performed in IMC conditions

4. To reset the GINA for <u>other than</u> a loss of GINA power, select RST on ACFT DATA display page

5. Maintain straight/level/unaccelerated flight until attitudes are valid and pitch ladder is displayed on the HUD

6. Keep airspeed below 250 KIAS until GPS data is valid

   NOTE: If GPS data is not valid within nine (9) minutes, check GINA status on BIT page, cycle power on the GINA and start again.

7. After attitudes are valid, 90-degree heading changes one (1) apart will reduce final alignment time

8. IFA normally takes 5-15 minute

Sg 6, fr 3
Fig 13: *ACFT Data Page*

L. ACFT DATA page

1. BARO PRESS: Set using FWD standby altimeter

2. LAT/LONG: Aircraft present position as result of

   a. HYBD solution, or

   b. INS solution, or

   c. GPS solution

3. HDG: Aircraft magnetic heading

4. GND SPD: Aircraft groundspeed

5. WIND: Actual wind/velocity

6. ALGN: Time alignment has been in progress

7. QUAL: NM per hour error estimate of the alignment

   NOTE: During a normal full alignment this value will decrease to 00.59. During a SHIP alignment it may decrease to 00.86 at align-complete, and may or may not continue to improve to 00.59.

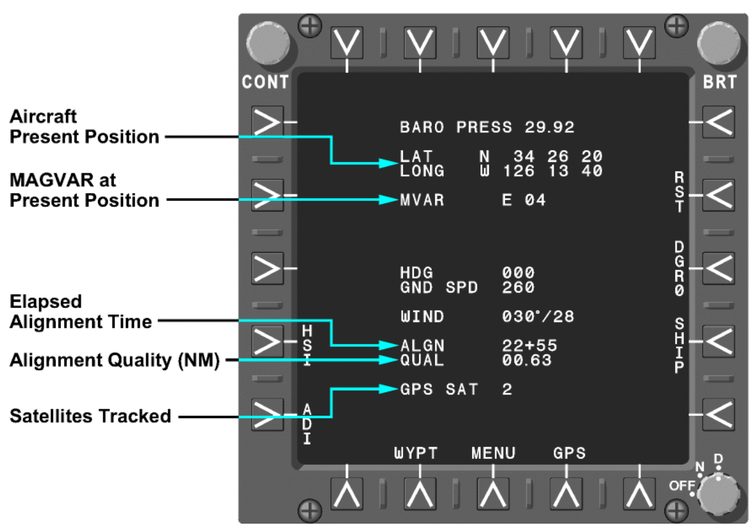


Figure 13: ACFT DATA PAGE

8. GPS: Number of GPS satellites being tracked

9. RST: GINA restart option

10. DGRO: Directional gyro mode selection option

11. SHIP: Alignment selection option

12. GPS: GPS DATA page format selection option

13. MENU: Return to main menu

14. WYPT: Waypoint DATA page format selection option

15. ADI: Change to ADI display

16. HSI: Change to HSI display option

M. GPS DATA page

Sg 6, fr 4
Fig 14: *GPS DATA Page*

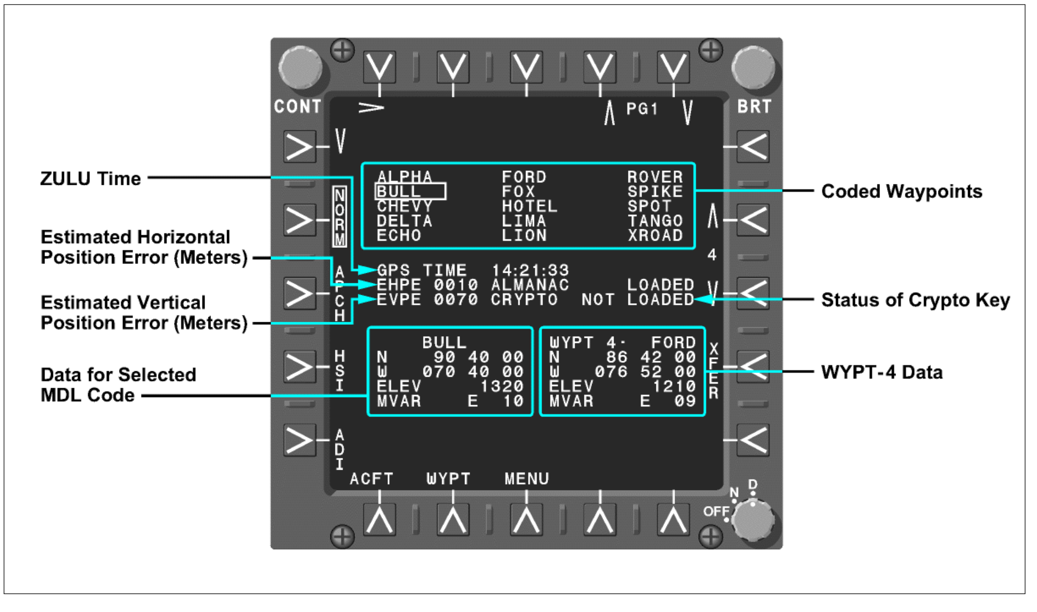


Figure 14: GPS DATA PAGE

1. Displays up to 200 coded waypoints from the Mission Data Loader (MDL)

    a. Fifteen waypoints at a time

    b. 14 pages

    c. Selected waypoint is highlighted

2. NORM and APCH corridor monitor limit selection

    a. Used to internally monitor GPS accuracy using internal GINA performance checks

    b. Activates a CORRIDOR advisory only when GPS is boxed as the sole navigation source

INSTRUCTOR NOTES

The corridor safety alert is designed to support navigation exclusively with GPS. Normally, the T-45C operates in HYBD mode. In the future, the T-45C will likely be certified for flying precision GPS approaches. Then, this corridor-warning feature will become important. The normal (NORM) mode will be used enroute, and the approach (APCH) mode will be used during GPS instrument approaches.

    c. NORM triggers a CORRIDOR advisory when Estimated Horizontal Position Error (EHPE) exceeds 333 meters for more than five (5) seconds

    d. APCH triggers a CORRIDOR advisory when Estimated Horizontal Position Error (EHPE) exceeds 33 meters for more than five (5) seconds and true airspeed is less than 300 knots

    e. When GPS is boxed, either NORM or APCH are also boxed

    f. NORM is default with landing gear – UP

g. APCH is default with landing gear – DOWN

h. Pilot can override default settings

3. GPS TIME

INSTRUCTOR NOTES

GPS TIME is normally displayed on this page. It reflects ZULU time, and is what the satellites and GINA use. If this time readout reverts to zero (not the actual ZULU time), it is indicative that the back-up DC batteries in the GINA are weak or have failed. If the GPS has a good satellite lock-on, the correct time will reappear in about 13 minutes and functionality should be nominal. After landing the aircraft should be written-up so Maintenance is alerted to check the system.

4. CRYPTO NOT LOADED

NOTE: Since the T-45C crypto system is not active, CRYPTO NOT LOADED is always displayed

Sg 6, fr 5
Fig 15: *BIT Display Page (Weight-On-Wheels)*

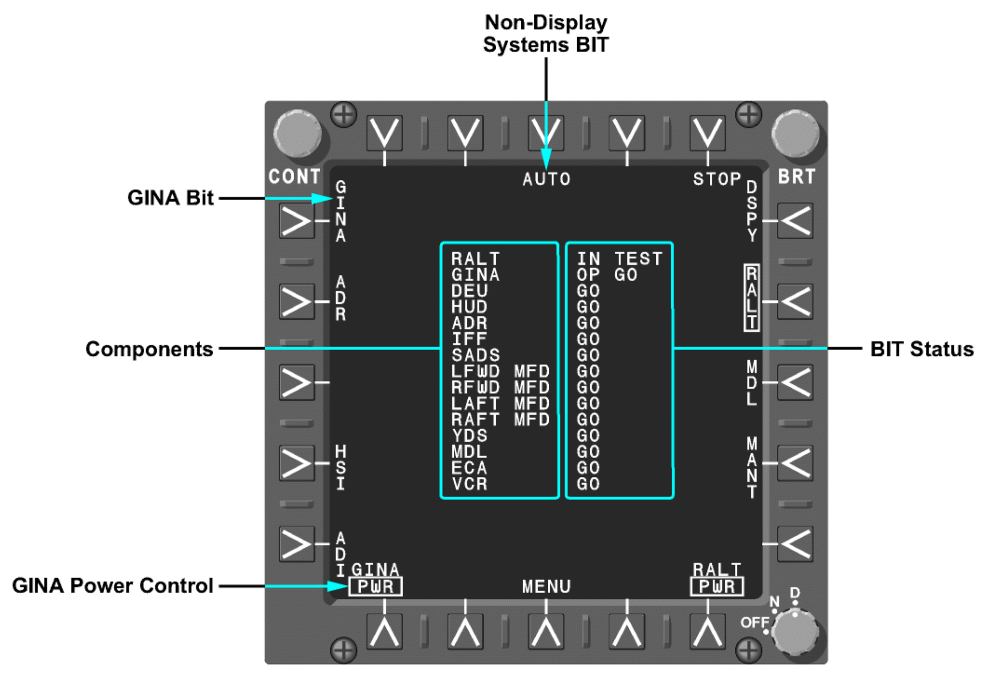


Figure 15: BIT DISPLAY PAGE (WEIGHT-ON-WHEELS)

N. GINA BIT checks

1. BIT codes

   a. IN TEST: Listed for the duration of a PBIT or IBIT tests

   b. DEGD

      (1) BIT failure

      (2) Equipment OFF or not installed

      (3) 1553 bus failure on both channels

   c. OPGO

      (1) No detected BIT failure

      (2) 1553 bus failure on one (1) channel

   d. GO

      (1) No detected BIT failures

      (2) Dual 1553 bus communications are established

2. Power-Up BIT (PBIT) checks

   a. Automatically performed on GINA (and other WRA [Weapons Replaceable Assembly] equipment) when power is first applied to aircraft and weight-on-wheels

   b. Most extensive form of BIT check

3. Initiated BIT (IBIT)

   a. Manually selected on the ground by pilot or maintenance

(1) Select GINA on BIT display page; parking brake must be set

(2) Select AUTO on BIT display page; checks all non-display avionics (including GINA)

b. Not available with weight-off-wheels; GINA and AUTO legends are blanked

4. Continuous BIT (CBIT)

a. Performed in the background whenever power is applied to the aircraft and PBIT has been performed

b. Primary means if BIT testing GINA (and other equipment) with weight-off-wheels

5. Maintenance BIT format (MANT)

a. Only available with weight-on-wheels

b. Available so maintenance personnel can check selected systems status

Sg 6, fr 6
Fig 16: *BIT Display Page (Weight-Off-Wheels)*

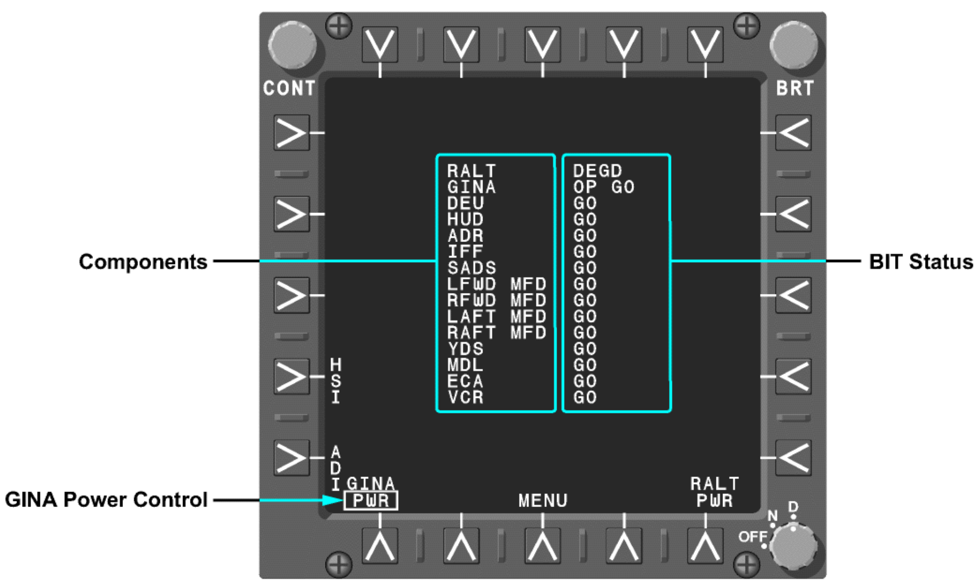


Figure 16: BIT DISPLAY PAGE (WEIGHT-OFF-WHEELS)

Sg 6, fr 7
Fig 17: *GINA WRA*

6. STOP legend on BIT display page: Halts all in-progress WRA BIT tests

O. GINA system faults

1. When a problem is suspected

   a. Check BIT display page

   b. Check mode of GINA (HYBD, INS, GPS)

   c. Check ACFT DATA display page

      (1) Cross-check present position coordinates with GPS present position

      (2) Try to visually, or via other means, confirm present position coordinates

      NOTE: Recommend over-flying a known geographical position

      (3) Determine number of satellites locked-on

      (4) Determine if wind indication seems correct, or at least reasonable

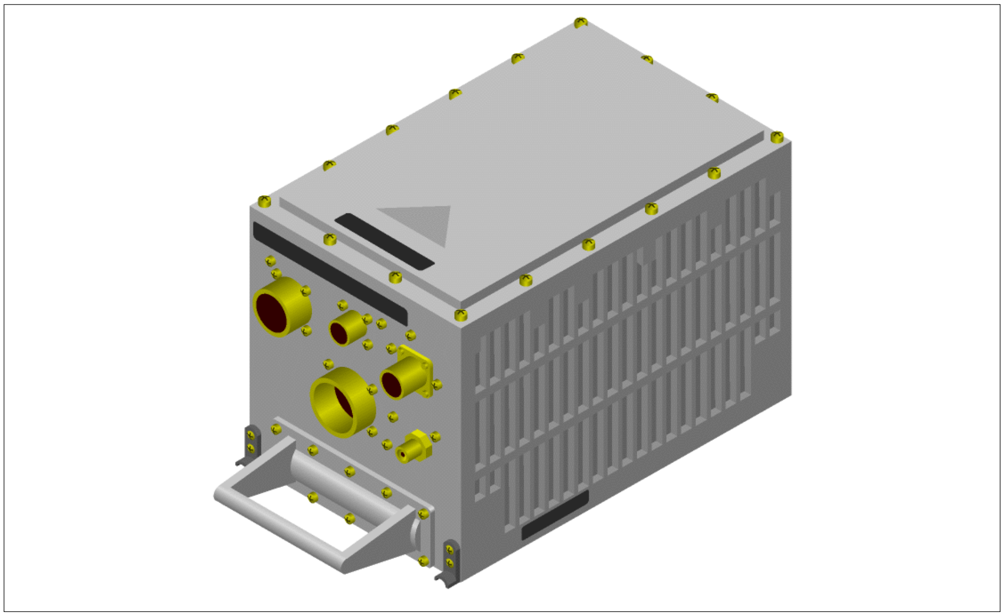


Figure 17: GINA WRA

d. Check GPS DATA page

(1) GPS TIME

(2) EHPE (Estimated Horizontal Position Error)

(3) EVPE (Estimated Vertical Position Error)

INSTRUCTOR NOTES

The indicated GPS TIME should equate to current ZULU time. With normal flight dynamics, EHPE can be expected to fluctuate between 33 to 100 meters; EVPE between 50 to 100 meters. During and shortly after aggressive maneuvering both EHPE and EVPE may fluctuate up to 1000 meters.

e. Check for erroneous or missing display symbology: HUD and MFDs

f. Cross-check standby instruments with MFD displays

2. Failure of internal GPS-INS comparison test

Sg 6, fr 8
Fig 18: *Got a Problem?*

GOT A PROBLEM?

MAINTAIN ACFT CONTROL

ANALYZE THE SITUATION

TAKE PROPER CORRECTIVE ACTION

Figure 18: GOT A PROBLEM

a. Three (3) sigma deviation

(1) Three sigma: Three (3) times (300%) normal deviation expected for position and velocity data entering Kalman filter

(2) Three (3) sigma deviation has persisted for 20-24 seconds

(3) Selected display symbology is removed from MFD/HUD

(a) Velocity vectors (from HUD) change to waterline symbol

(i) True

(ii) Ghost

(b) Ground speed (from both ADI and HUD)

(c) Digital vertical velocity (from HUD)

(d) VSI (from ADI)

(e) Wind/velocity (from HSI)

(f) TACAN, WYPT, WO/S estimated time of arrival (ETA) data

(4) BARO altitude on the HUD becomes unfiltered

NOTE: BARO altitude may fluctuate when unfiltered

(5) AVBIT advisory generated on all MFDs

(6) GINA listed as DEGD on BIT page

(7) Removed data restored if GINA problem is corrected

(8) This specific 3-sigma self-test and the removal of display data will not occur if less that four (4) satellites are locked-on

b. If GPS data is bad

(1) HUD and MFD displays will lose previously noted display items after a three (3) sigma deviation

(2) GINA reverts from HYBD to INS mode

(a) INS will box on the ADI

(b) HYBD legend will be removed from ADI

(c) GPS legend will be removed from ADI

(3) Check BIT page

(4) Check ACFT DATA page

(a) Number of satellites locked-on

INSTRUCTOR NOTE

GINA automatically reverts from HYBD to INS mode when all four (4) satellite lock-ons are lost for more than 65 seconds

(b) Coordinates on ACFT DATA page continue being computed with pure INS data, provided INS is functional, commencing at time of GPS loss

(c) Compare GPS coordinates on the ACFT page with INS mode coordinates, if possible

(d) Confirm present position coordinates by other means

(5) Removed MFD display data will be restored if problem corrects

c. If INS is bad

(1) HUD and MFD displays will lose previously noted items after a three (3) sigma deviation

(2) Depending upon nature of the INS problem, additional symbology (ADI ball, flight attitudes, heading reference, turn/slip, etc.) may be removed from displays

(3) GPS will <u>not</u> be automatically selected by the DEU

INSTRUCTOR NOTE

GPS is not a GINA mode, although, it is listed as a separate option on the ADI. The boxing of GPS is a DEU function, whereas the boxing of HYBD and INS are related to GINA functions. NOTE: Depending upon the INS problem, the GPS option on the ADI may or may not be displayed; nonetheless, going to GPS will <u>not</u> eliminate an INS problem

(4) GINA may revert to DGRO mode

(5) HYBD, INS, and GPS legends may all be removed from ADI display

(6) Check ACFT DATA page

(a) Number of GPS satellites locked-on

(b) Coordinates on ACFT DATA page <u>commence</u> being computed with pure GPS data, provided GPS is functional

NOTE: GPS must be selected (boxed) on the ADI display page; otherwise, coordinates will be blank.

(c) Compare INS coordinates on the ACFT page with GPS coordinates

(d) Check accuracy of present position coordinates

(7) Avoid flying in IMC condition if at all possible

(8) Land as soon as practical

(9) Removed MFD display data will be restored if problem corrects

PROGRESS CHECK

Question 8 -- 1.7.7.6.1
What does the Kalman filter, filter?

ANSWER: It is not a filter in the traditional sense of the word. Simply put, the Kalman filter provides a set of weights and balances. It allows the GINA to combine computerized data from different sources, emphasizing and minimizing appropriate values, so the derived solution is the best solution.

Question 9 -- 1.7.7.6.1
When is WYPT-0 used to align the system?

ANSWER: Only when specifically invoked by cycling GINA PWR, selecting RST, changing a WYPT-0 coordinate, or initiating a GINA IBIT.

Sg 7, fr 1
Review Options

SUMMARY

In this lesson, we discussed the following main topic areas:

- Gyroscope characteristics
- LITTON GINA INS design
- Global Positioning System characteristics
- LITTON GINA Global Positioning System design
- GINA components
- GINA functions

CONCLUSION

The T-45C GINA incorporates a compact and modern LITTON ring laser INS assembly, plus a ROCKWELL-COLLINS GPS unit. Both of these sub-assemblies are extremely accurate. The GINA links them together, functioning relatively autonomously and very reliably. Accurate attitude and navigation data is supplied to the pilot.

LESSON GUIDE

COURSE/STAGE: TS, ADV & IUT / Engineering

LESSON TITLE: Display System and Malfunctions

LESSON IDENTIFIER: T-45C TS, ADV & IUT ENG-25

LEARNING ENVIRONMENT: CAI

ALLOTTED LESSON TIME: 1.5 hr

TRAINING AIDS:

* Figures

Fig 1: Display System Major Components
Fig 2: DEU Interface Diagram
Fig 3: DEU Location
Fig 4: MFD Menu Display
Fig 5: Head-up Display (HUD)
Fig 6: DEU Functions as Bus Controller
Fig 7: Display System Electrical Diagram
Fig 8: Weight-off-Wheels
Fig 9: Weight-on-Wheels
Fig 10: BIT Status Report
Fig 11: DEU Data Source
Fig 12: Aircraft Data Display

STUDY RESOURCES:

* T-45C NATOPS Flight Manual, A1-T45AC-NFM-000
* T-45C Familiarization FTI

LESSON PREPARATION:

Read:

* Chapter 2, "Electrical" and "Avionics" and Chapter 21 Section 3 "Navigation," T-45C NATOPS Flight Manual, A1-T45AC-NFM-000, and the T-45C Familiarization FTI

Review:

* Fuel system interface with DEU (Eng-03)
* Engine page graphics (Eng-04)
* Flight instruments (Eng-19)
* CNI system (Eng-21)
* GINA operation (ENG-24)

REINFORCEMENT: N/A

LESSON EXAMINATION:

The objectives in this lesson will be tested in either Eng-29X & Eng-30X

LESSON OBJECTIVES

1.4.18.4.3.3
Recall major components of the Display System

1.4.18.4.3.2
Recall operating characteristics of the Display System

1.4.18.4.3.1
Recall function/purpose/location of Display System controls, switches, and indicators

1.4.18.4.3
Recall interfaces between the Display System and other A/C Systems

1.4.18.4.2
Recall function of the Multi-Function Display (MFD) BIT

2.8.2.1
Identify indications of Multi-Function Display (MFD) failure

4.4.5.4.1
Identify indications of Head-Up Display (HUD) failure

1.7.7.6.2
Recall indications of GINA failure

1.7.7.6.2.1
Identify indications of GINA failure

MOTIVATION

Use these exercises to solidify what you learned in previous lesson. If there is something that still doesn't make sense, now is the time to get it straightened out.

OVERVIEW

This lesson introduces the components, normal operation, interfaces with other a/c systems, and checking / testing techniques of the Display System, as well as indications, verifications, and effects on flight safety of selected system malfunctions.

REFRESHER

Recall the material covered in the following engineering lessons:

A. Fuel system interface with the Display Electronics Unit (Eng-03)

B. Engine page graphics (Eng-04)

C. Flight instruments (Eng-19)

D. CNI system (Eng-21)

E. GINA operation (Eng-24)

PRESENTATION

I. Display system major components **1.4.18.4.3.3**

A. The display system consist of three major components.

1. Display Electronics Unit (DEU)

a. There is only one DEU in the T-45C

2. Multi-Function Display (MFD)

a. There are four MFDs on the T-45C

b. Two MFDs in each cockpit

3. Head-Up Display (HUD)

a. There is only one HUD on the T-45C

b. The HUD is located in the forward cockpit only

II. Display system operating characteristics and function/ purpose/location of controls, switches and indications **1.4.18.4.3.2, 1.4.18.4.3.1**

A. Display Electronics Unit (DEU)

1. DEU has two capabilities

a. Mission Computer

b. Display Computer

2. Controls MIL-STD-1553B Multiplex Data Bus (MUX BUS)

a. Interfaces with ADR, MDL and GINA

3. Interfaces

a. The HUD interfaces for control of display formats and data

Fig 1: *Display System Major components*

Fig 2: *DEU Interfaces*

b. Both DEP's for pilot input and response

c. All MFDs for pilot input and receive display formats

d. Camera Electronics Unit (CEU) for imagery

e. Video Cassette Recorder (VCR) for display imagery and data recording

f. Caution/Warning system for cautions and warnings

g. MIL-STD-1553B MUX BUS

(1) GINA for pitch, roll, magnetic heading, position, and vertical and vertical velocity

(2) ADR for AOA, Total Air Temperature, radar altitude, and engine data

(3) MDL for waypoints, magnetic variation coefficients and GPS almanac data

h. VOR/ILS for navigation VOR or ILS data

i. TACAN for navigation TACAN data

j. RALT for on/off/test commands and altitude information

k. SADS for air data

l. Stores for weapon status and control

m. IFF for BIT functions

n. COMM AMP for LAWS and trigger audio

o. Misc. A/C switches/sensors and relays for input, commands and BIT

4. Interprets Data Entry Panel and MFD bezel push-button inputs and generates displays for the HUD and the MFDs

5. Located in the forward avionics bay

Fig 3: Display Electronic Unit Location

B. Multi-Function Display

1. Organized into display formats

   a. Formats of logically grouped flight and or mission data with selectable options

2. Has twenty option push-buttons

3. Controls for brightness, contrast, and power

4. Operate identical and independently

5. MENU display provides access to all top level displays

   a. ADI, HSI, HUD, VREC, STRS, BIT, DATA, ENG, TRNG and RPTR

Fig 4: MFD-Menu display

C. Head-Up Display

Fig 5: HUD

1. The HUD consists of a Pilot Display Unit (PDU) and Data Entry Panel (DEP)

2. Controlled by DEU

3. Has controls for data input, modes, and operation

4. Location is the forward instrument panel

5. An electro-optical device

6. Projects flight and weapon delivery information onto the PDU

Fig 6:
DEU Functions as BUS CONTROLLER

Fig 7:
Electrical Diagram

7. Utilizes BIT

8. Warning! HUD shall not be used as a primary flight instrument

9. Manual data inputs via Data Entry Panel (DEP)

10. Aft cockpit has DEP only for inputs to the HUD

III. Display system interfaces **1.4.18.4.3**

A. Hard-Wired interfaces

1. Used to transmit/receive analog, video, and discrete data between DEU and the: HUD, MFD, SADS, CEU, STRS, IFF, COMM. AMP., MISC. switches/ sensors/relays, CWS, VOR/ILS, TACAN, VTR, and RALT

B. MIL-STD-1553B Multiplex Data Bus

1. Provides path between DEU (controller) and ADR, GINA, and MDL (remote terminals)

2. Dual redundant twisted pair of shielded cables to transmit/receive digital data words

3. Digital data words used for commands, responses, status, and information

C. Electrical interfaces

1. Low resistance electrical power connections

2. 28 VDC Essential services bus

a. Left MFDs

b. DEU

c. VCR/CEU

3. 28 VDC Generator bus

    a. Right MFDs

    b. HUD

    c. DEP

4. 115 VAC NON-Essential Services Bus

    a. DEU cooling fan

5. 26 VAC NON-Essential Services Bus

    a. DEU

IV. Display system bit **1.4.18.4.2**

A. Built-In-Test (BIT) for initializing the DEU, MFDs, and HUD/PDU

1. Two BIT MENUs

    a. Weight-Off-Wheels gives real time status of equipment, Continuous BIT

    b. Weight-On-Wheels has selectable options, AUTO/ DSPY for component Initiated BIT

2. Maintenance display page.

3. BIT status report; GO, OPGO, DEGD, OVRHT, IN TEST

4 Display BIT-DBIT selectable on DEU, MFDs, and HUD/PDU

5. AUTO BIT-secondary BIT automatically for DEU followed by GINA, ADR, MDL and RALT

6. Monitors equipment status and notify aircrew fault

Fig 8: *MFD-Bit page W-off-W*

Fig 9: *MFD-Bit page W-on-W*

Fig 10: *BIT Status Report*

7. Power-up BIT performed when equipment power applied

8. Initiated BIT aircrew or groundcrew activated

9. Continuous BIT performed in background during normal operation of equipment

V. MFD Failure Indications **2.8.2.1**

A. Malfunctions

1. Flight data, mission data, and electrical power interruptions

2. Advisory window on all MFDs, provides display of malfunction

a. Will flash at 3 Hz rate. Advisories are inhibited during BIT, except LAW

b. Remain displayed until rejected or fault goes away

c. When rejected, will remain off until fault comes back

d. Not displayed on the HUD/PDU

e. Multiple faults displayed by priority; SIM MODE, LAW, BINGO, ATTITUDE, POSITION, CORRIDOR, ILS, GLIDESLOPE and LOCALIZER

3. MFD anomalies

a. Blinking screen

b. Invalid data displayed

c. Blank screen

d. Stuck or sticking push-buttons

e. Verify data, recycle power, still invalid turn system off

f. Multiple displays same problem, set Display Power switch to momentarily reset, this cycles power to DEU

g. Generator failure

(1) Left MFDs in both cockpits revert to ADI display and remain on for two minutes

(2) Right MFDs in both cockpits go off and remain off

(3) All display format options available on left MFDs with generator failure

(4) Selecting Power switch to ORIDE overrides two minute timer and provides continuous operation of left MFDs while 28 VDC ESSENTIAL BUS battery voltage is adequate

VI. HUD Failure Indications **4.4.5.4.1**

A. Power-Up

1. No display after IBIT plus 25 seconds

2. Adjust AUTO/DAY and BRT controls

3. BIT fault - column of numbers down middle of screen

B. In-Flight

1. Missing symbology

2. Data disappearing and not returning indicate input failure fault

3. Out-of-Limits data, data returns after transition to within limits

Fig 11:
DEU Data Source

VII. GINA system

A. The GINA is a self contained all attitude, world wide, strap-down inertial system with an embedded GPS receiver

B. GINA initialization

1. Attitudes from gyros

2. Heading

a. GPS position

b. Accelerometer sensed rotation of earth

c. Stored magnetic variation algorithms

C. Initialized GINA provides DEU with:

1. INS portion

a. Pitch

b. Roll

c. Magnetic heading

d. Vertical and horizontal velocities

2. GPS portion

a. Position

b. Time

D. GINA and other sensor information used by DEU to generate MFD and HUD displays

E. GINA power status

1. Shown on BIT display

2. System initializes to GINA power ON

3. Pressing GINA option turns GINA power OFF or ON

F. GINA BIT status reported on BIT display

1. GO - GINA operating on both MUX bus channels and no BIT failure

2. OPGO - GINA reporting on only one MUX bus channel and no BIT failure

3. DEGD - GINA BIT failure, GINA off, or not responding on either MUX bus channel

4. IN TEST - GINA BIT in progress

G. GINA information on aircraft DATA display

Fig 12:
Aircraft Data Display

1. ALGN

   a. time in minutes and seconds GINA has been in alignment mode

   b. Removed when alignment complete

2. QUAL

   a. Alignment quality in nautical miles per hour

   b. Removed when alignment complete

3. RST

   a. Initiates GINA re-initialization

   b. Switches GINA to directional gyro mode and begins alignment

4. DGRO, Directional Gyro - backup attitude and heading mode

5. EHDG, Entered Heading

   a. Displayed when DGRO selected

b. When selected magnetic heading can be entered using the HUD DEP

c. GINA may or may not accept entered heading, depending on state of GINA re-initialization

6. SHIP

a. Signals GINA that alignment is a shipboard alignment

b. Must be selected before selecting RST

c. Attitudes available in about 20 seconds

d. Position and heading available in about 8 minutes

H. GINA Failure

1. GPS failure

a. Indications

(1) INS automatically selected

(2) HYPD and GPS removed from ADI display

b. No degradation of attitude or position data if INS operating properly

c. No pilot corrective action available

d. Verification

(1) GINA status on BIT display reported as DEGD

(2) Aircraft DATA display may show GPS tracking 4 satellites

(3) GPS DATA display

(a) GPS time removed

(b) GPS estimated horizontal and vertical position data removed

e. Effects on Flight Safety

(1) INS portion of GINA providing position data

(2) May be degradation of position data over time

f. Following a GPS failure, if GPS data becomes valid the HYBD and GPS options are displayed and the position source option selected prior to the failure is automatically selected (boxed)

2. INS failure

a. Indication

(1) ATTITUDE advisory displayed on all MFDs

(2) Attitude, vertical velocity, and navigation information removed from displays

(3) ADI data removed

(a) HYBD, INS, and GPS options

(b) Attitude

(c) Heading

(d) Vertical speed

(e) g

(f) Turn and slip

(g) Navigation information

(4) HSI data removed

(a) Heading

(b) Winds

(c) Ground speed

(d) Navigation information

(5) HUD data removed

(a) Attitude

(b) Heading

(c) Vertical speed

(d) g

(e) Groundspeed

(f) Navigation information

b. Effect on flight safety

(1) Standby instruments must be used

(2) Limited to PAR approach

(3) If INS becomes valid

(a) Attitude return first

(b) Heading, vertical speed and turn needle return second

(c) Position returns last

3. Inflight alignment

Note: If the GINA fault was the result of power interruption to the GINA, the GINA power should be cycled OFF then ON from the BIT display. If the GINA failure is other than a power loss, initiate the inflight alignment with the RST push-button on the aircraft DATA display.

a. Straight and level flight required for about four minutes

b. Inflight alignment for other than GINA power loss is initiated from aircraft data display

   (1) Press RST

   (2) ATTITUDE advisory flashes

   (3) In 6-10 seconds pitch attitude, g and slip indications displayed and advisory window changes to POSITION

   (4) Maintain airspeed below 250 KIAS until GPS data valid

   (5) After attitude displayed, 90-degree heading changes one minute apart will reduce alignment time

   (6) When INS calculates the heading it is displayed

c. The alignment quality is improving as the QUAL number decreases

d. When alignment complete, HYBD, INS options are displayed on the ADI display and all information returns on the aircraft data display

e. If the alignment quality is not improving, QUAL number decreasing, the INS or GINA has failed

4. GINA Velocity/Position Mis-compare

a. GINA continuously comparing velocity and position data from GPS and INS

b. Indications

   (1) AV BIT displayed on all MFDs

   (2) ADI data effected

(3) Vertical velocity removed

(b) Barometric altitude not filtered

(4) HSI data removed

(a) Time-to-go

(b) Ground track marker

(c) Ground speed

(d) Winds

(5) HUD data effected

(a) Time-to-go removed

(b) Ground speed removed

(c) Vertical speed removed

(d) Velocity vector removed

(e) Water line displayed

(f) Barometric altitude unfiltered

c. Verification

(1) GINA velocity and position data removed

(2) HYBD position option still displayed

(3) GINA BIT status DEGD

d. Effect on flight safety

(1) Unfiltered barometric altitude distracting when maintaining constant altitude

(2) Must use standby VSI, with its inherent lag, for vertical speed information

(3) Increased workload because ground speed and time-to-go must be calculated manually

(4) Transition from instrument to visual scans more difficult without velocity vector

SUMMARY

This lesson has provided you with information on the:

* Display System with major components
* Physical characteristics, functional descriptions, and operating limitations of the Display System components
* Purpose, function, and location of controls
* Procedures for checking/testing flight instruments to determine appropriate operation
* Interfaces between Display System components and other T-45C systems
* GINA operation and malfunctions

CONCLUSION

Knowing the display system operations and recognizing the significance of cockpit indications are essential to aircraft control and mission completion. Knowledge of the aircraft, its systems, and malfunctions is imperative to safe operation.

FIGURES

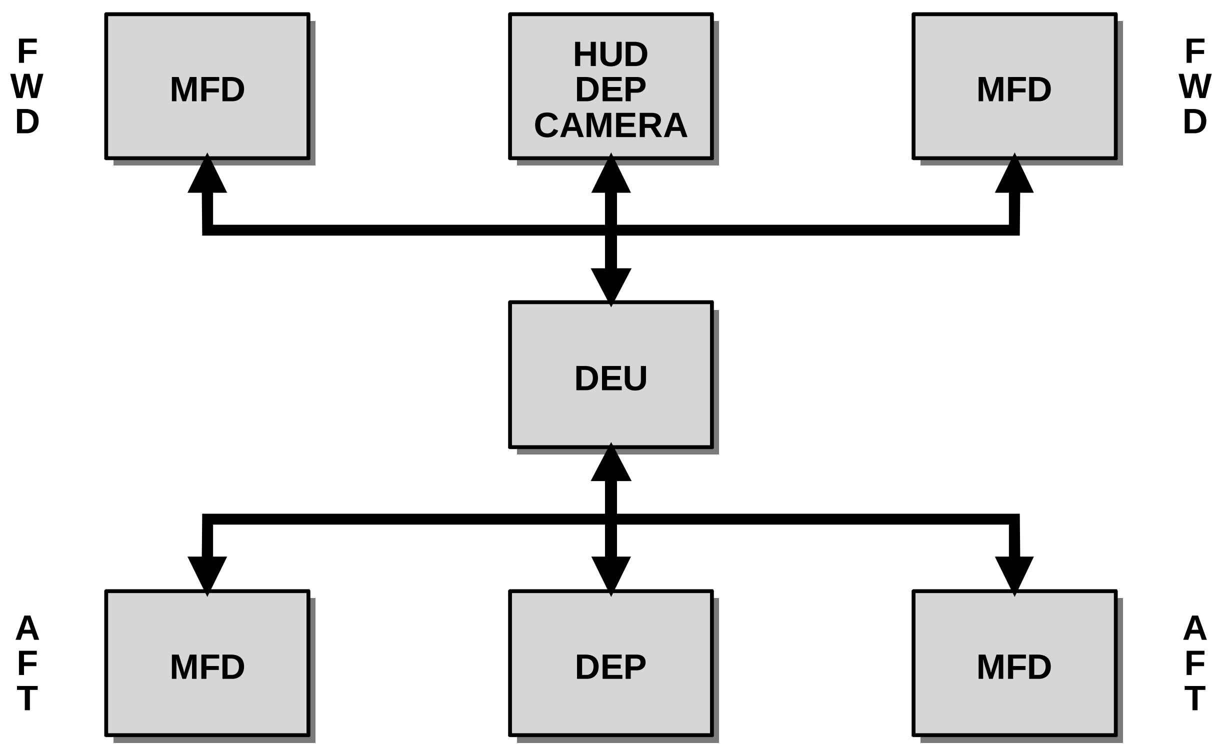


Figure 1: DISPLAY SYSTEM MAJOR COMPONENTS

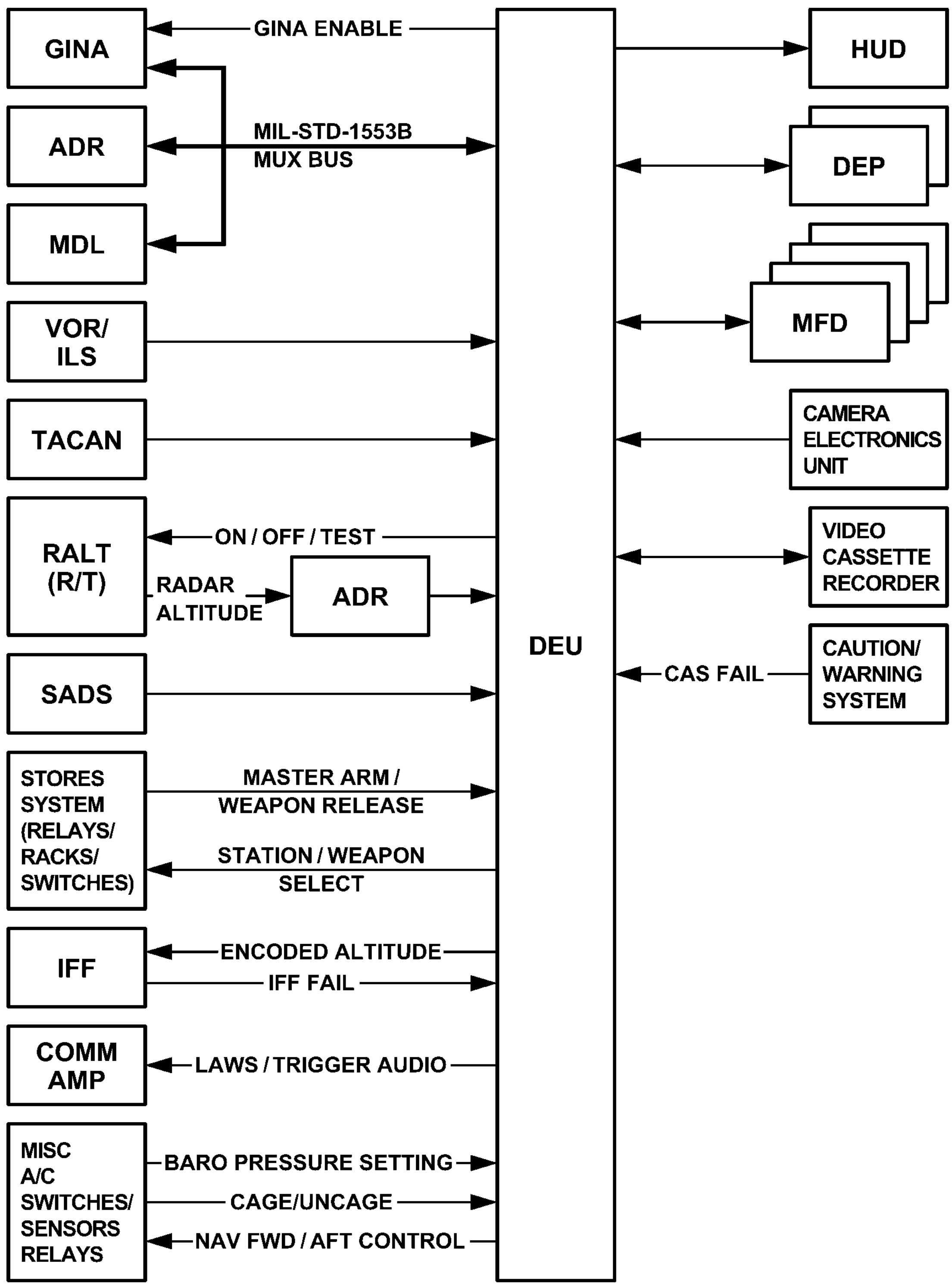


Figure 2: DEU Interface Diagram

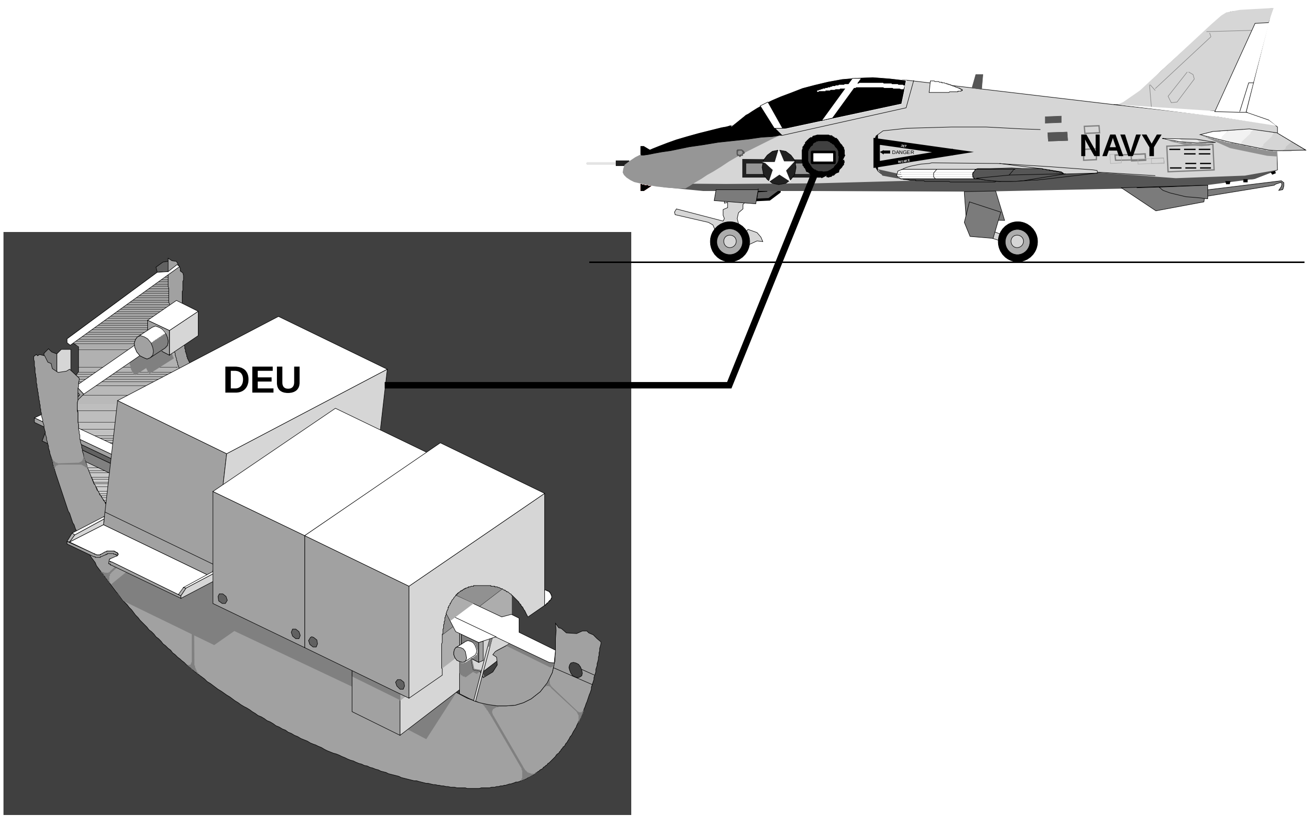


Figure 3: DEU Location

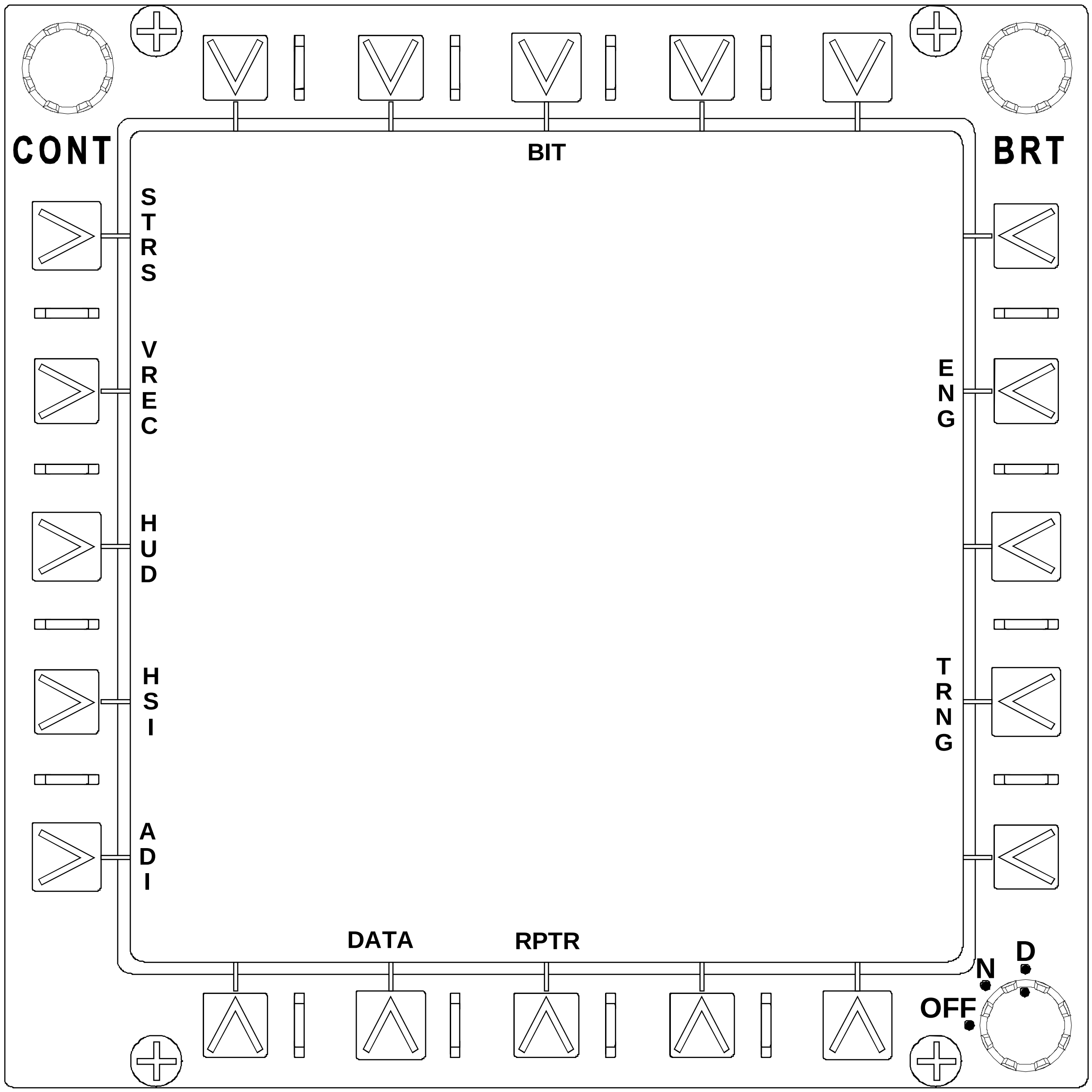


Figure 4: MFD MENU DISPLAY

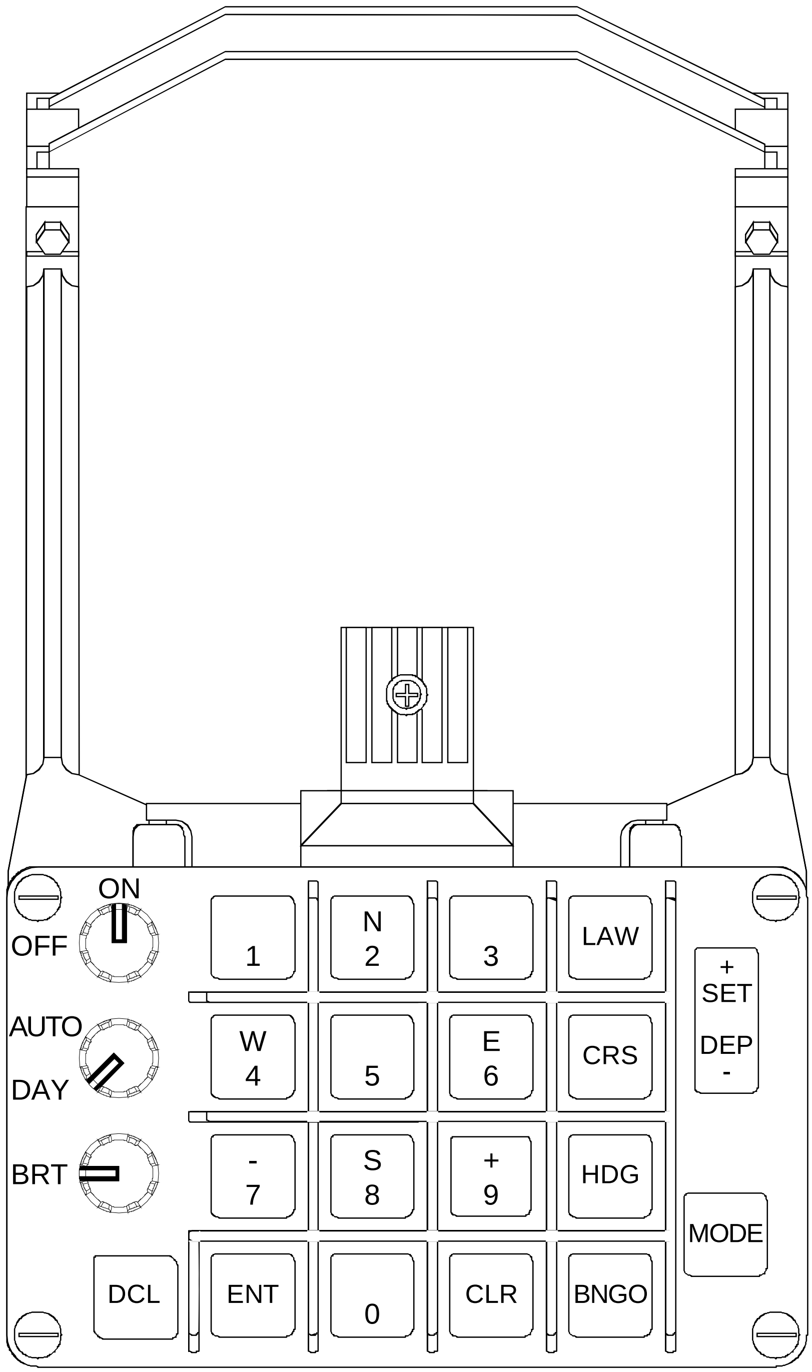


Figure 5: HEAD-UP DISPLAY (HUD)

