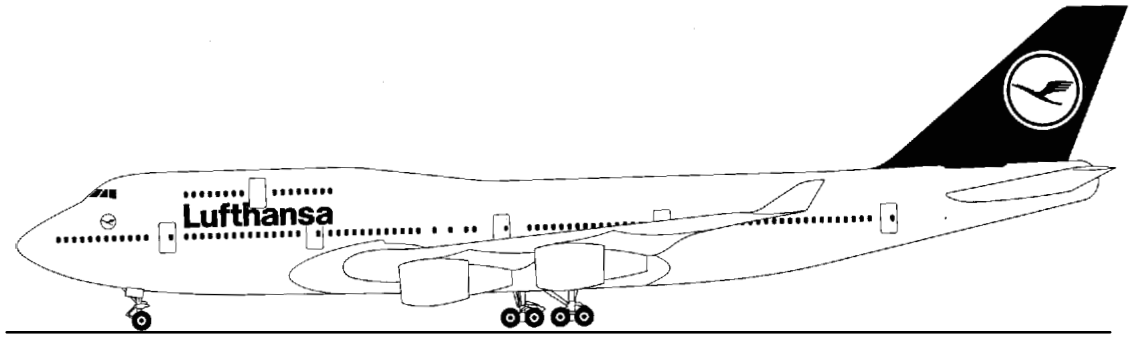
Lufthansa Technical Training

Training Manual B 747-400



ATA 34-45
TCAS

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ATA 34-45 TRAFFIC ALERT AND COLLISION AVIODANCE SYSTEM

TCAS - INTRODUCTION

General

The Traffic Alert and Collision Avoidance System (TCAS) alerts the flight crew of potential conflicts with other airplanes in the same area. WAS tracks these other airplanes or intruders, if equipped with a Air Traffic Control Radar Beacon System (ATCRBS), or a Mode S ATC transponder.

WAS provides two types of collision avoidance alerts they are:

- Traffic advisory (TA)
- Resolution advisory (RA)

A TA shows the relative position of any intruder airplanes. An RA shows a vertical maneuver to avoid a possible airplane collision.

TCAS I

TCAS I is the system intended for use on small commuter or general aviation airplanes. WAS I supplies proximity traffic advisories (TAs), but does not produce resolution advisories (RAs).

TCAS II

WAS II is the system installed on 747-400 airplanes. It supplies both visual and aural advisories to the flight crew. Both TAs and RAs are generated by this system. All commercial airlines and some general aviation airplanes will be equipped with this system.

WAS III

WAS III is still under development. When finished, it will have all the capabilities of WAS II, plus the ability to provide horizontal collision avoidance maneuvers.

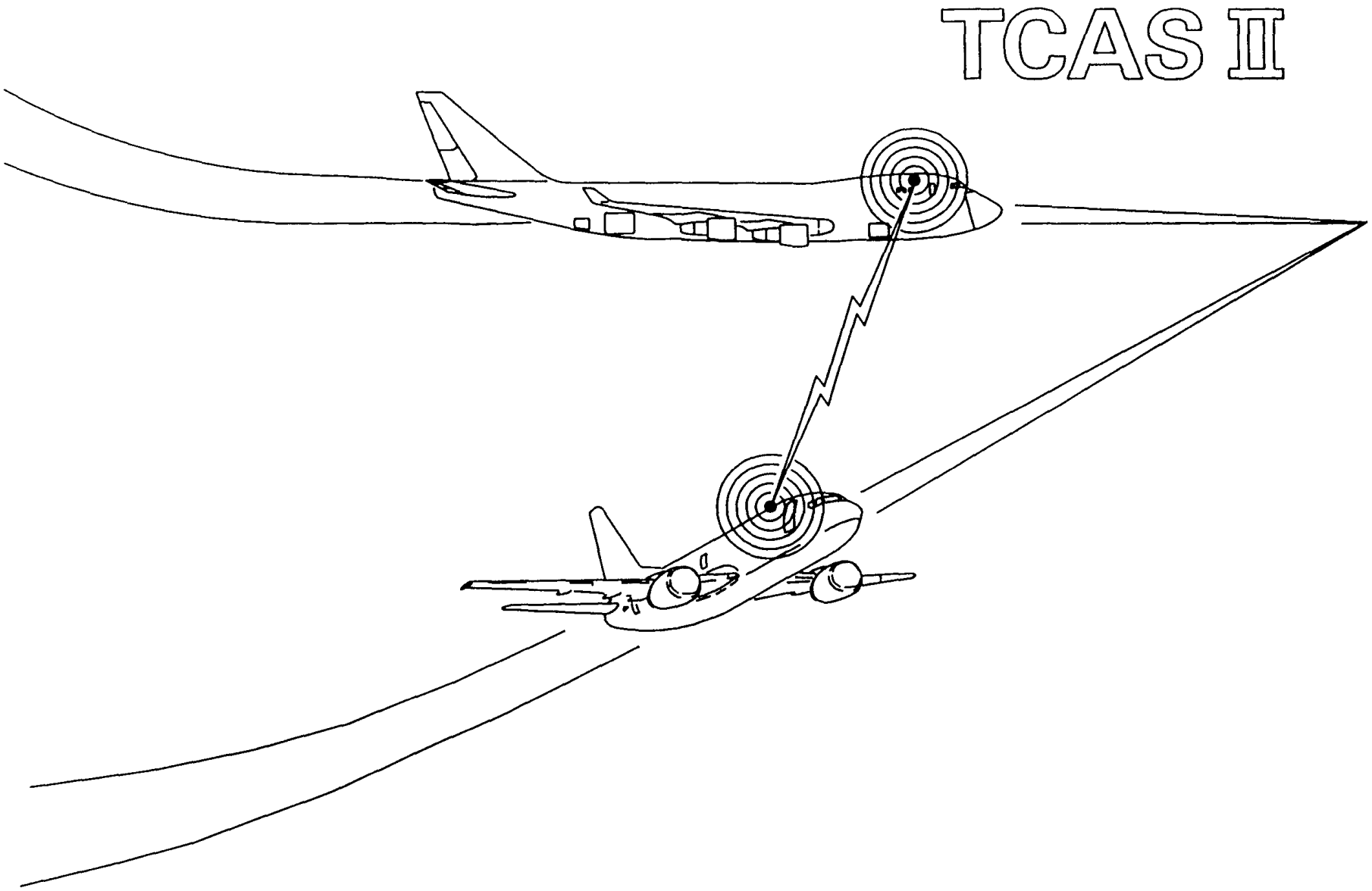

Figure 1 TCAS - INTRODUCTION

TCAS II

General

The TCAS II components are the:

- TCAS computer
- Dual directional TCAS antennas
- ATC/TCAS control panel

Components that interface with the TCAS II are the:

- L & R ATC mode S transponder
- L & R radio altimeter (RA)
- R, C, or L inertial reference units (IRUs)
- Ground proximity warning computer (GPWC)
- Modularized avionics and warning electronics assembly (MAWEA)
- Integrated display system (IDS)
- L & R central maintenance computers (CMCs)
- L & R distance measurement equipment (DME's)
- Data management unit (DMU)
- Software data loader
- Landing gear module
- Air/ground relay

Component Description

The WAS II system is composed of only airborne components. The WAS computer is the main component of the system and communicates with both intruder airplane and on-board ATC transponders.

The WAS II computer works like an ATC ground station interrogator. It transmits pulse coded interrogations at 1030 MHz on both a top and bottom directional antenna. The WAS II computer sends a suppression pulse to both ATC transponders and to both DME's upon rf transmission.

ATC transponder replies are received on 1090 MHz. The WAS II computer analyzes all inputs and computes the position of all intruders and any possible collision courses.

The navigation displays (NDs) show the intruder symbols in different shapes and colors. These symbols show the intruder's priority, position, relative altitude, along with a vertical speed arrow. Collision avoidance flight cues show on the PFD display.

The software data loader is used to load the WAS II processor with current software programs.

The WAS II computer sends aural collision avoidance messages through the MAWEA to the aural warning speakers.

The CMC monitors the WAS II status and starts the WAS II ground test.