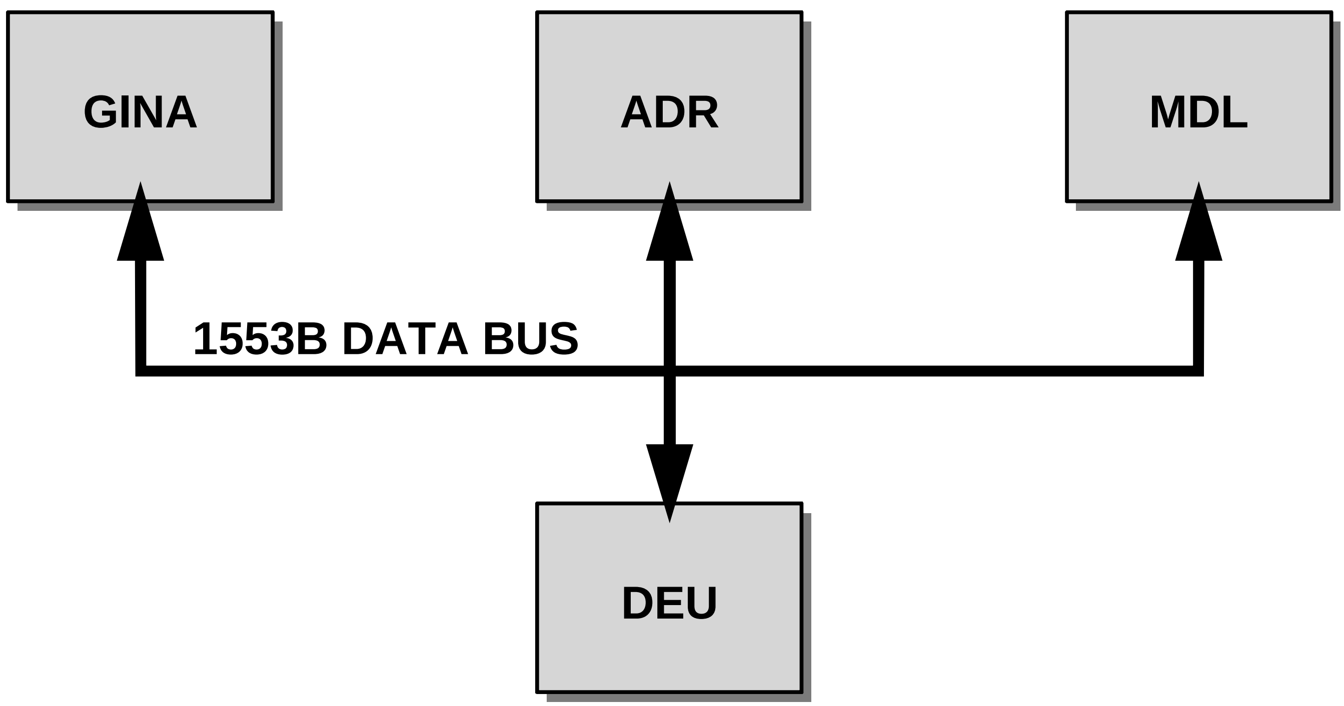


Figure 6: DEU Functions as Bus Controller

28 VDC ESSENTIAL SERVICES MFD, LEFT DEU VCR / CEU
28 VDC GENERATOR MFD, RIGHT HUD DEP
115 VAC NON-ESSENTIAL DEU COOLING FAN
26 VAC NON-ESSENTIAL DEU

Figure 7: Display System Electrical Diagram

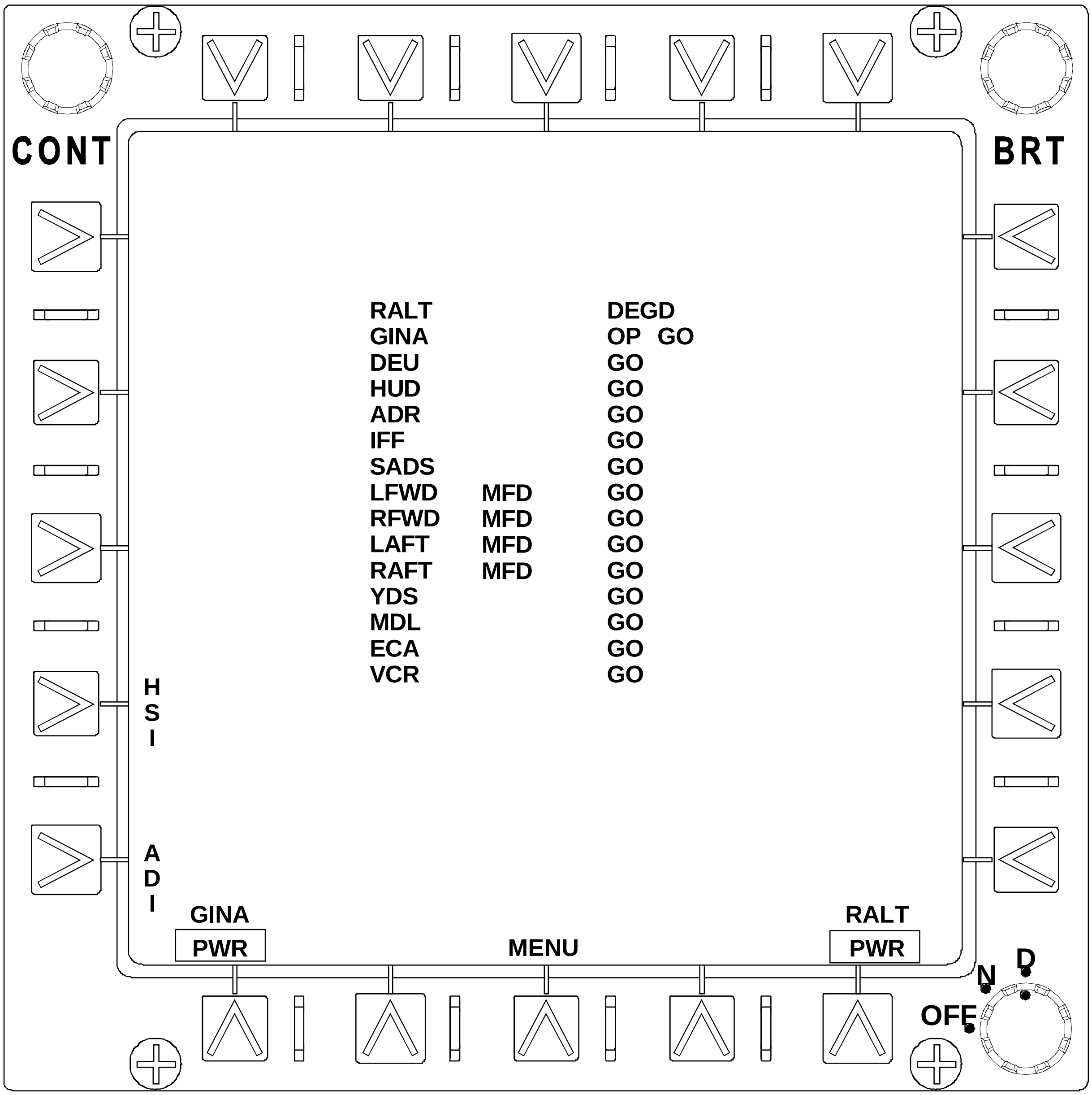


Figure 8: WEIGHT-OFF-WHEELS

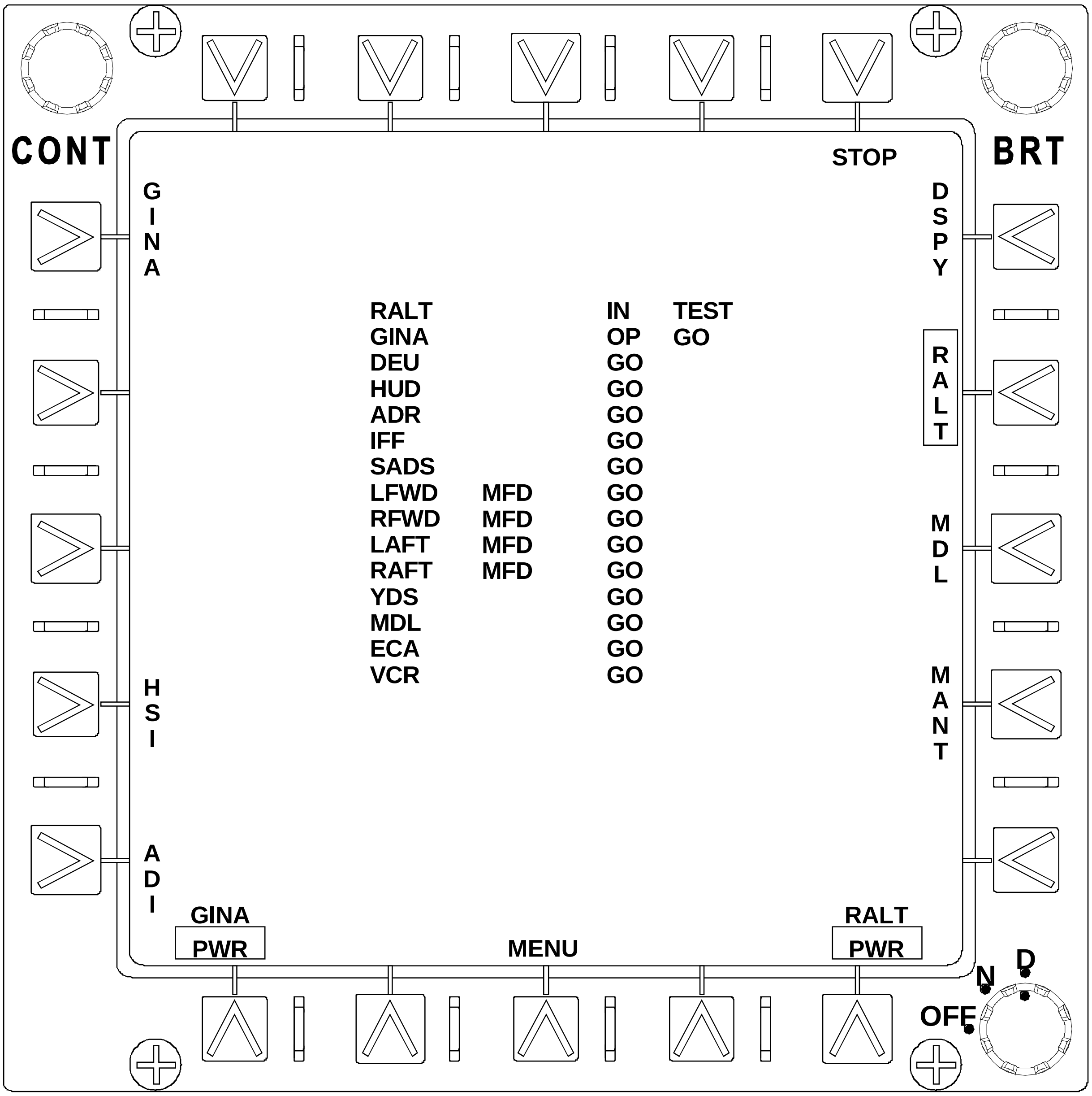


Figure 9: WEIGHT-ON-WHEELS

	AVAILABLE BIT STATUS LEGENDS				
SYSTEM	GO	OP GO	DEGD	OVRHT	IN TEST
RALT	X		X		X
GINA	X	X	X		X
DEU	X		X	X	
HUD	X		X		
ADR	X	X	X		X
IFF	X		X		
SADS	X		X		
LFMFD	X		X		
RFMFD	X		X		
LAMFD	X		X		
RAMFD	X		X		
YDS	X		X		
MDL	X	X	X		X
ECA	X		X		
VCR	X		X		

Figure 10: BIT STATUS REPORT

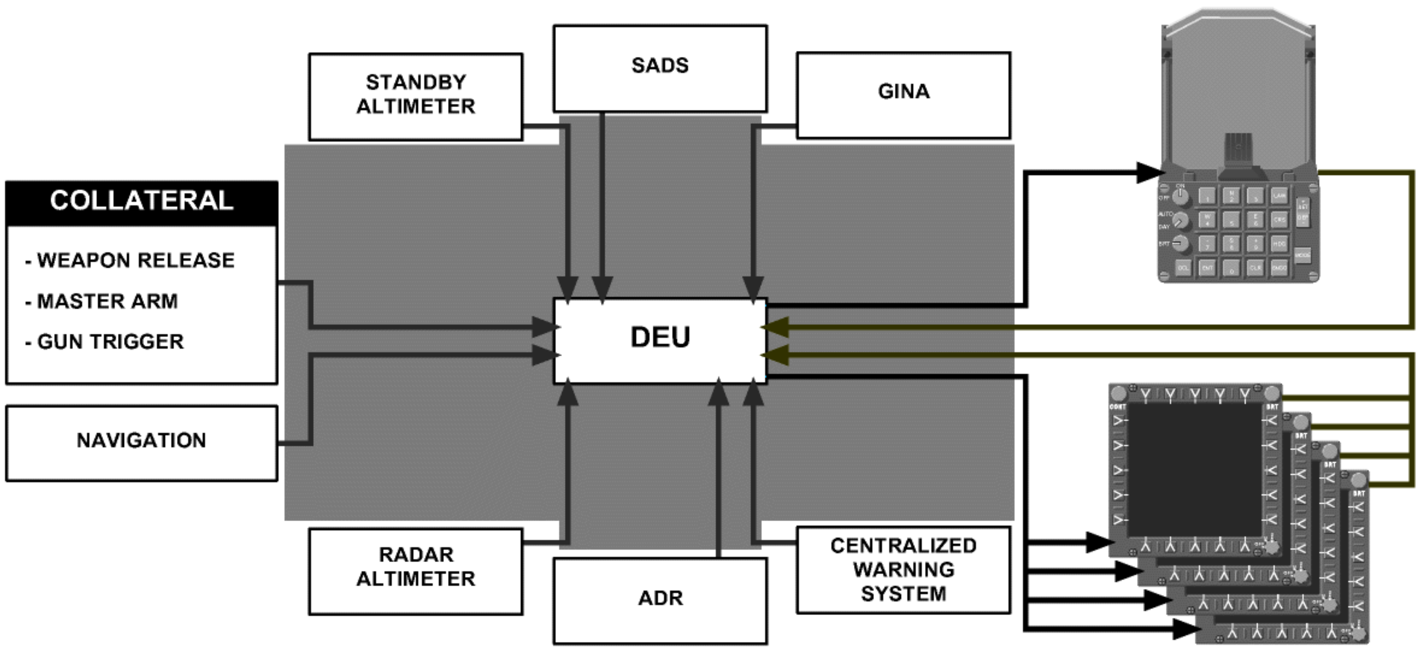


Figure 11: DEU DATA SOURCES

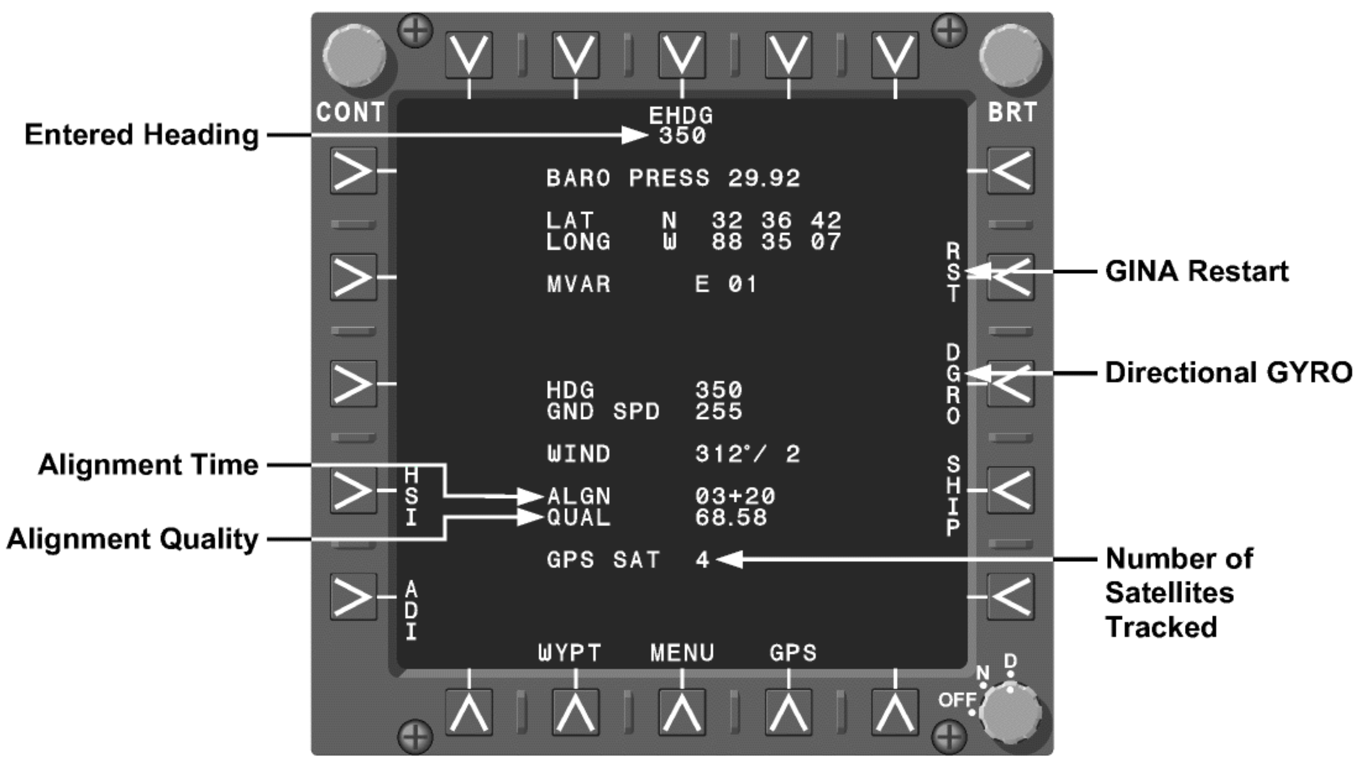


Figure 12: AIRCRAFT DATA DISPLAY

LECTURE GUIDE

COURSE/STAGE: TS, ADV & IUT / Engineering

LESSON TITLE: Engine Start Procedures

LESSON IDENTIFIER: T-45C TS, ADV & IUT   ENG-26

LEARNING ENVIRONMENT: Classroom

ALLOTTED LESSON TIME: 1.0 hr

TRAINING AIDS:

* Figures
  Fig 1: Front Cockpit Component Locator
  Fig 2: Engine Controls (Fwd Cockpit)
  Fig 3: Engine Start System
  Fig 4: Engine Instruments and Indicators
  Fig 5: Engine Start Sequence

STUDY RESOURCES:

* T-45C NATOPS Flight Manual, A1-T45AC-NFM-000

LESSON PREPARATION:

Read:

* The section on the engine in Part I, Chapter 2, "Systems," and Chapter 7, para 7.5, 7.6, 7.7, T-45C NATOPS Flight Manual, A1-T45AC-NFM-000

REINFORCEMENT: N/A

EXAMINATION:

The student is required to read engine system and operating limitations paragraphs in the NATOPS flight manual, receive classroom instruction, and complete assigned CAI lesson(s). The student shall demonstrate knowledge by completing, from memory with 80% accuracy, true/false and multiple choice block examinations. The objectives in this lesson will be tested in either Engineering 29X or Engineering 30X.

LESSON OBJECTIVES

1.4.1.1.2.1
Locate controls for engine start

1.4.1.1.2
Recall function of controls for engine start

1.4.1.1.1
Recall engine start procedures

1.5.3.1.2.3
Identify unacceptable conditions for engine start checks

MOTIVATION

There is nothing more embarrassing than an engine that will not start due to the pilot not following the correct procedures; unless it is an engine that has been damaged on start due to the pilot not following the correct procedures.

OVERVIEW

In this lesson we will build on the basic understanding of engine operation that you gained during Eng-04. You will identify the location and function of engine starting controls and indicators, state the start procedures, and identify acceptable and unacceptable engine starting indications.

In this lesson we will be covering:

* The purpose, function, and location of engine starting controls, switches, and indicators
* The procedures for starting the T-45C engine as well as indications during the starting procedure and starting limitations
* Unacceptable indications during engine start

REFRESHER

* Recall the T-45C engine, fuel control, and engine starting systems.

PRESENTATION

I. Engine start controls and indicators **1.4.1.1.2.1, 1.4.1.1.2**

Sg 1, fr 2
Lesson Organization

ENGINE START PROCEDURES

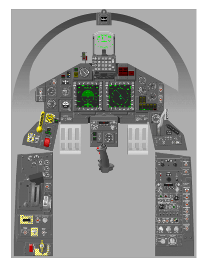
* **Controls and Indicators**
* Starting procedures
* Unacceptable conditions

LESSON NOTES

Refer to Figure 1, Front Cockpit Component Locator, throughout this lesson.

A. Controls

Sg 1, fr 3
Fig 1: *Front Cockpit Component Locator*



Sg 1, fr 4
Fig 2: *Engine Controls (Fwd Cockpit)*

1. IGNITION switch

a. Location: left console, aft of engine control/trim panel, fwd cockpit only

b. Description: two-position switch marked IGNITION - NORMAL/ISOLATE

(1) NORMAL (guarded): controls electrical power supply to ignition system

(2) ISOLATE: deenergizes ignition system (both engine and GTS)

NOTE: Battery switches must be on for power to be present on the 28 VDC essential services bus. Engine start on external power is not authorized.

2. ENGINE start switch

a. Location: left console, aft of throttle, both cockpits

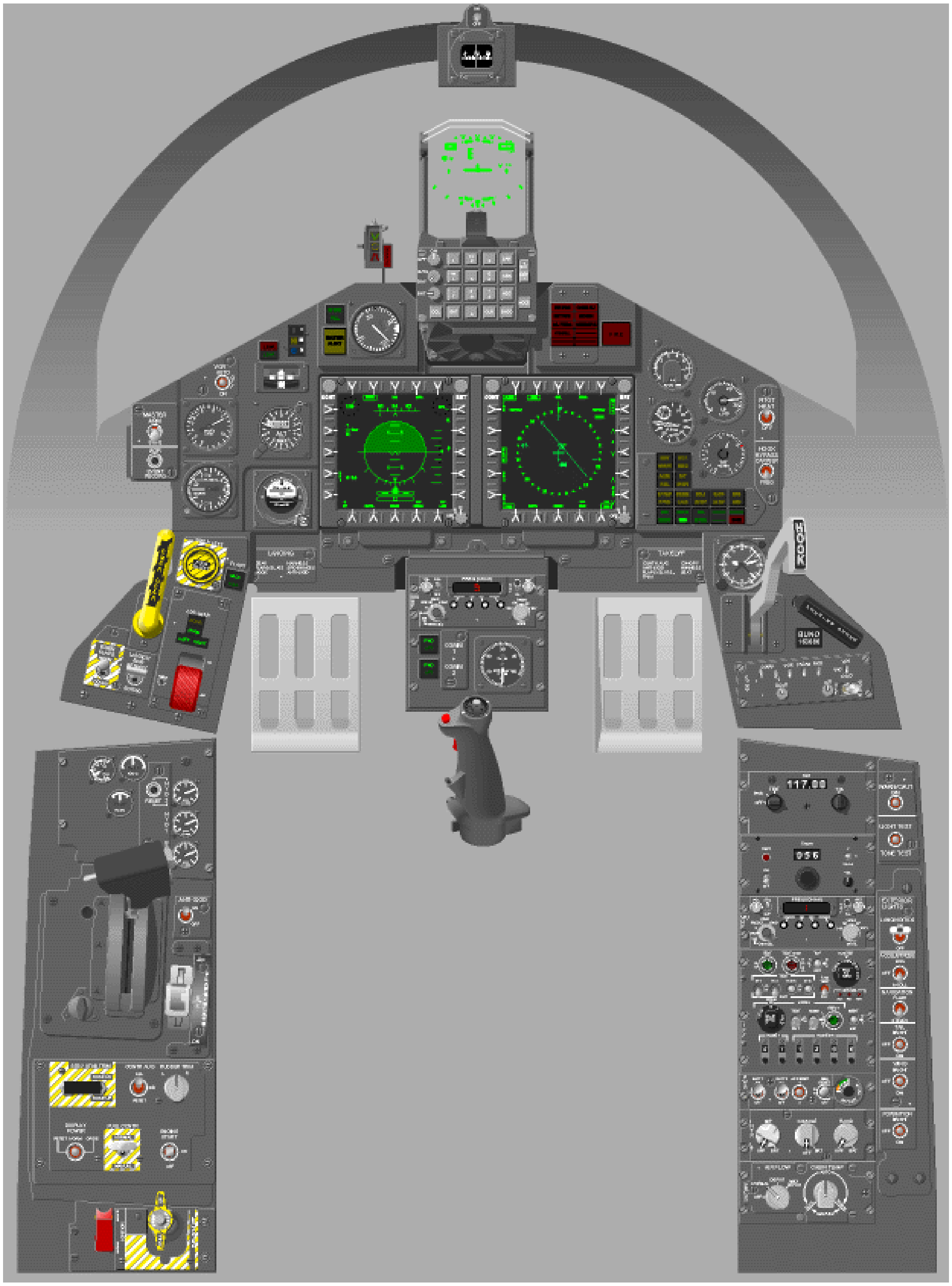


Figure 1: FRONT COCKPIT COMPONENT LOCATOR

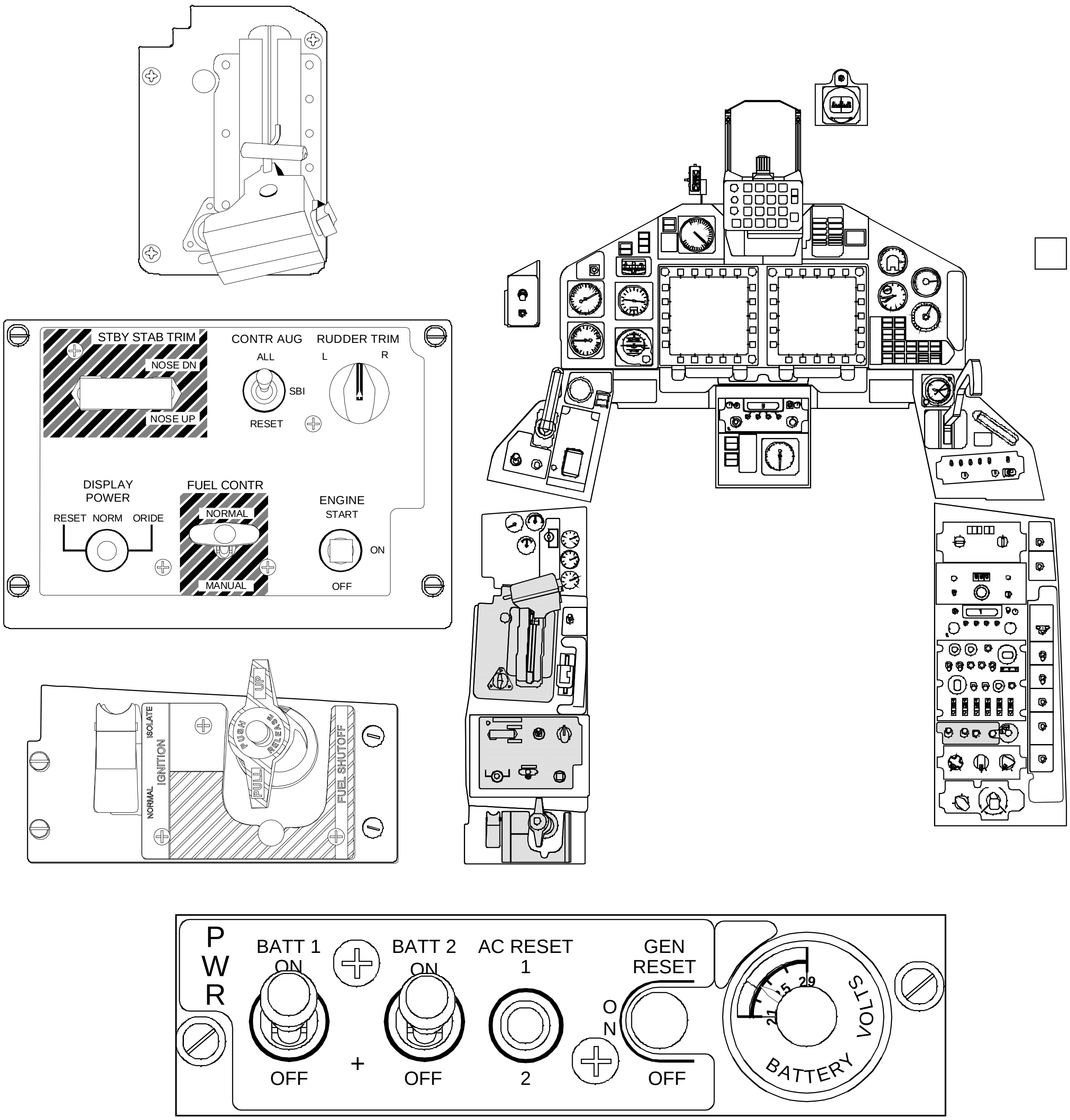


Figure 2: ENGINE CONTROLS (FWD COCKPIT)

b. Description: three-position switch marked ENGINE - START/ON/OFF

(1) START (spring-loaded to ON):

Sg 1, fr 6
Fig 3: Engine Start System

(a) Accelerates GTS from idle to full power

(b) Opens start valve to admit air to air turbine starter (ATS)

(c) Closes start air dump valve

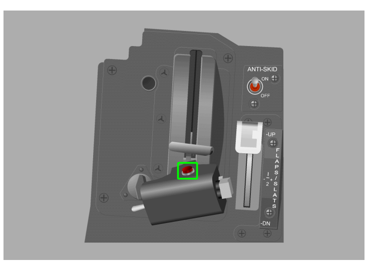
(d) Completes electrical circuit to engine igniters

(2) ON: energizes start control unit

(3) OFF: manually shuts down GTS operation and deenergizes start control unit

3. GTS start button

Sg 1, fr 7
GTS Start Button



a. Location: mounted on front of throttle grip handle, both cockpits

b. Description: momentary press switch

NOTE: The GTS button will fire the engine igniters, with weight on wheels, for duration of press.

(1) Press (momentary):

(a) Signals start control unit (SCU) to start GTS

(b) Energizes engine ignition circuitry to the SCU and engine start switch (with IGNITION switch in NORMAL)

(2) Activates engine igniters for duration of press plus 30 seconds with weight off wheels

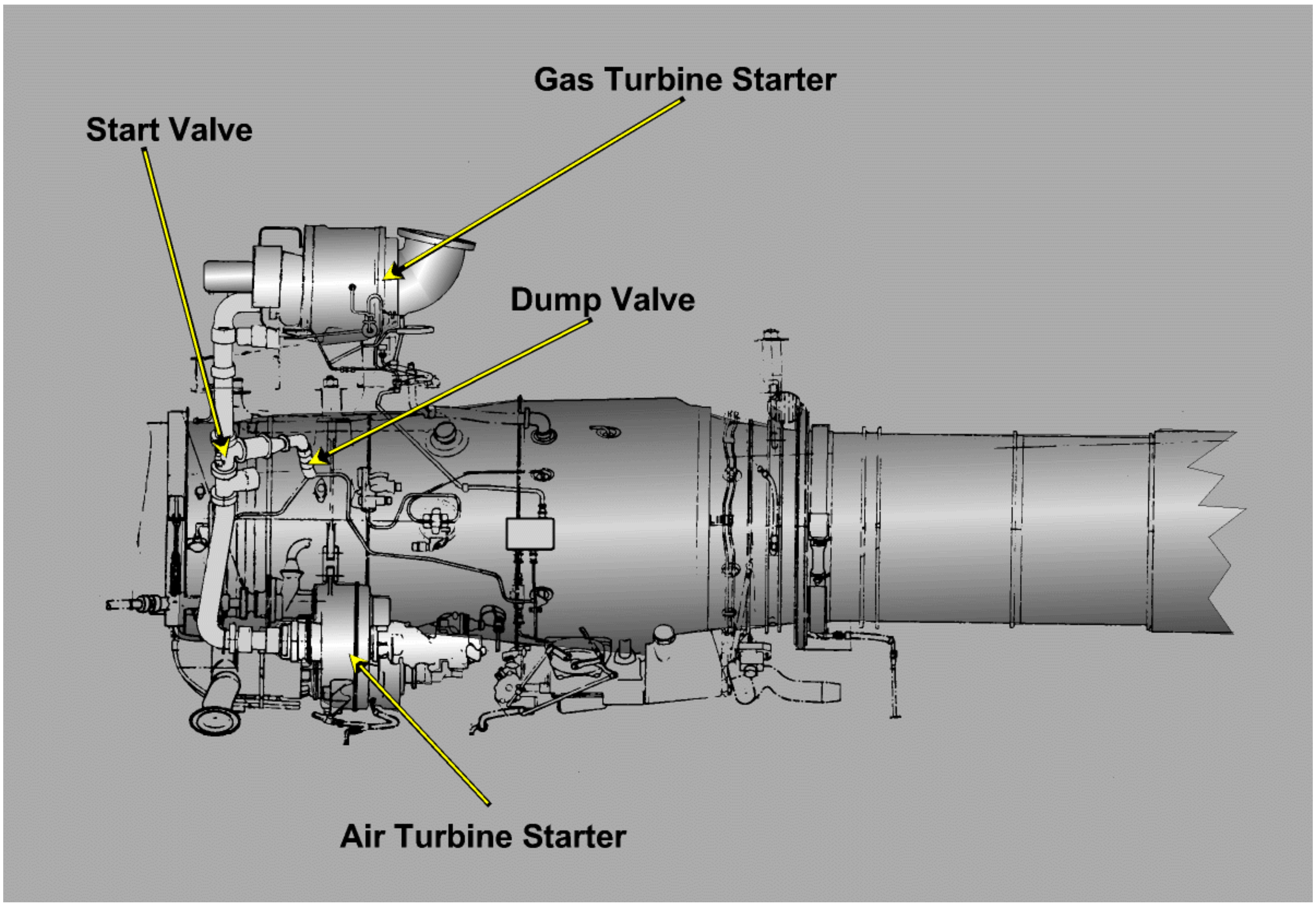
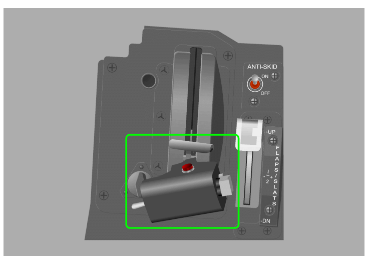


Figure 3: ENGINE START SYSTEM

NOTE: After the GTS start button is released, the ignition ON period is automatically started by a logic circuit in the ECA and terminated by a signal from the start control unit when N_2 accelerates through 45% RPM or after 45 seconds when ignition is terminated and GTS returns to IDLE. ECA monitors N_1 RPM. When N_1 shaft speed reaches 100 RPM in correct direction of rotation, ECA signal is sent to illuminate READY advisory light and fire engine igniters.

Sg 1, fr 8
Throttle



4. Throttle

   a. Location: left console, both cockpits

   b. Description: interconnected and mechanically linked variable position fuel control lever with stops for OFF, IDLE, APPROACH IDLE and full forward (MRT)

      (1) OFF: interrupts or prevents fuel flow to engine

      (2) IDLE: opens fuel shutoff valve to direct fuel to fuel spray nozzles

      (3) APPROACH IDLE: with landing gear down and aircraft weight off wheels, maintains minimum RPM at approximately 72 %

      NOTE: With weight on wheels, ANTI SKID switch set to ON, the approach idle stop retracts immediately. With the ANTI-SKID switch set to OFF, the approach idle stop retracts after two seconds with weight on wheels.

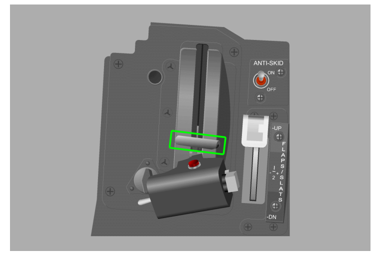
      (4) Full forward: operates engine at military rated thrust (MRT) or full throttle

      NOTE: Pulling release handle above “mid-range” position will hold throttle in position to prevent accidental shutdown of engine.

(5) Finger Lift: Raising the finger lift allows the throttle to be moved past the APPROACH IDLE stop, when engaged, or past the IDLE stop into OFF. The throttle cannot be retarded from above the mid-throttle position to IDLE, or to APPROACH IDLE, with the finger lift raised. To pull the throttle past the APPROACH IDLE stop or IDLE stop, do not raise the finger lift until the throttle is positioned against the stop.

WARNING: To prevent inadvertently shutting down the engine, when bypassing the APPROACH IDLE stop, be sure to release the finger lift before reaching the IDLE position.

Sg 1, fr 8a
Throttle Finger Lift



LESSON NOTES

Refer to Figure 4, Engine Instruments and Indicators, to identify the indicators used when starting the engine.

B. Indicators

Sg 1, fr 9
Fig 4: *Engine Instruments and Indicators*

1. TGT indicator: indicates exhaust gas temperature in degrees centigrade

2. RPM indicator: indicates N_2 compressor speed in percent RPM

3. FUEL FLOW indicator: indicates rate of fuel flow to engine combustion chamber in pounds per hour

4. Voltmeter: indicates battery or generator voltage

5. GTS advisory light: when illuminated, indicates gas turbine air producer has attained idling speed prior to engine start

6. READY advisory light: when illuminated, indicates a low pressure (N_1) shaft speed of 100 RPM or greater in the correct direction of rotation and the igniter circuitry is energized

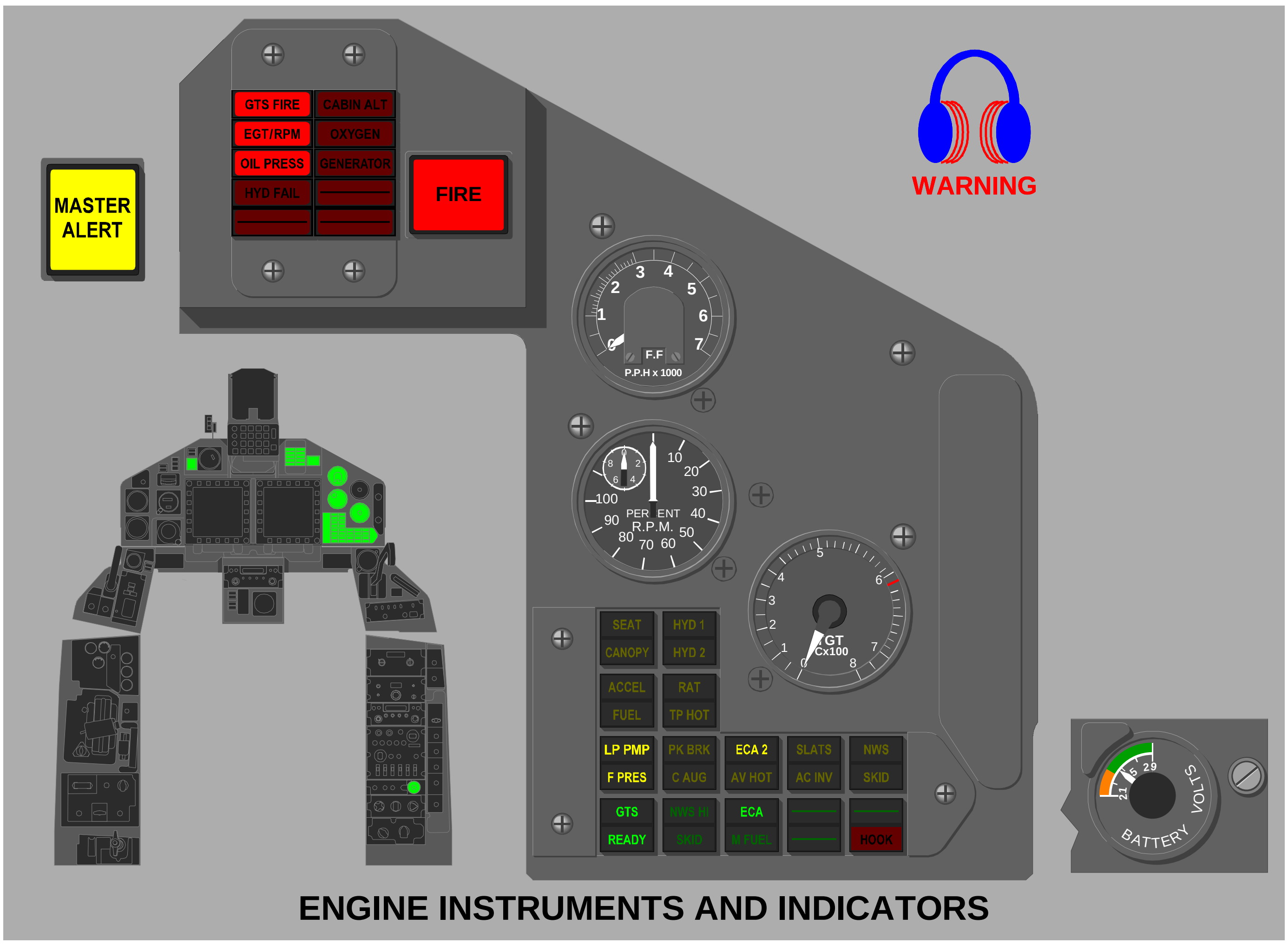


Figure 4: ENGINE INSTRUMENTS AND INDICATORS

7. OIL PRESS warning light: when illuminated, indicates an oil pressure differential (< 10 psi) for more than 10 seconds has occurred

8. F PRES caution light: when illuminated, indicates loss of fuel tank pressurization or an insufficient pressure differential across the boost pump(s)

9. LP PMP caution light: when illuminated, indicates engine driven low pressure fuel pump failure/outlet pressure low

10. FIRE warning light (start malfunction only); when illuminated, indicates engine bay temperature in excess of 300 degrees C

11. GTS FIRE warning light (start malfunction only): when illuminated, indicates air producer bay temperature in excess of 300 degrees C

12. EGT/RPM warning light (start malfunction only): when illuminated, indicates that either the EGT temperature exceeds 650 +/- 8 degrees C or the N_1 rpm exceeds 112.4 +- 1%

13. TP HOT caution light (start malfunction only): when illuminated, indicates temperature greater than 150 degrees C in the tailpipe bay

II. Engine starting procedures **1.4.1.1.1**

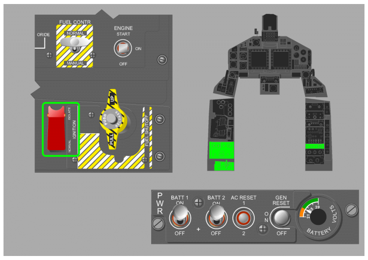
Note: The following italicized steps on preflight checks/ services and engine starting procedures are excerpted from the NATOPS manual.

Sg 2, fr 2
Lesson Organization

ENGINE START PROCEDURES

* Controls and Indicators
* **Starting procedures**
* Unacceptable conditions

Sg 2, fr 3
Switch Positions for Engine Start



A. Exterior inspection

NOTE: Ensure tail pipe pulled full aft prior to starting engine.

B. Interior check - left console

1. Fuel shutoff handle - LOCKED (DOWN)

2. IGNITION switch - NORMAL (GUARDED)

3. ENGINE switch - ON

4. FUEL CONTR switch - NORMAL

5. Throttle friction - OFF

6. Throttle - OFF

C. Prestart checks - battery switches

1. BATT 1 and BATT 2 - ON

2. Alternately select each battery OFF to check individual voltage: 24 volts

3. BATT 1 and BATT 2 - CHECK ON

D. Starting engine

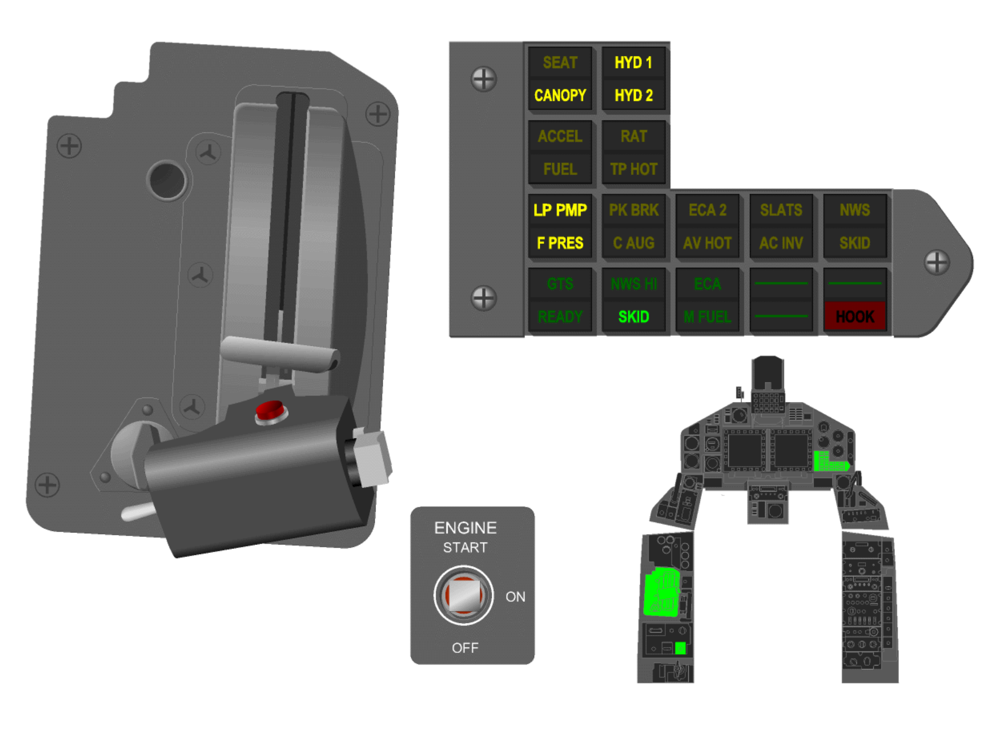
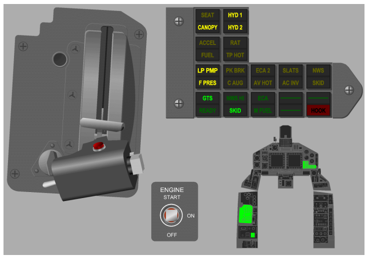


Figure 5: ENGINE START SEQUENCE

Sg 2, fr 4
Fig 5: *Engine Start Sequence*

Sg 2, fr 5, ov 1
Engine Start Sequence



1. *GTS start button - PRESS MOMENTARILY*

   CAUTION: If GTS start attempts are longer than acceptable start time of the GTS START ENVELOPE, subsequent in-flight attempts may exceed the GTS auto shutdown limit.

   a. Signals Start Control Unit to start the GTS

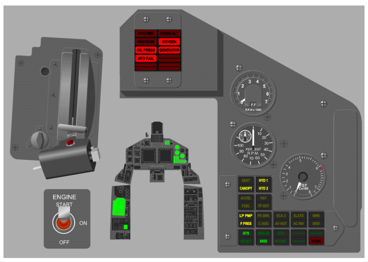
   b. Applies Essential Services Bus power to GTS fuel/oil-pump, GTS starter motor, GTS igniters (through start control unit), and engine igniters

   c. GTS unit starts and reaches idle speed of 86% within 20 seconds

GTS advisory light illuminates

NOTE: Protection circuits within the starting system will shut down the GTS if idle speed is not achieved within 30 seconds after the GTS button is pressed.

Sg 2, fr 6, ov 2
Engine Start Sequence



Sg 2, fr 7, ov 3

2. *Engine switch - START*

   a. Spring-loaded detent initiates engine starting sequence

   b. GTS accelerates to 100%, supplying air-to-air turbine starter

      READY advisory light illuminates within 15 seconds

   c. Air turbine starter (ATS) rotates N_2 shaft

   d. READY advisory light: Indicates that N_1 shaft is rotating in correct direction with shaft speed $\geq$100 rpm and that starting sequence may continue

      CAUTION: If the READY advisory light does not illuminate within 15 seconds, discontinue start attempt, otherwise mechanical damage may result from an overheat condition.

   e. Engine igniter relay applies 28 VDC essential services power from ignition switch to engine igniters

   f. RPM should rise rapidly to approximately 10%

Sg 2, fr 8, ov 4

3. *Throttle - IDLE WHEN RPM BETWEEN 15%-20%*

   a. Opens throttle shutoff valve, allowing SIFCU and FCU to begin metering fuel to engine spray nozzles

   b. You should see an indication of fuel flow

c. Oil pressure warning light should extinguish at approximately 18% N_2 rpm

NOTE: Light-off is indicated by an initial rise in EGT.

WARNING: Do not start the engine with the throttle above ground idle, severe engine damage/turbine destruction may occur.

CAUTION: Advancing throttle to IDLE before READY advisory light illuminates may cause damage to the engine from overheat.

CAUTION: Light-off must occur within 15 seconds after advancing throttle to IDLE.

CAUTION: Secure engine if start EGT limit is rapidly approached and appears likely to be exceeded.

4. TGT and RPM indicators - MONITOR
Ensure GTS and READY advisory lights go out at approximately 45% rpm

Sg 2, fr 9, ov 5

NOTE: TGT, rpm, and fuel flow indications must be closely monitored throughout the engine starting sequence to ensure safe starting and to prevent engine damage.

a. EGT indications during starting phases

(1) Rises rapidly to approximately 300-350 degrees C

(2) Rate of rise should slow above 350 degrees C

(3) Normal starting EGT peaks at approximately 400-450 degrees C

NOTE: Maximum EGT should not exceed 550 degrees C. (570 degrees with a 10-second overshoot)

Sg 2, fr 10, ov 6

b. RPM climbs rapidly toward, and should reach, 52% within 30 seconds of IDLE selection

NOTE: If 45% N_2 RPM not attained within 45 seconds from release of the start switch, the GTS will return to idle.

c. Fuel flow slowly rises with rpm to idle flow of 300-400 pph

d. At starter cut-out speed (45% rpm)

(1) Start control unit shuts down GTS and GTS and READY advisory lights extinguish

(2) Engine ignition units deenergize

(3) Generator comes on-line, and GENERATOR warning light out (may not occur until after N_2 rpm above 61%)

Sg 2, fr 11, ov 7

5. When RPM and EGT stabilize, check:

a. All warning/caution panel lights - OUT EXCEPT HYD 2, CANOPY (if open or unlocked), AND OXYGEN

b. RPM - NOTE, APPROXIMATELY 52%

c. EGT - NOTE, 450 DEGREES C MAXIMUM

Sg 2, fr 12, ov 8

E. Post-start

1. Throttle - ADVANCE SLOWLY TO 70% RPM

CAUTION: Following a start, do not advance the throttle rapidly before the bleed valve closes, as there is a possibility that the engine will overheat. Once the bleed valve is closed there are no restrictions on the rate of throttle movement.

2. *FUEL CONTROL switch - MANUAL*
   M FUEL advisory light illuminates. Note engine RPM may decrease by up to 6%

3. *FUEL CONTROL switch - NORMAL*
   M FUEL advisory light goes out and ensure previous RPM is achieved

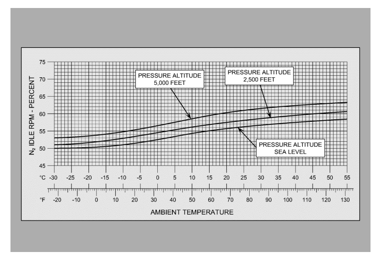
4. *HYD 2 RESET button - PRESS*
   Check that HYD 2 caution light goes out and hydraulic pressure indicates in normal range

5. *Hydraulic pressure - 3000 PSI*

6. *Throttle - IDLE, CHECK EGT AND RPM, ENSURE BLEED VALVE CLOSED AND RPM +/- 2 PERCENT IDLE RPM PER FIGURE 4-2*

   NOTE: Bleed valve closure can be confirmed by noting RPM increased approximately 3% and EGT decreased by 50 degrees C from previous indications.

Sg 2, fr 13
Engine Idle RPM
(NATOPS Fig. 4-2)



PROGRESS CHECK

Question 1 — 1.4.1.1.2
What is the source of electrical power to the engine igniters?

ANSWER: 28 VDC essential services bus

Question 2 — 1.4.1.1.2
Explain the indications of the GTS and READY advisory lights.

ANSWER: The GTS light indicates that the gas turbine starter has started and has reached its idle speed of 86%. The READY light indicates that the engine N_1 shaft is rotating in the correct direction with a shaft speed $\geq$ 100 rpm.

Sg 3, fr 2
Lesson Organization

ENGINE START PROCEDURES

* Controls and Indicators
* Starting procedures
* **Unacceptable conditions**

III. Unacceptable conditions during engine start **1.5.3.1.2.3**

LESSON NOTES

The procedures for ground emergencies occurring during engine start will be covered during the EMFP block.

A. RPM

1. IDLE

a. N_2 rpm not within 55 + 2% (bleed valve closed)

b. Any sudden changes in idle rpm

NOTE: Deviations in engine idle rpm may occur due to any one or a combination of the following: generator loading, bleed valve open or closed, external bleed air demands, hydraulic loading, and altitude adjustments of approximately 1% rpm increase for every 1,500 feet above sea level.

B. Low battery voltage: below 24 VDC prior to start

C. Fuel flow: abnormal indications normally accompanied by high or low EGT and rpm indications

1. IDLE: with bleed air valve opened or closed

a. Maximum: 400 pph

b. Minimum: 300 pph

D. Bleed air valve

1. Failure to close after accelerating rpm above 61 +/- 4% and returning throttle to IDLE

NOTE: The bleed air valve closes at 61 +/- 4% N_2. The Post Start procedure sets the power to 70% to accomplish fuel control, HYD 2 system, and idle/rpm (bleed air valve) checks simultaneously.

a. EGT fails to decrease approximately 50 degrees C

b. RPM remains lower than normal (fails to increase approximately 3%)

2. Closed during engine start cycle: if idle rpm exceeded 57% during start, bleed valve may have closed automatically

a. RPM does not show increase of approximately 3%, but stabilizes at normal idle rpm (55 +/- 2%)

b. EGT does not show decrease of 50 degrees C but stabilizes at normal idle EGT

E. Wet Start: there is an indication of fuel flow but EGT and rpm don't increase after 15 seconds from moving the throttle to idle you have a WET START

F. HUNG Start: RPM stagnates below 45% while EGT continues to rise toward the starting limit of 550 degrees C you have experienced a HUNG start

G. HOT Start: there is an indication of fuel flow and rpm increasing normally but EGT is rapidly approaching 550 degrees or will overshoot 570 degrees for more than 10 seconds you have a HOT start

NOTE: Wind blowing up the tailpipe, extremely high ambient temperature, and starting a hot engine may cause higher than normal EGT indications

H. NO READY ADVISORY: if the READY advisory light doesn't illuminate within 15 seconds of placing the ENGINE switch to START it indicates that N_1 is not rotating in the correct direction or is less than 100 rpm

I. OIL PRESS warning light: if the OIL PRESS warning light fails to go out or illuminates during the start sequence, it indicates inadequate oil pressure differential

J. FIRE warning light: the FIRE warning light indicates an engine bay fire has been detected. The MASTER ALERT caution light flashes and the warning tone will accompany the warning light.

K. GTS FIRE warning light: the GTS FIRE warning light indicates a GTS bay fire has been detected. The MASTER ALERT caution light flashes and the warning tone will accompany the warning light.

L. GTS and READY advisory light remaining on: if the GTS or READY advisory lights do not extinguish with engine rpm above 45%, the GTS and engine ignition have not shut down; this is an unacceptable condition for engine start.

PROGRESS CHECK

Question 3 — 1.5.3.1.2.3
Describe the difference between the indications of a hung start and a wet start.

ANSWER:
1. A hung start is indicated by stagnated rpm below 52% and with slowly rising EGT.

2. A wet start is indicated by fuel flow and no EGT rise within 15 seconds of setting throttle to IDLE.

Question 4 — 1.5.3.1.2.3
During engine start, you observe a rapidly climbing EGT that appears likely to exceed the maximum EGT (550 degrees C). Identify what this indicates and list three causes.

ANSWER: This indicates a hot start and can be caused by wind blowing up the tailpipe, starting a hot engine, or high ambient air temperature.

SUMMARY

Sg 6, fr 2
Review Options

The IGNITION switch controls 28 VDC essential services power to the engine igniter relays and GTS start buttons on each throttle grip. The ENGINE start switches control 28 VDC essential services power to the start control unit and provide the start-main-engine signal. The forward and aft cockpit ENGINE start switches are connected in series, and both must be set to ON to start the engine. Momentarily pressing the GTS start button causes the gas turbine starter to start and accelerate to idle speed and the ignition relay circuitry to be energized. The engine igniters are also activated while the GTS button is depressed. When the engine start switch is set to START, the GTS accelerates to full power and the start valve is open to allow the GTS to supply low pressure air to the ATS which rotates the N_2 shaft. Engine igniters are activated by ECA.

Monitor TGT and rpm gauges during engine start for indications of abnormal operation. No rise in EGT within 15 seconds after introducing fuel is an indication of a wet start. Stagnated rpm below 52% and slowly rising EGT indicate a hung start. A rapid increase in EGT that appears likely to exceed the maximum (550 degrees C) is an indication of a hot start. Starting a hot engine can also result in a higher than normal EGT. Heavy generator or hydraulic loading, an open bleed valve, or high bleed air demands can reduce rpm to below normal.

Abnormal fuel flow indications normally accompany high or low rpm/EGT indications. If abnormal fuel flow is indicated, check the other engine instruments to aid you in determining the problem. The normal idle fuel flow range is 300-400 pph.

CONCLUSION

Properly following the checklist procedures during engine start and recognizing the significance of cockpit indications will significantly increase engine life.

NOTES

LESSON GUIDE

COURSE/STAGE: TS, ADV & IUT / Engineering

LESSON TITLE: Engineering Review

LESSON IDENTIFIER: T-45C TS, ADV & IUT Eng-27/Eng-28

LEARNING ENVIRONMENT: Eng-27 CAI & Eng-28 MIL

ALLOTTED LESSON TIME: Eng-27 -- 2.0
Eng-28 -- 1.0

TRAINING AIDS:

* Wall Charts: Cutaway View T-45C
* Figures
  Fig 1: Electrical System Block Diagram
  Fig 2: Electrical Load Distribution
  Fig 3: Basic Engine Block Diagram
  Fig 4: Engine Fuel System Block Diagram
  Fig 5: Engine Starting System Block Diagram
  Fig 6: Simplified Fuel System Block Diagram
  Fig 7: Aircraft Fuel System Block Diagram
  Fig 8: Hydraulic System Block Diagram
  Fig 9: Main Landing Gear (MLG) Major Components
  Fig 10: Nose Landing Gear (NLG) Major Components
  Fig 11: Nose Wheel Steering (NWS) System Major Components
  Fig 12: Wheel Brake/Anti-Skid System Block Diagram
  Fig 13: Flight Controls
  Fig 14: Flight Controls--Rudder System Components
  Fig 15: Flight Controls--Aileron System Components
  Fig 16: Flight Controls--Stabilator System Components
  Fig 17: Flaps/Slats, Speed Brakes
  Fig 18: Canopy

(9-98) CHANGE 5

TRAINING AIDS (cont.):

Fig 19: Ejection Seat
Fig 20: Minimum Safe Ejection Altitudes
Fig 21: OBOGS Block Diagram
Fig 22: Pilot's Services Panel
Fig 23: ECS Block Diagram
Fig 24: Attitude Director Indicator (ADI) Display
Fig 25: Horizontal Situation Indicator (HSI) Display
Fig 26: AOA System
Fig 27: UHF/VHF Control Panel
Fig 28: IFF Control Panel
Fig 29: COMM Control Panel
Fig 30: Display System Major Components
Fig 31: BIT Status Report
Fig 32: DEU Interface Diagram
Fig 33: Engine Controls (Forward Cockpit)

STUDY RESOURCES:

* T-45C NATOPS Flight Manual, A1-T45AC-NFM-000
* Lesson Guides for Eng-01 through Eng-26

LESSON PREPARATION:

Review:

* Materials from Eng-01 through Eng-26 and note any questions or problems concerning content and progress check questions

REINFORCEMENT: N/A

EXAMINATION:

The objectives in this lesson will be tested in either Engineering 29X or Engineering 30X.

LESSON OBJECTIVES

1.4.4.3.1
Recall major components of the electrical system

1.4.4.2.1
Recall operating characteristics of the electrical system

1.4.4.2
Recall interfaces between the electrical system and other a/c systems

1.4.6.3.1
Recall major components of the engine system

1.4.6.2.1
Recall operating characteristics of the engine system

1.4.6.2
Recall interfaces between the engine system and other a/c systems

1.8.1.1.5.1
Identify indications of engine stalls

1.8.1.1.10.1
Identify indications of engine vibrations

1.8.1.1.13.1
Identify indications of engine icing

1.4.7.2.1
Recall operating characteristics of the fuel system

1.4.7.3
Recall function and location of fuel system controls, switches, and indicators

1.4.7.2
Recall interfaces between the fuel system and other a/c systems

1.8.1.2.5.1
Identify indications of boost pump failure

1.8.1.2.2.1
Identify indications of fuel tank pressurization failure

1.4.8.3.1
Recall major components of the HYD 1 system

1.4.8.3.2
Recall major components of the HYD 2 system

1.4.8.2.1
Recall operating characteristics of the HYD 1 system

1.4.8.2.2
Recall operating characteristics of the HYD 2 system

1.4.8.3
Recall function, purpose, and location of HYD 1 system controls, switches, and indicators

1.4.8.5
Recall function, purpose, and location of HYD 2 system controls, switches, and indicators

1.4.8.2
Recall interfaces between the hydraulic system and other a/c systems

1.8.1.5.6.1
Identify indications of HYD 1 slow loss of pressure

1.8.1.5.7.1
Identify indications of HYD 2 slow loss of pressure

1.5.4.1.1.1
Recall operating characteristics/limitations of the landing gear system

1.5.4.1.1.1.1
Locate landing gear controls and indicators

1.4.10.3.1
Recall major components of the brake system

1.4.11.3.1
Recall major components of the anti-skid system

1.4.10.3
Recall function, purpose, and location of brake system controls, switches, and indicators

1.4.11.3
Recall function, purpose, and location of anti-skid system controls, switches, and indicators

1.4.10.2.1
Recall operating characteristics of the brake system

1.4.11.2.1
Recall operating characteristics of the anti-skid system

1.4.9.3
Recall function, purpose, and location of nose wheel steering system controls, switches, and indicators

1.4.9.2.1
Recall operating characteristics of the nose wheel steering system

1.4.12.3
Recall function, purpose, and location of launch bar system controls, switches, and indicators

1.4.12.2.1
Recall operating characteristics of the launch bar system

1.4.13.3
Recall function, purpose, and location of tail hook system controls, switches, and indicators

1.4.13.2.1
Recall operating characteristics of the tail hook system

1.4.9.2
Recall interfaces between the nose wheel steering system and other a/c systems

1.4.10.2
Recall interfaces between the brake system and other a/c systems

1.4.12.2
Recall interfaces between the launch bar system and other a/c systems

1.4.11.2
Recall interfaces between the anti-skid system and other a/c systems

1.4.13.2
Recall interfaces between the tail hook system and other a/c systems

1.4.14.3.1
Recall major components of the flight control system

1.4.14.2.1
Recall operating characteristics of the flight control system

1.4.14.2.1.1
Recall operating characteristics of the aileron system

1.4.14.3.1.3
Recall major components of the stabilator system

1.4.14.2.1.2
Recall operating characteristics of the stabilator system

1.4.14.3.1.4
Recall major components of the rudder system

1.4.14.2.1.3
Recall operating characteristics of the rudder system

1.4.14.3
Recall function, purpose, and location of the flight control system controls, switches, and indicators

1.5.4.1.2.1
Recall operating characteristics of the flap/slat system

1.4.19.3
Recall function, purpose, and location of speed brake system controls, switches, and indicators

1.4.19.2.1
Recall operating characteristics of the speed brake system

1.4.14.2
Recall interfaces between the flight control system and other a/c systems

1.5.4.1.2.1.5
Recall interface between the flap/slat system and other a/c systems

1.4.19.2
Recall interfaces between the speed brake system and other a/c systems

1.3.5.1.4.5
Recall major components of the T-45 canopy

1.3.5.1.4.2
Recall purpose and function of ejection seat components and controls

1.3.5.1.3
Recall operating characteristics of the ejection seat

1.3.5.1.3.1
Recall the ejection parameters

1.4.16.2.1
Recall operating characteristics of the OBOGS

1.4.15.2.1
Recall operating characteristics of the ECS

1.4.15.3
Recall function, purpose, and location of the ECS controls, switches, and indicators

1.4.5.3.1
Recall major components of the flight instrument system

1.4.5.2.1
Recall operating characteristics of the flight instrument system

1.4.5.3
Recall function, purpose, and location of flight instrument controls, switches, and indicators

1.4.5.2
Recall interfaces between the flight instruments and other a/c systems

1.4.18.3.1
Recall major components of the CNI system

1.4.18.2.1
Recall operating characteristics of the CNI system

2.4.7.1.1
Recall the function and operation of the radio instruments

1.4.18.3
Recall function, purpose, and locations of CNI system controls, switches, and indicators

1.4.1.1.2
Recall function of controls for engine start

1.4.1.1.1
Recall engine start procedures

1.5.3.1.2.3
Identify unacceptable conditions for engine start checks

1.4.18.4.3
Recall interface between the display system and other a/c systems

1.4.18.4.3.1
Recall function, purpose, locations of display controls, switches, indicators

1.4.18.4.3.2
Recall operating characteristics of the display system

2.8.2.1
Identify indications of multi-function display failure

MOTIVATION

We have covered the T-45C Engineering block. You are responsible for all material. This lesson reviews T-45C systems to clear up any questions you may have.

OVERVIEW

This lesson provides a review of the material in the test and a sampling of the content from each lesson in the Engineering block to include:

* Major aircraft systems
  - Major components
  - Associated cockpit controls and indicators
  - Major aircraft interfaces
* Engine starting procedures

Sg 5, fr 1

Fig: 1
Electrical System Block Diagram

PRESENTATION

I. Electrical System & Electrical System Malfunctions

A. Electrical system major component

Sg 5, fr 2
Generator

1. Generator

a. Functional: produces aircraft main source of electrical power

b. Physical: 28 VDC, 9 KW brushless generator

Sg 5, fr 3
Batteries

2. Batteries

a. Functional

(1) Provide DC power to start aircraft, emergency power if generator fails

(2) With generator failure, two good batteries will give power for 27 minutes. With only one good battery, power will only be available for 12 minutes

b. Physical: two sealed lead/acid 24 VDC, 18 AH batteries

Sg 5, fr 4
Inverters

3. Inverters

a. Functional: convert aircraft 28 VDC to 115 VAC and 26 VAC, 400 Hz, single-phase power

b. Physical: two identical 500 W inverters

4. Power control

Sg 5, fr 5
Voltage Regulator

a. Voltage regulator controls generator output to match electrical loads

Sg 5, fr 6
Overvoltage Unit

b. Overvoltage unit monitors generator voltage and takes generator off-line if output voltage exceeds 30.2 VDC

c. Undervoltage unit

Sg 5, fr 7
Undervoltage Unit

(1) At 25 volts or less deenergizes

(a) On aircraft 165456 and below without AFC 199

(i) Activates relay disabling one inverter illuminating AC INV caution light

(ii) Activates relay disconnecting non-essential AC bus

(b) On aircraft 165457 and up and on aircraft 165456 and below with AFC 199 incorporated

(i) Both inverters remain on-line and AC INV caution does not illuminate

(ii) Activates relay disconnecting non-essential AC bus

(2) Functional: monitors voltage on generator bus

(3) Physical: consists of transistorized voltage-sensing, time-delay circuit and changeover relay

5. Power protection

a. Fuse connects generator to 28 VDC generator bus and provides 300 amp generator protection

Sg 5, fr 8
Fuse

b. Buses and circuit breakers

(1) Three essential buses (two AC and one DC) powered by battery power if generator fails -- e.g., IFF, fire detection, warning and caution advisory panels, and UHF/VHF #1

Sg 5, fr 9
Essential Buses

(2) Three non-essential buses (two AC and one DC) drop off the line if the generator fails

(3) Push-pull thermal circuit breakers of various amperage levels provide

(a) Bus connection for aircraft electrical systems

(b) Isolation/protection for their respective functions in the event of electrical failures

Sg 5, fr 10
Relays

6. Power distribution relays and contactors

a. Generator Fail and Inverter No. 2 Power Input Relay removed and inverter No. 2 wired directly to 28 VDC essential services bus on aircraft 165457 and up and on aircraft 165456 and below with AFC 199 incorporated

b. AC isolation relays disconnect non-essential services 115 and 26 VAC buses from 115 and 26 VAC essential buses when generator goes off-line

c. Three contactors provide bus connection to battery and external power

Sg 5, fr 11
Fig 1:
Electrical System Block Diagram

B. Electrical system operational characteristics

Sg 5, fr 12
Generator

1. DC power system: consists of two batteries, generator, voltage regulator, overvoltage unit, two 28 VDC buses, and undervoltage unit

a. Power generation

(1) Main electrical power supplied by 28 VDC generator

Sg 5, fr 13
Voltage Regulator

(2) During ground starts the GEN caution light will extinguish when a suitable DC output is obtained 25-25.2 VDC (at approximately 42% RPM) the voltage regulator controls output voltage to 28.2-29.2 VDC by adjusting generator excitation voltage

Sg 5, fr 14
Overvoltage Unit

(3) Overvoltage protection unit monitors generator output and prevents voltage from exceeding 30.2 VDC by shutting down generator

b. Distribution

Sg 5, fr 15
Generator Bus

(1) 28 VDC generator bus supplies non-essential services

Sg 5, fr 16
28 VDC Essential Services Bus

(2) 28 VDC essential services bus links to 28 VDC generator bus through two power isolation diodes and supplies power for charging batteries

c. Battery operations

Sg 5, fr 17
Batteries

(1) Two 24 volt, 18 AH lead acid batteries supply power to essential services bus providing DC power during engine start and emergency voltage to 28 VDC essential services bus with generator failure

Sg 5, fr 18
Ground Service Bus

(2) Battery #1 supplies power to ground services bus

Sg 5, fr 19
Electrical System Block Diagram

2. AC power system: consists of two identical 26/115 VAC, 400 Hz single phase inverters, two 26 VAC buses, and two 115 VAC buses

Sg 5, fr 20
Inverters

a. 26 and 115 VAC power developed by two identical inverters powered by 28 VDC essential services bus

b. Inverters are internally protected for input or output faults

(1) Automatically reset when input fault clears

(2) Require manual reset for output fault

Sg 5, fr 21
26/115 VAC Essential Services Buses

c. 26 and 115 VAC essential buses provide distribution for AC essential services

Sg 5, fr 22
Non-Essential AC Buses

d. 26 and 115 VAC non-essential buses provide distribution for non-essential services

e. When generator is off-line, 26 and 115 VAC non-essential buses are taken off-line

f. Two 6 VAC buses provide distribution from 115 VAC essential and non-essential buses to wing navigation and formation lights

Sg 5, fr 23
External Electrical Connections

3. Ground power system

   a. External 28 VDC power may be connected to aircraft for battery charging and ground maintenance

Sg 5, fr 24
Ground Power Panel

   b. Ground power panel has external power monitor sw and ground power sw #1 and #2

Sg 5, fr 35
Electrical Load Distribution - Part 1 of 3

Fig 2: *Electrical Load Distribution*

C. Electrical system aircraft interfaces **1.4.4.2**

1. 28 VDC generator bus: equipment powered

   a. Cockpit light

   b. LDN/TAXI light

   c. ANTI-COLL/STROBE lights

   d. Right Hand-Multifunction Display (MFD)

Sg 5, fr 35
Electrical Load Distribution - Part 2 of 3

2. 28 VDC essential services bus: equipment powered

   a. MAP lights

   b. EMERG lighting

   c. NAV lights - TAIL

   d. Left Hand-Multifunction Display (MFD)

   e. TACAN

Sg 5, fr 35
Electrical Load Distribution - Part 3 of 3

3. 115 VAC essential bus: equipment powered

   a. GPS/Inertial Navigation Assembly (GINA)

   b. Warning/caution/advisory dimming (14/10 VAC)

   c. Emergency NLG door actuator

4. 115 VAC non-essential bus: equipment powered

   a. Display Electronics Unit (DEU) cooling fan

   b. Head-up Display (HUD)

c. Radar altimeter

5. 26 VAC essential bus: equipment powered

   a. Airborne data recorder

   b. TACAN-azimith computer

6. 26 VAC non-essential bus: equipment powered

   a. HUD

   b. VOR/ILS/MB

   c. Control augmentation

7. 28 VAC essential bus - left and right console lights

8. 6 VAC essential bus - NAV lights (wing)

9. 6 VAC non-essential bus - formation lights

10. 5 VAC non-essential bus - main instrument panel lights

D. Electrical system malfunctions

1. Generator failure **1.8.1.3.1.1.1**

Sg 5, fr 36
Generator Failure

   a. Generator failure: can be described as either undervoltage or overvoltage condition

      (1) At 25 volts or less deenergizes, illuminating the GENERATOR warning light

         (a) On aircraft 165456 and below without AFC 199

            (i) Activates relay disabling one inverter illuminating AC INV caution light

            (ii) Activates relay disconnecting non-essential AC bus

(b) On aircraft 165457 and up and on aircraft 165456 and below with AFC 199 incorporated

(i) Both inverters remain on-line and AC INV caution does not work

(ii) Activates relay disconnecting non-essential AC bus

(c) C AUG caution light (airspeed (less than 217 knots), F PRES caution light (after 30 sec) illuminate and right MFD disabled

(2) Overvoltage: If generator output exceeds 30.2 VDC, overvoltage unit takes generator off-line, creating an undervoltage condition and indications as described above

(3) Generator reset: reset may be attempted by moving generator switch momentarily to GEN RESET

b. Verifications

(1) Voltmeter reads 24 volts or less

(2) Loss of generator bus equipment

(3) Loss of nonessential services

c. Effects on flight safety

(1) If generator will not reset, two good batteries will give power for 27 minutes. With only one good battery, power will only be available for 12 minutes

(2) Requires maintaining VMC and landing as soon as possible

NOTE: Reducing the electrical load on the batteries will prevent premature loss of emergency battery power.

2. Inverter failure

Sg 5, fr 39
Single/Double Inverter Failure

a. Single inverter failure

(1) AC INV caution light illuminates (along with MASTER ALERT and caution tone)

(2) GENERATOR warning light remains off

(3) Loss of non-essential AC services

b. Double inverter failure: indications same as single inverter loss, except all AC services are lost

(1) If reset of AC inverter not possible, TACAN azimuth, and GINA will be lost due to loss of VAC

(2) Requires use of standby instruments for IMC

NOTE: The standby attitude indicator does not depend on aircraft AC inverters. It will continue to operate with 28 VDC supplied from the 28 VDC essential services bus.

(3) Maintain VMC if possible and land as soon as practicable

(4) Normal instrument approaches impossible -- limited to radar approaches

II. Engine System

A. Engine system major components

Sg 2, fr 6
Major Engine Components

Fig 3: *Basic Engine Block Diagram*

1. Engine: twin spool, medium bypass, axial flow turbofan producing approximately 5527 lb of thrust

a. Air intake and compression

(1) Air intake and compression: two inlet ducts route air to N_1, a two-stage low pressure compressor

(2) Compressed air from N_1 then routed to N_2 five stage compressor and to bypass duct

b. Combustion

(1) Fuel is introduced through 18 fuel spray nozzles and mixed with N_2 compressed air in annular combustion chamber

(2) Two high energy 12-joule igniter plugs ignite fuel/N_2 air mixture. Mixture expands, forcing high pressure gases into turbine section

c. Power generation

(1) N_2 and N_1 turbines extract energy from gases exiting combustion chamber to drive their respective compressors through coaxial shafts

(2) Internal gearbox extracts mechanical energy from N_2 shaft, providing power to external gearbox

(3) External gearbox mechanically drives aircraft accessories, e.g., generator, hydraulic pumps, and fuel pumps

Sg 2, fr 18
Engine Fuel Control System

Fig 4: *Engine Fuel System Block Diagram*

2. Engine fuel system: engine-driven low- and high-pressure fuel pumps with manual and automatic fuel metering controls

a. Automatic (NORMAL) controls override mechanical controls, preventing engine from exceeding operating limits (fuel control selector switch set to NORMAL)

b. Fuel transferred to engine LP fuel pump from aircraft fuel system

c. LP fuel pump: mounted on and driven by external gearbox; maintains fuel pressure to HP fuel pump, preventing HP fuel pump cavitation

d. HP fuel pump: mounted on and driven by external gearbox; supplies HP fuel to fuel control unit (FCU) and sub-idle fuel control unit (SIFCU)

e. Engine control amplifier (ECA): trims fuel flow in response to T6 temp (EGT) and N_1 speed

3. Engine lubrication system: self-contained, engine-driven, full-flow recirculating system

Sg 2, fr 29
Lubrication System

4. Engine starting system: engine is started (on ground or by assisted relight in flight) by gas turbine starter (GTS) and air turbine starter

Sg 2, fr 40
Engine Starting System

Fig 5: Engine Starting System Block Diagram

a. Starting system component function

(1) Gas turbine starter: annular reverse-flow gas turbine air-producer unit which supplies starting air to motor the Air Turbine Starter (ATS)

(2) Air turbine starter: output shaft drives engine N_2 shaft through external gearbox

(3) Start control unit: sequences start cycle by monitoring speeds of GTS, air turbine starter, and engine

b. Engine starting component function

(1) Bleed air valve: relieves pressure from N_2 compressor to ease engine starting and prevent N_1 compressor stalls

(2) Igniters: two high-energy, 12-joule igniter plugs fitted to engine combustion chamber are supplied by 28 VDC essential services bus

5. Bleed air system

a. Internal airflow: continuous flow of compressor air, used internally in engine for

Sg 1, fr 3
Engine Controls

Fig 33: *Engine Controls (Forward Cockpit)*

(1) Pressurizing oil seals to prevent oil bleeding into engine airflow and hot gases fromentering oil system

(2) Cooling

(a) Engine shafts and bearing thrust loading

(b) Rear face of N_2 turbine

(c) Both sides of N_1 turbine

(d) N_1 turbine vane

(e) N_2 turbine bearings

(3) Anti-icing intake spinner

b. External airflow: fifth-stage N_2 compressor delivery air (P3), tapped from four areas on engine case for

(1) On-board oxygen generation system (OBOGS)

(2) Environmental control system (ECS) and overboard engine bleed

(3) Fuel tank pressurization

(4) P1 probe anti-icing

c. Engine bleed air valve; reduces engine load during start

NOTE: An engine bleed air valve that has failed to the open position could cause up to a 25% loss in thrust.

B. Engine system controls, switches, and indicators cockpit controls: all engine function controls located on left consoles, both cockpits

1. IGNITION switch (fwd cockpit only)

a. NORMAL (guarded): controls power supply to ignition system

b. ISOLATE: deenergizes ignition system

2. ENGINE start switch

Sg 1, fr 4
Engine Controls

a. START (spring loaded to ON): accelerates GTS to full power to start engine, closes GTS dump valve, routes air to ATS

b. ON: energizes start control unit

c. OFF: manually shuts down GTS operation and deenergizes start control unit

3. GTS start button

Sg 1, fr 5
Engine Controls

a. When momentarily pressed, starts the GTS and energizes ignition

b. Activates engine igniters for duration of press (+30 seconds airborne)

4. Throttle friction knob (fwd cockpit only): when rotated, adjusts throttle friction. Clockwise rotation increases friction

5. Throttle

Sg 1, fr 6
Engine Controls

a. OFF: interrupts or prevents fuel flow to engine

b. IDLE: opens fuel shutoff valve to direct fuel to fuel spray nozzles

c. APPROACH IDLE: with landing gear down and aircraft weight off wheels, maintains minimum rpm at approximately 72%

d. Full forward: operates engine at military rated thrust (MRT)

6. Idle stop lever: when pulled, permits movement of throttle past APPROACH IDLE stop to OFF

a. Located on front of throttle below throttle grip in both cockpits

b. Pulling lever up allows throttle to be moved aft past approach idle stop (if engaged) or idle stop (throttle off)

   NOTE: The stop lever should be gradually released while moving the throttle from APPROACH IDLE to IDLE. The lever should be pulled again to move the throttle past APPROACH IDLE stop and IDLE stop to OFF.