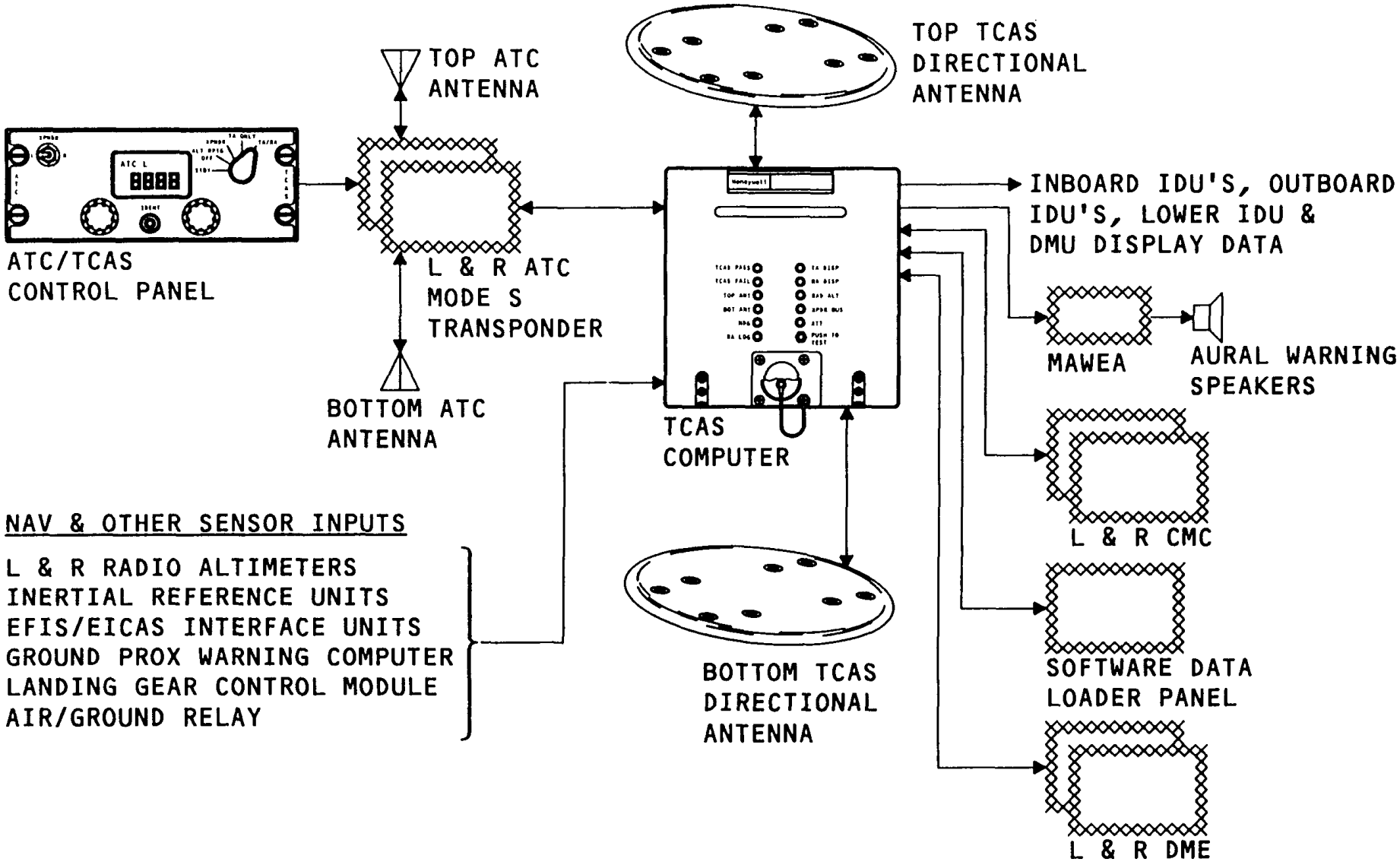

Figure 2 TCAS II

COMPONENT LOCATIONS

The WAS II components are the:

- TCAS II computer
- Top directional TCAS II antenna
- Bottom directional WAS II antenna

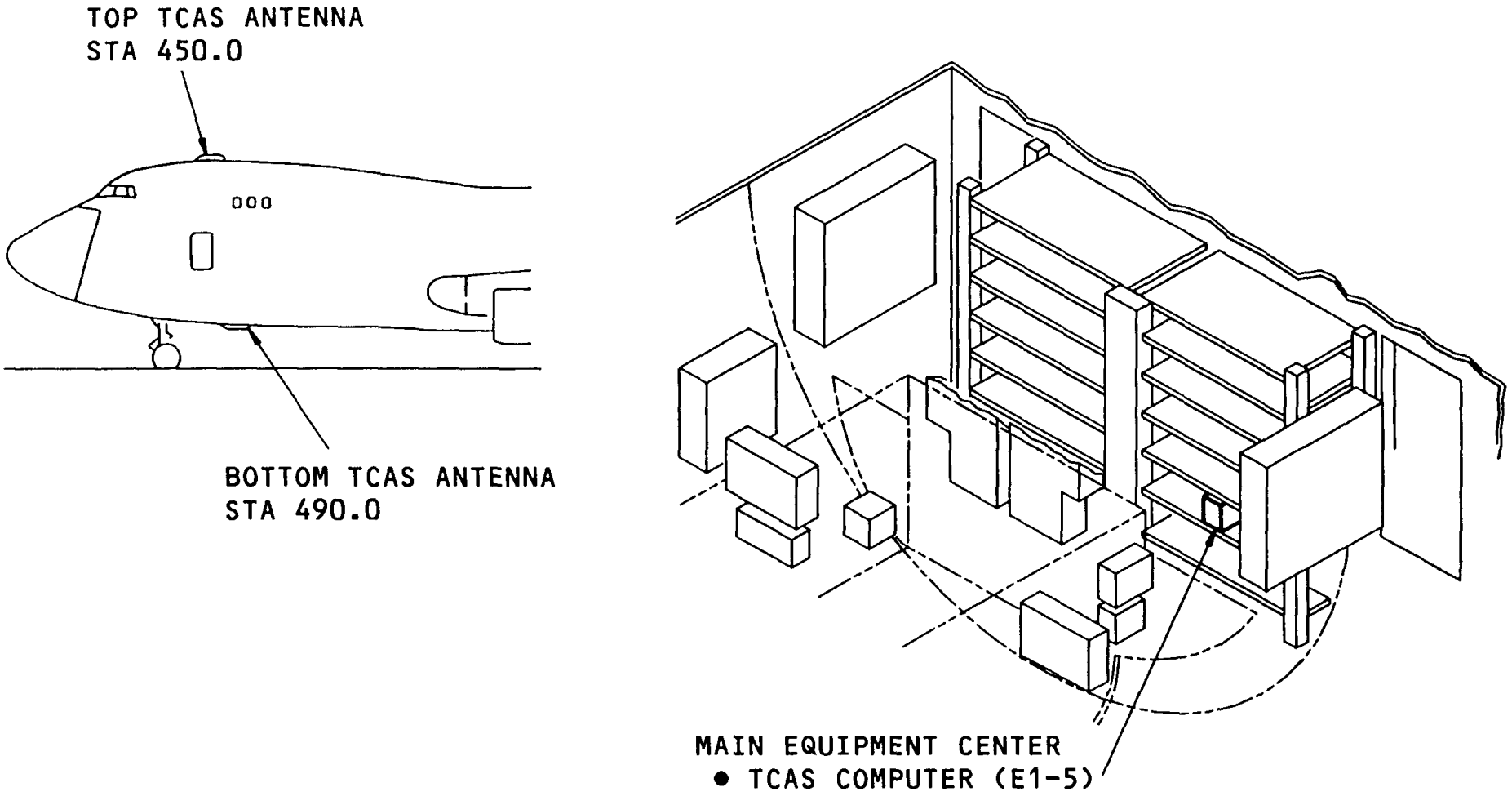

Figure 3 COMPONENT LOCATIONS

COMPONENT LOCATIONS - FLIGHT DECK

The TCAS II components in the flight deck are the:

- ATC/TCAS control panel
- TCAS circuit breaker

Components in the flight deck that interface with TCAS II are the:

- Left inboard and outboard IDU
- Right inboard and outboard IDU
- Lower IDU
- Left EFIS control panel
- Right EFIS control panel

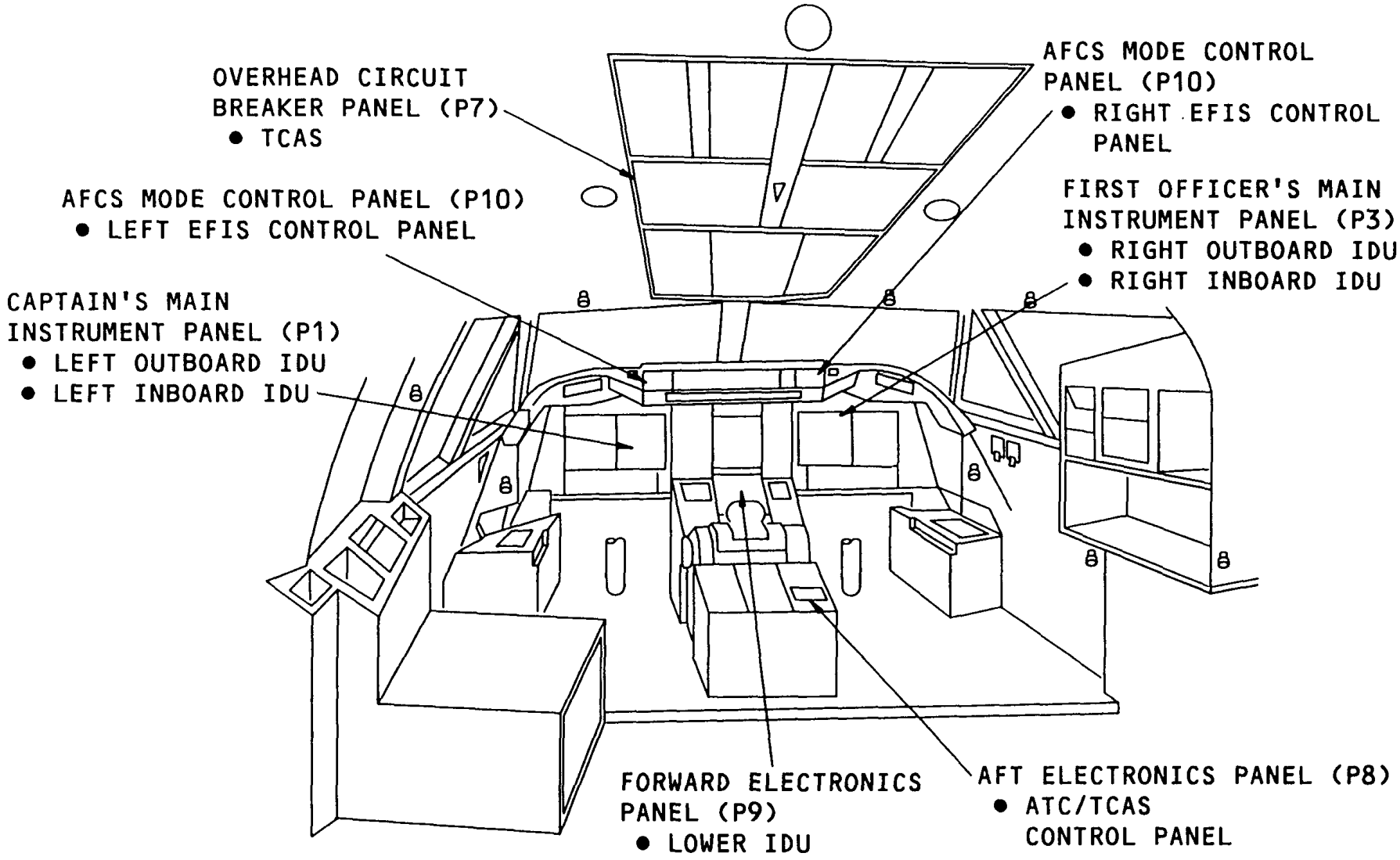

Figure 4 COMPONENT LOCATIONS - FLIGHT DECK

INTERFACES-1

Power

The TCAS II computer gets 115 volts ac from ac bus 3.

Radio Altimeter Inputs

The TCAS II computer gets radio altimeter (RA) data from the left and right RAs. The TCAS II processor uses RA data to:

- Set sensitivity levels
- Calculate intruder advisories

Inertial Reference Unit Inputs

The TCAS II computer gets inertial reference unit (IRU) data from the IRU selected by the first officer. The IRU inputs are not presently used by TCAS. These inputs are reserved for future TCAS applications.

GPWC Inputs

The GPWC sends three discretes to the WAS computer. These discretes inhibit intruder resolution advisories during windshear, ground proximity warning or ground proximity alert conditions.

Landing Gear Control Module Input

The TCAS II computer uses the landing gear input discrete to make the bottom TCAS antenna perform as an omnidirectional antenna when the landing gear is down.

Air/Ground Relay Input

The TCAS II computer uses the air/ground relay discrete to prevent TCAS test in the air. The air/ground discrete increments flight legs in the TCAS fault history when the CMC fails.

Program Pin Inputs

Six strapping type program pins set:

- The airplane altitude limit of 48 thousand feet for RA performance calculations (no climb or increase climb cues when at this altitude)
- A self-test inhibit function to prevent self-test in air
- The audio level of voice outputs

EIU Inputs

The left and center EIUs send resolution advisory RA display status #1 discrete and the right EIU sends a RA display status #2 discrete to the TCAS processor.

These discretes provide the TCAS with the IDU display capability. When the Captain and First Officer's PFD is unable to display RA data, both RA #1 and RA #2 are set from a ground to an open. TCAS FAIL message shows on the NDs when in the TA/RA mode.

Switch to the TA only mode to allow TCAS to continue to display TA data.

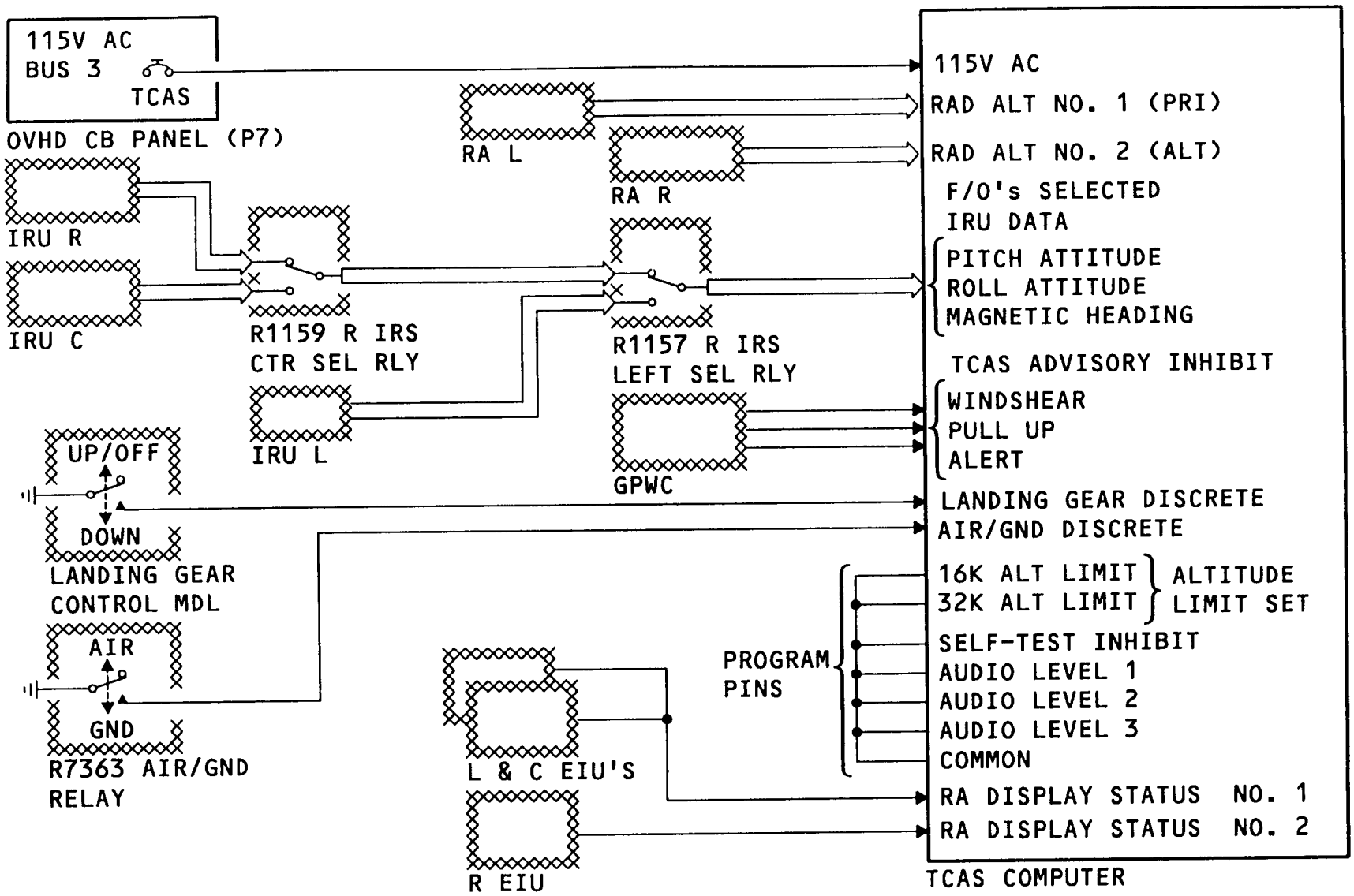

Figure 5 INTERFACES-1

INTERFACES-2

ATC Inputs/Outputs

The WAS II computer gets ATC and control data from the ATC/TCAS control panel through the selected left or right ATC. The ATC provides the WAS processor with:

- WAS mode selection (TA only, or TA/RA)
- Uncorrected baro altitude
- Airplane identification code
- Maximum airspeed

The WAS computer sends coordination data to the active ATC transponder on a high speed ARINC 429 data bus. The on-board transponder is a part of the data link system when WAS is working with other WAS equipped airplanes.

Suppression Inputs/Outputs

The TCAS II computer gets a suppression pulse when the selected ATC or the DMEs transmit. This suppression signal turns off the TCAS receiver for the suppression period. When WAS transmits, it sends a suppression pulse to the selected ATC and the DMEs.

CMC Inputs/Outputs

The WAS II computer gets CMC data from the left CMC. The CMC provides the WAS processor with a ground test start cue. The TCAS computer sends the CMC's WAS status data.