Sg 1, fr 8
Engine Controls

7. FUEL SHUTOFF handle (fwd cockpit only)

   a. Down: permits fuel flow to supply engine and GTS

   b. Pull up: isolates aircraft fuel system from the engine and GTS

Sg 1, fr 9
Engine Controls

8. FUEL CONTROL switch (lever-locked)

   a. NORMAL: selects main fuel control system

   b. MANUAL: selects manual fuel control system

9. Cockpit indicators

Sg 1, fr 10
Engine Indicators, a-d

   a. M FUEL advisory light: indicates manual fuel control system selected

   b. ECA advisory light: indicates single-lane ECA failure

   c. ECA 2 caution light: indicates total engine control amplifier failure (both lanes)

   d. LP PUMP caution light: indicates engine-driven low pressure fuel pump failure or clogged low pressure fuel filter (<35 psi)

Sg 1, fr 11
Engine Indicators, e-j

   e. ACCEL caution light: indicates initial shot solenoid valve and/or steam ingestion bleed valve is not in the commanded position

f. READY advisory light: indicates a low pressure (N_1) shaft speed of 100 rpm or greater in the correct direction of rotation and the igniters are energized

g. GTS advisory light: indicates gas turbine starter has attained idling speed prior to engine start

h. RPM indicator: indicates N_2 compressor speed in percent rpm

i. EGT indicator: indicates exhaust gas temperature in degrees C

j. FUEL FLOW indicator: indicates rate of fuel flow to combustion chamber in pounds per hour (pph)

k. FIRE warning light: indicates engine bay temperature exceeds limits (572 degrees F/300 degrees C)

Sg 1, fr 12
Engine Indicators, k-i

l. TP HOT caution light: indicates tailpipe bay temperature exceeds limits (302 degrees F/150 degrees C)

m. GTS FIRE warning light: indicates GTS bay temperature exceeds limits (572 degrees F/300 degrees C)

Sg 1, fr 13
Engine Indicators, m-o

n. EGT/RPM warning light: indicates either EGT or N_1 rpm exceeds limits (650 +/- 8 degrees C/112.4 +/- 1% RPM)

o. OIL PRESS warning light: indicates low oil pressure differential (<10 psi)

C. Engine operating characteristics

Sg 2, fr 45
Engine Normal Operation

1. EGT and RPM

a. Idle

(1) rpm 55% +/- 2% at sea level with bleed valve closed

(2) EGT varies between 350° and 450° C

b. Takeoff

(1) rpm is 98 - 100%

(2) EGT should not exceed 610° C. May raise to 645° C for up to 20 seconds

(3) Fuel flow approximately 4800 pph

c. In flight

(1) MRT - 104% and 610° C for 30 min/ flight hour

(2) Maximum transient/acceleration is 104% and 645° C for 20 seconds

(3) Maximum continuous is 100% and 550° C

Sg 2, fr 54
Engine Pressure and Temperature

2. Air intake and compression

a. Compressor (N_1): two compressor stages

b. Compressor (N_2): five compressor stages which raises air pressure and discharges it into combustion chamber

c. Bypass air (N_1 compressor air)

(1) N_1 compressor bypass air is routed through an annular bypass duct and mixed with turbine exhaust gases in exhaust mixer

(2) Small portion of bypass air is tapped from bypass duct and used to cool exhaust cone

3. Combustion (N_2 compressor air) fuel from fuel control system introduced through 18 fuel spray nozzles and mixed with N_2 compressed air in annular combustion chamber

4. Power generation

   a. N_2 and N_1 turbines extract energy from gases exiting combustion chamber to drive their respective compressors through coaxial shafts

   b. Internal gearbox extracts mechanical energy from N_2 shaft, providing power to external gearbox

   c. External gearbox mechanically drives engine and aircraft accessories, e.g., generator, hydraulic pumps, and fuel pumps

5. Monitoring **1.4.6.5**

   Sg 2, fr 55
   Primary Instruments and MFD Engine Display

   a. RPM: sensed by a tachometer generator attached to high-speed gearbox measures N_2 shaft speed

      (1) Max rpm: 104%

      (2) Max continuous rpm: 100%

      (3) Idling speed: 55 +/- 2% at sea level (with bleed valve closed)

   b. Exhaust gas temperature (EGT): thermocouple junction box derives EGT information from two thermocouples mounted in gas flow just aft of N_1 turbine

      (1) Military Rated Thrust (MRT): 610 degrees C, time restricted to 30 minutes per flight hour

      (2) Maximum continuous: 550 degrees C, time unrestricted

(3) Idle: 450 degrees C, time unrestricted

(4) Transient/acceleration: 645 degrees C, time restricted to less than 20 seconds

(5) Ground start: 550 degrees C

(6) Transient during ground start: 20 degrees C overshoot, time restricted to 10 seconds

(7) Airstart: 600 degrees C

(8) Transient during airstart: 50 degrees C overshoot, time restricted to 10 seconds

c. Fuel flow

(1) Idle: 300-400 pph

(2) Maximum: 6410 pph

d. Fire detection system

(1) Detects fire or overheat condition in GTS and engine bays

(2) Fire detected if engine or GTS bay temperature reaches 300 degrees C (572 degrees F)

e. Tailpipe hot detection system: TP HOT Caution Light on if tailpipe bay temperature exceeds 150 degrees C (302 degrees F)

Sg 2, fr 56
Fig 4:
Engine Fuel System Block Diagram

5. Normal fuel control

a. Functional description: fuel transferred to engine LP fuel pump from aircraft fuel system. Automatic (NORMAL) controls override mechanical controls, preventing engine from exceeding operating limits (when FUEL CONTROL switch set to NORMAL)

(1) LP fuel pump: driven by external gearbox, pump maintains fuel pressure to HP fuel pump, preventing HP fuel pump cavitation

Sg 2, fr 57
LP Fuel Pump

(2) Fuel-cooled oil cooler (FCOC): heat exchanger unit transfers oil heat to fuel, reducing or eliminating fuel system icing

Sg 2, fr 58
Fuel Cooled Oil Cooler

(3) Filter: removes foreign matter from fuel

Sg 2, fr 59
Filter

(4) HP fuel pump: driven by external gearbox, supplies HP fuel to fuel control unit (FCU) and SIFCU

Sg 2, fr 60
HP Fuel Pump

(5) FCU: fuel flow scheduling unit with acceleration control and altitude and airspeed compensation

Sg 2, fr 61
FCU

(a) Initial shot solenoid provides increased fuel flow to increase engine surge margin during engine acceleration

i) Enabled when altitude decreases through 7,700 +/- 500 feet

ii) Disabled when altitude increases through 9,500 +/- 300 feet

(b) Acceleration switch dampens throttle valve response for rapid throttle movements

Sg 2, fr 62
Acceleration Switch

(c) Servo pressure control maintains constant pressure drop across throttle valve, compensating for changes in airspeed and altitude

Sg 2, fr 63
Servo Pressure Control

(d) Solenoid (fuel trim): trims basic fuel flow in response to engine control amplifier (ECA) inputs

Sg 2, fr 64
Solenoid (Fuel Trim)

(e) ACCEL caution light illuminates if solenoid not in commanded position

Sg 2, fr 65
Engine Control Amplifier

(6) ECA: trims fuel flow to maintain EGT and N_1 rpm within limits

(a) Two independent control modules (lanes), adjust fuel trim in conjunction with fuel trim solenoid

i) Each lane operates independently, with only one in control

ii) If one lane fails, green ECA advisory illuminates, and backup lane takes control

iii) If both lanes fail, ECA 2 caution light illuminates

(b) If either EGT or N_1 shaft speed exceeds operating limits, ECA signals the FCU, reducing fuel flow

Sg 2, fr 66
SIFCU

(7) SIFCU: meters fuel to spray nozzles during start cycle to ensure proper initial acceleration

b. Monitoring: fuel flow is automatically controlled by FCU in conjunction with ECA and throttle position when FUEL CONTROL switch set to NORMAL

Sg 2, fr 67
Manual Fuel System

6. Manual fuel control system

a. Functional description

(1) Operates similarly to main fuel control, but automatic engine limiting controls do not function (FUEL CONTROL switch set to MANUAL)

(2) Receives fuel from HP fuel pump

(3) Special cautions must be observed because automatic fuel protections are inoperative

(a) Rapid throttle movements may cause erratic engine operation

(b) SIFCU inoperative when MANUAL FUEL is selected

(c) ECA inoperative: pilot must monitor and control N_2 shaft rpm and EGT through throttle movements

b. Monitoring: engine indications (RPM, EGT, and FUEL FLOW) in manual fuel control same as normal fuel control indications

7. Engine lubrication system

Sg 2, fr 68
Engine Lubrication System

a. Functional description provides lubrication of engine shaft bearings and internal and external gearboxes

Sg 2, fr 69
Engine Lubrication System Block Diagram

b. Components

(1) Oil tank and system:

Sg 2, fr 70
Oil Tank

(a) Contains approximately 25.2 U.S. pints with unusable, quantity of 9.6 U.S. pints

(b) Minimum oil level for flight: 2 liters (4.2 U.S. pints) below FULL mark. Consumption is approximately 0.8 pints per flight hour

(2) Oil pumps: engine-driven, mounted on the accessory gear box

Sg 2, fr 71
Oil Pumps

Sg 2, fr 72
FCOC

Sg 2, fr 73
FCOC Bypass Valve

Sg 2, fr 74
Filter

Sg 2, fr 75
Distribution Block

Sg 2, fr 76
Differential Pressure Switch

Sg 2, fr 77
OIL PRESS Light

Sg 2, fr 78
Scavenger Pumps

Sg 2, fr 79
Fig 5:
Engine Starting System Block Diagram

Sg 2, fr 80
GTS

Sg 2, fr 81
GTS Starter Motor

Sg 2, fr 82
GTS Fuel System

Sg 2, fr 83
GTS Start Button

Sg 2, fr 84
GTS Advisory Light

(3) FCOC heat exchanger unit provides oil cooling through heat exchange with engine fuel and integrated FCOC bypass valve ensures adequate engine lubrication under cold temperature conditions

(4) Oil filter: filters all oil entering engine and gearboxes

(5) Distribution: oil distributed to engine turbine bearings, engine internal gearbox, and external gearbox

(6) Oil differential switch signals centralized warning system (CWS) if the differential oil pressure drops below 10 psi, causing OIL PRESS warning light to illuminate

(7) Scavenge system three oil pumps scavenge and return oil to oil tank from three distribution areas

D. Engine starting system: engine is started on ground or by assisted relight in flight via GTS and ATS

1. Starting system component function

a. GTS: gas turbine air producer unit

(1) GTS starter motor and GTS igniters powered by 28 VDC essential services bus

(2) GTS fuel obtained from aircraft fuel system downstream from LP fuel shutoff valve

(3) Started by pressing GTS start button

(a) When GTS reaches speed, a green GTS advisory light illuminates

(b) GTS accelerates to 100% for engine starting when ENGINE start switch is momentarily set to START

(4) When engine start switch is momentarily set to START, the GTS accelerates, the start valve is opened, the dump valve closes and the GTS supplies compressed air to the engine ATS

Sg 2, fr 85 *Dump Valve*

Sg 2, fr 86 *Engine Start Switch*

Sg 2, fr 87 *GTS Air to ATS*

(5) Shuts down after engine reaches 45% rpm

b. ATS: air turbine starter output shaft drives engine N_2 shaft through external gearbox

Sg 2, fr 88 *Air Starter Motor*

c. Start control unit

Sg 2, fr 89 *Start Control Unit*

(1) Sequences start cycle by monitoring speeds of GTS, air turbine starter, and engine

(2) Electrically off-loads DC generator and HYD 2 system until engine N_2 rpm reaches 45% to ease strain on ATS

(3) Shuts down GTS and engine ignition when engine N_2 rpm reaches 45%

2. Engine starting component function

Sg 2, fr 90 *External Bleed Air*

a. Bleed air valve: relieves pressure from N_2 compressor to ease engine starting and prevent compressor stalls

b. Igniters: two high-energy 12 joule igniter plugs fitted to engine combustion chamber

(1) Powered by 28 VDC essential services bus, produce approximately 80 sparks per minute

(2) Controlled by IGNITION switch and starter control unit during normal start

(3) Controlled by GTS start button during air start--igniters energized while GTS start button is pressed (+30 seconds when airborne)

E. Bleed air system

1. Internal air flow: continuous flow of compressor air, used internally in engine for

    a. Pressurizing oil seals to prevent oil bleeding into engine air flow and hot gases from entering oil system

    b. Cooling

        (1) Engine shafts and bearing thrust loading, N_2 turbine, and N_1 turbine

    c. Anti-icing intake spinner

2. External air flow: fifth-stage N_2 compressor delivery air (P3), tapped from four areas on engine case for

    a. On-board oxygen generating system (OBOGS)

    b. Environmental control system (ECS) and overboard engine bleed

    c. Fuel tank pressurization

    d. P1 probe anti-icing

F. Bleed air vents: two bleed valves that have significant effects on engine operation, one functions during engine start, and the other functions during catapult launch

1. The engine bleed valve relieves pressure from N_2 compressor during engine start and prevents N_1 compressor stalls (approx. 25% loss of thrust)

2. A steam ingestion bleed valve vents additional bleed air from the N_2 during (approx. 10% loss of thrust)

    a. Catapult launch to preclude compressor surge due to steam ingestion

G. Engine/aircraft interfaces **1.4.6.2**

Sg 2, fr 91

Fig 6: *Simplified Fuel System Block Diagram*

1. Inputs

   a. Fuel: aircraft fuel system

   b. Mechanical: throttle controls

   c. Electrical power: 28 VDC essential services bus from electrical system for engine igniters, ECA power and fuel control switching

2. Outputs

   a. Air

      (1) OBOGS

      (2) ECS

      (3) Fuel tank pressurization

      (4) P1 probe anti-icing

   b. Mechanical drive items: in addition to engine peculiar items (fuel and oil pumps)

      (1) Generator

      (2) HYD 1 and HYD 2 pumps

   c. Electrical (sensing)

Sg 2, fr 92
Warning and Caution Advisory Panels

      (1) CWS signals

         (a) Warning/caution: FIRE, GTS FIRE, EGT/RPM, OIL PRESS, TP HOT, LP PUMP, ACCEL, and ECA 2

Sg 2, fr 93
Caution Advisory Panels

         (b) Advisory: GTS, READY, ECA and M FUEL

Sg 2, fr 94
Primary Instruments and MFD Engine Display

         (c) Instruments: EGT indicator, RPM indicator, FUEL FLOW indicator, and Engine Display MFD

Sg 3, fr 4
Engine Stalls

H. Engine System Malfunctions

1. Engine stalls **1.8.1.1.5.1**

a. Indications

(1) “Pop” or “bang” followed by a “buzzing” sound and vibrations

(2) Lack of engine acceleration

b. Verifications

(1) Sudden increase in EGT

(2) Decrease in rpm

c. Effects on flight safety

NOTE: The seriousness of the effects of this malfunction depends on its cause. An engine stall may warrant abort and landing as soon as possible. If the stall is “locked in” (unclearable) the engine must be shut down to prevent serious damage. Once shut down an airstart may be attempted depending on the situation and flight envelope.

(1) Possible engine flameout

(2) Possible loss of engine performance

(3) Possible undetected engine damage

Sg 3, fr 10
Engine Vibration

2. Engine vibrations **1.8.1.1.10.1**

NOTE: Vibrations may be caused by the engine, engine accessories, flight controls, airframe, gear doors, or other components.

a. Indications

(1) Tactile: vibrating airframe

(2) Aural: rumbling or buzzing noise

b. Verifications

(1) Reduce throttle to locate vibration range

(2) Wingman inspects for abnormalities

c. Effects on flight safety

(1) May indicate mechanical failure of internal engine parts, which could lead to engine failure

(2) May indicate degradation or failure of other engine-driven accessories

3. Engine icing **1.8.1.1.13.1**

Sg 3, fr 13
Engine Icing

a. Indications

NOTE: Degraded engine performance can result from ice obstructing the intakes.

(1) Loss of thrust

(2) Possible surging and chugging

(3) Probable increase in EGT

(4) Loss of airspeed

b. Verification: visually check for ice accumulation on intakes/airframe

c. Effects on flight safety

NOTE: Departure from icing conditions should soon restore the engine to normal operation.

(1) Engine performance degraded

(2) Engine stall possible

(3) Engine damage possible

Sg 3, fr 17
Engine Overtemp

4. Engine overtemp **1.8.1.1.4.1**

a. Indications

(1) EGT reads above normal (over 610 degrees C)

NOTE: The maximum transient temp is 645 degrees C for less than 20 seconds. (The CWS will activate when the temperature is 650 +/- 8 degrees C.)

(2) MASTER ALERT flashes

(3) Warning tone sounds

(4) Warning panel: EGT/RPM light illuminates

NOTE: The probable cause of this malfunction is an uncontrolled fuel flow due to a malfunctioning ECA. If this is the case, the ECA caution light will illuminate prior to the above-mentioned indications.

b. Verifications same as indications

c. Effects on flight safety

(1) Possible engine/aircraft damage

(2) Possible loss of thrust

(3) Possible fire

Sg 3, fr 24
Engine Overspeed

5. Engine overspeed **1.8.1.1.7.1**

NOTE: The max allowable N_2 rpm is 104% on rpm gauge. EGT/RPM warning light indicates N_1 rpm is above 112.4 +/- 1%.

NOTE: The T-45C is equipped with only an N_2 rpm gauge. N_1 rpm is only available on the MFD engine display along with N_2 rpm.

a. Indications

(1) N_2 -- 104% or above reading on rpm gauge

(2) N_1

(a) MASTER ALERT light flashes

(b) Warning tone sounds

(c) EGT/RPM warning light illuminates

b. Verifications

(1) Select ENGINE display

(2) Verify N_1 rpm

c. Effects on flight safety

(1) Could cause engine damage

(2) Could cause engine overtemp

6. Engine fire

Sg 3, fr 30
Engine Fire

a. Indications

(1) Warning tone sounds

(2) MASTER ALERT flashes

(3) FIRE light illuminates

NOTE: The FIRE light may illuminate momentarily, then goes out. This does not indicate the absence of a fire. It could mean, for example, that a fire has burned the wires carrying the signals that enable the FIRE light. It could also indicate a malfunction in the centralized warning system (i.e., a false indication). To verify that an engine fire does exist, secondary indications must be present.

b. Verifications

NOTE: Any or all of the following, in conjunction with the MASTER ALERT and FIRE lights, may be used to verify that an engine fire exists. The absence of secondary indications and the FIRE light extinguishing after throttle reduction could indicate a bleed air leak.

(1) Any engine abnormality

(a) Rising or falling EGT

(b) RPM fluctuations

(c) Excessive fuel flow

(d) Smoke apparent in rear view mirrors

(2) Warning and caution advisory lights

(a) EGT/RPM warning light illuminates

(b) TP HOT caution light illuminates

(c) OIL PRESS warning light illuminates

(d) HYD 1 caution light illuminates

(e) HYD 2 caution light illuminates

(f) RAT caution light illuminates

(g) AC INV caution light illuminates

(3) From external sources

(a) Plane captain/ground personnel via intercom system or hand signals (horizontal figure-eight motion)

(b) Tower

(c) Other aircraft

c. Effects on flight safety

(1) Loss of aircraft

(2) Serious engine/related components damage

(3) Possible loss of control

(4) Loss of thrust

(5) Possible explosion

7. Steam ingestion bleed valve failure **1.8.1.1.19.1**

Sg 3, fr 35
Steam Ingestion Bleed Valve Failure

a. Indications

(1) MASTER ALERT light flashes

(2) Caution tone sounds

(3) ACCEL caution light illuminates

b. Verifications

(1) Valve OPEN (shore-based takeoff)

(a) RPM may be lower than normal

(b) EGT may be higher than normal

(c) Slower than normal aircraft acceleration

(d) Reduced climb performance

(2) Valve CLOSED (catapult takeoff) - Engine surge/stall due to steam ingestion

c. Effects on flight safety

(1) Valve open

(a) Expect 10% reduction in MRT thrust

(b) Increased fuel consumption

(2) Valve closed: possible engine surges/stall during catapult launch due to steam ingestion

Sg 3, fr 40
ECA Failure (Full Trim)

8. ECA failure (full trim) **1.8.1.1.9.1.1**

NOTE: Loss of one of the dual ECA systems will cause the ECA 2 advisory light to illuminate with no loss of performance. Loss of both ECA systems will cause the ECA 2 advisory light and the ECA 2 caution light to illuminate, and you will lose automatic overspeed/overtemp control of the engine.

a. Indications

(1) ECA advisory light

(2) MASTER ALERT light

(3) Caution tone sounds

(4) ECA 2 caution light

III. Aircraft fuel system

A. Aircraft fuel system major components

Sg 4, fr 1

Fig 7: *Aircraft Fuel System Block Diagram*

1. Fuel tanks

NOTE: The T-45C has a total fuel capacity of 443 U.S. gallons, 3012 lb JP-5 (2904 lb JP-5, 2776 lb JP-4 usable).

a. Fuselage tank

Sg 4, fr 2
Fuselage Tank

(1) Baffled, rubberized bag tank, hung inside fuselage (not a self-sealing tank)

(2) Fitted for plumbing connections

(a) Gravity filler cap

(b) Pressure control valve

(c) Vent/pressurization lines

(d) Fuel transfer lines

(e) Capacitance-type fuel quantity indicating system

(3) Capacity: approximately 220 gallons (1500 lb)

b. Integral wing tank

Sg 4, fr 3
Integral Wing Tank

(1) Formed by wing surface above and below (wet wings and is not a self-sealing tank)

(2) Capacity: approximately 223 gallons (1540 lb), including collector tank with negative-g compartment

c. Collector tank

Sg 4, fr 4
Collector Tank

(1) Separated from wing tank by diaphragms

(2) Capacity: 60 gallons (approximately 400 lb), including negative-g compartment

(3) Functional description: sump into which fuel feeds from wing tank

d. Negative-g compartment contains enough fuel for 30 seconds of inverted flight

Sg 4, fr 5
Negative-G Compartment

Sg 4, fr 6
Boost Pumps

2. Fuel delivery

   a. Boost pumps

      (1) Location two boost pumps are mounted on a manifold and installed in the negative-g compartment of the wing tank

      (2) Functional description

         (a) Provides fuel under pressure to LP pump during all aircraft maneuvers

         (b) A time delay will take the electric fuel boost pumps off-line 30 seconds after loss of aircraft generator

         (c) Fuel system feeds the engine LP pump for initial fuel supply

Sg 4, fr 7
Engine Fuel Supply

   b. Engine fuel supply flow from negative-g compartment boost pumps to bypass valve to fuel shutoff valve to engine

Sg 4, fr 8
GTS Fuel Supply

   c. GTS fuel supply downstream of fuel shutoff valve

3. Venting

Sg 4, fr 9
Vent Tank

   a. Vent tank: assists in transfer of air and fuel vapors from collector tank to atmosphere; allows condensed fuel and surplus GTS fuel to drain back into collector tank

Sg 4, fr 10
Main Vent

   b. Main vent large outlet line from vent tank

Sg 4, fr 11
Refueling Coupling

4. Refueling self-sealing valve assembly with bayonet flange

B. Fuel system operational characteristics

Sg 4, fr 12
Aircraft Fuel System Block Diagram

1. Pressurization

a. Function

(1) Suppresses tendency of fuel to boil at high altitudes

(2) Aids in transfer of fuel

(3) Keeps collector tank full

b. Operational description

(1) Bleed air from high pressure fifth stage of the high pressure compressor is regulated to 6 psi above ambient by tank pressure control valve

(2) Dual datum relief valve prevents overpressure damage to fuel tanks and structure

(3) Air pressure switch senses pressurization loss

2. Fuel delivery

a. Provides fuel to GTS and engine fuel system

b. Operational description

(1) Internal tanks

(a) Fuel level in fuselage tank falls as fuel is drawn from negative-g compartment

(b) Pressurized air aids gravity in fuel transfer to wing tank

(c) Wing tank feeds collector tank, collector tank feeds negative-g compartment

(d) Fuel from negative-g compartment supplies GTS and engine

(2) Boost pump(s)

(a) Driven by AC motor through dedicated inverter

(b) Inverter receivers power from 28 VDC essential services bus

NOTE: A delay relay secures the boost pump(s) 30 seconds after a generator failure or shutdown to conserve batteries.

(c) Provides fuel during all aircraft maneuvers

(d) Prevent fuel starvation during certain negative-g maneuvers

Sg 4, fr 16
Fuel System Status Indications

C. Fuel system controls, switches, and indicators

NOTE: The T-45 does not have fuel dumping capability.

1. System status

a. FUEL FLOW

(1) Fuel Flow indicator gauge: right instrument panel, both cockpits

(2) ENGINE display page: center instrument panel, either MFD, both cockpits

(3) Function: indicate rate of fuel to the engine combustion chamber in pounds per hour

b. FUEL QUANTITY

(1) Fuel Quantity indicator gauge: right instrument panel, both cockpits

(2) Engine display page: center instrument panel, either MFD both cockpits

(3) Function: indicate fuel remaining in 100 pound increments (uses capacitance type measuring system)

2. Caution/advisory

Sg 4, fr 17
Fuel System
Caution Advisory

a. FUEL caution light: caution advisory panel, both cockpits

(1) Function: indicates the available fuel remaining is less than 350-lb

(2) Operates off a different circuit than fuel quantity indicator

b. F PRES caution light: caution advisory panel, both cockpits, indicates loss of fuel tank pressurization (less than 2 psi above ambient) or insufficient pressure differential across the electrical fuel boost pumps

c. BINGO advisory: advisory window on all MFDs, both cockpits, advises pilot fuel level remaining is less than set

NOTE: BINGO fuel level is set by the pilot using option push-buttons on the DEP or the MFD.

3. Controls

Sg 4, fr 18
Fuel System Controls

a. FUEL SHUTOFF T -handle: aft panel of left console, fwd cockpit only opens and closes fuel shutoff valve, controlling fuel supply to engine (normal-open; during certain emergencies-closed)

(1) Down: permits fuel flow supply to the engine and GTS

(2) Pull up: isolates aircraft fuel system from the engine and GTS

Sg 4, fr 22
Fig 6: *Simplified Fuel System Block Diagram*

D. Fuel system interfaces **1.4.7.2**

1. Inputs

a. Electrical system

(1) Indicators: 28 VDC essential services bus power source (boost pumps continue operating for 30 seconds after generator loss)

(2) Boost pumps: 28 VDC essential services bus power source

(a) During starting (both ground and air starts), energized by 28 VDC essential services bus when the GTS start button is pressed and will drop off line 30 seconds after GTS shutdown unless generator comes on line

b. Engine air system: output of fifth stage high pressure compressor filtered, regulated to 6.0 psi, and distributed to fuel tanks for pressurization

2. Outputs

a. Engine starting system

b. Engine fuel system

c. Centralized warning system (CWS): MASTER ALERT light flashes concurrently with caution advisory indications (FUEL, F PRES and BINGO)

d. Intercom system (ICS): caution tone sounds in headset concurrently with caution advisory indications (FUEL and F PRES)

e. Airborne data recorder (ADR): monitors fuel quantity and fuel flow signals

3. Venting: releases air/vapor to atmosphere through pressure relief valves

a. Operational description: outward venting

(1) Collector tank: collector tank and negative-g compartment vent air or vapor to vent tank. Condensed fuel returns to collector tank from vent tank

(2) Integral wing tank: vented to upper part of fuselage tank

(3) Fuselage tank

(a) Vented to atmosphere through dual-setting pressure relief valve and an electrically operated bleed valve

(b) Normal pressure relief occurs at pressure in excess of 9.5 psi

(c) Reduced pressure relief of 4.0 psi when FLIGHT/REFUEL/DEFUEL switch is set to REFUEL or tail hook is down

b. Operational description inward venting: provides datum air (ram air) inward venting, if tank pressurization fails

4. Refueling: acceptable fuels (no adjustment to fuel control required)

a. Grade JP-5

b. Grade JP-4

Sg 4, fr 19
Left Side of T-45C

Sg 4, fr 20
Refueling Panel

c. Jet A+, Jet A-1+

d. Pressure refueling operation

(1) Location: access door engine left air intake fairing

(a) Door open: three-position switch automatically set to REFUEL

(b) Door closed: FLIGHT position automatically selected

(c) Defuel position can be selected manually

(2) Refueling valve

(a) Location: bottom of fuselage tank

(b) Solenoid-operated

(c) Receives electrical power from 28 VDC ground services bus (either battery or ground power)

(3) Fuel distribution

(a) Through refueling valve to fuselage tank

(b) Through fuselage tank to wings when fuel level covers transfer lines

(4) Displaced air

(a) Rises to top of fuselage tank

(b) Vented to atmosphere through main vent

Sg 4, fr 21
Safety Warnings

(5) Refueling restrictions

(a) Refueling must be stopped immediately if fuel is discharged through main vent above tail cone

(b) Refueling pressure not to exceed 50 psi

(c) Refueling flow rate not to exceed 180 US gal/min

(d) Aircraft must be grounded during refueling procedure

E. Fuel system malfunctions

Sg 4, fr 23
Fuel Boost Pump Failure

1. Boost pumps failure **1.8.1.2.5.1**

a. Indications

(1) F PRES caution light illuminates

(2) MASTER ALERT flashes

(3) Caution tone sounds in headset

b. Verifications

(1) No secondary indications

(2) No verification possible

NOTE: Assume that a malfunction has occurred whenever the primary indications occur.

c. Effects on flight safety

(1) Fuel to engine maintained by LP pump suction via boost pump bypass valve

Sg 4, fr 26
Fuel Tank Pressurization Failure

(2) Negative-g maneuvers may cause the engine to flame out

2. Fuel tank pressurization failure **1.8.1.2.2.1**

a. Indications

(1) F PRES caution light illuminates

(2) MASTER ALERT flashes

(3) Caution tone sounds in headset

b. Verifications

(1) Above 25,000 ft, fuel vaporization may cause

(a) Fuel venting (confirm by checking with wingman, if available)

(b) Excessive fuel loss

(2) Below 25,000 ft: no verification

CAUTION: In the absence of any verification, always assume that any warning or caution light accurately indicates a malfunction.

c. Effects on flight safety

(1) Possible fuel loss

(2) Possible adverse effects on engine performance at high power settings

(3) Fuel transfer affected by erratic maneuvers

IV. Hydraulic System

A. Hydraulic system general

Sg 6, fr 1
Simplified Hydraulic System Block Diagram

1. T-45C has two independent hydraulic systems: HYD 1 and HYD 2. Each system contains a reservoir and is pressurized by an engine-driven pump (EDP)

a. HYD 1 provides hydraulic pressure to power the flight controls (ailerons and stabilator) and the general services

b. HYD 2 provides hydraulic pressure to power only the flight controls

2. A deployable ram air turbine (RAT) provides emergency hydraulic system pressure which, in case of a failure of HYD 2 EDP, should provide pressure to the flight controls. The emergency system is integral to the HYD 2 system

B. Hydraulic system major component and operating characteristics

Sg 6, fr 3

Fig 8: *Hydraulic System Block Diagram*

1. Hydraulic system no. 1 (HYD 1)

a. Description: the HYD 1 reservoir supplies fluid to the HYD 1 EDP which produces hydraulic pressure to power the flight controls (ailerons and stabilator) and aircraft general services (speed brakes, flap/slats, landing gear/gear doors, wheel/parking brakes, nose wheel steering, launch bar, and the arresting hook). Control of the rudder is mechanical

b. HYD 1 components

(1) Reservoir

Sg 6, fr 4
HYD 1 Reservoir

(a) Location: ram air turbine (RAT) bay, top side of aircraft, forward of the tail section

(i) Stores hydraulic fluid for HYD 1 operation

(ii) Provides fluid under nitrogen preload pressure to HYD 1 to prevent EDP cavitation

(iii) Provides fluid pressure to component seals during nonoperating periods to minimize leaks

(b) Physical

(i) Consists of a cylinder with a free-floating piston that separates fluid from nitrogen

(ii) Pressurized by nitrogen during ground maintenance

(iii) Fluid quantity depends both on quantity remaining in accumulators and the hydraulic fluid temperature

(iv) Has external quantity gauge

Sg 6, fr 5
HYD 1 EDP

(2) Engine-driven pump (EDP)

(a) Location: aft right side of engine accessory gearbox

(b) Description

(i) Produces hydraulic pressure for HYD 1 system

(ii) Output volume varies in response to demand

(c) Physical

(i) Mounted on and driven by engine accessory gearbox

(ii) Variable displacement pump

(iii) Constant output pressure: 3000 psi at 9.6 gallons per minute

(3) Flight control (FC) accumulator

Sg 6, fr 6
HYD 1 FC Accumulator

(a) Location: aft of right intake

(b) Description

(i) Stores power for ailerons and stabilator during periods of high demand

(ii) Dampens pressure fluctuations

(c) Physical

(i) Consists of a cylinder with a free-floating piston that separates fluid from nitrogen

(ii) Pressurized with nitrogen (1100 $\underline{+}$ 50 psi)

(4) Wheel brake/emergency flap accumulator

Sg 6, fr 7
Wheel Brake/ Emergency Flap Accumulator

(a) Location: right main landing gear wheel bay

(b) Description

(i) Stores power for emergency use of wheel brakes in event of HYD 1 failure

(ii) Stores power for emergency deployment of full flaps in event of HYD 1 failure (no retraction)

(iii) Supplies enough pressure for at least 10 full wheel brake applications following emergency flap extension

(iv) Dampens pressure fluctuations

(c) Physical

(i) Consists of a cylinder with a free-floating piston that separates fluid from nitrogen

(ii) Pressurized with nitrogen (1300 ± 50 psi)

Sg 6, fr 8
Power Supply Package

(5) Power supply package

(a) Flight control

(i) Description: a priority valve isolates general services and redirects HYD 1 pressure to flight controls when HYD 1 pressure drops below 1500 psi

Sg 6, fr 9
Wheel Brake/ Emergency Flap Priority Valve

(b) Wheel brake/emergency flap valve

(i) Description: with HYD 1 system loss, priority valve disables emergency flap operation from the wheel brake/emergency flap accumulator at 2200 psi

(ii) Physical: part of multi-valve package consisting of a priority valve, a thermal relief valve, and a standby flap system emergency valve

Sg 6, fr 10
Hand Pump

(6) Hand pump

(a) Location: right intake, door labeled HYD HAND PUMP/ GROUND LOCK PINS

(b) Functional: hand pump supplies up to 2800 psi to recharge wheel brake/ emergency flap accumulator without starting engine or applying external hydraulic pressure (wheel brakes must be operative prior to towing aircraft)

2. Hydraulic system no. 2 (HYD 2) **1.4.8.3.2**

Sg 6, fr 13
Reservoir

a. Description the HYD 2 reservoir supplies fluid to the HYD 2 engine-driven pump (EDP) that, in turn, produces hydraulic pressure to power the flight controls.

b. HYD 2 components

(1) Reservoir

(a) Location: RAT bay, topside of aircraft, forward of the tail section

(i) Stores hydraulic fluid for HYD 2 operation

(ii) Provides fluid under nitrogen preload pressure to HYD 2 to prevent EDP cavitation

(2) Engine-driven pump (EDP)

Sg 6, fr 14
Engine-Driven Pump (EDP)

(a) Produces hydraulic pressure for HYD 2 system

(b) Output volume varies in response to demand

(c) Constant output pressure: 3000 psi at 6 gpm flow due to smaller load

Sg 6, fr 15
FC Accumulator

(3) FC accumulator

(a) Stores power for aileron and stabilator during periods of high demand and dampens pressure fluctuations

(b) Pressurized with nitrogen (1100 $\pm$ 50 psi)

Sg 6, fr 16
Emergency Package Assembly (EPA)

(4) Emergency package assembly

(a) Automatically deploys RAT and directs emergency hydraulic pressure to flight control services when HYD 2 pressure drops below 1500 psi

(b) Isolates sections of the HYD 2 system from the emergency hydraulic system when the RAT is deployed

(c) Allows resetting of the HYD 2 system via solenoid valve with HYD 2 pressure above 1800 psi

NOTE: The emergency package assembly isolates the HYD 2 EDP from the system when the RAT is deployed. To regain HYD 2 EDP pressure (and stow the RAT), the HYD 2 RESET button must be pressed.

Sg 6, fr 17
EDP Bypass Valve

(5) EDP bypass valve

(a) Reduces load on engine by bypassing output of EDP to return side of system during low rpm periods (engine start)

(b) Bypass in effect from 0% to 45% rpm

(c) Reset above 45% rpm (above 1800 psi) by pressing HYD 2 RESET button

(d) Bypass valve activates when engine rpm drops below 42%, such as during engine flameout

3. Emergency hydraulic system: acts as a backup to the HYD 2 system, by deploying the RAT when HYD 2 pressure falls below acceptable levels. The RAT automatically extends whenever HYD 2 EDP pressure falls below 1500 psi. Since the RAT is a

fixed displacement pump, emergency hydraulic pressure will fluctuate between 2500 and 3000 psi displayed on the HYD 2 gauge, whenever the RAT is in operation

a. Emergency hydraulic system components

(1) RAT

(a) Produces hydraulic pressure for emergency hydraulic system in event of HYD 2 EDP pressure loss

(b) Raised into airstream automatically by hydraulic actuator when HYD 2 EDP pressure drops below 1500 psi

(c) Output volume and pressure vary with pump speed (fixed displacement pump)

(2) RAT accumulator

(a) Carries nitrogen preload and provides hydraulic pressure to extend, and keep fully extended, the RAT actuator when HYD 2 EDP pressure drops below 1500 psi

(b) Regulator valve cycles pressure between 2500 and 3000 psi, because the RAT is a fixed displacement pump whose output pressure is not internally regulated

(c) Emergency package assembly automatically deploys the RAT and directs Emergency Hydraulic System pressure to flight controls when HYD 2 pressure below 1500 psi

Sg 6, fr 29
Hydraulic System Normal System Indications

(d) To regain HYD 2 EDP pressure (and stow the RAT), the HYD 2 RESET button must be pressed

C. Hydraulic system operational characteristics

1. HYD 1 operational characteristics

a. EDP receives hydraulic fluid from HYD 1 reservoir under low pressure and produces output of 3000 psi

b. HYD 1 failure signal to centralized warning system (CWS) to illuminate HYD 1 caution light when pressure drops below 600 + 50 psi. When HYD 1 pressure rises above 725 + 50 psi, HYD 1 caution light goes out

c. Output of EDP is applied to power supply package

d. FC priority valve normally supplies hydraulic pressure to both FC services and general services distribution

e. Flight control service

(1) Left and right aileron power control units (PCUs): tandem hydraulic cylinders, one side supplied by HYD 1 and other by HYD 2 (HYD 1 supplies forward side of aileron PCUs; HYD 2 supplies aft side)

(2) Stabilator PCU (also a tandem PCU)

(3) System redundant with HYD 2

f. General services

(1) Landing gear (hydraulic pressure used for both extension and retraction)

(2) Nose wheel steering (hydraulic pressure through the down side of the normal landing gear system)

(3) Launch bar (hydraulic pressure used for extension only; retraction is mechanical by spring force)

(4) Speed brake (hydraulic pressure used for both extension and retraction)

(5) Arresting hook (hydraulic pressure used for retraction only; extension is by gravity free-fall, with pneumatic snubber pressure assist)

(6) Flaps and slats (hydraulic pressure used for both extension and retraction)

(7) Wheel brakes and anti-skid (hydraulic pressure used for both operations)

2. HYD 2 operational characteristics **1.4.8.2.2**

a. EDP receives hydraulic fluid from HYD 2 system reservoir and produces 3000 psi but at reduced (6 gpm) flow because of smaller load

b. Bypass valve controls output of EDP

(1) Engine rpm controls the bypass valve through the airborne data recorder (ADR), and HYD 2 RESET button

(2) On engine start, bypass valve opens to send HYD 2 EDP output to return (reduces load on ATS during engine start)

(3) May be reset (bypass valve closed) by pressing HYD 2 RESET button once engine rpm has reached 45%

(4) If engine rpm drops below 42% (flameout), bypass valve opens to reduce load on engine during start (airstart)

(5) When engine rpm rises above 45%, bypass valve may be closed by pressing the HYD 2 RESET button

3. HYD 2 output distribution

   a. Supplies flight controls: trailing edge side of aileron PCUs and stabilator PCU

   b. Charges HYD 2 system FC accumulator

   c. Supplies emergency package assembly

4. Emergency hydraulic system: operational characteristics

   a. Emergency package assembly directs RAT accumulator pressure to RAT actuator, raising RAT into airstream

   b. Supplies HYD 2 flight control services through emergency package assembly

   c. If HYD 2 EDP is producing more than 1800 psi, and engine rpm is equal to or greater than 45%, HYD 2 RESET button can be used to retract RAT

   d. Normal engine shutdown: RAT will extend when HYD 2 pressure drops below 1500 psi and will retract due to spring loading when HYD 2 pressure drops below 700 psi (air loads permitting)

Sg 6, fr 37
Hydraulic System Pressure Gauges/Reset Button

5. Hydraulic system controls and indicators

   a. Cockpit controls and indicators

(1) HYD 1, HYD 2, and BRAKE pressure gauges (left console, both cockpits)

(2) HYD 2 RESET button: located on the left console, forward of the throttle. Pressing the button with HYD 2 EDP pressure above 1800 psi closes the HYD 2 system bypass valve after engine start/restart or airstart and retracts the RAT if deployed

(3) Warning/caution light panel (WCP), both cockpits

Sg 6, fr 38
Warning and Caution Advisory Light Panels

(a) HYD FAIL warning light: indicates total hydraulic failure; illuminates when HYD 1 pressure is less than 600 ± 50 psi, HYD 2 pressure is less than 1660 ± 110 psi and emergency hydraulic system pressure is less than 600 ± 50 psi, indicating combined HYD 1, HYD 2 and emergency hydraulic system failure

(b) HYD 1 PRESS caution light: warns aircrew of HYD 1 failure; illuminates when HYD 1 EDP pressure drops below 600 ± 50 psi, indicating HYD 1 EDP not maintaining pressure to power flight controls and that all hydraulic pressure to general services has been lost; extinguishes when pressure rises above 725 ± 50 psi

NOTE: HYD 1, HYD 2, or the Emergency hydraulic system, if functioning, will back up each other to provide pressure to operate flight controls.

(c) HYD 2 PRESS caution light alerts aircrew to possible HYD 2 EDP failure: illuminates when HYD 2 pressure drops below 1660 ± 110 psi. In some cases this may be caused by excessive demand. It extinguishes when HYD 2 EDP pressure is above 2000 psi.

NOTE: As long as the HYD 2 pressure gauge is cycling between 2500 and 3000 psi, the emergency hydraulic system is functioning and is producing hydraulic pressure to power the flight controls. Loss of HYD 2 fluid will render the HYD 2 and the emergency hydraulic system inoperative. A subsequent loss of the HYD 1 system will result in loss of control of the aircraft.

NOTE: The capability of the RAT to provide sufficient hydraulic power for controllable flight during a total hydraulic pressure loss has not been determined. Safe ejection envelopes may be exceeded if control is lost during a landing attempt on emergency hydraulic power. Landing approaches on emergency hydraulic power alone should not be attempted.

b. Checking/testing the hydraulic system

Sg 6, fr 39
Wheel Brake/ Emergency Flap Accumulator Pressure Gauge

(1) Right main wheelwell

(a) Wheel brake/emergency flap accumulator pressure gauge

(i) Indicates pressure in wheel brake/ emergency flap accumulator (same measurement as cockpit BRAKE pressure gauge)

(ii) Calibrated from 0 to 4000 psi in 100 psi increments and labeled every 1000 psi

(iii) When hydraulic fluid supply depleted from accumulator, gauge displays nitrogen pressure only

(iv) 1300 psi or greater

(b) HYD 1 FC accumulator pressure gauge

Sg 6, fr 40
HYD 1 FC Accumulator Pressure Gauge

(i) Indicates pressure in HYD 1 FC accumulator (accumulator pressure, as opposed to system output pressure read from HYD 1 pressure gauge in cockpit)

(ii) Calibrated from 0 to 4000 psi in 100 psi increments and labeled every 1000 psi

(iii) When hydraulic fluid supply is depleted from accumulator, gauge displays nitrogen pressure only

(iv) Serviced to 1100 ± 50 psi

(2) Aft fuselage (right side)

Sg 6, fr 41
Hydraulic 1 System Servicing

(a) HYD 1 filter indicators

(i) Two indicators, forward one for pressure line and aft one for return line

(ii) Service required when red band visible

NOTE: The indicator protrudes (pops out), exposing the red band, when the filter is clogged and the internal bypass valve opens.

NOTE: Indicators occasionally pop out due to pressure fluctuations or g forces encountered during hard landings.

Sg 6, fr 42
HYD 1 Reservoir Indicator

(b) HYD 1 reservoir indicator

(i) Indicates quantity of HYD 1 reservoir

(ii) Quantity will vary according to temperature of fluid and pressure in system

(iii) Calibrated 0-340 cubic inches in 10 cubic-inch increments and labeled every 100 cubic inches

(3) Left main wheelwell

Sg 6, fr 43
HYD 2 FC Accumulator Pressure Gauge

(a) HYD 2 FC accumulator pressure gauge identical to HYD 1 FC accumulator pressure gauge

(b) Indicates pressure in HYD 2 FC accumulator (accumulator pressure, as opposed to system output pressure read from HYD 2 pressure gauge in cockpit)

(c) Calibrated from 0 to 4000 psi increments and labeled every 1000 psi

(d) When hydraulic fluid supply is depleted from accumulator, gauge displays nitrogen pressure only

(4) Aft fuselage (left side)

(a) HYD 2 filter indicators: identical to HYD 1 filter indicators

(i) Two indicators, forward one for pressure line and aft one for return line

(ii) Service required when red band visible

(b) HYD 2 reservoir indicator

Sg 6, fr 44
Left Side External Locator

(i) Indicates quantity of HYD 2 reservoir

(ii) Quantity will vary according to temperature of fluid and pressure in system

(iii) Calibrated 0 to 340 cubic inches in 10 cubic-inch increments and labeled every100 cubic inches

c. Aircraft interfaces

(1) Inputs

(a) Electrical system: all WCP lights, HYD 2 RESET button, and system solenoid valves supplied by 28 VDC essential services bus

(b) Engine accessory gearbox: provides mechanical power to drive two hydraulic pumps

(2) Outputs

(a) HYD 1

(i) Power supply pkg; Priority valve directs pressure to:

- Flight controls supplied continuously
  - Ailerons
  - Stabilator

NOTE: The rudder is mechanical and does not receive hydraulic power.

(b) General services when HYD 1 pressure is above 1600 psi

(i) Landing gear

(ii) Nose wheel steering

(iii) Launch bar

(iv) Speed brakes

(v) Arresting hook

(vi) Flaps/slats

(vii) Wheel brakes and anti-skid

b. HYD 2

(1) Flight control PCU

(2) HYD 2 system FC accumulator

(3) Emergency pkg assembly

c. Emergency HYD system

(1) RAT supplies emergency hydraulic pressure utilizing HYD 2 fluid

(2) Backup for HYD 2 EDP pressure to ailerons and stabilator

d. Centralized warning system (CWS): MASTER ALERT light flashes concurrently with HYD FAIL warning light and HYD 1, HYD 2, and RAT EXTEND caution lights

e. Intercom system (ICS): caution sounds in headset concurrently with WCP indications of

HYD 1, HYD 2, and RAT EXTEND caution lights; warning tone sounds with HYD FAIL warning light

D. Hydraulic system malfunctions

Sg 6, fr 45
HYD 1 Slow Loss of Pressure

1. HYD 1 and HYD 2 slow pressure loss

a. Indications: in flight, pressure in either system is lower than normal or visibly decreasing, as indicated by HYD 1 or HYD 2 pressure gauges in both cockpits

b. Verifications

(1) HYD 1

(a) Pressure continues decreasing

(b) At approximately 1500 psi, loss of general services (e.g., speed brake) noted

(c) At approximately 600 psi

(i) MASTER ALERT light flashes

(ii) Caution tone sounds

(iii) HYD 1 caution light illuminates

(2) HYD 2

Sg 6, fr 49
HYD 2 Slow Loss of Pressure

(a) Pressure continues decreasing

(b) At approximately 1660 psi

(i) MASTER ALERT light flashes

(ii) Caution tone sounds

(iii) HYD 2 caution light illuminates

(c) After pressure has dropped 1500 +/- 100 psi, RAT will deploy and the RAT caution light will illuminate

d. If pressure drop due to fluid loss, pressure may temporarily rise and cycle after RAT extends but then will continue to drop

NOTE: The HYD 1 & 2 caution lights indicate EDP pressure only. Since the EDP is the sole source of hydraulic pressure in the HYD 1 system, the HYD 1 gauge normally reflects the serviceability of the pump. The only exception to this would be loss of pressure due to hydraulic fluid leakage. The HYD 2 gauge shows system pressure resulting from <u>either</u> the HYD 2 EDP or the Emergency Hydraulic System. Neither the pump or the RAT will maintain HYD 2 pressure if a system leak depletes HYD 2 system reservoir. Should HYD 2 fluid depletion result in less than 700 psi system pressure, spring tension will cause the RAT to automatically retract, however, in-flight aerodynamic loading may prevent retraction.

c. Effects on flight safety

(1) HYD 2 or Emergency Hydraulic System maintains hydraulic pressure for flight controls if HYD 1 fails

(2) HYD 1 maintains pressure for flight controls if HYD 2 fails

(3) If pressure loss is in HYD 1, normal operation is lost for landing gear, brakes, flaps, slats, hook, speed brakes, nose wheel steering (NWS), and launch bar

NOTE: Proper use of emergency backup systems for these services is covered in NATOPS and is the subject of future lessons.

(4) Loss of fluid in both systems would render aircraft unflyable

V. Hydraulic Subsystems

Sg 7, fr 1 *Landing Gear/ Doors Operation*

A. Landing gear system

1. Major components

Fig 9: Main Landing Gear (MLG) Major Components

Fig 10: Nose Landing Gear (NLG) Major Components

a. Main landing gear (MLG)

b. Nose landing gear (NLG)

2. Controls and indicators

a. LDG GEAR UP/DN handle

(1) Location: left forward console, both cockpits

(2) Purpose: UP raises gear, DN lowers gear;

(3) Function: to raise and lower landing gear; light in handle indicates handle position and gear position do not agree, one or more of the gear are not down and locked, or up selected and all doors not fully closed

b. EMER GEAR handle

(1) Location: left forward console, both cockpits

(2) Purpose: rotated clockwise and pulled, it unlocks gear/doors and activates emergency gear extension

CAUTION: If the landing gear is emergency extended, hydraulic pressure will not be supplied to the nose wheel steering and the system will be inoperative.