WAS II Voice Outputs

WAS II sends aural alert annunciations to the MAWEA to alert the flight crew to TAs and RAs. These signals go to both the left and right aural synthesizer cards.

IDU Display Outputs

IDU display data is sent out on ARINC 429 data buses to the PFDs and NDs, the DMU and the AUX EICAS IDU. This data is the colored TCAS II symbols on the NDs and the RA avoidance cues on the PFDs.

Software Data Loader Control Panel Inputs/Outputs

The software data loader control panel sends an enable discrete to the TCAS processor. When the TCAS II computer is ready, load the TCAS processor with a new software program.

Directional Antenna Inputs/Outputs

The top and bottom directional antennas transmit ATC interrogation rf and receive transponder rf replies. The antennas contain four steerable element passive arrays that are mounted at 0 degrees, 90 degrees, 180 degrees, and 270 degrees relative to the airplane centerline. These antennas are unpowered, passive devices.

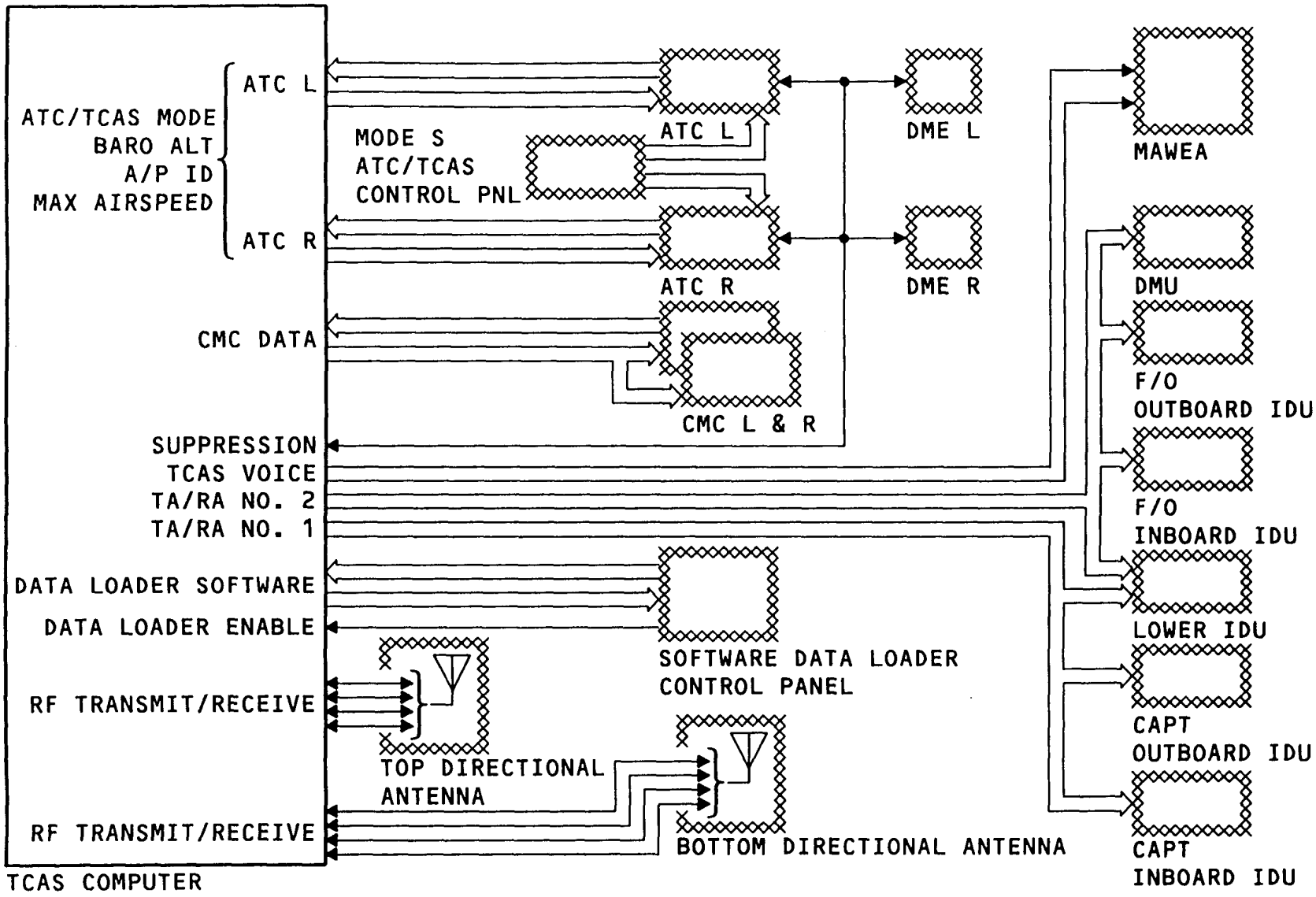

Figure 6 INTERFACES-2

TCAS COMPUTER

General

The microprocessor-based TCAS computer is the master control unit for TCAS II. It has a computerized control system and an L-band receiver/transmitter. Operation of TCAS is controlled by TCAS II software resident in the TCAS processor memory.

Characteristics

The TCAS II computer controls all surveillance, data acquisition, tracking, advisory, and air-to-air maneuver coordination functions.

TCAS II Computer Physical Description

The TCAS II computer is a 6 MCU size unit that weighs 24 lb (10.89 kg).

Power

The TCAS II computer operates on 115v ac.

Bite Display

Eleven panel test lights on the front of the TCAS II computer show failure status indications after a functional test. Use the push-to-test button to start a test.

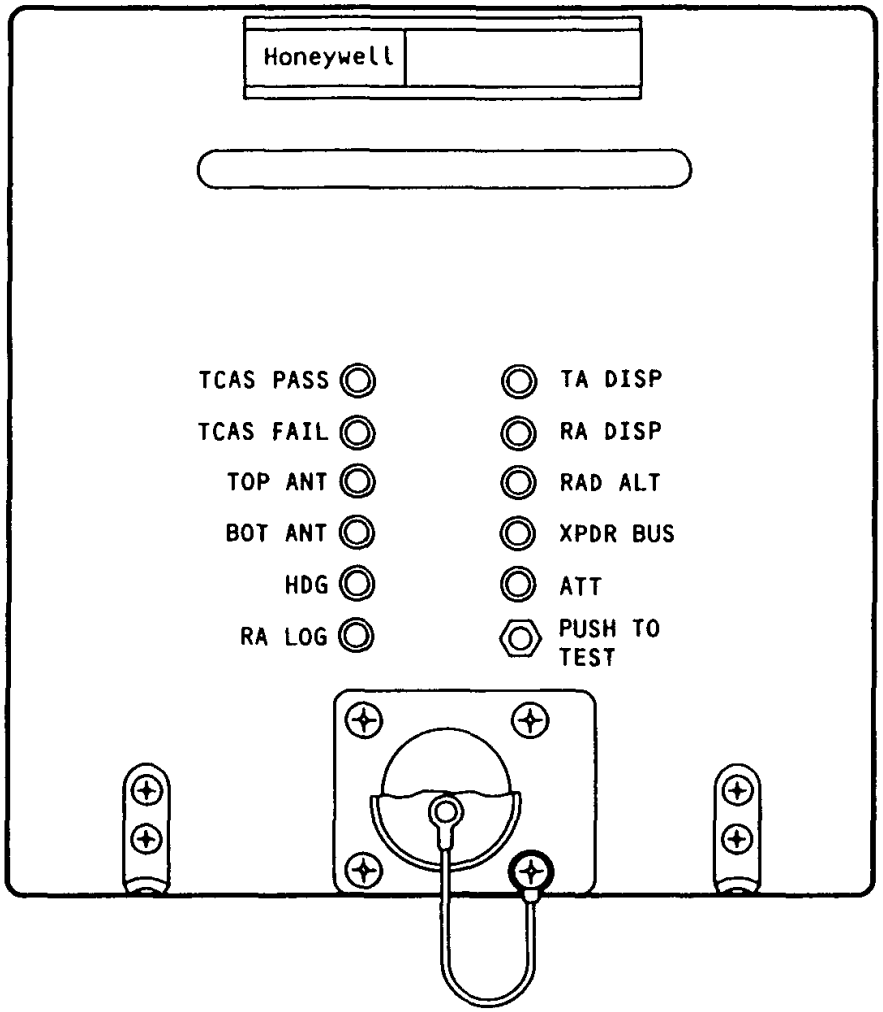

Figure 7 TCAS COMPUTER (Honeywell)

TCAS II - COMPUTER

General

The microprocessor-based TCAS computer is the master control unit for TCAS II. It has a computerized control system and an L-band receiver/transmitter. Operation of TCAS is controlled by TCAS II software resident in the TCAS processor memory.

Characteristics

The TCAS II computer controls all surveillance, data acquisition, tracking, advisory, and air-to-air maneuver coordination functions.

Some computer capabilities are:

- Surveillance of up to 45 targets/intruder, out of 30 nm
- Display up to 30 closest intruders
- Communicate up to 150 mode S transponder-equipped airplanes.
- Maneuver coordination functions air-to-air

TCAS II Computer Physcal Description

The TCAS II computer is a 6 MCU size unit that weighs 28 lb (12,7 kg).

Power

The TCAS II computer operates on 115v ac.

Bite Display

Two alphanummerical LED displays on the front of the TCAS II computer shows failure status indications after a functional test. Use the push-to-test button to start a test.

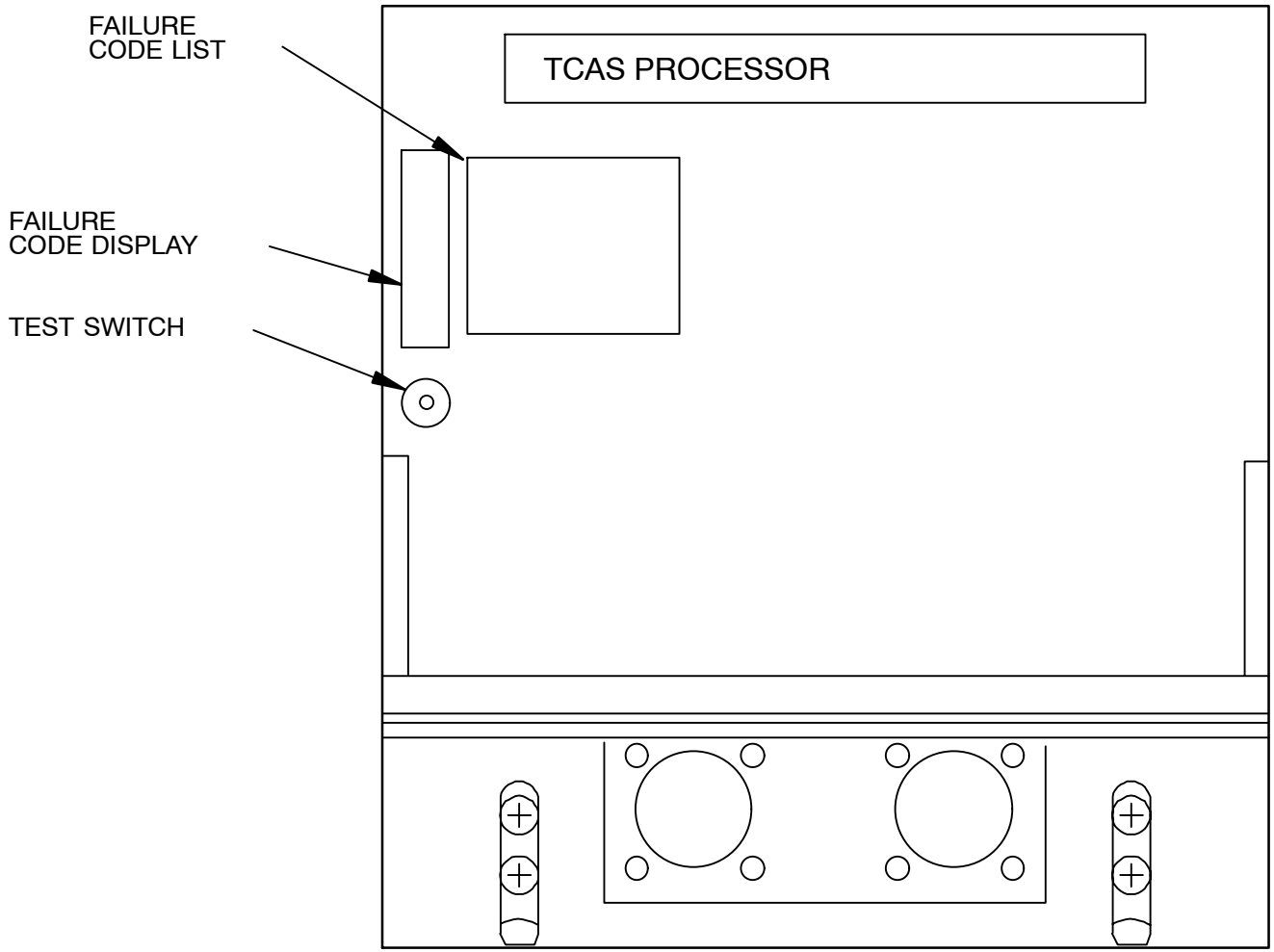

Figure 8 TCAS II - COMPUTER (Bendix)

TCAS II - COMPUTER

General

The microprocessor-based TCAS computer is the master control unit for TCAS II. It has a computerized control system and an L-band receiver/transmitter. Operation of TCAS is controlled by TCAS II software resident in the TCAS processor memory.

Characteristics

The TCAS II computer controls all surveillance, data acquisition, tracking, advisory, and air-to-air maneuver coordination functions.

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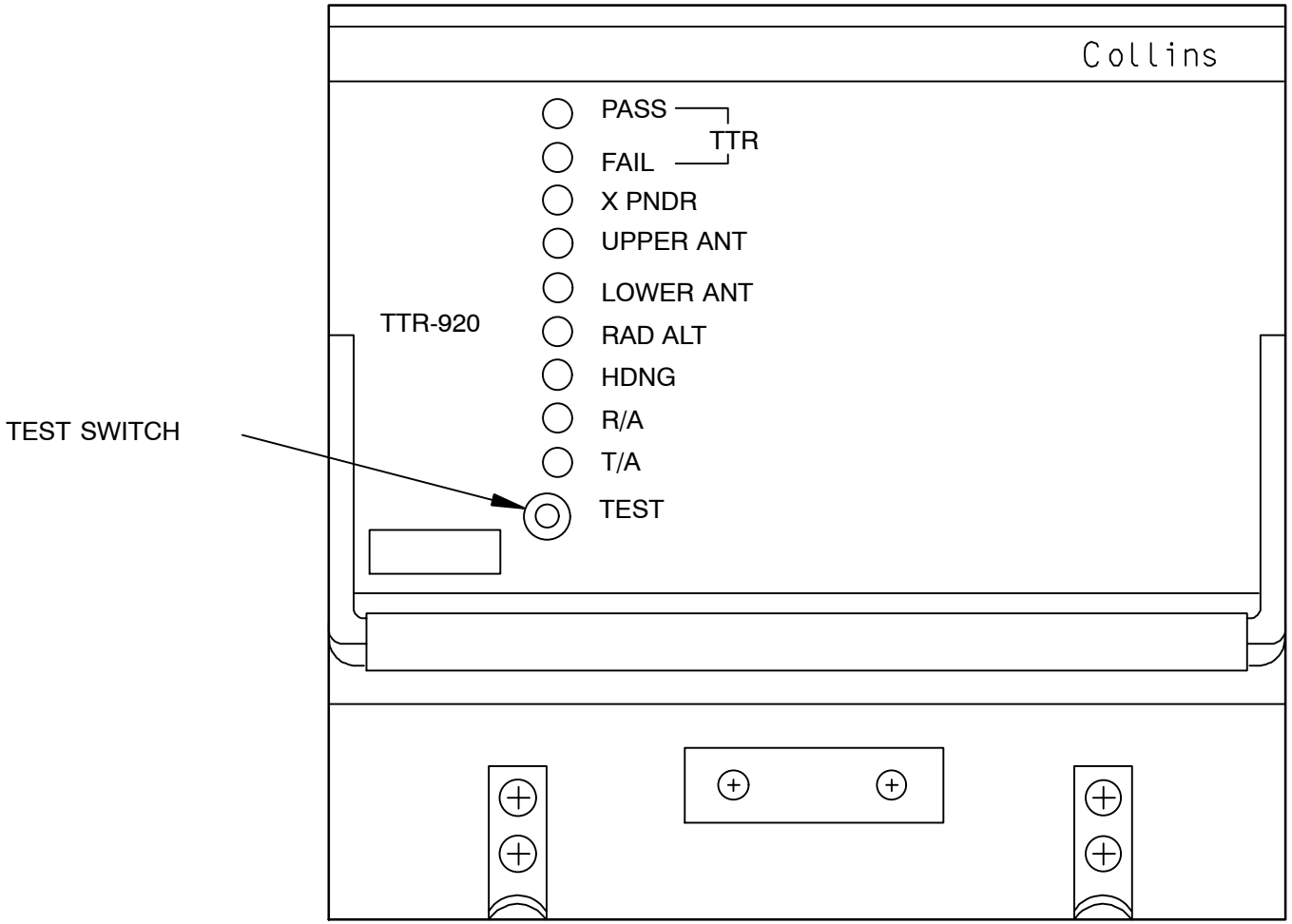


Figure 9 TCAS II - COMPUTER (Collins)

ATC / TCAS CONTROL PANEL

The ATC/TCAS control panel controls both ATC mode S transponders and the TCAS II computer. The ATC functions were covered in the ATC lesson. The TCAS functions are:

- TA mode select is a Traffic Advisory only mode. In this mode all intruder traffic except RAs are displayed.
- TA/RA mode select is a Traffic Advisory/Resolution Advisory mode. In this mode both traffic and resolution advisories are displayed.