NOTE: It may be necessary to apply slight g loads/yaw on the aircraft to lock the gear in position.

c. LDG GEAR LEFT, RIGHT, and NOSE lights: green lights on when left-hand (LEFT), right-hand (RIGHT), and nose (NOSE) gear are down and locked

NOTE: The three individual gear-down-and-locked lights are active whether emergency or normal gear extension is used.

d. LDG GEAR DOOR caution light: amber light on when any hydraulically operated gear door (forward doors for NLG and inner doors for MLG) is not closed and locked during either gear-up or gear-down cycles

NOTE: The LDG GEAR DOOR caution light will remain on during emergency landing gear extensions.

e. WHEELS warning light: red light flashes (and wheels warning tone sounds)

(1) When gear handle not down, throttle position less than 95% N_2 rpm, and either of the following exists

(a) Aircraft below 7,200 ft MSL (may occur as high as 9,800 ft MSL) and airspeed below 170 knots

(b) Either FLAPS/SLATS lever is not in the UP position

f. TONE button: left of LDG GEAR UP/DN handle, both cockpits; silences landing gear warning tone

3. Operation: both NLG and MLG are electrically controlled and hydraulically operated

4. Limitation: maximum airspeed for lowering gear and flying with gear extended is 200 KIAS

B. Nose wheel steering (NWS); dual-gain, full-time (low-gain)

Fig 11: Nose Wheel Steering (NWS) System Major Components

1. Major components

   a. Steering motor: hydraulic motor mechanically moves nose wheel

   b. Gearbox (gear train): mechanically transmits steering motor movement to nose wheel

   c. Electronic control box

   d. Steering collar: support bearing between fixed strut and moveable nose wheel

2. Controls and indicators

   a. NWS button

      (1) Selects high gain (± 65 degrees) when pressed and held

      (2) Reselects low gain (± 12 degrees) when pressed momentarily after emergency off with paddle switch or NWS shutdown due to fault protection

      (3) Selects ± 20 degrees NWS when pressed and held with launch bar down

   b. Paddle switch: selects NWS emergency off (ground) and deactivates control augmentation (ground/airborne)

   c. NWS caution light indicates system failure or nose wheel steering disconnected with the paddle switch

   d. NWS HI advisory light indicates high gain selected

e. Rudder pedals: provide electromechanical directional input to NWS to control direction of aircraft

Sg 7, fr 13
Nose Wheel Steering Operation

3. NWS Operation

a. NWS on all the time in low gain

b. NWS high gain selected with NWS button

c. Emergency off by pressing paddle switch

d. NWS disabled when launch bar extended, $\pm$ 20 degrees NWS available if NWS button pressed and held

NOTE: High gain nosewheel steering should be used for low speed taxi operations only at less than 10 knots ground speed.

***Fig 12:** Wheel Brake/ Anti-Skid System Block Diagram*

C. Brakes/anti-skid

1. Major components

a. Master cylinder: converts foot pressure into hydraulic pressure that controls brake control valve

Sg 7, fr 22
Wheel Brake Operation

b. Brake control valve: supplies HYD 1 hydraulic pressure to operate wheel brakes whenever the brake pedals are depressed, the parking brake is engaged, or upon command from the de-spin actuator

Sg 7, fr 35
Anti-Skid Operation

c. Anti-skid control valve: when anti-skid is selected and excessive wheel deceleration is sensed (impending skid), directs pressure to the return lines, thus releasing the brakes

d. Brake unit: transmits HYD 1 hydraulic pressure into mechanical energy required to stop rotation of main gear wheels

e. De-spin actuator: signals brake control valve to apply hydraulic power to brake units to stop wheel rotation when gear handle is raised

f. Parking brake: mechanically operates brake control valve to apply hydraulic pressure simultaneously to both wheel brake units to park aircraft

g. Anti-skid control box: “brains” of anti-skid system; controls operation of anti-skid valve

h. Speed sensors: measure rotation speed of each wheel; resulting signal sent to anti-skid control box and used to predict when a wheel is about to skid

i. Wheel brake/emergency flap accumulator: provides smooth, even brake response with HYD 1 operational; provides 10 full brake applications in the event of HYD 1 failure with anti-skid off

2. Controls and indicators

   a. Brake pedals

   b. BRAKE pressure gauge and wheel brake/ emergency flap accumulator pressure gauge indicate pressure in wheel brake/emergency flap accumulator

   c. PARKING BRAKE caution light: illuminates when parking brake is engaged and throttle is past 70% rpm

   d. PARKING BRAKE handle

   e. ANTI-SKID switch

   f. SKID caution light

   g. SKID advisory light

Sg 7, fr 27
Launch Bar Operation

NOTE: ANTI-SKID switch must be on in both cockpits to illuminate the advisory light and for system operation.

D. Launch bar

1. Major components

a. Power unit: converts hydraulic force into mechanical energy required to extend launch bar

b. Launch bar: physically connects to carrier deck shuttle to transfer energy of catapult to aircraft during catapult launches

c. Redundant launch bar drive linkage system: dual linkage/springs provide mechanical force to

(1) Hold launch bar on deck when extended

(2) Return launch bar to up position

(3) Hold launch bar stowed when retracted

2. Controls and indicators

a. LAUNCH BAR switch: used to extend and retract launch bar

b. L BAR lights

(1) Green L BAR light on when launch bar is extended on deck with LAUNCH BAR switch set to EXTEND

(2) Green L BAR light off when launch bar retracted or RETRACT selected and launch bar held extended in shuttle

(3) Red L BAR light illuminates (MASTER ALERT flashes and warning tone sounds)

after 10 second delay when launch bar fails to retract after launch and the landing gear is down and locked

3. Operating characteristics

a. Electrically controlled, hydraulically extended, mechanically retracted

b. Spring pressure assists hydraulics in providing positive load on deck

E. Arresting hook

Sg 7, fr 41
Tail Hook Operation

1. Major components

a. Hydraulic actuator/damper

b. Oleo-pneumatic centering unit

c. Arresting hook assembly: engages deck arresting cable or field arresting gear to stop aircraft

d. Uplatch mechanism: mechanically retains arresting hook in UP position

e. Arresting hook safety pin

2. Controls and indicators

a. Arresting HOOK handle

b. Arresting HOOK warning light: illuminates when hook is in transit or hook doesn't match selected position

c. HOOK BYPASS switch

(1) When set to CARRIER, AOA indexer and approach lights flash when aircraft is in landing configuration and hook is not down

(2) When set to FIELD, above function is bypassed and lights are steady

NOTE: The HOOK BYPASS switch does not affect the operation of the arresting hook. Instead, it controls the operation of the AOA indexer and approach lights and serves as a reminder to lower the hook during arrested landings.

F. Aircraft interfaces

1. Hydraulic system

a. All hydraulic subsystem items powered by HYD 1

b. If HYD 1 fails, services retained due to backup/ alternate means include

(1) Landing gear/doors: gravity free-fall extension and lock

(2) Forward NLG doors partially close electrically

(3) Arresting hook: gravity/pneumatic extension

(4) Wheel brakes: wheel brake/emergency flap accumulator provides enough braking for one normal landing (a minimum of 10 brake applications)

(5) Flaps: full extension with wheel brake/ emergency flap accumulator pressure > 2200 psi

c. If HYD 1 fails, services lost include

(1) NWS: use differential braking instead

(2) Anti-skid: must be selected OFF to conserve wheel brake/emergency flap accumulator pressure for wheel brakes

(3) Launch bar: will retract due to mechanical (spring) pressure; extension not possible

(4) Arresting hook: retraction not possible

(5) Landing gear & MLG inner doors: retraction not possible

(6) Slats: remain in position set when HYD 1 is lost

2. Electrical system

a. 28 VDC essential services bus

(1) Arresting hook (up/down proximity switches, hook warning lights)

NOTE: The arresting hook itself is mechanically controlled and gravity operated with pneumatic assist. Even if batteries or the essential services bus itself fails, the hook will extend.

(2) Landing gear control (control and lights)

(a) If power to essential services bus fails, normal gear extension not possible

(b) Emergency gear extension system (mechanical) will still be operable

(3) Landing gear position indicator (light in handle)

(4) WOW control

(5) Anti-skid control: available with generator failure

(6) Nose wheel steering: available with generator failure

G. Hydraulic Subsystem Malfunction

Sg 7, fr 45
Wheel Brake/ Emergency Flap Accumulator Failure

1. Wheel brake/emergency flap accumulator failure

a. Indications: wheel brake/emergency flap accumulator pressure gauge in starboard wheelwell and left console BRAKE gauge display 0 psi

NOTE: Under normal conditions the wheel brake/emergency flap accumulator pressure gauge and brake gauge should display a minimum of 1300 psi on preflight and 3000 psi with the engine operating.

b. Verifications: braking may be jerky and/or uneven

c. Effects on flight safety

(1) No backup brake system if HYD 1 inoperative

(2) No backup flaps system if HYD 1 inoperative

NOTE: Slats not available. Slats do not have a backup.

VI. Flight Control System

Sg 8, fr 1
Flight Control System, Flap/Slats, Speed Brakes

NOTE: The flight controls consist of ailerons to control roll, stabilator to control pitch, and rudder to control yaw. The control augmentation system enhances flight characteristics and compensates for pitch transients during speed brake operation. The T-45C also employs flaps and slats to increase lift and speed brakes to increase drag. All flight controls except the rudder are hydraulically operated. The rudder is a mechanical system and should be secured with the gust lock lever when the aircraft is parked.

NOTE: The flight control system controls and indicators consist of the following: aileron/stabilator trim switch, AILERON trim indicator, STBY STAB TRIM switch, STABILATOR position indicator, rudder pedals, RUDDER trim indicator, RUDDER TRIM control, C AUG caution light, RUDDER PEDAL ADJUST knob, CONTR AUG switch, FLAPS/SLATS switch, EMER FLAPS switch, FLAP position advisory light, SLATS caution light, SP BRK and FULL advisory lights, extend/retract switch.

Sg 8, fr 2
Flight Controls

Fig 13: *Flight Controls*

Sg 8, fr 3
Flaps/Slats

The flaps/slats should not be lowered above 200 KIAS.

A. Major components

1. Flight controls

a. Aileron system

b. Stabilator system

c. Rudder system

NOTE: Two stabilator vanes (strakes) are fixed surfaces located on each side of the rear fuselage, forward of the stabilator. With the flaps extended and a high angle of attack, they help direct airflow over the stabilator, providing enhanced aircraft pitch control.

2. Flaps/slats, speed brakes

Sg 8, fr 5
Normal Operation Rudder Trim

B. Flight controls

1. Rudder system

Fig 14: *Flight Controls -- Rudder System Components*

a. Control surface components

(1) Rudder

(2) Rudder trim tab

(3) Trim/Yaw damper actuator

Sg 8, fr 10
Normal Operation Aileron Trim

Fig 15: *Flight Controls -- Aileron System Components*

(4) Rudder centering unit

(5) Yaw damper controller

(6) Rudder pedal shaker and audio tone activated when AOA exceeds 21.5 units

b. Operating characteristics

(1) Control augmentation system

WARNING: Initiating the CONTR AUG BIT cycles the rudder and rudder tab. Ensure the CONTR AUG BIT is completed prior to taxi or takeoff.

(2) Yaw damping system and aileron rudder interconnect operate automatically with weight off wheels and airspeed less than 217 KIAS

(3) Rudder pedal operation may override yaw damp system

(4) Operates in three modes

(5) Rudder deflection maximum: 20 ± 0.5 degrees from neutral, including 6 ± 1 degree maximum trim (limited by electronic damping system)

(6) Rudder lock protects from wind up to 70 mph

(7) Simultaneously operating both trim switches in opposite directions disables the trim motor

2. Aileron system

a. Control surface components

NOTE: There are no aileron trim tabs on the T-45C.

(1) Ailerons: provide primary lateral control and lateral trim

(2) Aileron actuators: provide mechanical power to move aileron control surfaces

(3) Aileron trim actuator: provides power to trim aileron control surfaces

(4) Aileron spring feel unit: compensates for aerodynamic forces acting on control surfaces and provide artificial feel for the pilot

3. Stabilator system

a. Control surface components

Sg 8, fr 31

Fig 16: *Flight Controls -- Stabilator System Components*

(1) Stabilator: provides primary pitch control

(2) Stabilator actuator provides mechanical power to move stabilator via stabilator trim input

Sg 8, fr 43
Normal Operation -- Stabilator Trim

(3) Stabilator maximum trim is 8 degrees nose up and 3 degrees nose down

(a) Main stabilator trim motor powered by 28 VDC essential services bus

(b) Standby trim motor powered by 28 VDC generator bus

(4) Stabilator spring feel unit simulates aero-dynamic loading

b. Cockpit controls/switches/indicators

(1) Aileron/stabilator trim switch

(2) Standby stabilator trim switch (guarded): located on each left console

(3) Stabilator position indicator: located on left console, left of aileron trim indicator

NOTE: Simultaneous operation of trim switches in opposite directions inhibits operation of the stabilator trim main and standby motors.

Fig 17: *Flaps/Slats Speed Brakes*

c. Flaps/slats, speed brakes

(1) Flap system

(a) System overview: augments lift to wing, allowing flight operations at lower airspeed

(b) Control surface components

(i) Flap panels

(ii) Flap actuator

(iii) Pressure/thermal relief valves

(c) Cockpit controls/switches/indicators (all located on left instrument panel, both cockpits)

(i) FLAPS/SLATS lever: three-position switch (UP, 1/2, DOWN) adjacent to throttle in both cockpits

(ii) EMERG FLAPS switch: directs pressure from wheel brake/ emergency flap accumulator in event of HYD 1 failure to fully extend flaps

(iii) FLAP position indicator

Sg 8, fr 37
Flaps Normal Operation

d. Operating characteristics/limitations

(1) Flaps raised and lowered via single actuator

(2) Powered by HYD 1 via push-pull control rods and bellcrank levers

(3) Extension of flaps via wheel brake/emergency flap accumulator in event of HYD 1 failure

(4) Forward and aft cockpits FLAPS/SLATS switches are mechanically interconnected

(5) Full extension of flaps is approximately 50 degrees, half approximately 25 degrees

(6) EMERG FLAPS switch fully extends flaps by commanding wheel brake/emergency flap accumulator to discharge; no flap extension if accumulator pressure is less than 2200 psi

(7) Maximum speed for full or one half extension 200 KIAS

(8) Maneuvering envelope with flaps extended: 0 to +2.0 g max; maneuvering envelope with a split flap condition: +1.0 to +1.5 g max

NOTE: Because of their design, it is highly unlikely that split flaps will occur in the T-45C. Should this occur, it will cause serious control problems.

2. Slat system

a. System overview: augments lift to wing when extended, decreasing stall speed and increasing aircraft control and stability during slow speed flight

b. Control surface components

   (1) Slat panels

   (2) Slat actuators

   (3) Pressure/thermal relief valves

c. Cockpit controls/switches/indicators

d. FLAPS/SLATS lever

   (1) UP: slats retracted

   (2) 1/2 or DOWN: slats fully extended

e. SLAT position indication: SLATS caution light illuminated when slats not in selected position, split slats, slat extension attempted above 217 KIAS, or when accelerating to above 217 KIAS with slats extended

Sg 8, fr 40
Slats Normal Operation

f. Operating characteristics/limitations

   (1) Slats raised and lowered by HYD 1 powered actuators in each wing that drive rods linked to the inner and outer slat segments

   (2) Normal operation of actuators maintains slats symmetrical during extension/ retraction

   (3) Backup synchro cable between actuators if normal system fails

   (4) No system to extend slats with HYD 1 failure

   (5) Full extension of slats is 15 degrees

   (6) Speed restriction for deployment: 200 KIAS

NOTE: There is no blow back feature in the slat hydraulic system.

(7) Maneuvering envelope with slats extended: 0 to +2.0 g max; maneuvering envelope with split slats: +1.0 to +1.5 g max

NOTE: A split slat condition is highly unlikely in the T-45; however, it is not impossible and would be very dangerous should it occur.

3. Speed brake system

a. Components

(1) Left/right speed brakes

(2) Hydraulic actuator

b. Cockpit controls/switches/indicators

Sg 8, fr 52
Speed Brakes Controls/ Indicators

(1) SPD BRK advisory light: illuminates green to indicate brakes not fully retracted

(2) Speed brake FULL advisory light: illuminates green to indicate speed brakes fully extended

(3) Extend/retract switch: three-position switch located on throttle grip controls deployment of speed brakes; aft--speed brakes out, fwd--speed brakes in, spring-loaded to center

c. Operating characteristics

(1) At speeds greater than 380 KIAS, speed brakes blow back from full extension

Sg 8, fr 11
Flight Controls Switches and Indicators

C. Flight controls/switches/indicators

1. Aileron/stabilator trim switch

   a. Location: top of control sticks

   b. Function: five-position switch which provides for four-way trim

2. AILERON trim indicator (each cockpit)

   a. Location: left console, forward of throttle quadrant

   b. Function: shows position of aileron trim

3. Stabilator controls/switches/indicators

   a. Aileron/stabilator trim switch: located on top of control sticks

   b. Standby stabilator trim (STBY STAB TRIM) switch (guarded): located on each left console

   c. STABILATOR position indicator: located on left console, left of AILERON trim indicator

4. Rudder controls/switches/indicators

   a. Rudder pedals

      (1) Adjustable via rudder pedal adjust knob, just forward of stick in both cockpits

      (2) Toe pedals independently operate hydraulic wheel brakes

   b. RUDDER trim indicator

      (1) Location: left console forward of throttle quadrant, below AILERON trim indicator in both cockpits

      (2) Function: displays position of rudder trim

c. RUDDER TRIM knob

(1) Location: on left console, directly adjacent to STBY STAB TRIM switch in both cockpits

(2) Function: three-position switch, spring loaded to center activates rudder trim actuator

(3) Rudder trim is not available with CONTR AUG BIT in progress

d. C AUG caution light

(1) Location: on caution advisory panel in both cockpits

(2) Function: illuminates when control augmentation is off, degraded, or indicates BIT in progress

e. RUDDER PEDAL ADJUST knob

(1) Location: panel assembly attached to control support struts, forward of control stick in both cockpits

(2) Function: adjusts pedals to accommodate leg reach

f. CONTR AUG switch

(1) Location: adjacent to RUDDER TRIM control on left console in both cockpits

(2) Function: three-position switch

(a) ALL -- provides Dutch-roll damping, turn coordination, rudder trim, and speed brake-stabilator interconnect capabilities; also initiates BIT

(b) SBI -- provides rudder trim and speed brake-stabilator interconnect capabilities

(c) RESET (momentary, spring loaded to SBI) -- resets the system

g. Paddle switch

(1) Location: lower front side of control stick

(2) Function: (momentary switch) deactivates control augmentation system (airborne) or NWS system (ground)

h. Rudder lock lever

(1) Location: right control unit support strut, fwd cockpit only

(2) Function: locks rudder in neutral position for protection while aircraft is parked

5. Flaps/controls/switches/indicators

a. FLAPS/SLATS lever

(1) Location: inboard of the throttle quadrant

(2) Function: three position control with detents for selecting flaps UP, 1/2, or DN. Forward and aft controls are mechanically linked and operate the flap hydraulic valve via a common switch

b. EMER FLAPS switch

(1) Location: landing gear panel, below emergency gear handle

(2) Function: directs pressure from wheel brake/emergency flap accumulator in event of HYD 1 failure to fully extend flaps

c. FLAP position indicator

(1) Location: left instrument panel, to the right of the EMER JETT button

(2) Function: displays flaps as half full

6. Slats controls/switches/indicators

a. FLAPS/SLATS lever

(1) Location: inboard of the throttle quadrant

(2) Function: three position control with detents for selecting flaps/slats UP, 1/2, or DN. Forward and aft controls are mechanically linked and operate the flap hydraulic valve via a common switch

(a) UP: slats retracted

(b) 1/2 or DN: slats extended

b. SLATS caution light

(1) Location: caution advisory panel

(2) Function: illuminated when

(a) Slats not in selected position or split slats

(b) Slats extended and airspeed increases above 217 KIAS

(c) Slats selected when airspeed is above 217 KIAS (slats will not extend)

7. Speed break controls/switches/indicators

Sg 8, fr 44
Normal Operation
Speed Brakes

a. SP BRK advisory light

(1) Location: on upper left instrument panel in both cockpits

(2) Function: illuminates to indicate speed brakes not fully retracted

b. FULL advisory light

(1) Location: on upper left instrument panel in both cockpits

(2) Function: illuminates to indicate speed brakes are fully extended

c. Extend/retract switch

(1) Location: on throttle grip under COMM switch

(2) Function: three-position switch

(a) Forward (momentary) -- retracts speed brakes. Released, switch returns to center position

(b) Center -- speed brakes remain in selected position

(c) Aft -- holding switch in this position extends the speed brakes, as long as the switch is held, until full extension (60 degrees). Released, switch returns to center position

NOTE: Extension of the speed brakes (moving the switch aft) can occur incrementally. However, the speed brakes will fully retract when the speed brake switch is moved to the forward position.

Sg 8, fr 30
Hydraulic System Block Diagram

d. Aircraft systems interfaces

(1) Hydraulic system

(a) Ailerons and stabilator are tandem actuator design -- failure of one hydraulic system does not affect operation

(b) Flaps interface with HYD 1 on -- wheel brake/emergency flap accumulator provides backup power in event of failure

Sg 8, fr 42
Flap System Components

(c) Slat system has no redundancy

(d) Speed brake system has no redundancy

Sg 8, fr 46
Speed Brake System Components

(2) Electrical system

(a) 28 VDC generator bus powers

(i) Aileron trim and indicator

(ii) Rudder trim and indicator

(iii) Standby stabilator trim and stabilator position indicator

(b) 28 VDC essential services bus powers

(i) Stabilator trim

(ii) Flaps/slats control

(iii) Emergency flaps

(iv) Speed brake control and indicator

D. Flight control system malfunction

Sg 8, fr 47
Indications -- Split Flaps/Split Slats

1. Split flaps/slats

a. Indications:

(1) Aircraft rolls and yaws after flaps are lowered or raised

Sg 9, fr 1
Canopy Locking Procedures

Fig 18: *Canopy*

(2) FLAPS/SLATS lever and FLAP position indicator may not match or SLATS caution light illuminated

b. Verifications: roll stops when FLAPS/SLATS lever is returned to previous setting

c. Effects on flight safety: split flaps/slats cause a serious control problem

VII. Canopy and egress systems

A. Canopy

1. Shell: provides pilots a sealed transparent enclosure

2. Frame components

a. Fwd and aft rear view mirrors

b. Fwd and aft canopy internal canopy control levers/safety catch/decal

c. Canopy external handle lever

d. Standby compass

e. Canopy grab handle

f. Canopy damper/locking strut

g. Mild detonating cord (MDC) firing handle

3. Cockpit controls/indicators

a. Fwd/aft canopy control levers/safety catches/ unlock decals (red)

b. Canopy external handle

c. Canopy open: CANOPY caution light, (MASTER ALERT light and caution tone when throttle above 95% position)

d. Canopy damper/locking strut

e. Fwd/aft canopy mild detonating cord (MDC) firing handles

WARNING: Actuation of the MDC inadvertently or through the ejection process with the helmet visor up could result in severe eye injury. Do not use the MDC firing handle or initiator cover as a handhold.

4. MDC

a. Overhead MDC

b. Peripheral MDC

c. Fuselage-mounted shielded MDC (SMDC)

d. Canopy-mounted SMDC

B. Navy aircrew common ejection seat (NACES)

1. Major components

Sg 9, fr 9
Catapult Assembly

a. Catapult assembly

b. Main beam assembly

c. Parachute assembly

d. Canopy breakers

e. Seat bucket

Sg 9, fr 16
Seat Bucket

Fig 19: *Ejection Seat*

(1) Seat height adjustment switch

(2) Shoulder harness control lever

(3) Ejection handle

(4) SAFE/ARMED handle

(5) Emergency restraint release handle

(6) Leg restraint system

f. Survival kit (seat pan)

g. Main parachute

2. Cockpit controls: command ejection panel

a. Location: left console, aft cockpit

b. Function: seat light switch and command ejection selector handle allow pilot to set ejection sequence

c. Components

(1) SEAT LIGHT switch: must be pinned

(2) Command ejection selector positions

(a) BOTH: actuation of ejection handle from either cockpit immediately ejects the aft seat, followed 0.4 seconds later by the forward seat

(b) FWD-BOTH/AFT-SELF: when initiated by fwd seat, aft seat fires first, then fwd seat fires. When initiated from aft cockpit, ejects only the aft seat

NOTE: If ejection is initiated by the FWD seat, FWD firing circuit is routed through a 0.5-second delay cartridge. This serves as a backup to the 0.4-second delay initiator.

(c) SOLO: must have red metal selector collar and red safety pin on seat light switch installed

NOTE: With the selector handle in SOLO position, the 0.4-second delay between fwd and aft ejection is lost. The SOLO position shall not be used for a dual flight.

3. Operating characteristics

a. Secures crew member

b. Supplies life support and communication connection points

c. The seat's onboard pitot system automatically selects operating mode based on aircraft altitude and airspeed

Sg 9, fr 27
Ejection Seat Operation

d. Ejection

(1) Ejection seat has 0-0 (airspeed-altitude) ejection capability

(2) Canopy fragmentation system synchronized to ejection seat initiation

(3) Ejection seat sequence same whether canopy in place or shattered via MDC firing handle prior to ejection

(4) Upon separation of ejection seat from catapult, electronic sequencer controls all events (e.g., drogue chute deployment, man/seat separation, main chute deployment)

NOTE: The barostatic release mechanism is used as a backup in the event of an electronic sequencer failure. It automatically activates when below 18,000 feet MSL. The EMERGENCY RESTRAINT RELEASE handle is the manual backup.

(5) Parachute deployment totally dependent upon ejection seat initiation. If seat fails to fire, manual bailout is impossible

WARNING: Ejection with canopy in any position other than fully closed and locked is not recommended. Serious bodily injury and seat malfunction may occur.

WARNING: Pulling the emergency restraint release handle disables the ejection seat.

Sg 9, fr 32
Fig 20: *Minimum Safe Ejection Altitudes*

C. NATOPS ejection parameters

1. Minimum safe ejection altitudes--refer to charts in NATOPS section V, figure 17-2 (sheets 1 through 3)

VIII. On-board oxygen generation system (OBOGS) and environmental control system (ECS)

Sg 10, fr 1
OBOGS normal functions

Fig 21: *OBOGS Block Diagram*

A. OBOGS: converts engine compressor bleed air to oxygen-enriched air for breathing by removing nitrogen and contaminants through molecular sieves and oxygen concentrator

1. OBOGS bleed air shutoff valve

2. Heat exchanger

3. Temperature switch

4. Oxygen concentrator

5. Plenum

6. Oxygen monitor

7. Ejection seat: manifold provides common duct for OBOGS enriched air and oxygen from emergency oxygen bottle

8. Emergency oxygen bottle in survival kit activates:

    a. Automatically on ejection

    b. Manually by pulling the emergency oxygen actuator on left side of seat

9. Pilot's personal gear:

    a. Chest mounted O_2 regulator

    b. O_2 mask

    c. Anti-g suit; air for g-suit inflation is tapped from cooled bleed-air downstream from the OBOGS heat exchanger

B. Switches, indicators, and controls

Fig 22: *Pilot's Services Panel*

1. Pilot services panel both cockpits left console, aft

    a. OBOGS/OXYGEN quick disconnect: provides for immediate connection/disconnection of oxygen hose

    b. OBOGS/anti-g switch (fwd cockpit only): manually enables/disables OBOGS shutoff valve

    c. OBOGS FLOW selector: enables/disables OBOGS system in that cockpit

2. Oxygen monitor (fwd cockpit only): mounted on bulkhead above pilot services panel, enables oxygen monitor BIT

3. OBOGS BIT button - when pressed and held, activates the OBOGS internal test

4. OXYGEN warning light: indicates OBOGS failure

    a. Oxygen monitor senses low oxygen concentration

Sg 10, fr 19
ECS Normal Functions

Fig 23: ECS Block Diagram

b. OBOGS bleed air temperature exceeds 250 degrees F

c. OBOGS BIT fails

d. OBOGS/ANTI-G switch OFF

C. Environmental control system (ECS)

1. Air conditioning system

a. Primary heat exchanger

(1) Receives bleed air from fifth-stage engine compressor ECS port

(2) Reduces temperature of engine compressor bleed air before passing it to cold air unit (CAU)

b. CAU: compresses bleed air received from primary heat exchanger (temperature rises)

c. Secondary heat exchanger: cools compressed air before it reaches CAU turbine

d. CAU turbine: further cools air received from secondary heat exchanger by expansion through turbine

e. Temperature control system: controls final conditioned air temperature by mixing cold air from CAU turbine with hot air taken prior to primary heat exchanger

f. Cockpit air distribution

(1) Location: cooling ducts in both cockpits, under left and right canopy rails

(2) Function

(a) Temperature-controlled air distributed to crew ventilation ducts and head, body, and foot louvers

(b) Ram air and inducer shutoff valves operate automatically by proximity switches on landing gear

(c) Main pressure regulating and shutoff valve remains open in event of total power loss

2. Cockpit pressurization: maintains cockpit pressure at predetermined value with respect to aircraft altitude

a. Enables pneumatic canopy seal using fifth-stage bleed air

b. Safety relief valve ensures that positive cockpit pressure differential will not exceed 4.8 psi and that inward negative cockpit differential pressure will not exceed 0.5 psi

3. Canopy defog

a. Location: left and right base of windscreen and below canopy rails in both cockpits

b. Function: distributes conditioned air through canopy defogging ducts

4. Avionics cooling system

a. Receives conditioned air from cockpit air supply

b. Distributes air to fwd and aft avionics bays

Sg 10, fr 34
ECS Controls Switches and Indicators

5. ECS controls, switches and indicators

   a. Cockpit air condition knob positions

      (1) OFF: deactivates air conditioning pressurization system and opens RAM air valve

      (2) NORMAL

         (a) Directs 60% air to body sprays

         (b) Directs 40% air to canopy/windscreen

      (3) DEFOG

         (a) Directs 60% air to canopy sprays

         (b) Directs 40% air to body sprays

      (4) MAX DEFOG: provides additional hot air to defog ducts

   b. CABIN TEMP selector: aft of IFF provides automatic and manual adjustment of cockpit temperature control

   c. CABIN ALT warning light: provides indication of air conditioning failure

      (1) Overpressure to CAU

      (2) CAU outlet temperature in excess of 500 degrees F

      (3) CAU inlet temperature in excess of 250 degrees F

      (4) Cabin altitude above 24,000 +/- 500 feet

   d. AVIONICS HOT caution light illuminates only when on the ground and air temperature in the avionics cooling duct exceeds 67 degrees C (153 +/- 5 degrees F)

Sg 11, fr 1
GINA Major Related Component Location

IX. Flight instruments

A. Flight instrument system major components

1. Global Positioning System/Inertial Navigation Assembly (GINA)

a. The GINA provides all attitude (digital and analog), acceleration, position heading and time information to the Display Electronics Unit (DEU) over the MIL-STD-1553B MUX BUS for ADI, HSI and HUD displays

b. GINA

(1) Function:

(a) An inertial system using three (3) ring laser gyros and three accelerometers mounted on the three (3) aircraft axes

(b) Provides acceleration and rotation

(c) The embedded GPS receiver receives, tracks and processes GPS signals from the GPS antenna

(d) The GPS and Inertial System Navigation Data is sent to the DEU, Yaw Damper Controller (YDC), Mission Data Loader (MDL) and the VOR/ILS/MB over the MIL-STD-1553B MUX BUS

(2) Controls/switches/indicators:

(a) GINA PWR controlled by push-button on MFD BIT display; GINA PWR initializes to on

(b) Four (4) operational modes

(i) HYBD (hybrid) mode, the most accurate mode. Attitude and position data provided by inertial system and GPS. Automatically selected on initial power-up and weight-on-wheels or manually from the ADI display

(ii) GPS mode, position data provided by embedded GPS receiver automatically selected when in HYBD or INS and inertial system not available or manually when selected from ADI display

(iii) INS mode, position data provided by inertial system, automatically selected when in HYBD or GPS and GPS fails or manually when selected from ADI display

(iv) DGRO (directional gyro), an attitude heading backup mode, automatically commanded when insufficient initialization data or the parking brake is not set during alignment or manually when selected from ACFT DATA display

(c) GINA alignments

(i) Two stages of alignment, coarse and complete/fine

(ii) Ground alignment, GINA align complete takes approximately 3 minutes after present position initialization

(iii) In-flight alignment, GINA align complete takes between 15 and 22 minutes when using a straight and level profile, maybe less if S turns incorporated

(iv) Ship board alignment, GINA align complete takes between 15.5 and 17.5 minutes after present position initialization

2. Multi-Function Display (MFD): provide electronic displays of the ADI, HSI, HUD, BIT menus, weapons menus and aircraft/engine data pages

Fig 24: Attitude Director Indicator (ADI) Display

a. Attitude Director Indicator (ADI), an electronic display that replicates a standard electro-mechanical ADI with additional information

b. Horizontal Situation Indicator (HSI), an electronic display that replicates a standard electro-mechanical HSI with additional information

Fig 25: Horizontal Situation Indicator (HSI) Display

c. Controls/switches/indicators: the Multi-Function Display (MFD) option push-buttons provide selection of the ADI and HSI displays and their modes, sub-modes and pilot inputs

d. Subsystem interfaces: Display Electronics Unit (DEU) generates the ADI and HSI displays and provides the information for their readouts

B. Pitot static system major components

1. Standby barometric altimeter: provides standby altitude information from -1,000 to 50,000 ft MSL

a. Consists of gauge assembly containing:

(1) Counter displays ten thousand and thousands of feet, hundreds of feet fixed at 000

(2) Rotating pointer indicates hundreds of feet on circular scale with center graduations of 50 ft

(3) Barometric set window and knob

b. Controls/switches/indications: barometric set knob used to set local pressure in window (system has remote calibration screw for maintenance use)

c. Subsystem interfaces: both standby altimeters use same pitot static system inputs

(1) Power: 28 VDC generator bus vibrator power

(2) Forward standby altimeter provides barometric pressure for the entire system and Mode C altitude information to DEU then to IFF

d. Standby airspeed indicator: provides standby airspeed from 60 to 850 KIAS

e. Standby vertical speed indicator (VSI): provides standby indication of rate of descent and rate of climb feet per minute (ft/min)

Fig 26: *AOA System*

C. Angle of attack (AOA) major components

1. AOA indicator: indicates AOA, using needle and scale graduated from 0 to 30 units. The pointer position is proportional to the local AOA signal provided by an AOA transmitter, via two DC potentiometers, to AOA indicator in each cockpit

a. Controls/switches/indicators:

(1) OFF flag on each indicator to monitor power

(2) Stall warning index

(3) Optimum AOA for approach index

(4) Optimum rate of climb index

(5) Optimum AOA for cruise index

(6) AOA pointer

D. Flight instruments aircraft interfaces

Sg 11, fr 18
Electrical Power Inputs to Flight Instruments

1. Inputs to flight instruments

a. Electrical power

(1) 28 VDC generator bus: MFD right hand, (fwd/aft), standby barometric altimeter vibrator, VOR/ILS/control, AOA probe heater, and cockpit flood lights

(2) 28 VDC essential services bus: pitot heat, GINA, AOA indicator, TACAN, ADR, and MFD left hand (fwd/aft)

(3) 115 VAC non-essential bus: DEU cooling fan and radar altimeter receiver

(4) 115 VAC essential bus: GINA

(5) 26 VAC non-essential bus: VOR/ILS/MB and DEU

(6) 26 VAC essential bus: TACAN - azimuth computer

b. GINA signals

Sg 11, fr 19
System Interface Signals

(1) Heading to DEU for ADI, HSI, and HUD

(2) Roll to DEU for ADI, HSI, and HUD

(3) Pitch to DEU for ADI, HSI, and HUD

c. Pitot static system signals

(1) Static air pressure ratios: standby airspeed, standby VSI, and altimeter

(2) Ram air pressure information: standby airspeed

(3) Airspeed and altitude information to HUD, DEU, MFD

d. Acceleration

(1) Vertical positive-g load

(2) Vertical negative-g load

2. Systems interface

Sg 11, fr 20
ADR Inputs

a. Airborne data recorder (ADR): monitors structural fatigue of aircraft, engine parameters, and following flight instrument-related information

(1) Airspeed

(2) Mach number

(3) Altitude (barometric and radar)

(4) Pitch and bank

(5) Heading

(6) Acceleration

NOTE: This is only a partial listing of items monitored by the ADR.

Sg 11, fr 21
HUD Indications

b. HUD system: presents the following information from various pertinent aircraft systems and instruments via the display electronic unit (DEU) to the pilot display unit (PDU) on the HUD: pitch, roll, heading, AOA, altitude, barometric and radar, airspeed, KIAS, TAS, and Mach, G load and Peak G, and vertical speed

Sg 11, fr 22
GINA Normal Operation

E. Flight Instrument Operation

NOTE: The flight instrument system receives electrical, GINA, pitot static, COMM/NAV inputs, and 28 VDC essential bus and 5 VAC non-essential bus. Electrical inputs are from the 28 VDC essential services bus, the 115 VAC essential and non-essential buses, the 26 VAC essential and non-essential buses, and the 28 VDC generator bus.

NOTE: GINA provides acceleration, position, heading, digital and analog attitude (roll, pitch and heading), attitude rates and time to the DEU for the ADI, HSI and HUD displays, over the MIL-STD-1553B MUX BUS. The pitot static system provides static and ram air pressure for the standby attitude indicator, standby airspeed indicator, standby VSI and the DEU.

The COMM/NAV system provides navigation inputs to the DEU for the ADI, HSI and HUD displays, in the form of TACAN, VOR, ILS glideslope ILS localizer information. The flight instrument system provides output to the ADR and IFF systems.

1. GINA: the GINA three ring laser gyros and accelerometers provide stable and accurate information of acceleration, velocity, position, heading (true and magnetic), digital and analog attitude (roll, pitch, and heading), attitude rates and time. The GINA flexible initialization and alignments for ground, in-flight and on-board ship provide the best accuracy for flight profiles. The selection of modes for GINA operation are HYBD which incorporates inertial system and GPS data, INS that uses only inertial position data, GPS that uses embedded GPS position data only and DGRO as a backup for attitude heading information

2. MFD: the MFD generates the ADI and HSI displays of GPS/Inertial system heading, pitch, roll, and navigation information

Sg 11, fr 28
Pitot Static Normal Operation

3. Pitot static system: the pitot static system measures the static air pressure, rate of change of static air pressure, and the difference between pitot air pressure to provide airspeed, altitude, and rate of climb information for the system. Standby flight instruments receiving pitot static input are the standby altimeter, standby airspeed indicator, and the standby VSI

Sg 11, fr 31
AOA System Normal Operation

Fig 26: *AOA System*

4. AOA system: the AOA system is used to maintain precise airspeed necessary for carrier and field operations by monitoring the airflow relative to the fuselage. Airflow direction is detected by a probe using an internal potentiometer to transmit the DC voltages to SADs, YDC, and the AOA indicators in each cockpit

5. Independent instruments: the independent flight instrument systems include the radar altimeter, the standby AI, the standby compass, and the clock/ stopwatch

   NOTE: The standby AI and standby compass are used primarily as backups in the event that the main flight instruments/systems (ADI, HSI, HUD displays) have failed.

Sg 11, fr 34
Radar Altimeter Readout Normal Operation

   The radar altimeter is used primarily during low-level flight and landing operations. The clock/stopwatch is used as a timepiece and to identify elapsed mission time.

   a. Radar altimeter: uses pulse radar to provide altitude information from 0 to 5000 ft AGL, in 10 foot increments

      (1) Limits:

         (a) Pitch - 40 degrees nose up and 40 degrees nose down

         (b) Roll - 40 degrees left/right

(2) Uses transmitter/antenna and receiver/ antenna to send signals to the ADR then to DEU for display readout on the MFD (ADI) and the HUD

b. Standby attitude indicator: self-contained, two colored moving drum indicating aircraft attitude (accurate to 90 degrees nose up and 78 degrees nose down in pitch, and 360 degrees in roll) via an adjustable aircraft symbol

Sg 11, fr 34a
Standby Attitude Indicator

c. Standby turn and slip indicator: self-contained gyro driven rate of turn/slip indicator, with a power warning flag

Sg 11, fr 35
Standby Turn and Slip Indicator

d. Standby compass: conventional wet compass suspended in damping fluid used as a backup for heading

Sg 11, fr 37a
Standby Compass

e. Clock: combined mechanical clock/stopwatch with hands for hours, minutes, seconds, and time elapsed

Sg 11, fr 37b
Clock/Stopwatch

6. Standby compass

a. Location: mounted at top of each canopy bow

b. Function: conventional wet compass suspended in damping fluid used as a backup for heading

(1) Contains compass card graduated in 5 degree divisions with cardinal headings indicated as N, S, E, and W

(2) Compass card floats horizontally within case to align itself with earth's magnetic field

(3) Magnetic heading read off card under lubber line engraved upon lens

(4) Two internal bar magnets compensate for deviation

(5) Compass indication will lead or lag actual aircraft heading as shown by GINA on HSI, ADI, and HUD displays during turns

c. Controls/switches/indicators: light switch located above compass

d. Subsystem interfaces

(1) Power: 5 VAC non-essential bus

(2) Light switch and brightness control functional when interior lights MIP dimmer control is rotated out of OFF position

7. Clock controls/switches/indicators

a. Winding and setting knob: used to wind and set time on clock

b. Elapsed time knob: used to start and zero stopwatch time elapse hand

Sg 11, fr 38
Malfunctions of GINA and Related Instruments

F. Flight instrument malfunction

1. GINA and related flight components

Sg 11, fr 39
Indications ADI Display Failure

a. Attitude director indicator (ADI) display failure

(1) Indications

(a) Blank pitch, roll, and/or heading information

(b) Attitude advisory appear

(c) Blank screen

(2) Verifications

(a) Standby AI reading differs from ADI

(b) Cross-check outside references (e.g., horizon) and with rear cockpit

(c) Additionally verify by using BIT for equipment status

(3) Effects on flight safety: standby AI and compass provide backup attitude and heading information

b. Horizontal situation indicator (HSI) display failure

Sg 11, fr 47
Indications HSI Failure

(1) Indications

(a) Blank heading and navigation information

(b) Position advisory appear

(c) Blank screen

(2) Verifications

(a) Cross-check HSI reading in other cockpit and if possible with other aircraft or ATC

(b) Cross-check against ADI heading to ensure failure isolated to HSI

(3) Effects on flight safety

(a) Potential navigational errors with reduced accuracy

(b) Downgraded IFR approach capabilities

c. Vertical speed indicator readout

Sg 11, fr 54
VSI Readout Failure

(1) Indication: blank digital readout missing pointer/scale/dots/dashes and tic marks

(2) Verifications: cross-check with standby VSI an independent instrument

(3) Effect on flight safety: if VSI display fails you must use standby VSI

d. General GINA failure

Sg 11, fr 59
Indications GINA Failure

(1) Indications

(a) Input data source change from HYBD to INS to DGRO

(b) Missing heading indications on HSI and ADI and HUD

(c) Missing pitch and roll indications on ADI

(2) Verifications

(a) Look outside the cockpit, if VFR

(b) Standby compass reading conflicts with compass indications on both the ADI and HSI

(c) Standby attitude indicator (STBY AI) reading differs from ADI reading

(d) Rear cockpit indicators also fail

(e) Cross-check with other aircraft attitude information or ATC

(3) Effects on flight safety

(a) Possible disorientation due to missing pitch and roll information

(b) Transition to standby AI

(c) Potential navigation problems due to heading errors

(d) Instrument approach capabilities degraded due to heading errors

(e) You must use standby compass

X. CNI System

A. Major CNI components **1.4.18.3.1**

1. Communications system (AN/ARC-182)

Sg 12, fr 1
Communication System Major Components

Fig 27: UHF/VHF Control Panel

a. COMM 1/COMM 2 radio system

(1) UHF/VHF control panels: COMM 1: center pedestal, both cockpits and COMM 2: right console, forward of IFF control panel, both cockpits

(2) UHF/VHF receiver/transmitters (RTs): fwd avionics bay (COMM 1 and COMM 2)

(3) UHF/VHF antennas: COMM 1 antenna mounted on aircraft top centerline between anti-collision beacon and strobe and COMM 2 antenna mounted on fuselage under surface, aft of nose landing gear door

b. Communications control system/intercom system (ICS): COMM control panel, both cockpits

Sg 12, fr 2
Communications Control Panel

c. COMM transfer panel: center pedestal

Sg 12, fr 3

Fig 29: Communications Transfer Panel

d. Identification friend or foe (IFF) (AN/APX-100)

(1) IFF control panel: right console, aft of COMM 2 control panel, fwd cockpit only

(2) IFF transponder: nose equipment compartment

Sg 12, fr 4
IFF System -- Major Components

Fig 28: IFF Control Panel

(3) IFF antennas: fwd antenna upper surface of the nose and aft antenna upper right-hand side of tail cone

Sg 12, fr 5
GINA -- Major Components

2. Navigation

a. Global positioning system/inertial navigation assembly (GINA)

(1) T-45C GINA; forward equipment bay

(2) GPS antenna: top fuselage, forward of UHF/VHF No. 1 antenna

(3) MFD displays

(a) ADI display

(b) HSI display

(c) Data page

(d) HUD display

Sg 12, fr 6
VOR/ILS System -- Major Components

b. VOR/ILS system

(1) VOR/ILS control panel: right console, aft of COMM 2 control panel, both cockpits

(2) VOR/ILS receiver: fwd equipment bay

(3) Antennas

(a) Glideslope: starboard wing tip

(b) VOR/localizer: port wing tip

(c) Marker beacon: fuselage aft of nose gear

(4) Marker beacon lights: left of MASTER ALERT on instrument panel, both cockpits

(5) MFD display

(a) ADI display - ILS glideslope and azimuth

(b) HSI display - VOR bearing and ILS azimuth

(6) HUD display - ILS glideslope and azimuth

c. TACAN

Sg 12, fr 7
TACAN System Major Components

(1) TACAN control panel: right console, aft of VOR/ILS control panel

(2) TACAN receiver transmitter (RT): nose equipment compartment

(3) TACAN azimuth computer: nose equipment compartment

(4) Antenna: forward external under surface of nose cone

(5) MFD display TACAN data and bearing pointer on HSI display

(6) HUD display TACAN steering arrow, DME and time-to-go

3. Antenna locations (CNI)

Sg 12, fr 18
T-45C CNI Antenna Locations

a. Nose section

(1) IFF antenna (top)

(2) TACAN antenna (bottom)

b. Forward fuselage (underside)

(1) UHF/VHF 2 antenna

(2) Marker beacon antenna

c. Right wing

(1) Glideslope antenna

d. Top fuselage (right side)

(1) UHF/VHF 1 antenna

(2) GPS antenna

e. Tail section (right side)

(1) IFF antenna

f. Left wing

(1) VOR/LOC antenna

Sg 12, fr 25
UHF/VHF Radio Normal Operation

B. CNI operation

1. COMM 1/COMM 2 radio system: The UHF/VHF comm radio system provides air-to-air and air-to-ground communications. The system consists of two remote receiver transmitters (RT) (COMM 1, COMM 2), four radio control panels (two in each cockpit) and two UHF/VHF antennas

a. Allows pilots to select operational frequencies of AM and FM signals in UHF and VHF bands

(1) UHF frequency range: 225.0 to 399.975 MHz; commonly used in military aviation for communications

(2) VHF frequency range: 30.0 to 173.975 MHz; commonly used in civil aviation for communications and navigation

2. COMM control panel/intercom system (ICS): The ICS provides communications between cockpits and, when on deck, with the ground crew. It also generates the warning and caution tones initiated by the centralized warning system (CWS) when a malfunction or aircraft configuration problem occurs

Sg 12, fr 29
ICS Normal Operation

   a. Intercom system

      (1) Allows communication between cockpits and between cockpits and ground-handling via intercom receptacle in nose wheelwell

      (2) Generates seven different tones in response to inputs from various systems, including the TONE TEST switch

         (a) Warning tone

         (b) Caution tone

         (c) Wheels warning tone

         (d) Low altitude tone

         (e) Weapon release tone

         (f) Simulated gunfire tone

         (g) Stall warning tone

3. COMM control panel provides selection of comm amplifier (normal or alternate) master volume control for COMM radios, the ICS, and VOR/ILS, TACAN, and MKR audio and identification signals

Fig 29: *TACAN COMM Control Panel*

4. GINA: The T-45C GINA is a self-contained, all attitude, world wide, strap-down inertial system and embedded GPS receiver. GINA provides all attitude (digital and analog), acceleration, position heading and time to the Display Electronic Unit (DEU) over the MUX Bus for processing ADI and HSI display and the MFDs

Sg 12, fr 31
GINA Normal Operation

a. Inertial system

(1) Three gyros detect rotation in their respective axis for output to DEU

(2) Three accelerometers detect acceleration in their respective axis for output to DEU

b. GPS receiver/antenna

(1) Receiver RF ranging codes and navigation data broadcast from GPS satellites orbiting the earth

(2) Provides range and time data to DEU

Sg 12, fr 32
CWS Audio
Normal Operation

5. Intercom system (ICS): The ICS provides communications between cockpits and, when on deck, with the ground crew. It also generates the warning and caution tones initiated by the centralized warning system (CWS) when a malfunction or aircraft configuration problem occurs

a. Generates seven different tones in response to inputs from various systems, including the TONE TEST switch

(1) Warning tone

(2) Caution tone

(3) Wheels warning tone

(4) Low altitude tone

(5) Weapon release tone

(6) Simulated gunfire tone

(7) Stall warning tone

6. IFF system (transponder): The IFF transponder provides for aircraft identification and air traffic control functions. It is controlled remotely by the IFF control panel located in the fwd cockpit

Sg 12, fr 39
IFF Normal Operation

a. IFF control panel: controls operation of IFF transponder

b. IFF transponder

(1) Receives series of multiple-pulse interrogation signals from ground-based, shipboard, or airborne interrogator (encoded radar signal)

(2) Decodes interrogation signals

(3) Checks validity of signals

(4) Transmits reply to provide: aircraft identification and altitude from barometric altimeter (Mode C)

(5) Both antennas receive transmissions, but only antenna receiving the strongest signal transmits reply

7. TACAN system:

Sg 12, fr 45
TACAN System Normal Operation

a. TACAN provides magnetic bearing to/from the selected station. It also provides a distance measurement capability. It consists of a single TACAN RT that is controlled remotely by the TACAN control panel in either cockpit. TACAN navigational data are displayed on the HSI display and HUD

b. Testing

(1) TEST button initiates system built-in test (BIT) if pushed and held for a minimum of 5 seconds and the following conditions exist:

(a) TACAN steering selected on HSI display

(b) 180 course set on HSI

The following should occur:

(c) The TACAN bearing pointer and digital bearing will indicate 180 ± 2.5 degrees

(d) Range will read 0 ± 1 NM

(e) The CDI bar will be centered

(f) The indications of a valid TACAN BIT test are: TACAN bearing pointer and digital bearing - 180 ± 2.5 degrees - Range reads 0 ± 1 NM - CDI centered

c. Aircraft Interfaces - TACAN System

(1) Power

(a) 28 VDC essential services bus: TACAN RT, control panels, COMM control panels

(b) 115 VAC essential services bus: TACAN

(c) 26 VAC essential bus: TACAN RT, control panels

(2) Inputs

(a) RF TACAN magnetic bearing and distance measurement signals

(b) Fwd/aft navigation selection option in HSI display signals RT as to which cockpit has control

(3) Outputs

(a) TACAN course deviation information (CDI) to HSI and HUD

8. VOR/ILS system: The VOR/ILS system receives and processes signals from NAVAID ground stations to produce standard VOR/ILS navigation displays. The receiving unit can be set to receive either VOR or ILS transmissions. Additionally, a marker beacon receiver is also available for reception of marker beacon transmissions. Data received by the VOR/ILS system (other than marker beacon transmissions) are displayed on the MFD (HSI and ADI) displays and the HUD

Sg 12, fr 72
VOR/ILS System
Normal Operation

a. Function: Receives and processes signals from NAVAID ground stations to produce standard VOR/ILS displays

(1) VOR operation

(a) VOR/ILS control panel: frequency tuned (112.00 to 117.95)

(b) Navigation selection control on HSI display: allows either pilot to give or take control of the navigation system and HSI display modes

(c) Displays course deviation and the VOR radial on the VOR bearing pointer and digital VOR bearing

(d) Station identity processed to provide audio to pilot's headset when VOR switch on COMM control panel is set to VOR

b. ILS Operation

(1) Provides instrument landing system (ILS) information (localizer, glideslope, and marker beacon)

(2) ILS frequency is tuned (108.10 to 111.95) Automate all displays ILS deviation needles on HSI display

C. CNI controls and switches

1. Controls

Sg 12, fr 50
UHF/VHF Control Panel

a. COMM 1/COMM 2 radio system:

(1) UHF/VHF control panels enables preset of up to 30 operating frequencies, which allows for ease of frequency selection while flying formation or other demanding maneuvers

(a) MODE control selector

(i) OFF: power is removed from the set

(ii) T/R: set is energized to receive and transmit on selected channel or frequency

(iii) T/R & G: same as for T/R position except Guard receiver is energized to receive on guard frequency applicable to frequency band selected on main receiver

(iv) DF: not functional

(v) TEST: initiates built-in-test (BIT) for the RT. Test results are displayed on the frequency/ channel display

- 888.888 indicates system readiness

- Other number combinations indicate system problem and require service by mainte-nance personnel

(b) Frequency selector (outer knob)

(i) 243: RT is automatically tuned to 243.0 MHz (UHF Guard frequency) and overrides mode control selector function, independent of which cockpit currently has control. All other control functions except volume, brightness, and squelch are disabled

(ii) MAN: permits manual selection of operating frequency using frequency select switches; RT is disabled during frequency change

(iii) G: RT is tuned to Guard frequency in band in which set was last tuned (243.0 MHz UHF or 121.5 MHz VHF)

(iv) PRESET: enables selection of any one of 30 preset channels with channel selector (inner knob). Selected channel displayed by two center digit readouts on frequency/channel display

(v) READ: enables selection of any one of 30 preset frequencies with the channel selector (inner knob). Displays frequency (rather than channel number) of the preset channel on frequency/channel display

(vi) LOAD: automatically loads into system memory manual frequency displayed by selected preset channel

(c) Frequency select switches: used to manually select desired frequency when frequency selector in MAN position

(d) FREQ (CHAN) display window: displays digital readout of selected frequency or channel and BIT results

(e) UHF AM/FM mode switch

(i) Selects either AM or FM mode when RT is tuned to frequencies in 225.0 to 399.975 MHz band

(ii) Mode selection automatic in all other bands

(f) Squelch switch

(i) SQL: eliminates receiver background noise when no signal is being received (decreases reception sensitivity)

(ii) OFF: disables main receiver automatic squelch to increase reception range/sensitivity

(g) Brightness (BRT) control knob: adjusts light intensity of frequency/ channel display

(h) Receiver volume (VOL) control knob: adjusts level of UHF/VHF audio signals delivered to the communications amplifier

NOTE: With exception of the marker signals volume, volume of the COMM, VOR/ILS, and TACAN are adjustable from each cockpit through the individual system control unit.

b. Throttle

Sg 12, fr 51
Microphone Switch

(1) Microphone switch

(a) Location: above speed brake switch on throttle handle in both cockpits

(b) Function: three-position slider-type switch, spring loaded to center (off) position

(i) Up (XMIT-1): allows transmission on frequency/channel selected on COMM radio 1

(ii) Down (XMIT-2): allows transmission on frequency/ channel selected on COMM radio 2

(iii) Depress (ICS): allows intercommunication between cockpits and/or between cockpits and ground crew when MIC switch is in COLD position

c. COMM control panel

Sg 12, fr 52
Communications Control Panel

(1). Provides selection of comm amplifier (normal or alternate)

(2) Provides master volume control for COMM radios, the ICS, and VOR/ILS, TACAN, and MKR audio and identification signals

(3) Allows selection of COMM 1, COMM 2, VOR, TACAN, or MKR audio

(a) Switch Up turns on audio of selected COMM/NAV

(b) Switch Down turns off audio of selected COMM/NAV

(4) Provides HOT/COLD MIC selection

(5) MIC switch: two-position toggle switch

(a) HOT: permits intercom between cockpits/ground crew without depressing microphone switch

(b) COLD: permits intercom between cockpits/ground crew only when microphone switch is depressed

(6) ALT-NORM switch: two-position toggle switch

(a) ALT: selects alternate audio amplifier for use when normal amplifier fails. Amplifies all inputs at fixed audio level, i.e., receiver volume inoperative

(b) NORM: selects normal audio amplifier

(7) ICS volume control knob: When ALT-NORM switch in NORM, adjusts intercom reception volume independent of individual equipment volume settings

(8) RCVR volume control knob: adjusts volume of all receiver audio signals delivered to headsets. With exception of marker beacon audio, volume of all COMM/NAV signals is adjustable on individual control panels

d. IFF system (transponder): The IFF transponder provides for aircraft identification and air traffic control functions. It is controlled remotely by the IFF control panel located in the fwd cockpit

(1) IFF

(a) Master control selector (MASTER)

(i) OFF: disconnects power to system

(ii) STBY: places receiver-transmitter in warm-up (standby condition)

NOTE: Allow a minimum of 2 minutes for warm-up when system is first turned on.

(iii) NORM: applies power to receiver-transmitter at normal receiver sensitivity for full range operation

(iv) EMER: transmits emergency reply signals to Modes 1, 2, or 3/A interrogations regardless of Mode control settings. In addition, 7700 Mode 3/A is transmitted automatically

(b) STATUS lights

(i) ALT: not functional

(ii) KIT: not functional

(iii) ANT: illuminates during self test to indicate antenna function failure

(c) Identification of position (I/P) switch

(1) IDENT: initiates identification reply for approximately 20 seconds

(2) OUT (spring loaded from IDENT): prevents triggering of reply

(3) MIC: permits identification reply to be transmitted by pressing microphone switch

(d) Mode 4 controls and lights: not functional

(e) Mode 3/A code selectors: selects and displays Mode 3/A four-digit reply code number for air traffic control

(f) Mode 1 code selectors: selects and displays Mode 1 two-digit reply number for security identification (not normally used)

(g) Mode 2: displays a preset four-digit code with 4096 combinations for security identification (not normally used)

(h) Mode select/test switches (4)

- (i) TEST (spring loaded to ON): BIT function in receiver-transmitter self interrogates Modes 1, 2, 3/A, or C
- (ii) ON: permits receiver-transmitter reply to Modes 1, 2, 3/A, or C interrogations
- (iii) OUT: disables the receiver-transmitter for the mode selected

(i) RAD TEST switch: permits reply to test mode interrogations from test equipment (for maintenance use only)

(j) Test lights (2): functional when RAD TEST switch is set to RAD TEST or when mode select/test switch(es) set to TEST

- (i) GO (green): illuminates if system BIT successful
- (ii) NO GO (red): illuminates if system BIT fails

(k) Antenna (ANT) switch

(i) TOP: selects forward antenna

(ii) DIV: diverse setting, antenna is automatically selected

(iii) BOT: selects aft antenna

e. TACAN controls and indicators

Sg 12, fr 53
TACAN Control Panel

(1) Power switch (two-position switch)

(a) ON: connects power to system

(b) OFF: disconnects power to system

(2) Option select switch (three-position switch)

(a) Y: not functional

(b) X: selects X channel for TACAN operation. (There are 126 preset operating channels)

(c) XA/A: selects TACAN air-to-air mode. Participating aircraft must have 63-channel separation. Distance information to suitably equipped aircraft is displayed on HSI

(3) Channel selector: when rotated, selects desired channel for TACAN operations and displays selection on channel window

(4) Channel display window: displays selected TACAN channel

(5) Volume control knob (VOL): when rotated, adjusts volume of TACAN station identification signals

(6) TEST button: initiates system built-in test (BIT) if pushed and held for a minimum of 5 seconds and the following conditions exist:

(a) TACAN steering selected on HSI display

(b) 180 course set on HSI

The following should occur:

(c) The TACAN bearing pointer and digital bearing will indicate 180 ± 2.5 degrees

(d) Range will read 0 ± 1 NM

(e) The CDI bar will be centered

NOTE: The indications of a valid TACAN BIT test are: TACAN bearing pointer and digital bearing - 180 ± 2.5 degrees - Range reads 0 ± 1 NM - CDI centered.

NOTE: The system initiates an auto-test when lock-on is broken.

f. VOR/ILS controls and indicators

(1) Power/frequency selector (outer knob)

(a) OFF: disconnects power to system
(b) PWR: connects power to system
(c) TEST: initiates system BIT

(2) VOR/ILS BIT

(a) Select VOR/ILS option on the HSI display

(b) Set a course of OOO with CRS selected

(c) VOR bearing pointer will indicate 315 ± 3.0 degrees

(d) Course deviation line moves left 2 dots maximum

(e) Marker beacon lights illuminate

(f) If no valid VOR signal is received only the marker beacon lights will illuminate

(3) Power/frequency selector (inner knob): change frequency in 1 MHz increments

(4) Frequency display window: displays frequency in use

(5) Volumn/frequency selector (outer knob): adjust volumn of audio signals

(6) Volumn/frequency selector (inner knob): change frequency in 50 kHhz increments

(7) Marker beacon lights

(a) O (blue): indicates aircraft passing over outer marker beacon

(b) M (amber): indicates aircraft passing over middle marker beacon

(c) I (white): indicates aircraft passing over inner marker beacon

D. CNI malfunctions

1. Communication system malfunctions

Sg 12, fr 54
COMM 1 or COMM 2 Failure

a. COMM 1 and COMM 2 failure

(1) Indications: unable to receive and/or transmit

NOTE: Because of the redundant design of the COMM system, the possibility of a total COMM failure is minimal.

(2) Verifications

(a) Check Communications transfer switch settings

(b) Check COMM control panel switch settings

(c) Check UHF/VHF radio control panel switch settings

(d) Check helmet/mask connections

(e) Verify other cockpit experiences same problem

(f) Still receiving navigation audio

(g) Check with other aircraft

(h) Perform BIT

NOTE: If a malfunctioning UHF/VHF radio control panel is causing the problem, communications can be transferred to the other cockpit, if occupied. If a faulty receiver/ transmitter is causing the problem, select the other COMM system. If both COMM amplifiers have failed, the communication system is lost.

(3) Effects on flight safety: normal air-to-air and air-to-ground communications will be lost

Examples of hazards:

* Lost comm procedures will apply
* Possible traffic conflict

- * ASR/PAR approach will be impossible
- * Must rely on visual communications
- * Must maintain VFR conditions if possible

2. TACAN azimuth failure

Sg 12, fr 66
Indications -- TACAN Azimuth Failure

a. Indications

(1) Bearing and time-to-go blanked in TACAN data block, bearing pointer, course line, TACAN symbol, blanked on HSI display

NOTE: Counterclockwise rotation of the TACAN bearing pointer is normal during periods of "break lock".

(2) Course steering arrow and time-to-go blanked on HUD

b. Verifications

(1) Verify TACAN receiver control panel switch settings

(2) Verify TCN and CRS are Selected on HSI

(3) Verify navigation control is set for crewstation you are occupying

(4) Verify same indications present in other cockpit, if possible

(5) Verify position with other waypoint navigation source or other aircraft, if possible

(6) BIT fails

(7) Check more than one TACAN station

(8) Loss of aural ident

(9) Verify the Morse identifier for your station

c. Effects on flight safety

(1) If undetected, a TACAN azimuth failure could cause you to leave assigned airspace, with ensuing risk of midair collision

(2) Possible navigation errors

(3) Loss of TACAN navigation and approach capabilities

(4) May require alternate approach

XI. Display System

A. Display system major components: the display system consist of three major components

Fig 30: Display System Major Components

1. Display Electronics Unit (DEU): there is only one DEU in the T-45C

2. Multi-Function Display (MFD): two MFDs in each cockpit

3. Head-Up Display (HUD): there is only one HUD on the T-45C located in the forward cockpit only

Sg 13, fr 1 *Multi-Function Display*

B. Display system control and switches

1. Multi-Function Display

a. Power, brightness, contrast

b. Has twenty option push-buttons

2. Head-Up Display

a. The HUD consists of a Pilot Display Unit (PDU) and Data Entry Panel (DEP)

b. Controlled by DEU

c. Has controls for:

(1) Power AUTO/DAY, brightness

(2) Declutter (DCL), enter (ENT)

(3) Data entry butttons

(4) MIL depression rocker switch (SET DEP)

(5) MODE, clear (CLR) buttons

(6) Low altitude warning (LAW)

(7) Course (CRS)

(8) Heading (HDG)

(9) Bingo (BNGO)

C. Display system operation

Sg 13, fr 8
Display Electronics Unit

1. Display Electronics Unit (DEU)

a. DEU has two capabilities: mission computer and display computer

b. Controls MIL-STD-1553B Multiplex Data Bus (MUX BUS) and interfaces with ADR, MDL and GINA

2. Multi-Function Display

Sg 13, fr 30
Multi-Function Display

a. Display formats are logically grouped flight and or mission data displays with selectable options

b. Operate identically and independently

c. MENU display provides access to all top level displays: ADI, HSI, HUD, VREC, STRS, BIT, DATA, ENG, TRNG and RPTR

Sg 13, fr 34
Head-up Display (HUD)

3. Head-up Display

   a. Location is the forward instrument panel

   b. An electro-optical device

   c. Projects flight and weapon delivery information onto the PDU

   d. Utilizes BIT

   e. Warning! HUD shall not be used as a primary flight instrument

   f. Manual data inputs via Data Entry Panel (DEP)

Sg 13, fr 41
Display System BIT

D. Display system bit

1. Built-In-Test (BIT) for initializing the DEU, MFDs, and HUD/PDU

   a. Two BIT MENUs

      (1) Weight-Off-Wheels gives real time status of equipment, Continuous BIT

      (2) Weight-On-Wheels has selectable options, AUTO/ DSPY for component Initiated BIT

Fig 31: *BIT Status Report*

   b. Maintenance display page

   c. BIT status report; GO, OPGO, DEGD, OVRHT, IN TEST

   d. Display BIT-DBIT selectable on DEU, MFDs, and HUD/PDU

   e. AUTO BIT-secondary BIT automatically for DEU followed by GINA, ADR, MDL and RALT

   f. Monitors equipment status and notify aircrew fault

g. Power-up BIT performed when equipment power applied

h. Initiated BIT aircrew or groundcrew activated

i. Continuous BIT performed in background during normal operation of equipment

E. Display system interfaces

__Sg 13, fr 45__ Display System Interfaces

1. The HUD interfaces for control of display formats and data

2. Both DEP's for pilot input and response

3. All MFDs for pilot input and receive display formats

4. CEU for imagery

__Fig 32:__ DEU Interface Diagram

5. VTR for display imagery and data for recording

6. Centralized warning system for cautions and warnings

7. VOR/ILS and TACAN for navigation data

8. RALT for on/off/test commands and altitude information

9. SADS for air data

10. Stores for weapon status and control

11. IFF for BIT functions

12. COMM AMP for LAWS and trigger audio

13. Misc. A/C switches/sensors and relays for input, commands and BIT

Fig 33: Engine Controls (Forward Cockpit)

XII. Engine start procedures

A. Controls and indicators

1. Summary

The IGNITION switch controls 28 VDC essential services power to the engine igniter relays and GTS start buttons on each throttle grip. The ENGINE start switches control 28 VDC essential services power to the start control unit and provide the start-main-engine signal. The forward and aft cockpit ENGINE start switches are connected in series, and both must be set to ON to start the engine. Momentarily pressing the GTS start button causes the gas turbine starter to start and accelerate to idle speed and the ignition relay circuitry to be energized. The engine igniters are also activated while the GTS button is depressed. When the engine start switch is set to START, the GTS accelerates to full power and the start valve is open to allow the GTS to supply low pressure air to the ATS which rotates the N_2 shaft. Engine igniters are activated by ECA

Monitor TGT and rpm gauges during engine start for indications of abnormal operation. No rise in EGT within 15 seconds after introducing fuel is an indication of a wet start. Stagnated rpm below 52% and slowly rising EGT indicate a hung start. A rapid increase in EGT that appears likely to exceed the maximum (550 degrees C) is an indication of a hot start. Starting a hot engine can also result in a higher than normal EGT. Heavy generator or hydraulic loading, an open bleed valve, or high bleed air demands can reduce rpm to below normal

Abnormal fuel flow indications normally accompany high or low rpm/EGT indications. If abnormal fuel flow is indicated, check the other engine instruments to aid you in determining the problem. The normal idle fuel flow range is 300-400 pph

Sg 14, fr 1
Engine Controls

2. Engine start controls and indicators

a. Controls

(1) IGNITION switch: two-position switch marked IGNITION - NORMAL/ISOLATE

(a) NORMAL (guarded): controls electrical power supply to ignition system

(b) ISOLATE: deenergizes ignition system (both engine and GTS)

(2) ENGINE start switch: three-position switch marked ENGINE - START/ON/OFF

(a) START (spring-loaded to ON):

(b) ON: energizes start control unit

(c) OFF: manually shuts down GTS operation and deenergizes start control unit

(3) GTS start button momentary press switch

(a) Press (momentary):

(i) Signals start control unit (SCU) to start GTS

(ii) Energizes engine ignition circuitry to the SCU and engine start switch (with IGNITION switch in NORMAL)

(b) Activates engine igniters for duration of press plus 30 seconds with weight off wheels

(4) Throttle: interconnected and mechanically linked variable position fuel control lever with stops for OFF, IDLE, APPROACH IDLE and full forward (MRT)

(a) OFF: interrupts or prevents fuel flow to engine

(b) IDLE: opens fuel shutoff valve to direct fuel to fuel spray nozzles

(c) APPROACH IDLE: with landing gear down and aircraft weight off wheels, maintains minimum RPM at approximately 72%

(d) Full forward: operates engine at military rated thrust (MRT) or full throttle

b. Indicators

(1) TGT indicator: indicates exhaust gas temperature in degrees centigrade

(2) RPM indicator: indicates N_2 compressor speed in percent RPM

(3) FUEL FLOW indicator: indicates rate of fuel flow to engine combustion chamber in pounds per hour

(4) Voltmeter: indicates battery or generator voltage

(5) GTS advisory light: when illuminated, indicates gas turbine air producer has attained idling speed prior to engine start

(6) READY advisory light: when illuminated, indicates a low pressure (N_1) shaft speed of 100 RPM or greater in the correct direction of rotation and the igniter circuitry is energized

(7) OIL PRESS warning light: when illuminated, indicates an oil pressure differential (< 10 psi) for more than 10 seconds has occurred

(8) F PRES caution light: when illuminated, indicates loss of fuel tank pressurization or an insufficient pressure differential across the boost pump(s)

(9) FIRE warning light (start malfunction only); when illuminated, indicates engine bay temperature in excess of 300 degrees C

(10) GTS FIRE warning light (start malfunction only): when illuminated, indicates air producer bay temperature in excess of 300 degrees C

(11) EGT/RPM warning light (start malfunction only): when illuminated, indicates that either the EGT temperature exceeds 650 +/- 8 degrees C or the N_1 rpm exceeds 112.4 ± 1%

(12) TP HOT caution light (start malfunction only): when illuminated, indicates temperature greater than 150 degrees C in the tailpipe bay

3. Engine starting procedures

Note: The following steps on preflight checks/ services and engine starting procedures are excerpted from the NATOPS manual.

a. Exterior inspection

NOTE: Ensure tail pipe pulled full aft prior to starting engine.

Sg 14, fr 6
Switch Position for Engine Start

b. Interior check

(1) Left console

(a) Fuel shutoff handle - LOCKED (DOWN)

(b) IGNITION switch - NORMAL (GUARDED)

(c) Engine start switch - ON

(d) Fuel control switch - NORMAL

(e) Throttle friction - OFF

(f) Throttle - OFF

c. Prestart checks

(1) Battery switches

(a) No.1 and No. 2 - ON

(b) Alternately select each battery OFF to check individual voltage. For starting, minimum voltage for each battery is 24 volts

(c) No. 1 and No. 2 - CHECK ON

d. Starting engine

If throttle has been moved above cutoff with the engine off

(1) Clear engine procedure - PERFORM

(a) Serious engine damage from an overheat condition during START could occur

All starts

Sg 14, fr 7
Engine Start Sequence

(2) GTS start button - PRESS MOMENTARILY

(a) Signals Start Control Unit to start the GTS

(b) Applies Essential Services Bus power to GTS fuel/oil-pump, GTS starter motor, GTS igniters (through start control unit), and engine igniters

(c) GTS unit starts and reaches idle speed of 86% within 20 seconds

GTS advisory light illuminates

NOTE: Protection circuits within the starting system will shut down the GTS if idle speed is not achieved within 30 seconds after the GTS button is pressed.

(3) Engine start switch - START

Sg 14, fr 9
Engine Start Sequence

(a) Spring-loaded detent initiates engine starting sequence

(b) GTS accelerates to 100%, supplying air to starter

(c) Air turbine starter (ATS) rotates N_2 shaft

READY advisory light illuminates within 15 seconds

Sg 14, fr 10
Engine Start Sequence

(d) READY advisory light: Indicates that N_1 shaft is rotating in correct direction with shaft speed $\geq$100 rpm and that starting sequence may continue

Sg 14, fr 11
Engine Start Sequence

CAUTION: If the READY advisory light does not illuminate within 15 seconds, discontinue start attempt, otherwise mechanical damage may result from an overheat condition.

(e) Engine igniter relay applies 28 VDC essential services power from ignition switch to engine igniters

(f) RPM should rise rapidly to approximately 10%

(4) Throttle - IDLE WHEN RPM BETWEEN 15%-20%

(a) Opens throttle shutoff valve, allowing SIFCU and FCU to begin metering fuel to engine spray nozzles

(b) You should see an indication of fuel flow

(c) Oil pressure warning light should extinguish at approximately 18% N_2 rpm

NOTE: Light-off is indicated by an initial rise in EGT.

WARNING: Do not start the engine with the throttle above ground idle, severe engine damage/turbine destruction may occur.

CAUTION: Advancing throttle to IDLE before READY advisory light illuminates may cause damage to the engine from overheat.

CAUTION: Light-off must occur within 15 seconds after advancing throttle to IDLE.

CAUTION: Secure engine if start EGT limit is rapidly approached and appears likely to be exceeded.

(5) TGT and RPM indicators - MONITOR
Ensure GTS and READY advisory lights go out at approximately 45% rpm

NOTE: TGT, rpm, and fuel flow indications must be closely monitored throughout the engine starting sequence to ensure safe starting and to prevent engine damage.

(a) EGT indications during starting phases

(i) Rises rapidly to approximately 300-350 degrees C

(ii) Rate of rise should slow above 350 degrees C

(iii) Normal starting EGT peaks at approximately 400-450 degrees C

NOTE: Maximum EGT should not exceed 550 degrees C. (570 degrees with a 10-second overshoot)

(b) RPM climbs rapidly toward, and should reach, 52% within 30 seconds of IDLE selection

NOTE: If 45% N_2 RPM not attained within 45 seconds from release of the start switch, the GTS will return to idle.

(c) Fuel flow slowly rises with rpm to idle flow of 300-400 pph

Sg 14, fr 13
Engine Start Sequence

Sg 14, fr 14
Engine Start Sequence

(d) At starter cut-out speed (45% rpm)

(i) Start control unit shuts down GTS and GTS and READY advisory lights extinguish

(ii) Engine ignition units deenergize

(iii) Generator comes on-line, and GENERATOR warning light out (may not occur until after N_2 rpm above 61%)

(6) When RPM and EGT stabilize, check:

(a) All warning/caution panel lights - OUT EXCEPT HYD 2, CANOPY (if open or unlocked), AND OXYGEN

(b) RPM - NOTE, APPROXIMATELY 52%

(c) EGT - NOTE, 450 DEGREES C MAXIMUM

Sg 14, fr 15
Engine Start Sequence

e. Post-start

(1) Throttle - ADVANCE SLOWLY TO 70% RPM

CAUTION: Following a start, do not advance the throttle rapidly before the bleed valve closes, as there is a possibility that the engine will overheat. Once the bleed valve is closed there are no restrictions on the rate of throttle movement.

(2) FUEL CONTROL switch - MANUAL
M FUEL advisory light illuminates. Note engine RPM may decrease by up to 6%

(3) FUEL CONTROL switch - NORMAL
M FUEL advisory light goes out
and ensure previous RPM is achieved

(4) HYD 2 RESET button - PRESS
Check that HYD 2 caution light goes out and hydraulic pressure indicates in normal range

(5) Hydraulic pressure - 3000 PSI

(6) Throttle - IDLE, CHECK EGT AND RPM, ENSURE BLEED VALVE CLOSED

NOTE: Bleed valve closure can be confirmed by noting RPM increased approximately 3% and EGT decreased by 50 degrees C from previous indications.

4. Unacceptable conditions during engine start

Sg 14, fr 16
Unacceptable Conditions During Engine Start

a. EGT

(1) High

(a) Maximum starting: 550 degrees C; maximum overshoot of 20 degrees C for 10 seconds

(b) Slowly climbing EGT with stagnated rpm below 52% (hung start)

(c) Any very rapid climb in EGT that appears likely to exceed 550 degrees C (hot start)

NOTE: Wind blowing up the tailpipe, extremely high ambient temperature, and starting a hot engine may cause higher than normal EGT indications.

(2) Low

(a) Any EGT indication well below normal (hung start)

b. RPM

(1) During start

(a) RPM stagnation below 45% with slow EGT rise (hung start)

(b) Rapidly rising EGT that appears to exceed maximum EGT (hot start)

(2) IDLE

(a) N_2 rpm not within 55 $\pm$ 2% (bleed valve closed)

(b) Any sudden changes in idle rpm

NOTE: Deviations in engine idle rpm may occur due to any one or a combination of the following: generator loading, bleed valve open or closed, external bleed air demands, hydraulic loading, and altitude adjustments of approximately 1% rpm increase for every 1500 feet above sea level.

c. Low battery voltage: below 24 VDC prior to start

d. READY advisory light: failure to illuminate within 15 seconds of placing ENGINE start switch to START

e. Fuel flow: abnormal indications normally accompanied by high or low EGT and rpm indications

(1) During start: fuel flow without a rise in EGT and rpm within 15 seconds of setting throttle to IDLE (wet start)

(2) IDLE: with bleed air valve opened or closed

(a) Maximum: 400 pph

(b) Minimum: 300 pph

f. Bleed air valve

(1) Failure to close after accelerating rpm above 61 +/- 4% and returning throttle to IDLE

NOTE: The bleed air valve closes at 61 +/- 4% N_2. The Post Start procedure sets the power to 70% to accomplish fuel control, HYD 2 system, and idle/rpm (bleed air valve) checks simultaneously.

(a) EGT fails to decrease approximately 50 degrees C

(b) RPM remains lower than normal (fails to increase approximately 3%)

(2) Closed during engine start cycle: if idle rpm exceeded 57% during start, bleed valve may have closed automatically

(a) RPM does not show increase of approximately 3%, but stabilizes at normal idle rpm (55 +/- 2%)

(b) EGT does not show decrease of 50 degrees C but stabilizes at normal idle EGT

SUMMARY

We have provided a review of the test material including:

* Each T-45C system and its
    - Major components and their operational characteristics
    - Associated cockpit controls and indicators
    - Major aircraft interfaces
* Engine starting procedures

CONCLUSION

We have conducted an extensive review of the T-45C aircraft and its major systems to prepare you for testing. But more important, your thorough understanding of each of the T-45C systems is critical to safe and correct operation of the aircraft. Good luck on your examination.

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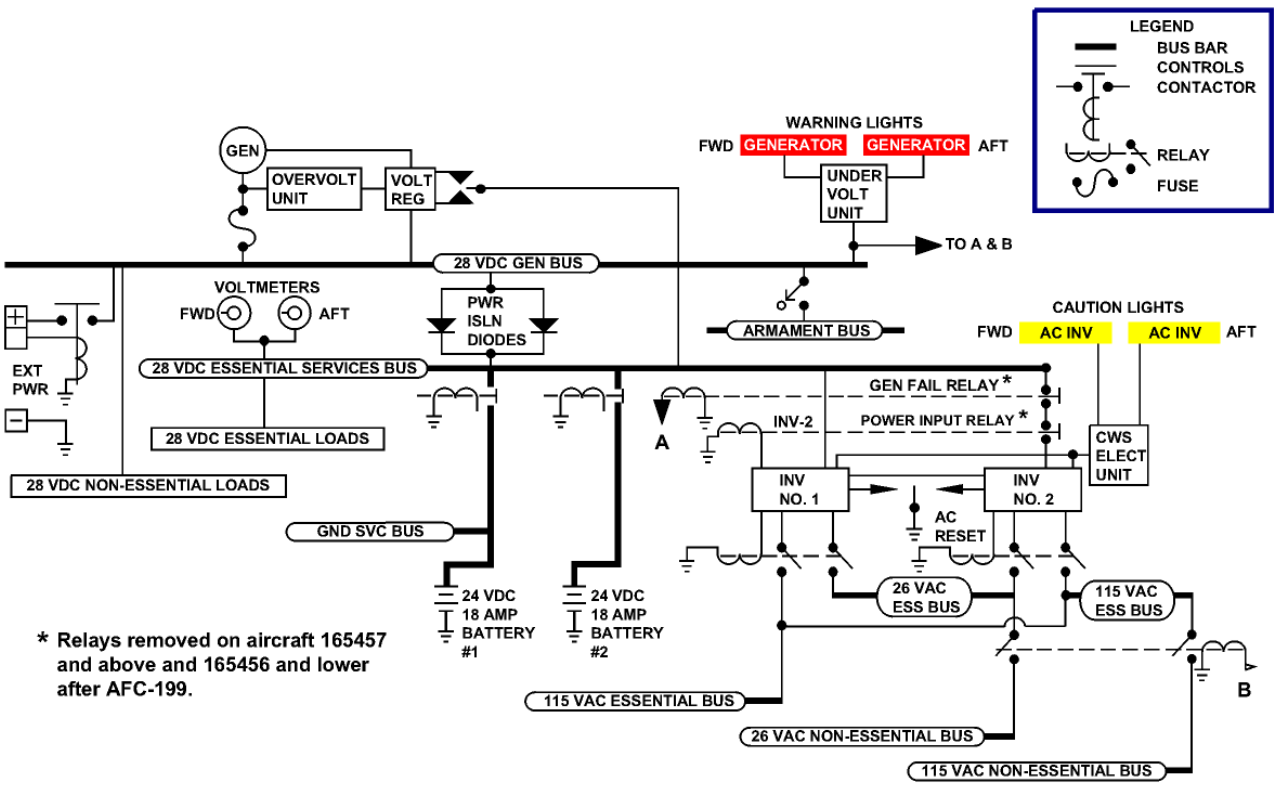
FIGURES



* Relays removed on aircraft 165457 and above and 165456 and lower after AFC-199.

Figure 1: ELECTRICAL SYSTEM BLOCK DIAGRAM

28 VDC - Generator Bus			
AC Isolation Relay ADRS Total Air Temp Htr Pwr Aileron Trim Control Aileron Trim Position Indicator Angle-of-Attack Heat Anti-Collison Lights Baro Altimeter, Stby	Bombs Release Cabin Presure Control 2 Comm Control Power B DEP, Fwd Flood Lighting GTS Drain Valve Landing/Taxi Light Master Arm MDL Power	MFDs, Right (Both Cockpits) OBOGS Heat Overvoltage Unit Reticle Light Rockets Release Rudder Trim Control Stabilator Position Indicator	Stabilator Trim Standby UHF/VHF 2 Undervoltage Sensing Voltage Regulator VOR/ILS Control Yaw Damper

28 VDC-Essential Services Bus			
Accel/Bleed Valve Control Accel/Bleed Valve Indicator ADI, Standby ADRS Angle-of-Attack Indicator Annunciator Lights Anti-Skid Control Approach Idle Stop Arresting Hook Cabin Pressure Control 1 Cabin Pressure Warning Cabin Temperature Control Caution Warning System Comm Control Pwr A DC Power External Supply DC Power Generator Reset DC Power Voltmeters-DEU [Note 2]	Ejection Enable Switch (IFF) Emergency Jettison (Wing Station Only) Emergency Lighting Emergency NLG Door Actuation Control Engine Bleed Valve Engine Control & EGT Indicator Pwr Engine Vibration and Pressure Monitor External Power Fire Detection Flaps Control (Emer) Flaps Control Main Flaps Position Indicator Fuel Boost Pump Inverters [Note 1] Fuel Boost Pumps Control [Note 1] Fuel Flow Indicator Fuel System Control Fuel System Low Level Warning	Fuel System Quantity Indicator Generator Off-Load Generator Undervoltage GINA GTS Fuel/Oil Pump HYD 1, 2, & Brake Transducer Hydraulic 2 Bypass IFF Control IFF RCVR/XMTR Igniters Inverters Protection Landing Gear Control Landing Gear Selector Valve Launch Bar Manual Fuel Sys Bleed Valve Time Delay Manual Fuel System Control Master Start 1 & 2 Master Switch Batt 2 MFD, Left (Both Cockpits) [Note 2]	Navigation Light, Tail Nose Wheel Steering OBOGS Monitor OBOGS Shutoff Valve Pitot Probe Heat Press to Test Ram Air Turbine Reset Rudder Pedal Shaker Motor SADS [Note 2] Seat Position Slats Position Indicator SpeedbrakeControl Speedbrake Position Indication Stabilator Trim Main TACAN Throttle Proximity Switches Turn/Slip Indicator UHF/VHF 1 VCR/CEU [Note 2] Weight-on-Wheels Control

115 VAC Buses		26 VAC Buses	
Essential	**Non-Essential**	**Essential**	**Non-Essential**
Annunciator Lights (Night) Emergency NLG Door Act (Pwr) GINA (Synchro. Signal)	DEU Cooling Fan Radar Altimeter	TACAN ADR	DEU VOR/ILS/MB Yaw Damper

6 VAC Buses	
Essential	**Non-Essential**
NAV Lights, Wing	Formation Lights

28 VAC Non-Essential Bus
Console Lights

5 VAC Non-Essential Bus
MIP Cockpit Lights

Legend

[NOTE 1] Operate for 30 seconds after loss of generator bus.

[NOTE 2] Operate for 2 minutes after loss of generator bus.