In any other mode, WAS is placed in standby.

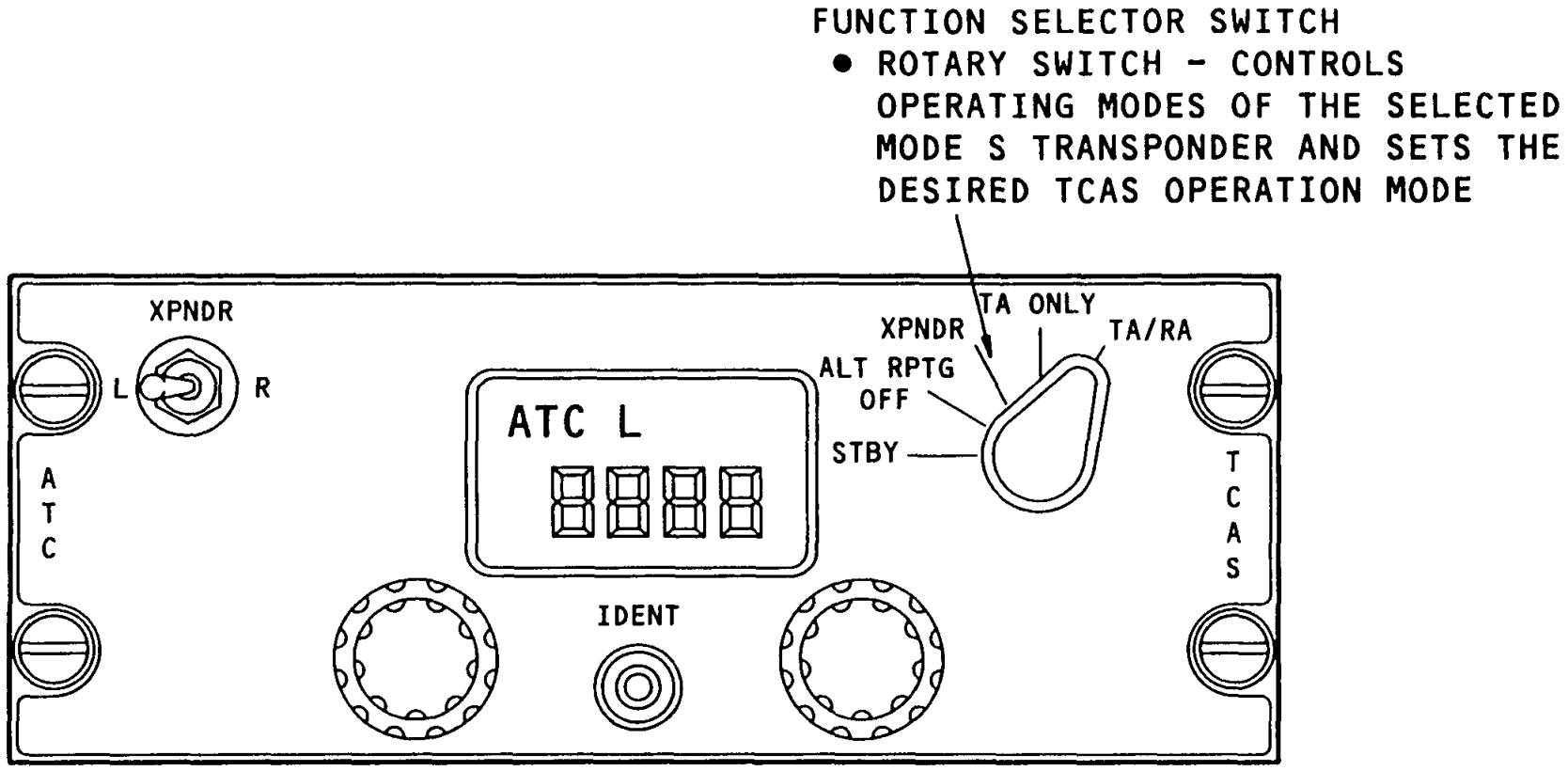


Figure 10 ATC / TCAS CONTROL PANEL

ATC / TCAS CONTROL PANEL

The ATC/TCAS control panel controls both ATC mode S transponders and the TCAS II computer. The ATC functions were covered in the ATC lesson.

The TCAS functions are:

- TA mode select is a Traffic Advisory only mode. In this mode all intruder traffic except RAs are displayed.
- TA/RA mode select is a Traffic Advisory/Resolution Advisory mode. In this mode both traffic and resolution advisories are displayed.
-

In any other mode, TCAS is placed in standby.

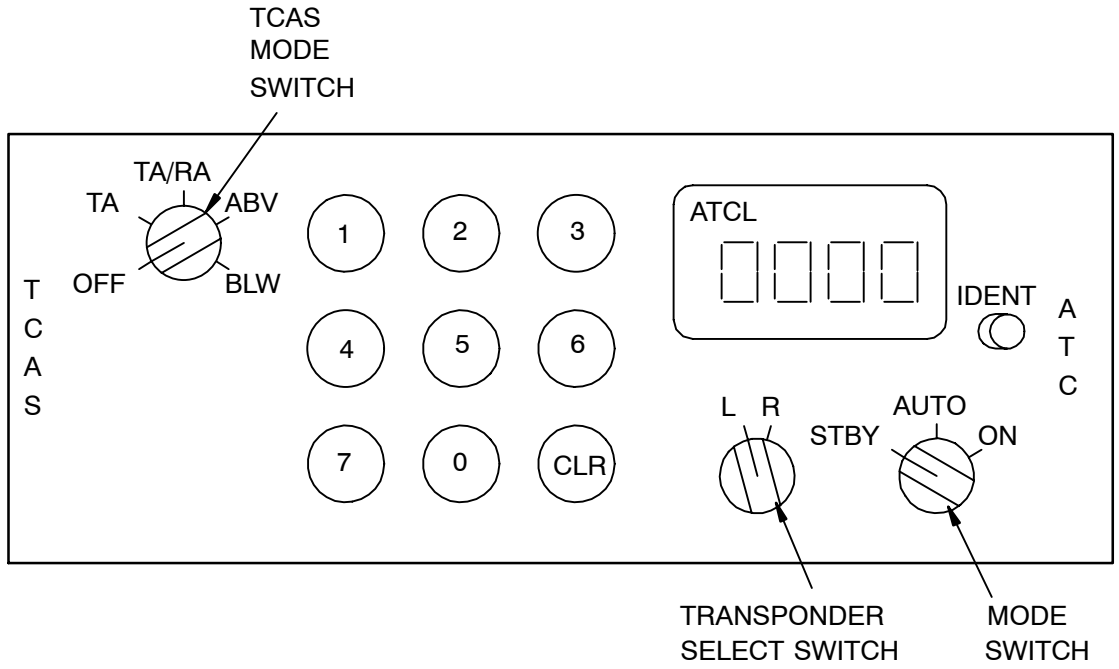


Figure 11 ATC / TCAS CONTROL PANEL

EFIS CONTROL PANEL

General

The left and right EFIS control panels control TCAS displays on the NDs.

TCAS II EFIS ND Mode Capabilities

TCAS intruder symbols show in these modes:

- Expanded and center MAP modes
- Expanded approach mode
- Expanded VOR mode

TCAS II EFIS ND Range Selection

The EFIS control panel range switch controls TCAS display capability. TCAS symbols show in all EFIS ranges, but show up better in ranges of 40nm or less.

TFC (Traffic) Pushbutton

The EFIS control panel TFC (traffic) pushbutton controls TCAS displays on the NDs. When a TCAS display mode is selected, the TFC button is used to turn on and off TCAS symbols. When not in a TCAS display mode, the TFC button is inactive. When selected off, no symbols show, but the word TRAFFIC shows in yellow for a TA, and in red for an RA.

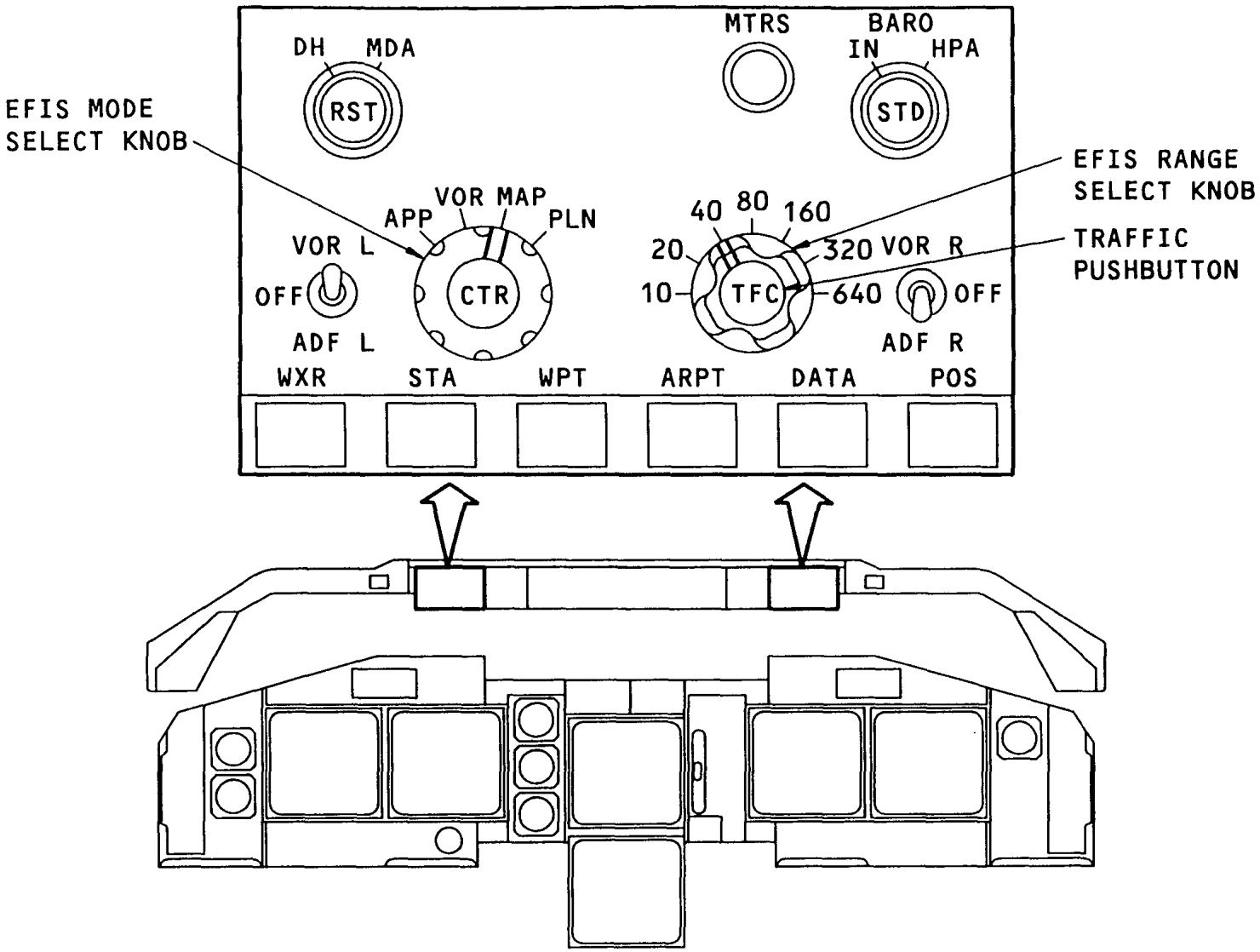


Figure 12 EFIS CONTROL PANEL

DIRECTIONAL ANTENNA

General

The TCAS II uses an upper and a lower directional antenna.

Directional Antennas

The directional antennas transmit interrogations on 1030 MHz at varying power levels in each of four 90 degree azimuth segment arrays. The TCAS computer receives intruder transponder replies on 1090 MHz. Each antenna is mounted using eight screws.

Physical Characteristics

The antenna weight is:

- 1.5 lbs (.68 kg).

The dimensions of the antenna are:

- Base diameter 9.3 inches (23.6 cm)
- Base thickness 0.8 inches (2 cm)

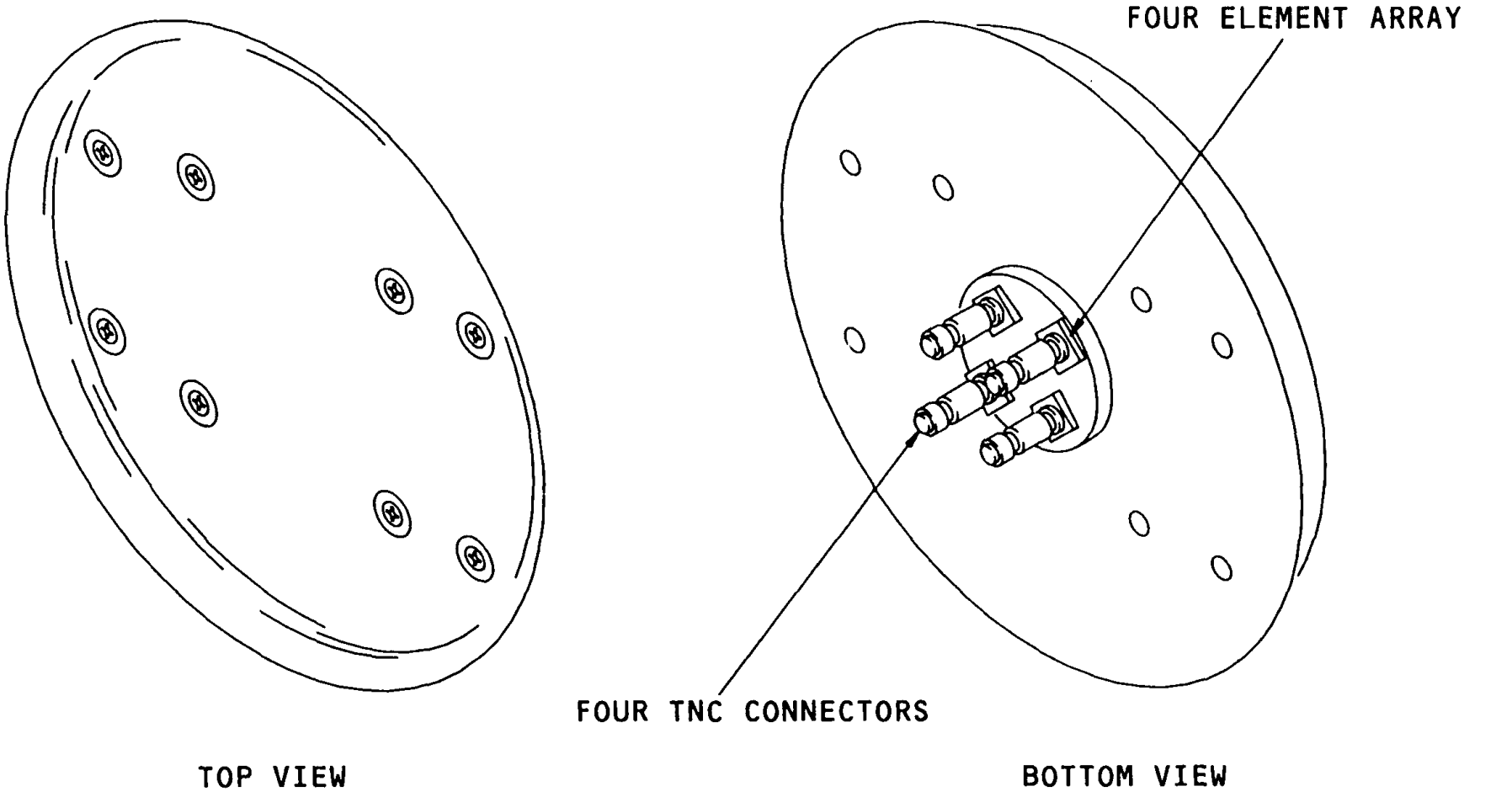


Figure 13 DIRECTIONAL ANTENNA (Honeywell)

DIRECTIONAL ANTENNA

General

The TCAS II uses an upper and a lower directional antenna.

Directional Antennas

The directional antennas transmit interrogations on 1030 MHz at varying power levels in each of four 90 degree azimuth segment arrays. The TCAS computer receives intruder transponder replies on 1090 MHz. Each antenna is mounted using four screws.

The radiating side of the antenna has black markings of forward (FWD) and „DO NOT PAINT“.

Physical Characteristics

The antenna weight is:

- 1.5 lbs (.68 kg).