Figure 2: ELECTRICAL LOAD DISTRIBUTION

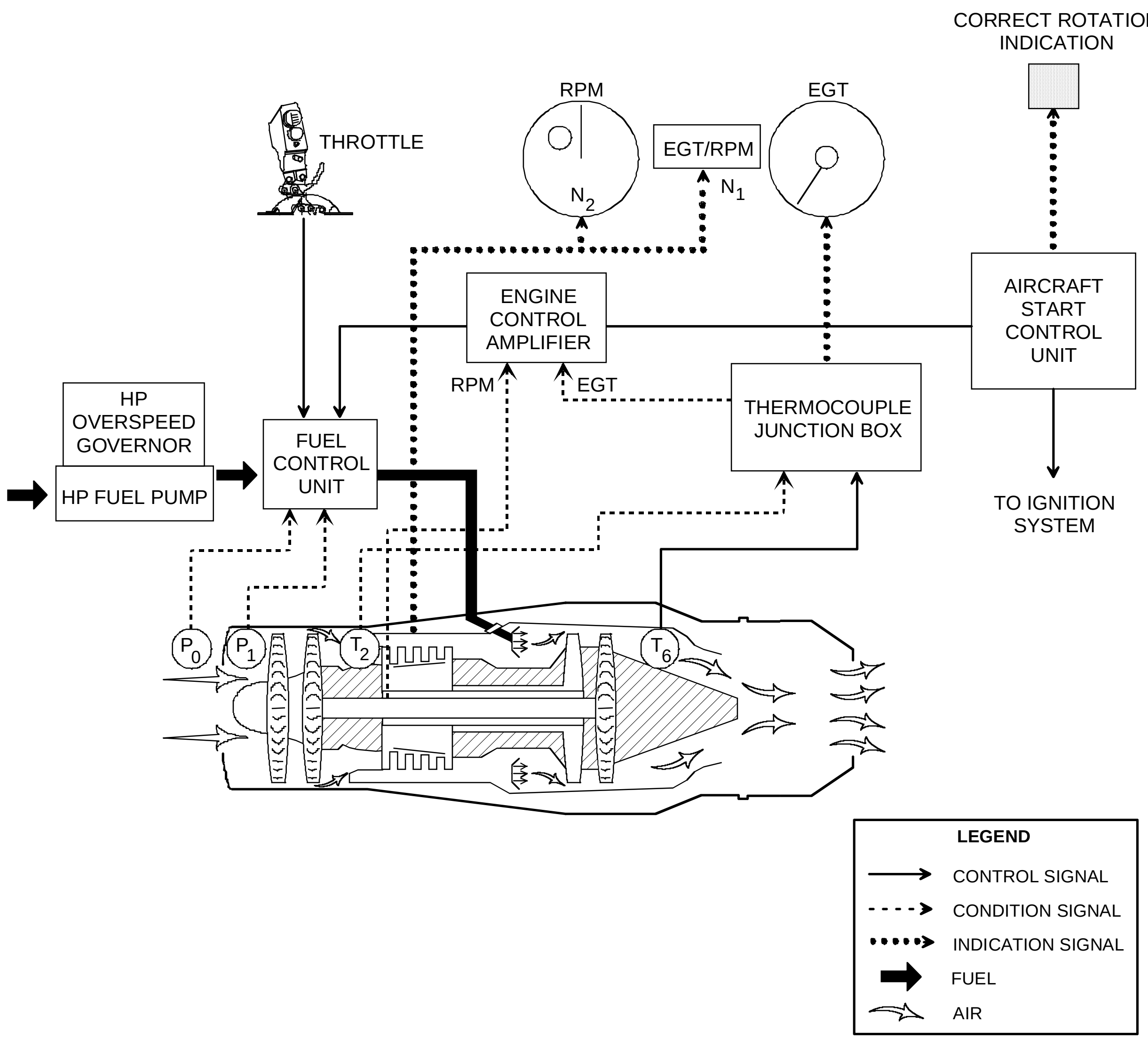


Figure 3: BASIC ENGINE BLOCK DIAGRAM

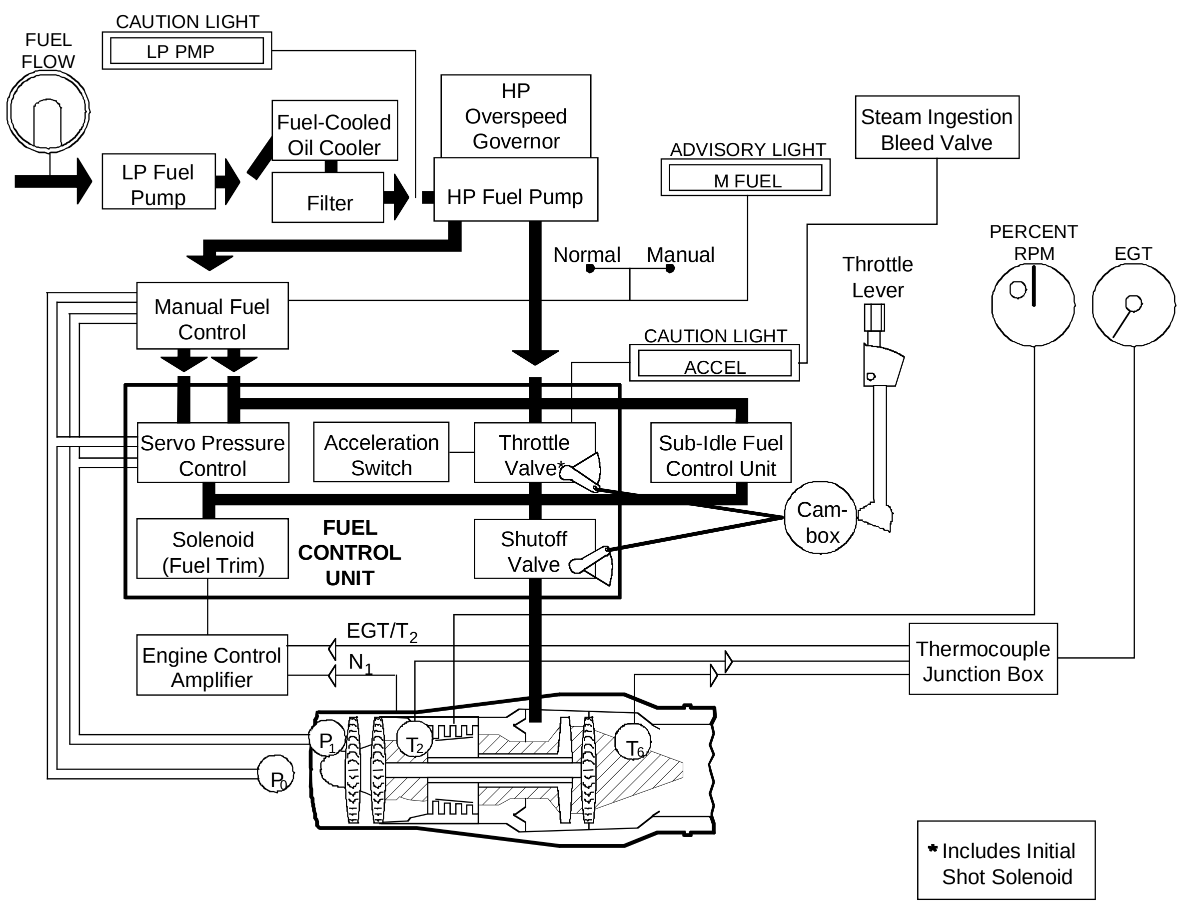


Figure 4: ENGINE FUEL SYSTEM BLOCK DIAGRAM

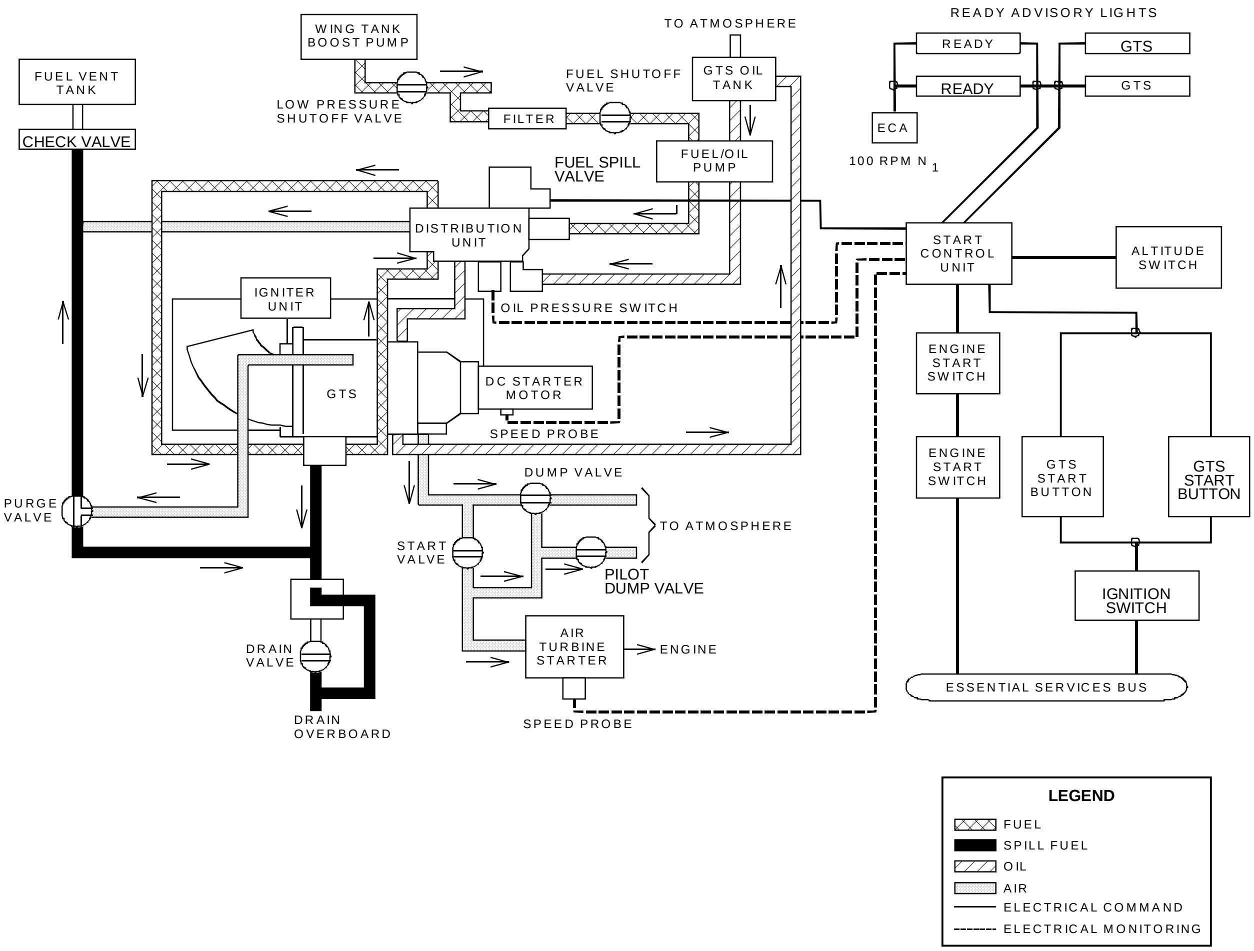


Figure 5: ENGINE STARTING SYSTEM BLOCK DIAGRAM

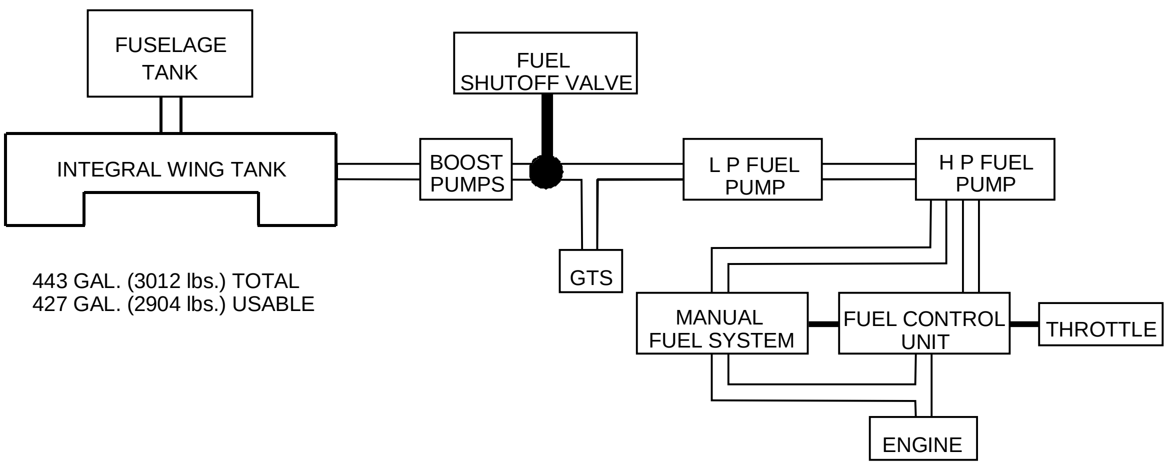


Figure 6: SIMPLIFIED FUEL SYSTEM BLOCK DIAGRAM

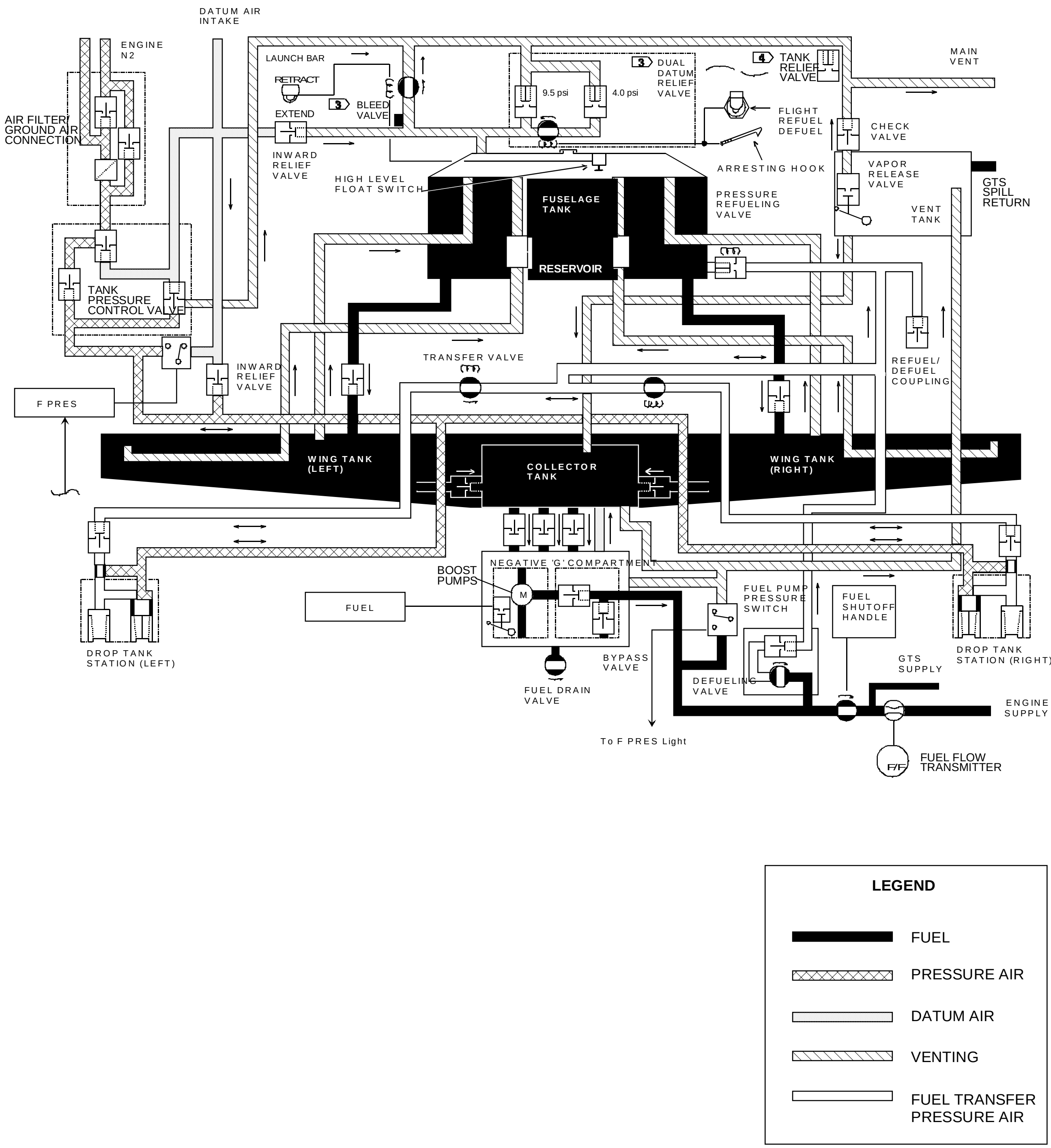


Figure 7: AIRCRAFT FUEL SYSTEM BLOCK DIAGRAM

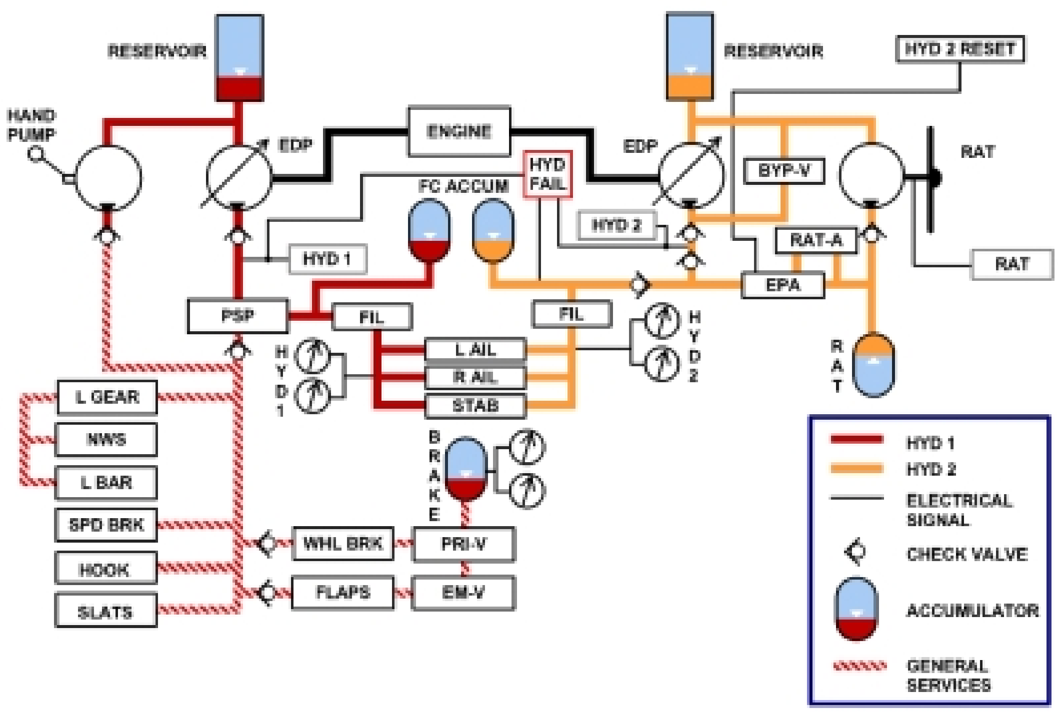


Figure 8: HYDRAULIC SYSTEM BLOCK DIAGRAM

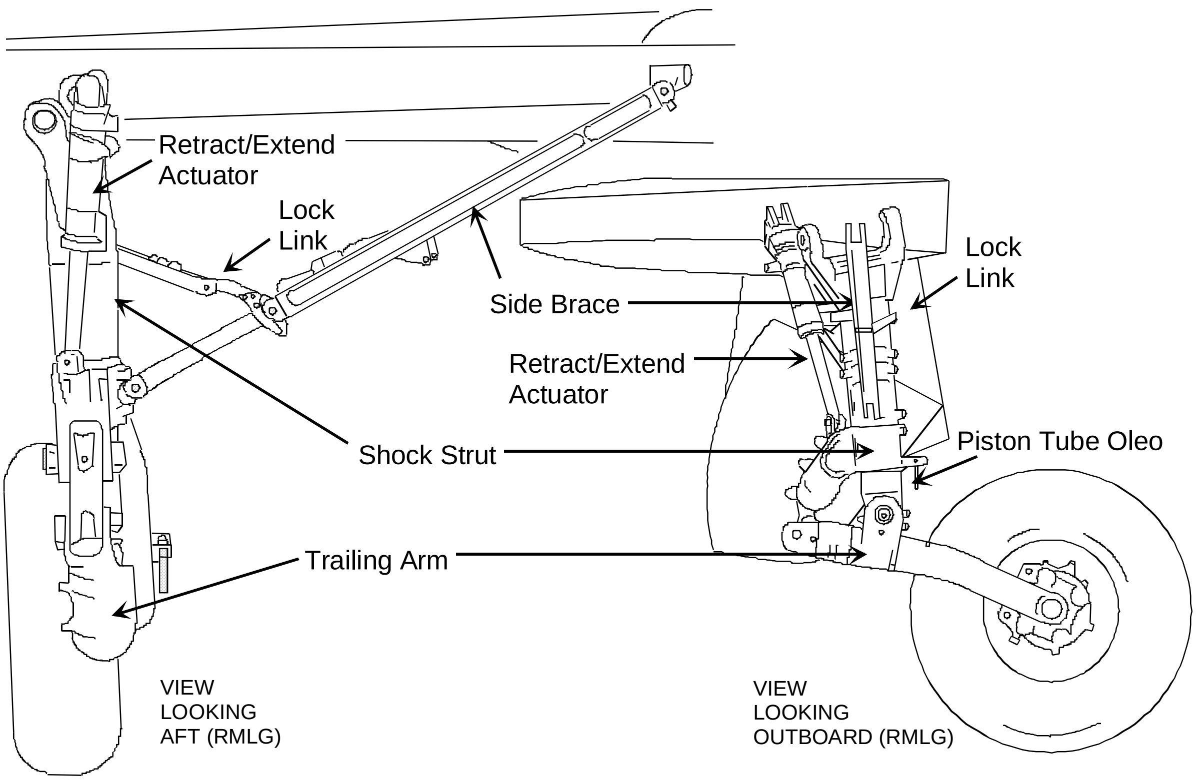


Figure 9: MAIN LANDING GEAR (MLG) MAJOR COMPONENTS

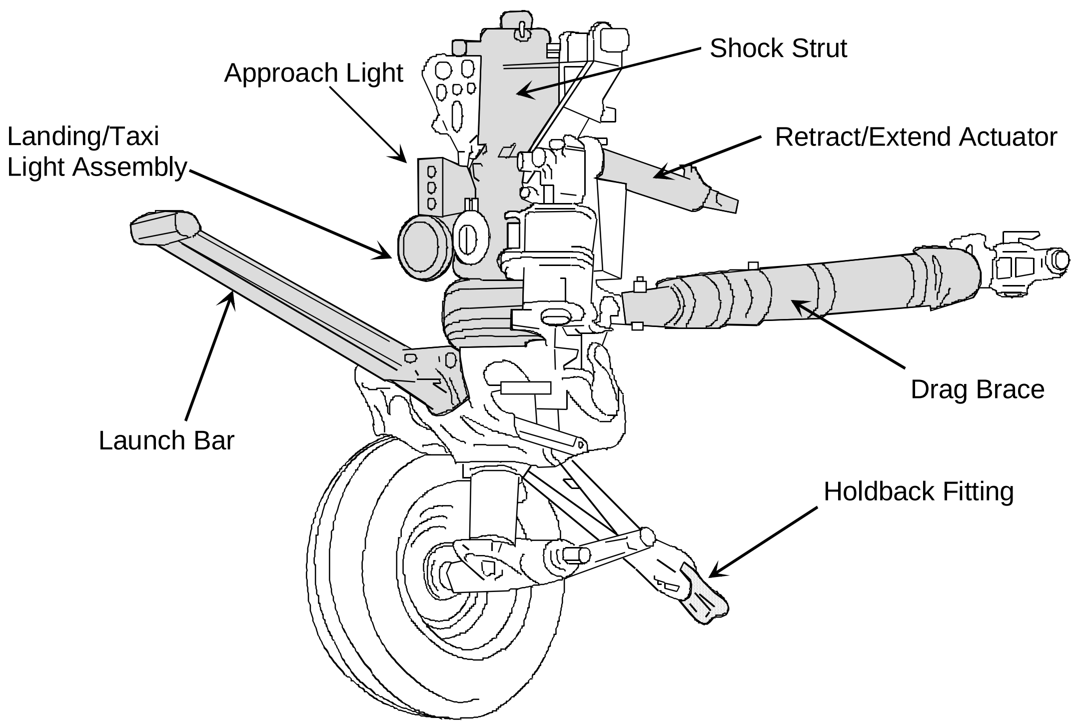


Figure 10: NOSE LANDING GEAR (NLG) MAJOR COMPONENTS

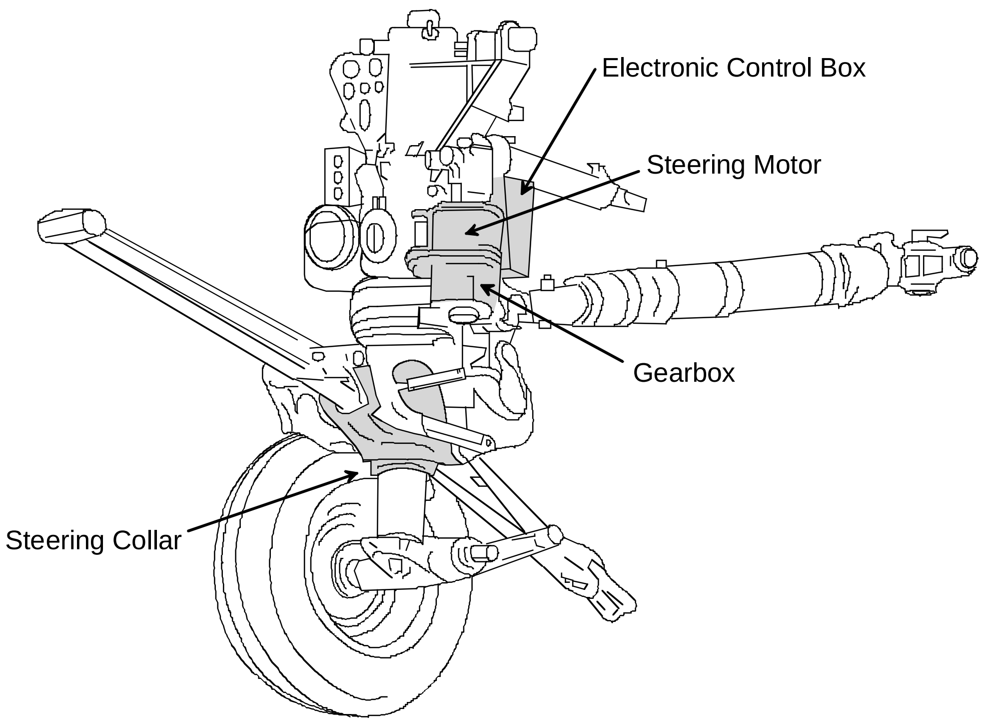


Figure 11: NOSE WHEEL STEERING (NWS) SYSTEM MAJOR COMPONENTS

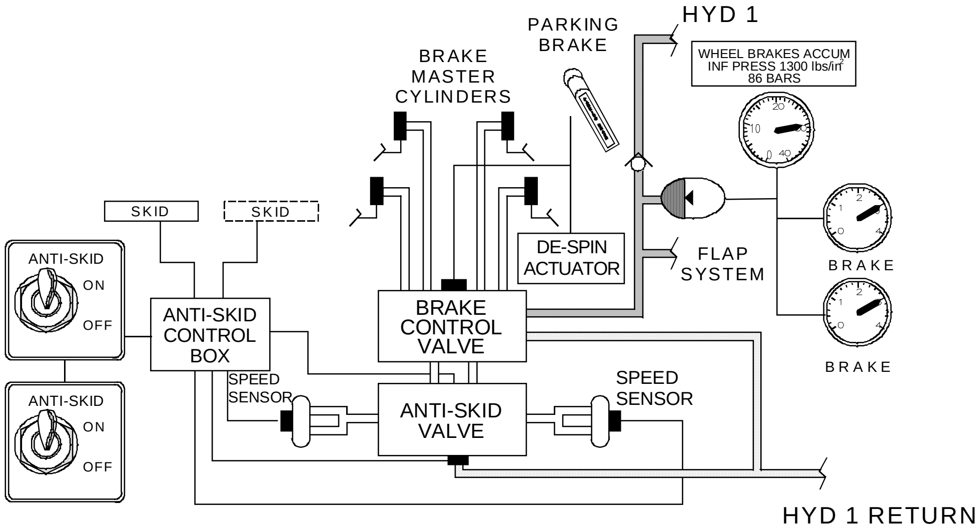


Figure 12: WHEEL BRAKE/ANTI-SKID SYSTEM BLOCK DIAGRAM

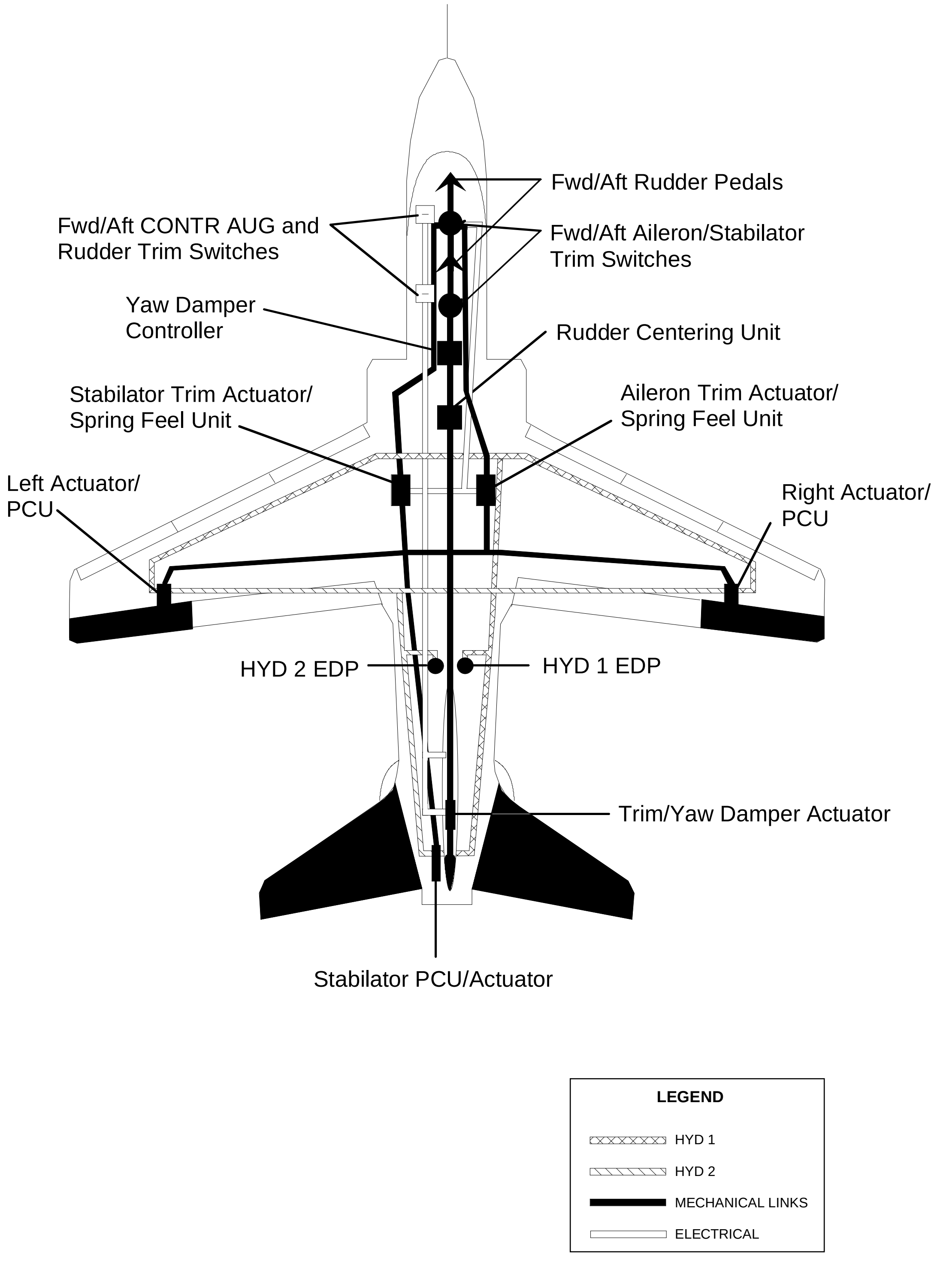


Figure 13: FLIGHT CONTROLS

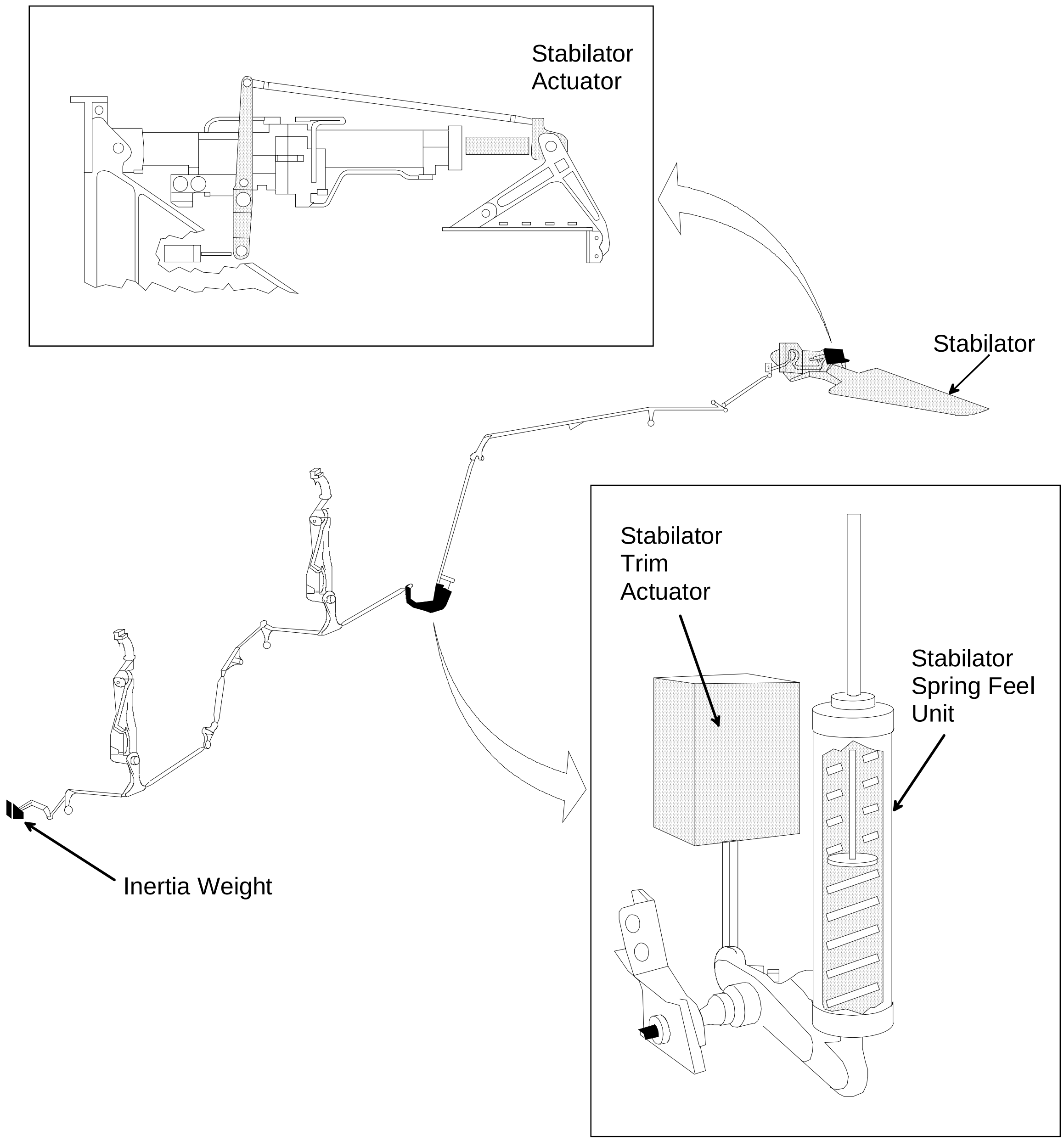


Figure 14: FLIGHT CONTROLS--RUDDER SYSTEM COMPONENTS

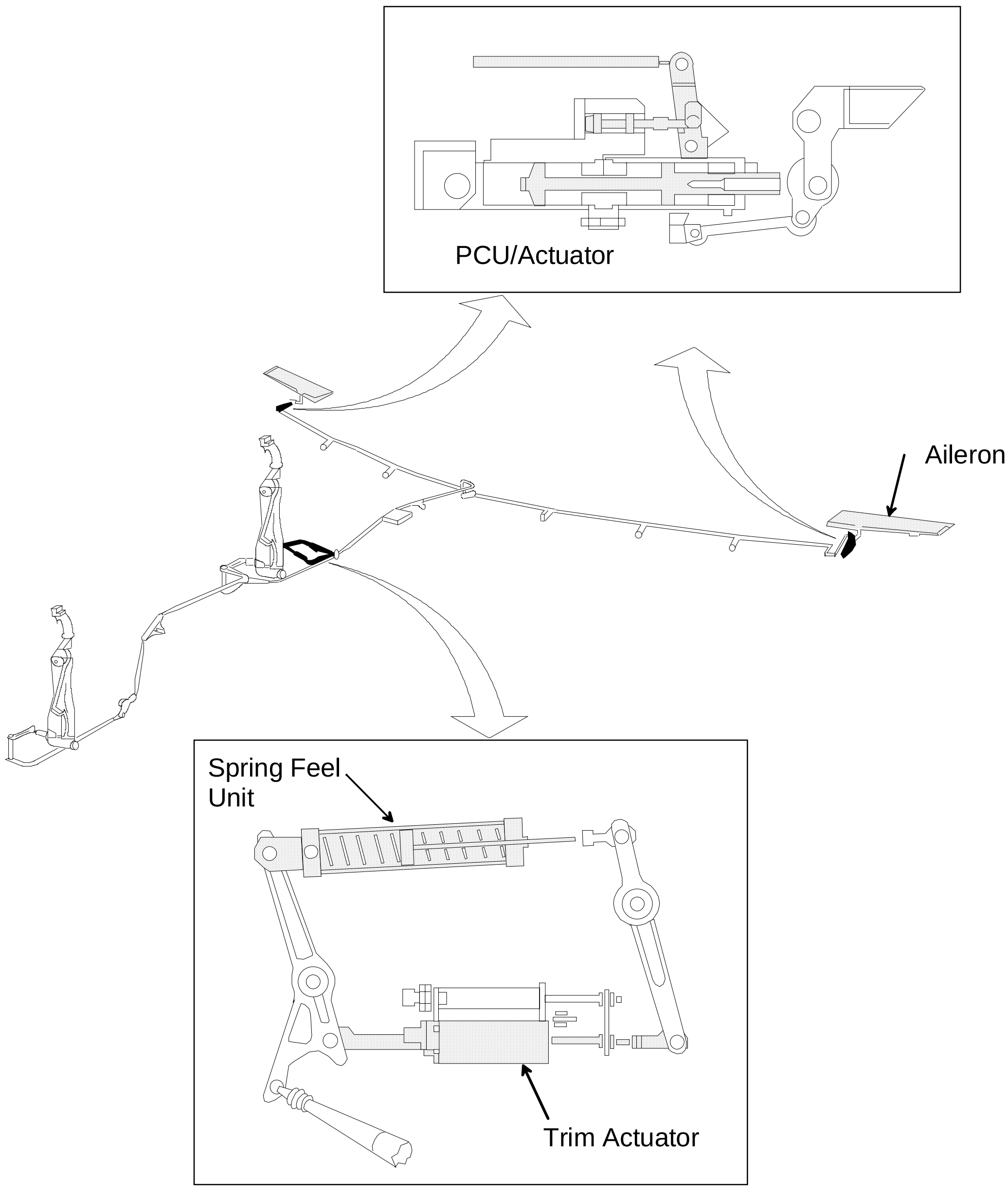


Figure 15: FLIGHT CONTROLS--AILERON SYSTEM COMPONENTS

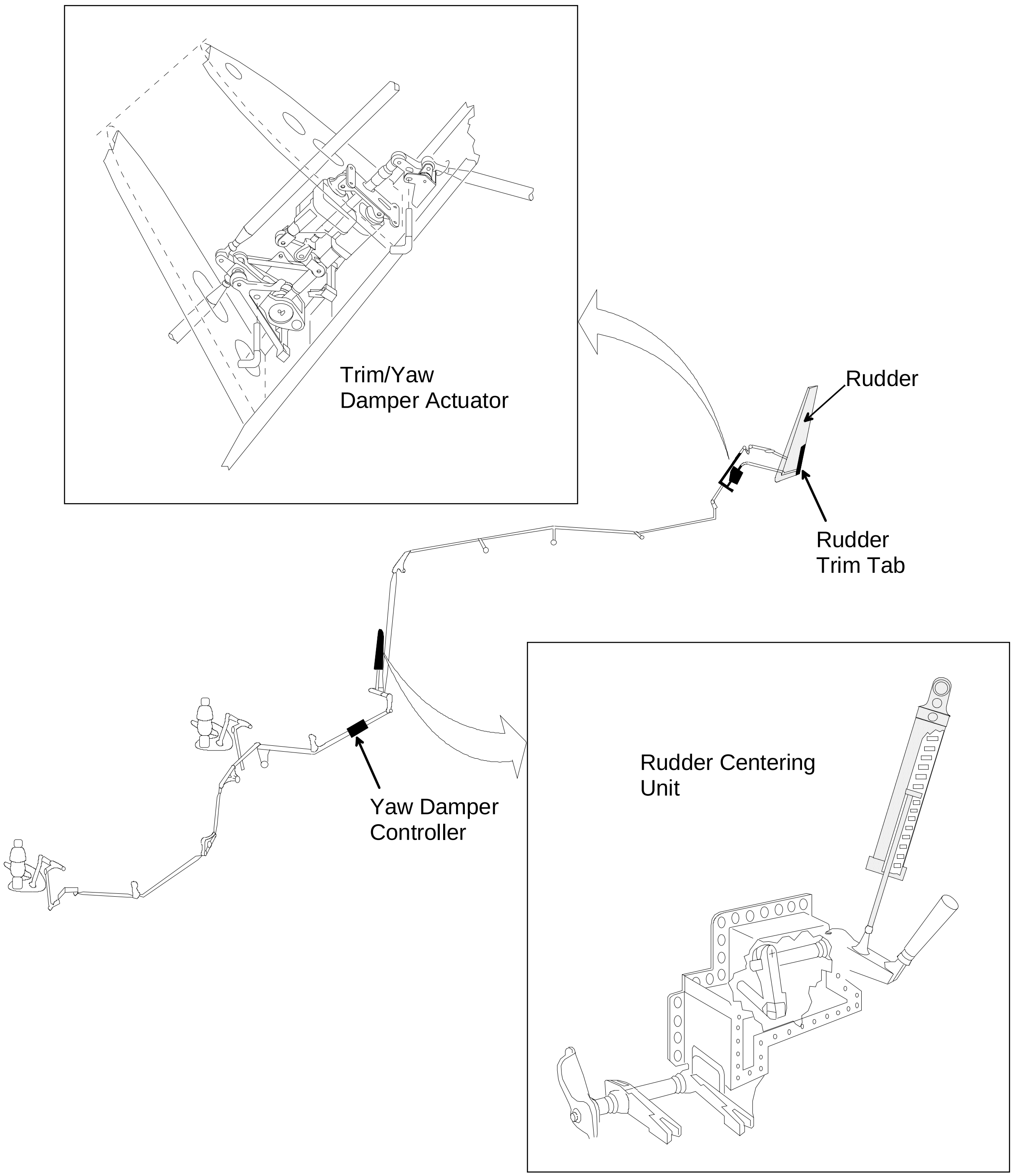


Figure 16: FLIGHT CONTROLS--STABILATOR SYSTEM COMPONENTS

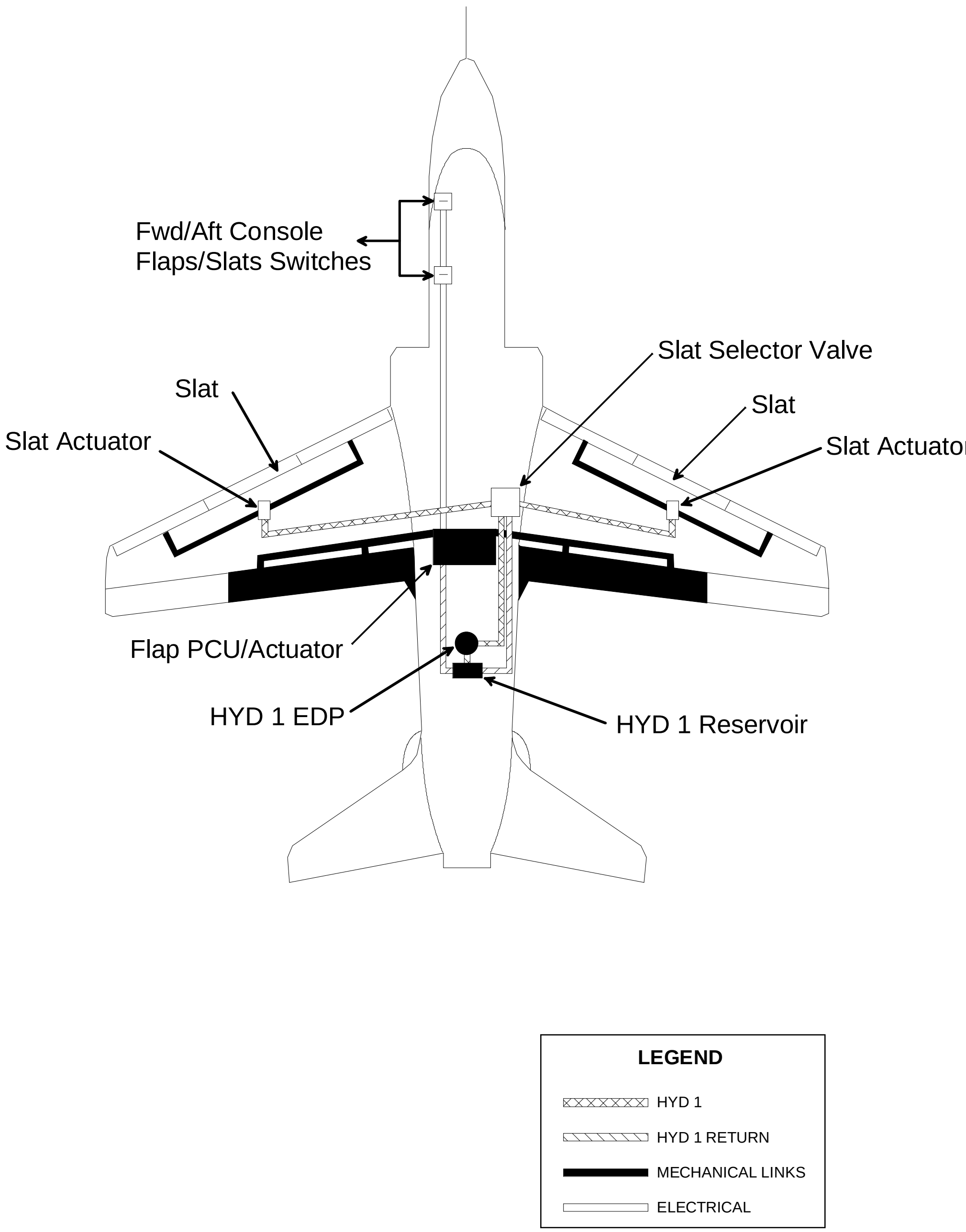


Figure 17: FLAPS/SLATS, SPEED BRAKES

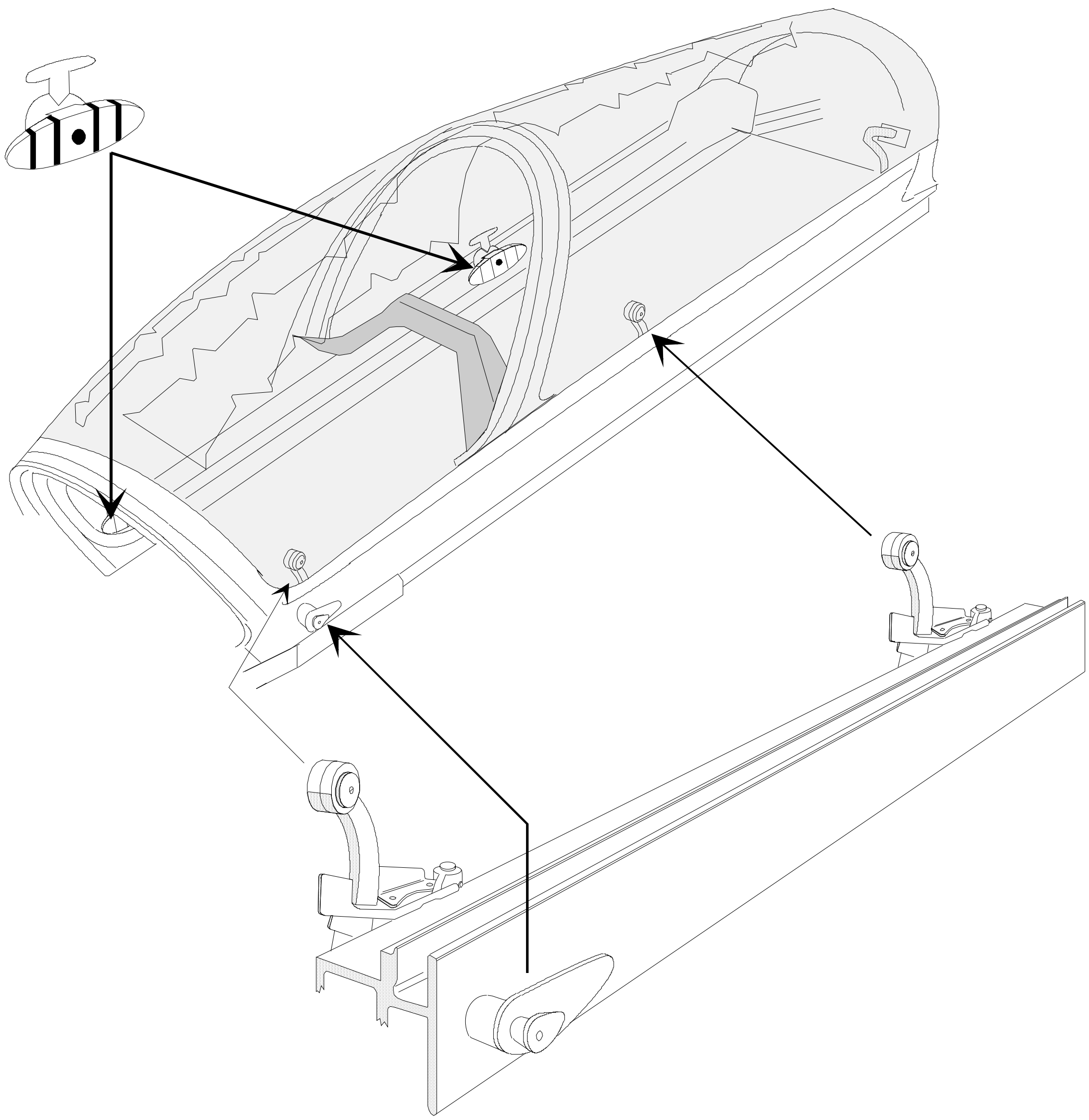


Figure 18: CANOPY

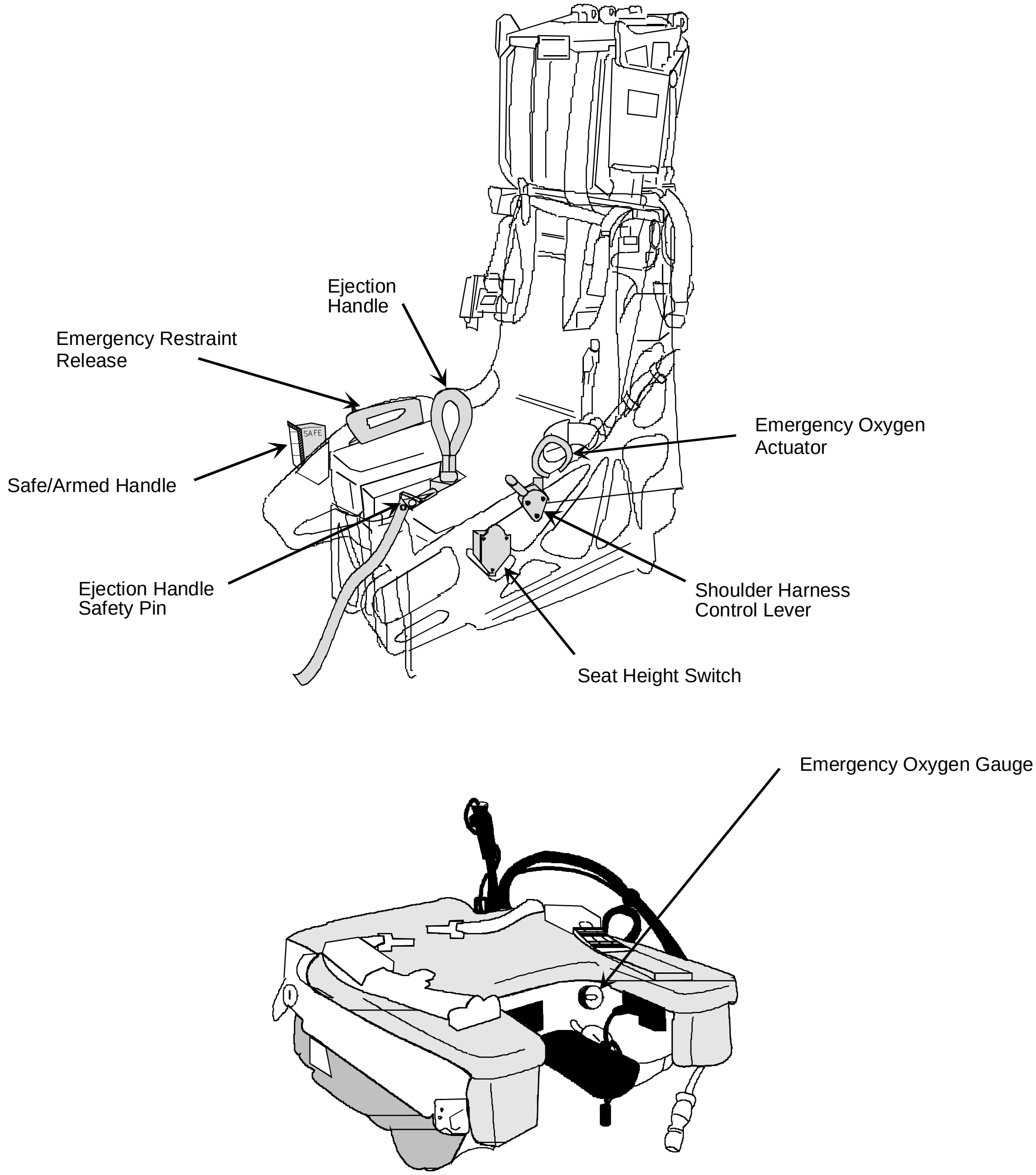
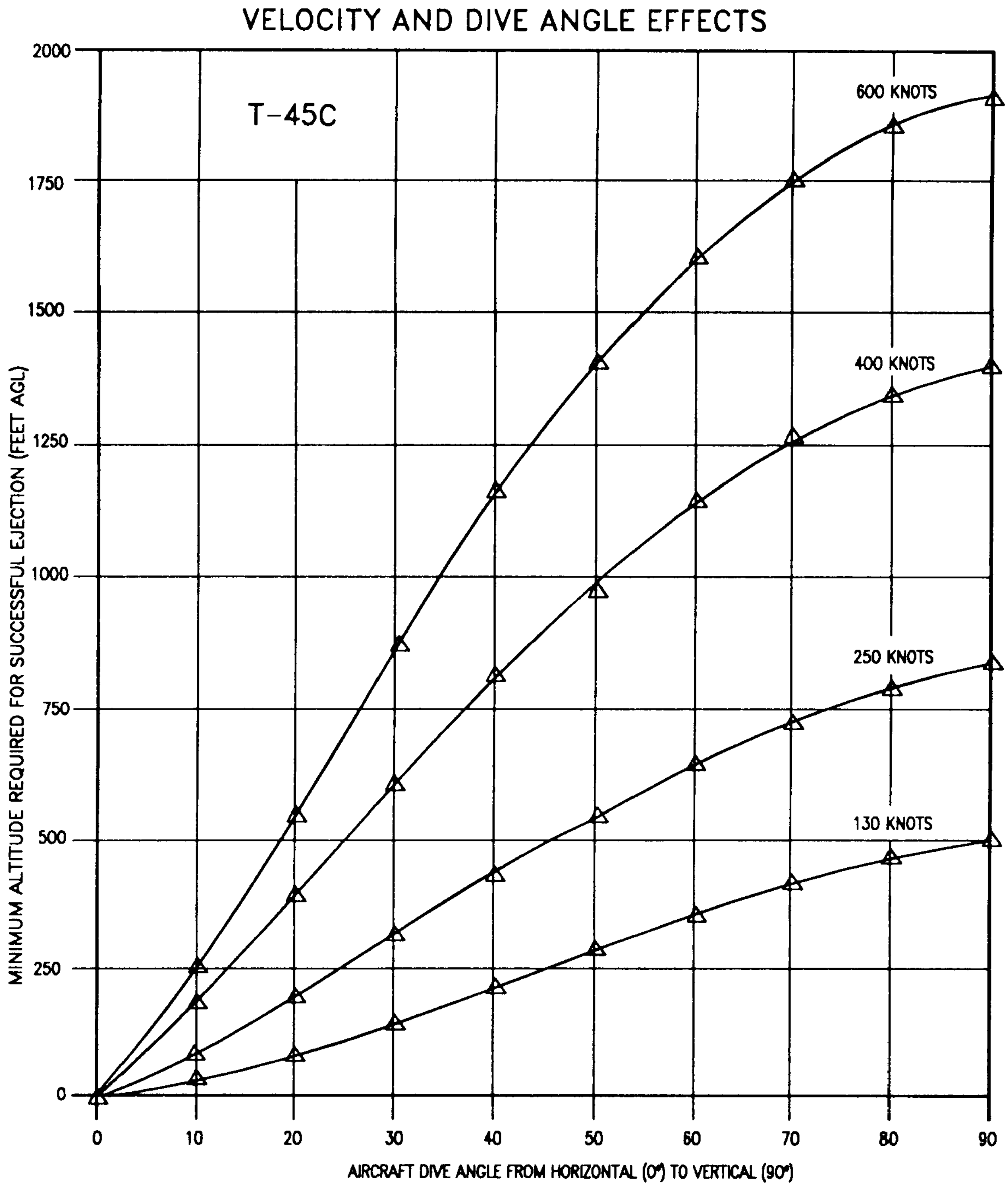


Figure 19: EJECTION SEAT



NOTES:

- Minimum ejection heights are based on initiation of the escape system, and the time required for a complete dual sequenced ejection is included.
- Pilot reaction time is not included.
- Ejection altitude is below 5000 feet MSL.

Figure 20: MINIMUM SAFE EJECTION ALTITUDES

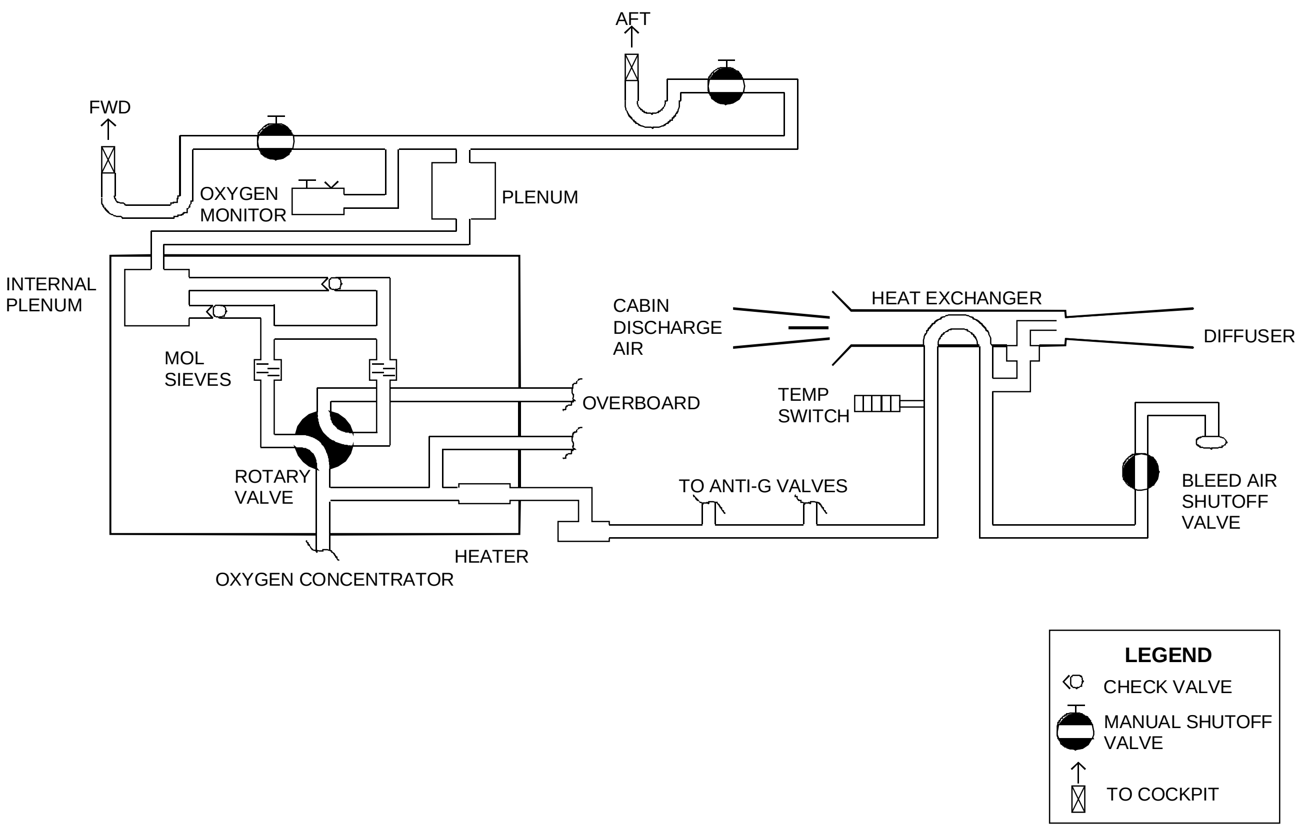


Figure 21: OBOGS BLOCK DIAGRAM

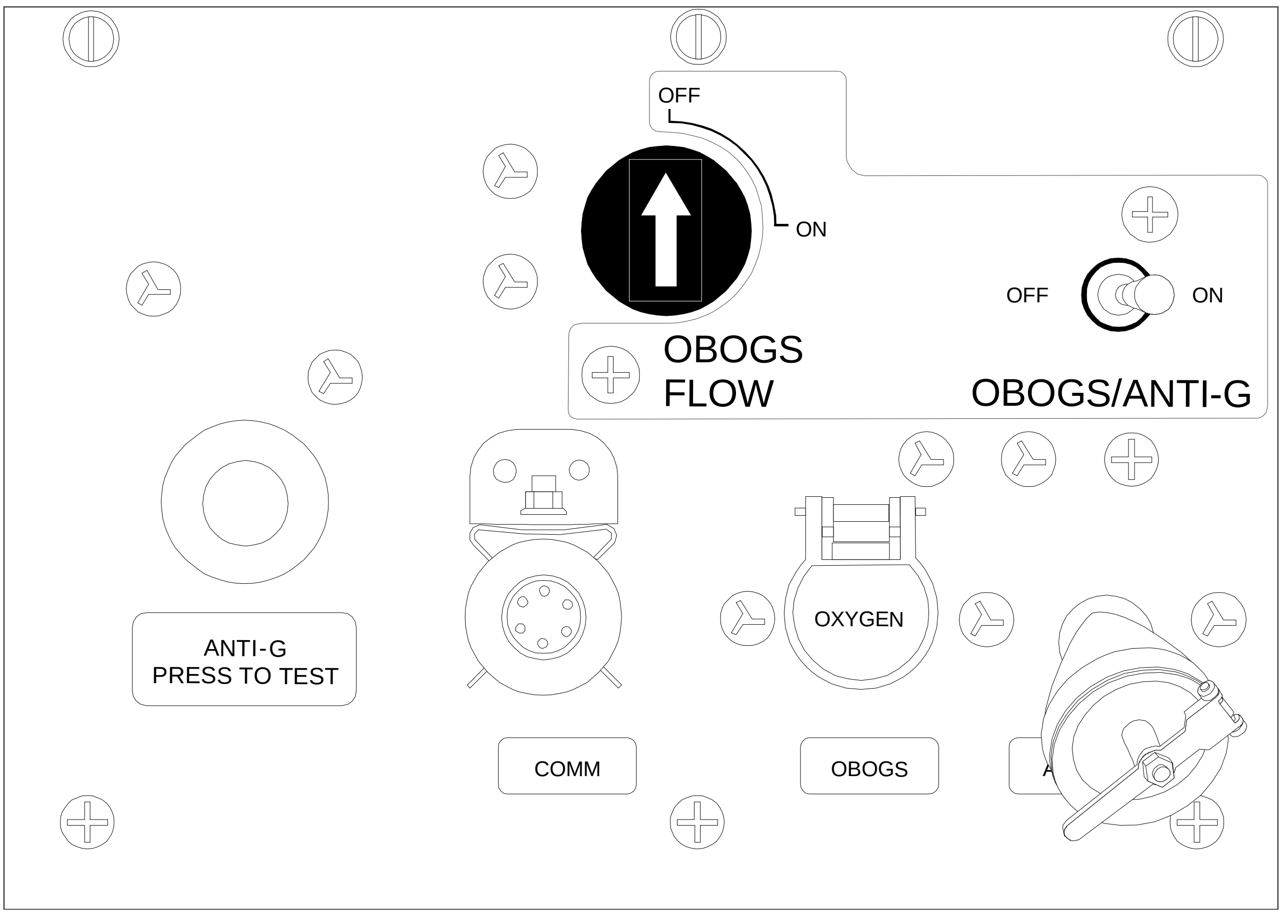


Figure 22: PILOT'S SERVICES PANEL

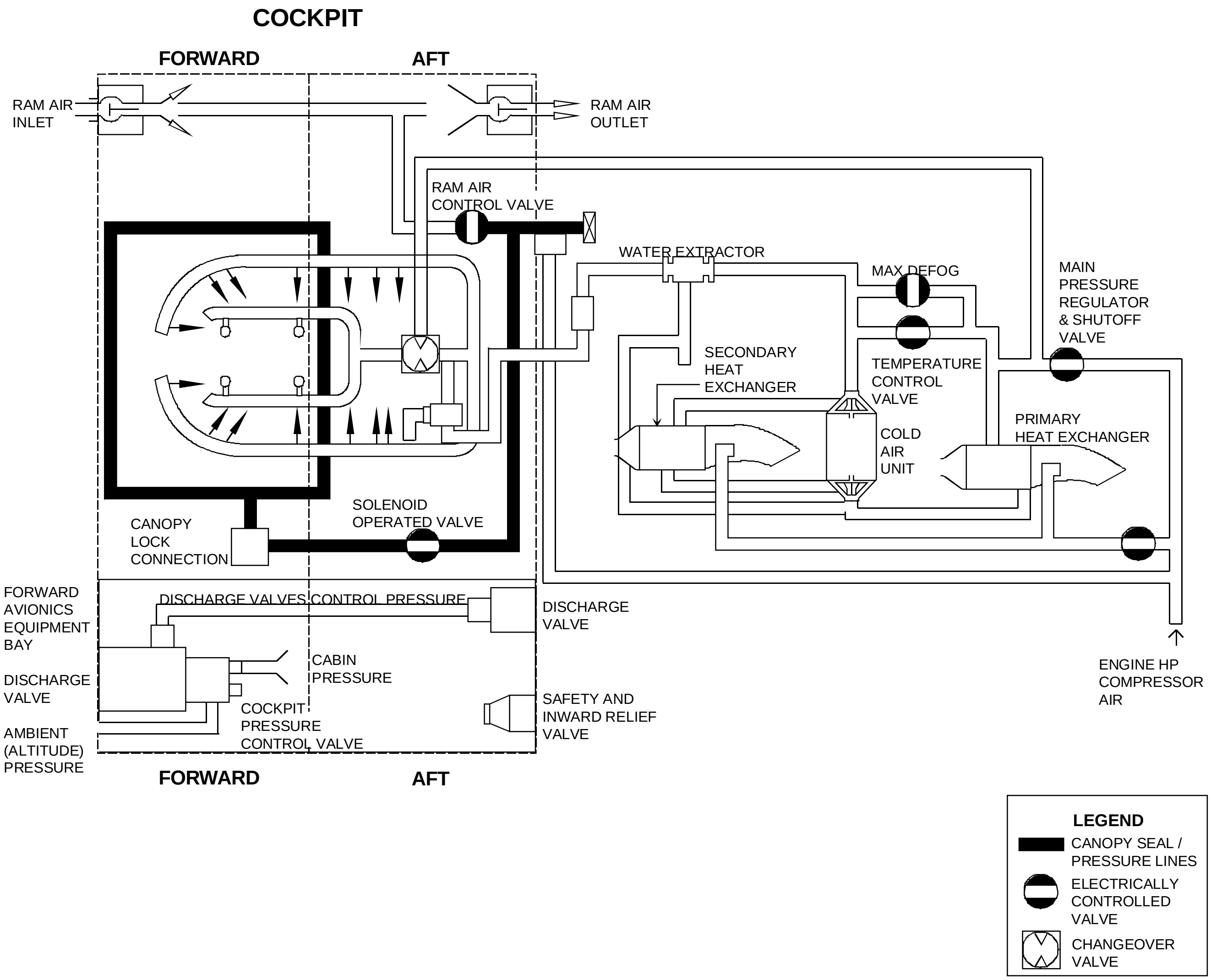
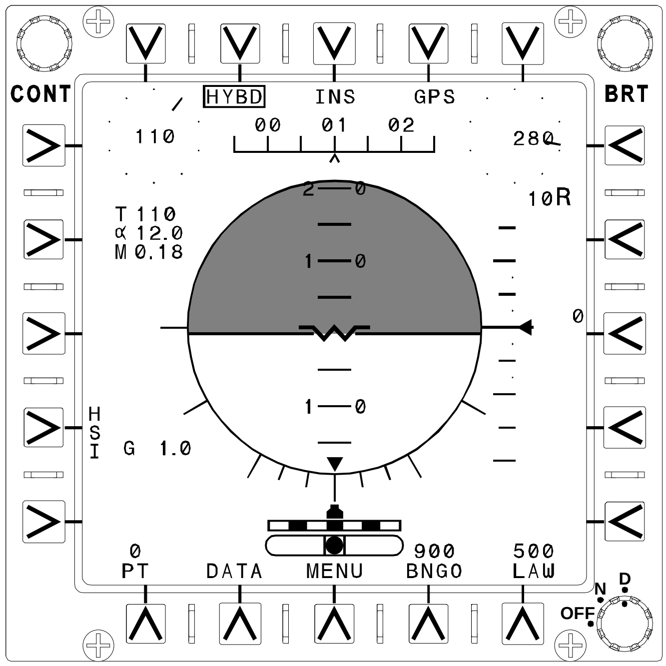
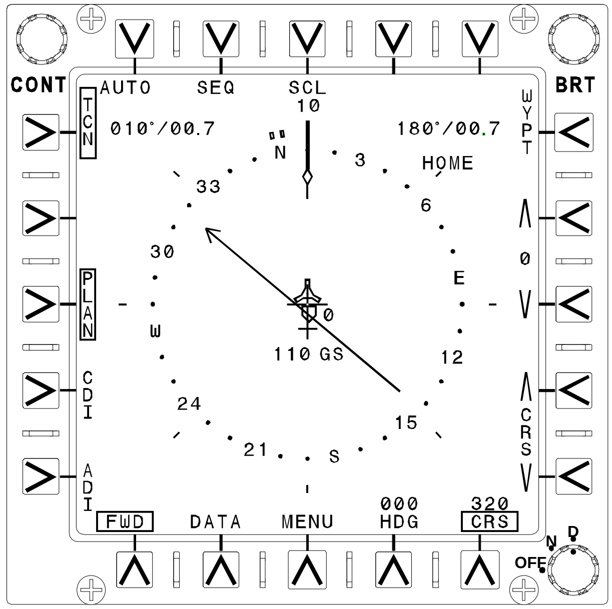


Figure 23: ECS BLOCK DIAGRAM



(1) Pitch ladder and horizon line
(2) Bank pointer and scale
(3) Aircraft heading reference and scale
(4) Rate of turn indicator
(5) Slip indicator
(6) Vertical velocity
(7) Barometric and radar altitude
(8) Indicated and true airspeed
(9) Angle of attack
(10) G and peak G
(11) ILS needles

Figure 24: ATTITUDE DIRECTOR INDICATOR (ADI) DISPLAY



(1) Waypoint
(2) Waypoint symbol
(3) Waypoint offset symbol
(4) VOR bearing pointer/tail
(5) VOR bearing
(6) TACAN symbol
(7) Waypoint/waypoint offset bearing pointer/tail
(8) Lubber line
(9) Ground track pointer
(10) Command heading marker
(11) Sequential steering lines
(12) CDI course line
(13) Course deviation dots
(14) Planimetric course line
(15) Aircraft symbol
(16) Groundspeed and wind detection/speed
(17) TACAN data
(18) Waypoint/waypoint offset data
(19) Heading readout
(20) Course line readout

Figure 25: HORIZONTAL SITUATION INDICATOR (HSI) DISPLAY

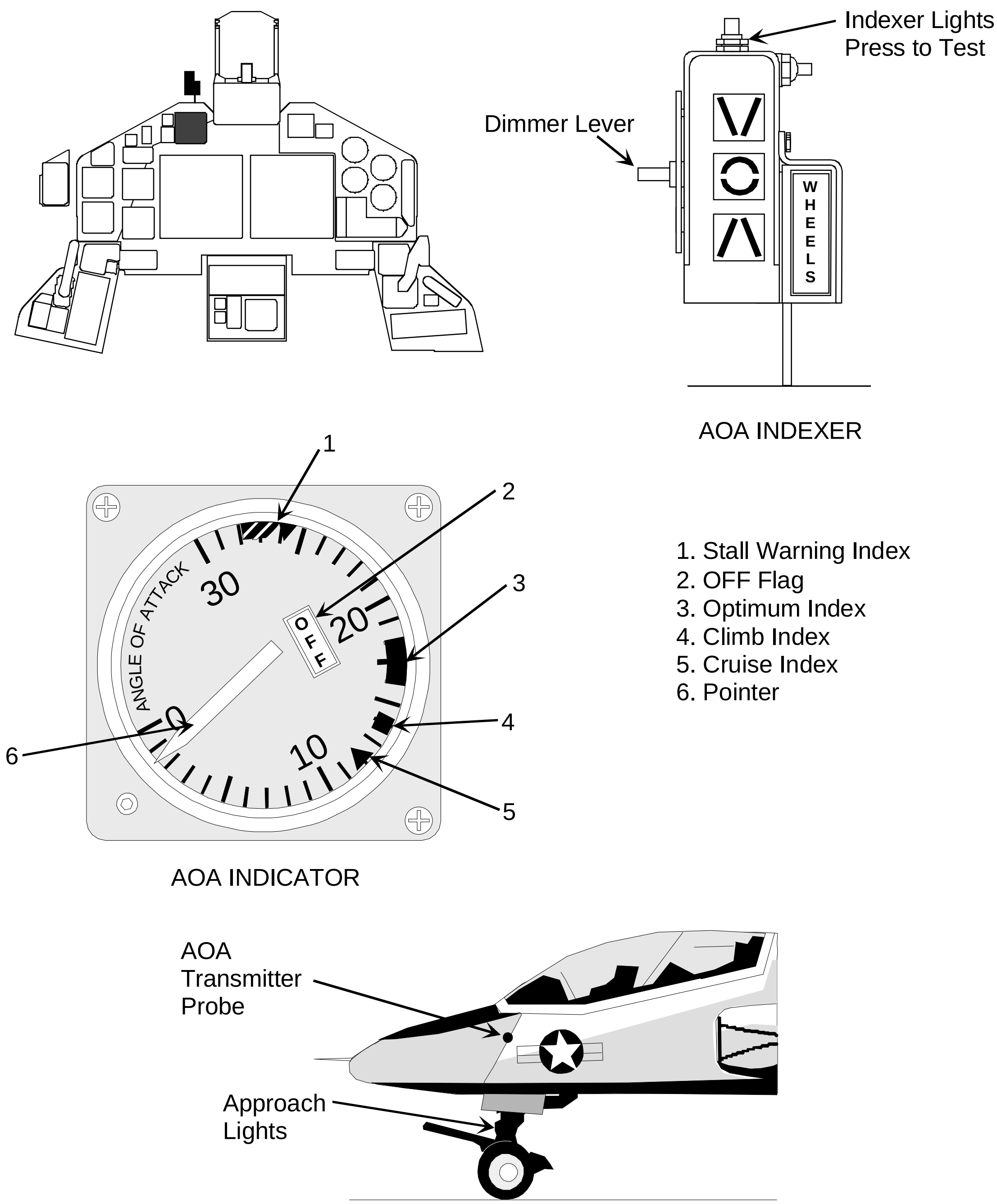


Figure 26: AOA SYSTEM

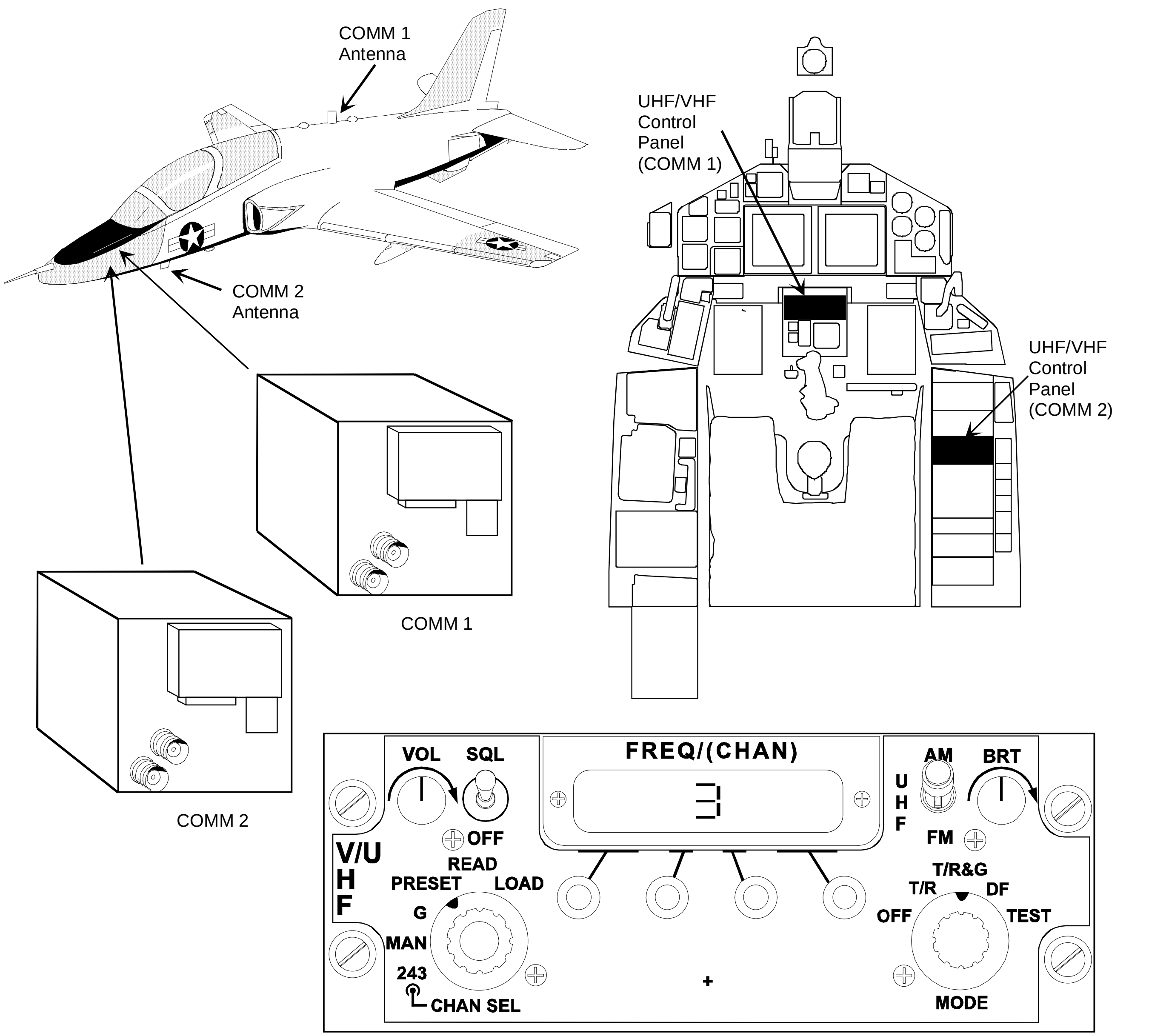


Figure 27: UHF/VHF CONTROL PANEL

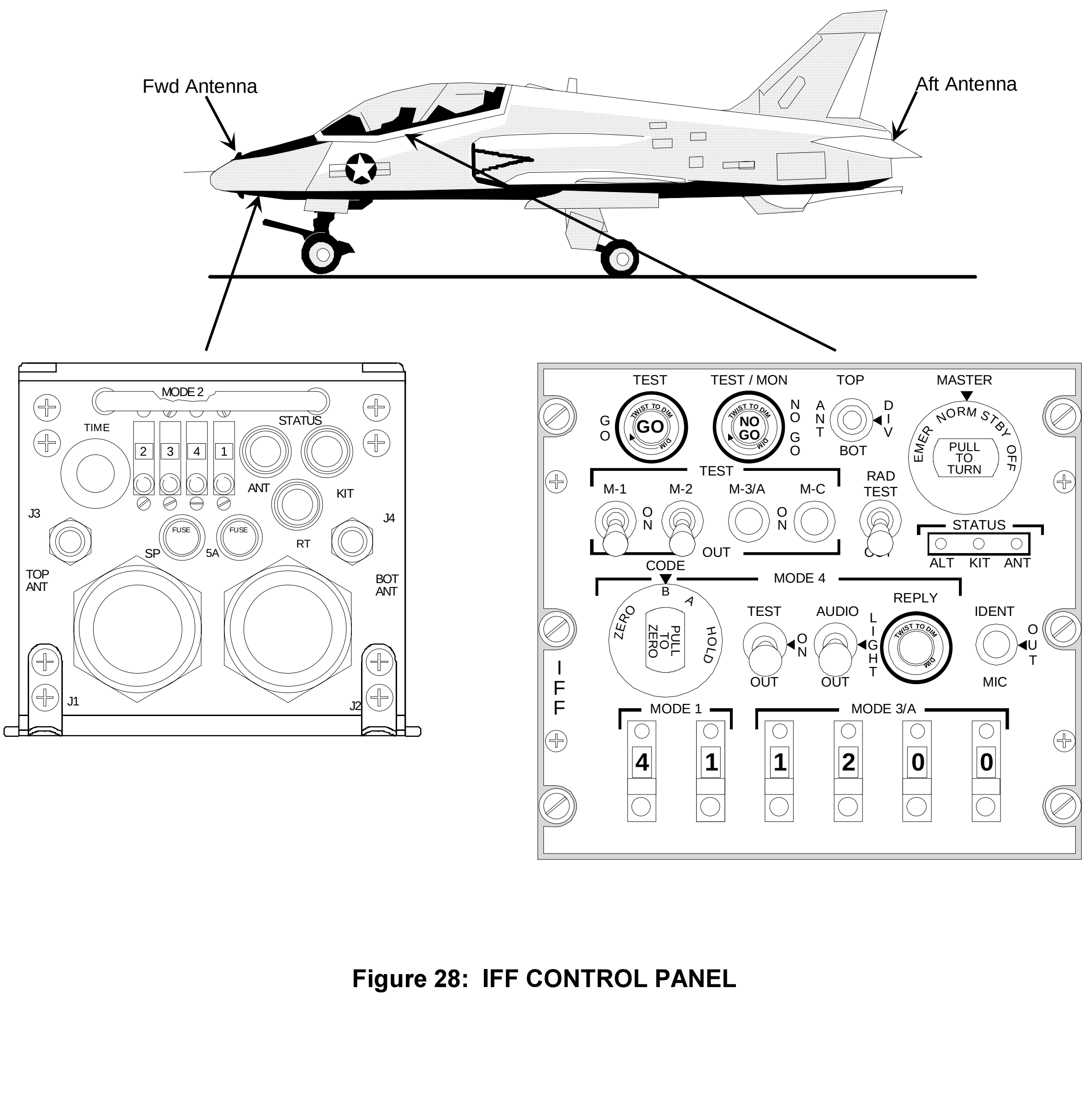


Figure 28: IFF CONTROL PANEL

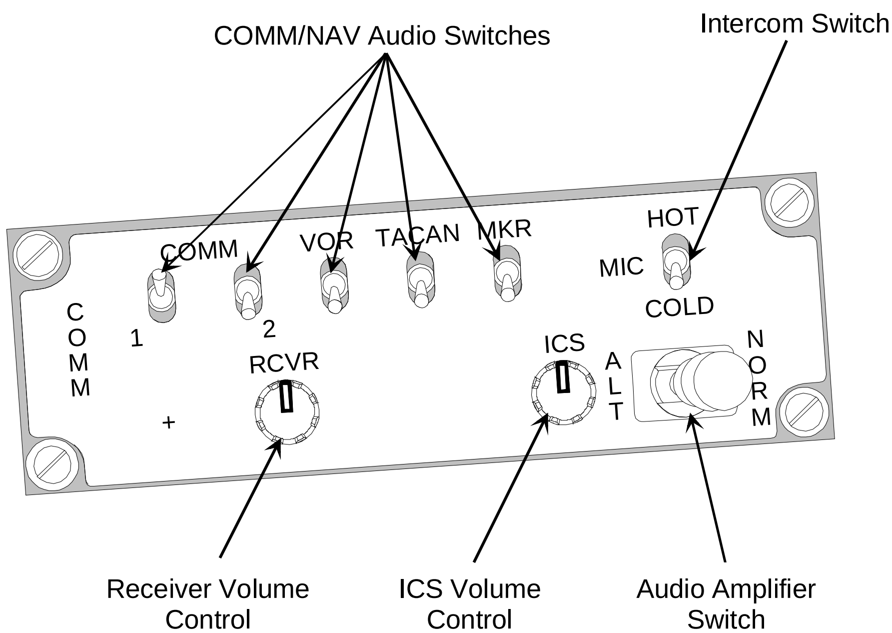


Figure 29: COMM CONTROL PANEL

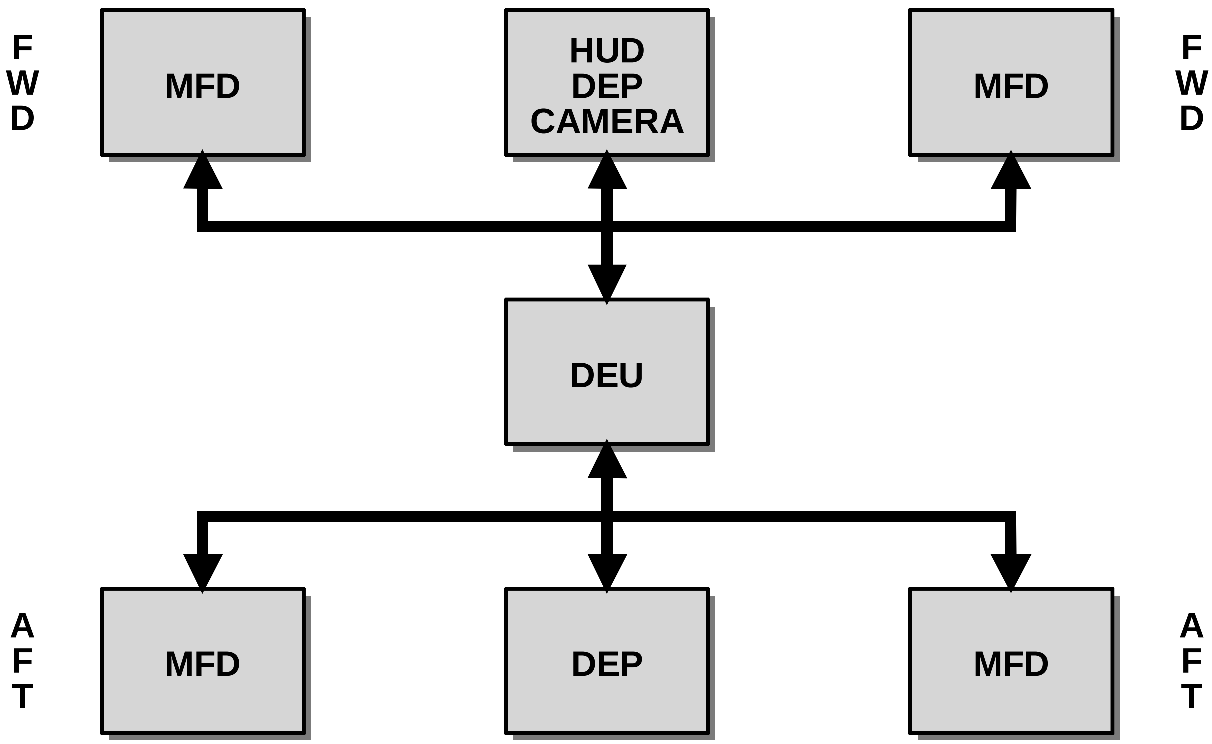


Figure 30: DISPLAY SYSTEM MAJOR COMPONENTS

	AVAILABLE BIT STATUS LEGENDS				
SYSTEM	GO	OP GO	DEGD	OVRHT	IN TEST
RALT	X		X		X
GINA	X	X	X		X
DEU	X		X	X	
HUD	X		X		
ADR	X	X	X		X
IFF	X		X		
SADS	X		X		
LFMFD	X		X		
RFMFD	X		X		
LAMFD	X		X		
RAMFD	X		X		
YDS	X		X		
MDL	X	X	X		X
ECA	X		X		
VCR	X		X		

Figure 31: BIT STATUS REPORT

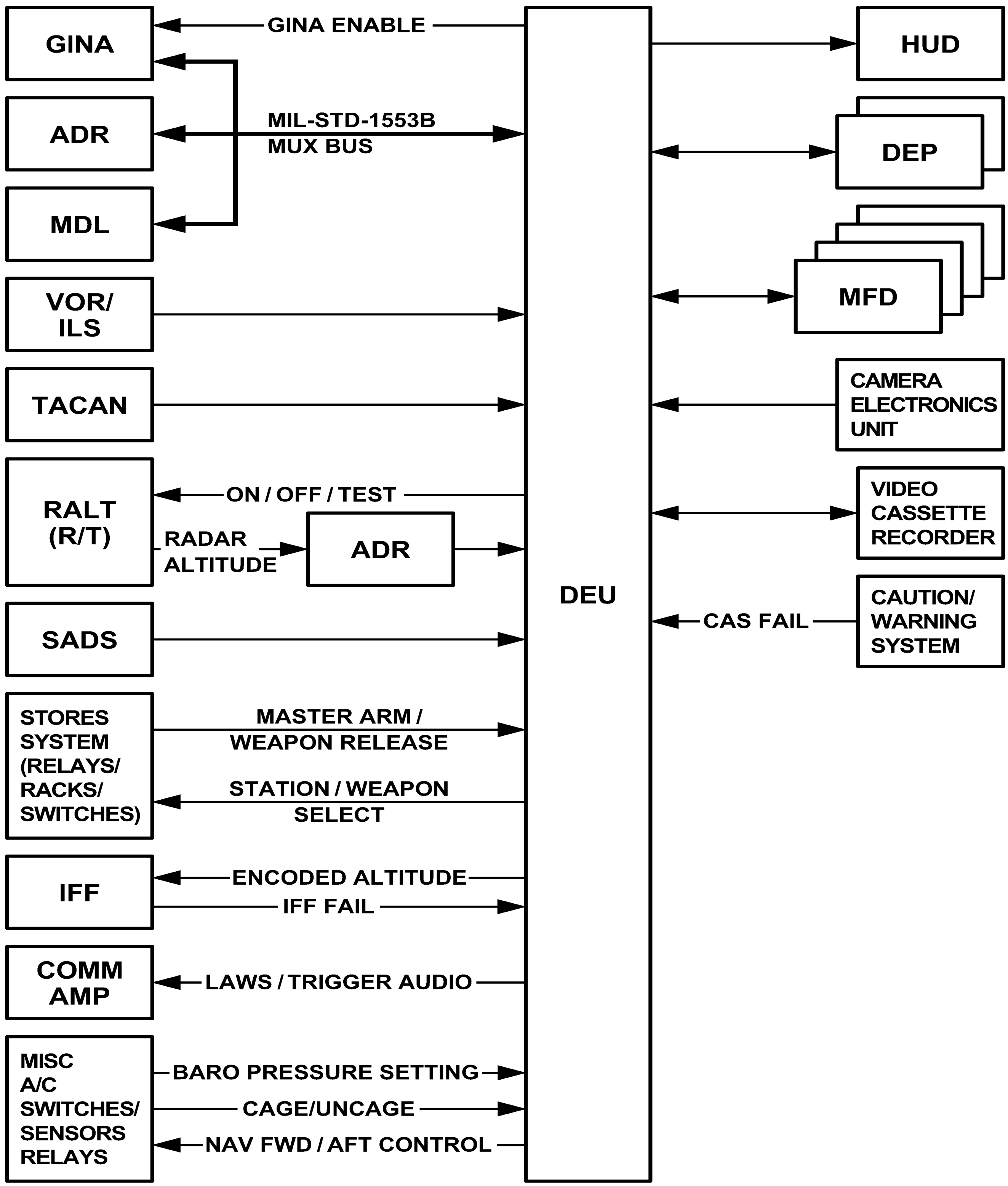


Figure 32: DEU INTERFACE DIAGRAM

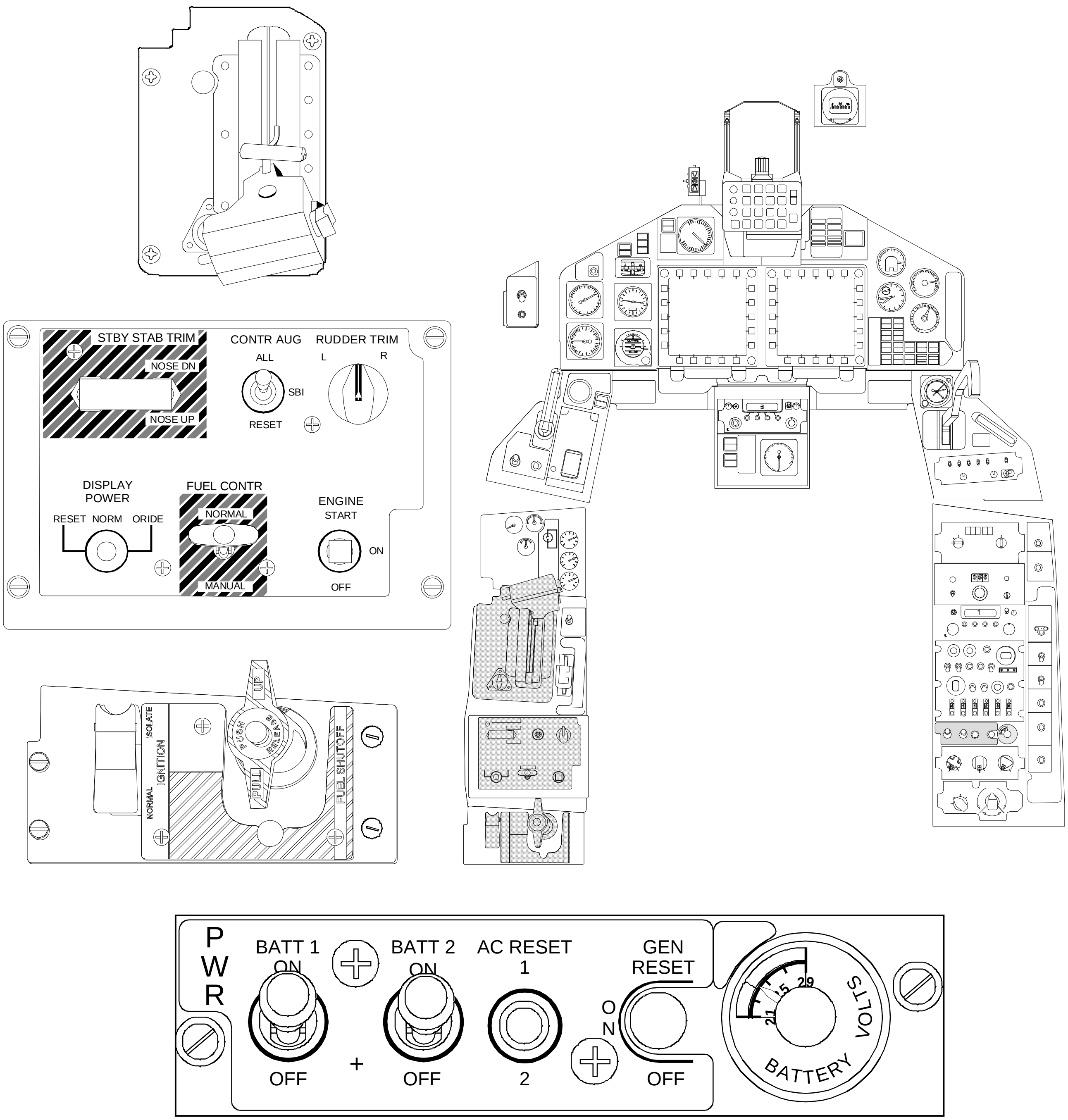


Figure 33: ENGINE CONTROLS (FORWARD COCKPIT)

NOTES