The dimensions of the antenna are:

- Base width 6.25 inches (15.8 cm)
- Base length 11 inches (27.3cm)
- Height 1.25 inches (3.1 cm)

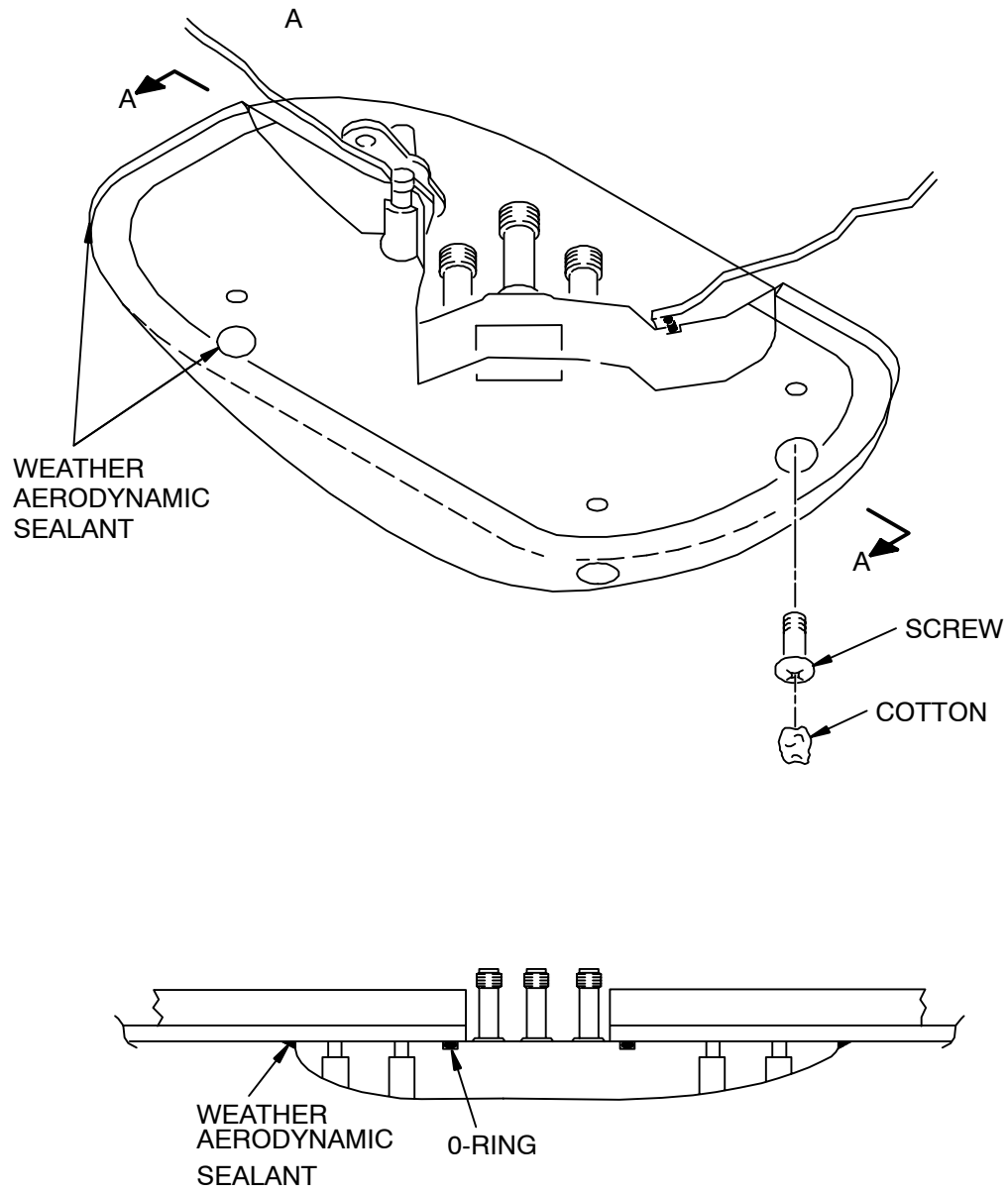


Figure 14 DIRECTIONAL ANTENNA (Bendix, Collins)

BASIC OPERATION

General

The TCAS II is similar to an ATC ground station, but operates independently. The TCAS computer is an airborne interrogator that detects the presence of all mode S or ATCRBS transponder equipped airplanes. TCAS II tracks and continuously evaluates the threat potential of all intruders. WAS II cannot detect airplanes that do not have a working ATC transponder.

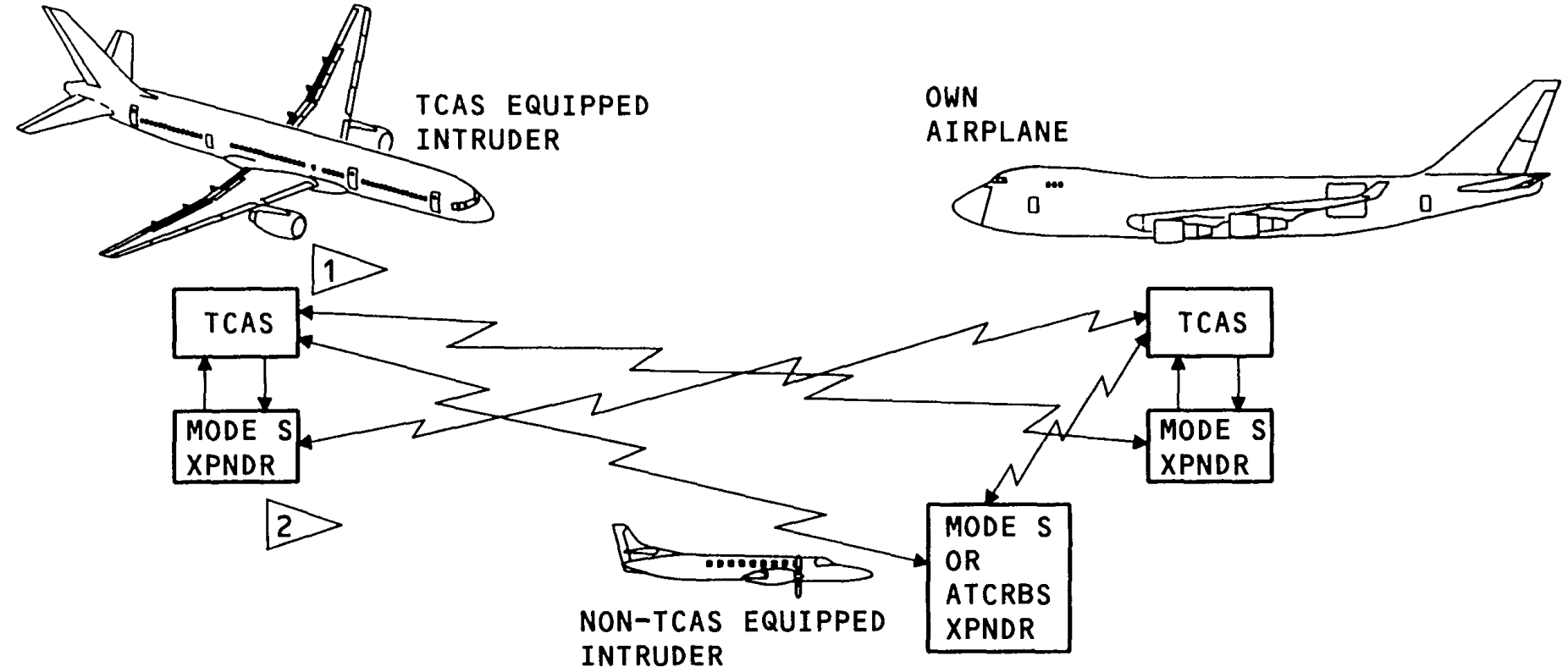
Detection Capability

WAS II actively searches for ATCRBS equipped intruders with an ATCRBS-only all-call interrogation. When WAS II interrogates ATCRBS intruders, it uses an interrogation technique called whisper shout. WAS uses this technique when it is operated in areas where multiple intruders replies could mask or interfere with each other.

The whisper shout technique varies the strength of the interrogation pulses (P1, P3 & P4) and a suppression pulse (S1) in relation to the intruders range. Close in targets are interrogated with low power (whisper).

Far away targets are interrogated with 24 power levels, up to the highest power (shout).

WAS II listens for mode S squitter pulse transmissions from mode S transponder equipped airplanes. This squitter pulse is transmitted once per second. When an ATCRBS or mode S transponder is detected, it is placed in the track mode. WAS II can track up to 45 intruders at once.



1 TCAS COMPUTER TRANSMITS ON 1030 MHz AND RECEIVES ON 1090 MHz

2 AIRBORNE TRANSPONDERS TRANSMIT ON 1090 MHz AND RECEIVE ON 1030 MHz

Figure 15 BASIC OPERATION

COMPUTER TRACKING SCENARIO

General

This scenario shows three airplanes which are possible collision threats to the TCAS equipped airplane in the center.

Mode S Equipped Airplanes

Airplane 1 is not WAS equipped, but has a mode S transponder. Airplane 2 is a TCAS equipped airplane. Airplane 1 transmits a mode S squitter signal once-per second on 1090 MHz. The WAS system monitors that frequency, and when a valid identification squitter signal is received, the airplane's ID code is added to a list of airplanes that WAS interrogates. This interrogation list is called a roll-call. In this scenario, airplane 2 adds airplane 1 to its roll-call, and then interrogates and tracks airplane 1 discretely. Both TAs and RAs are available in this situation.

ATCRBS Equipped Airplanes

Airplane 3 is equipped with an ATCRBS only transponder. Airplane 2 transmits an ATCRBS-only all-call once per second. Airplane 3 replies to this interrogation with a mode C reply, and airplane 2 can now track this airplane with updated ATCRBS only interrogations. Both TAs and RAs are available in this situation. No RAs are developed if the ATCRBS transponder does not have mode C altitude reporting capability.

Other WAS Equipped Airplanes

Airplane 4 is a TCAS equipped airplane. In this situation both TCAS airplanes produce a coordinated communication link between the mode S transponders and the WAS computers. Both TAs and RAs are produced and a coordinated evasive action results. This is the ideal situation for collision avoidance.

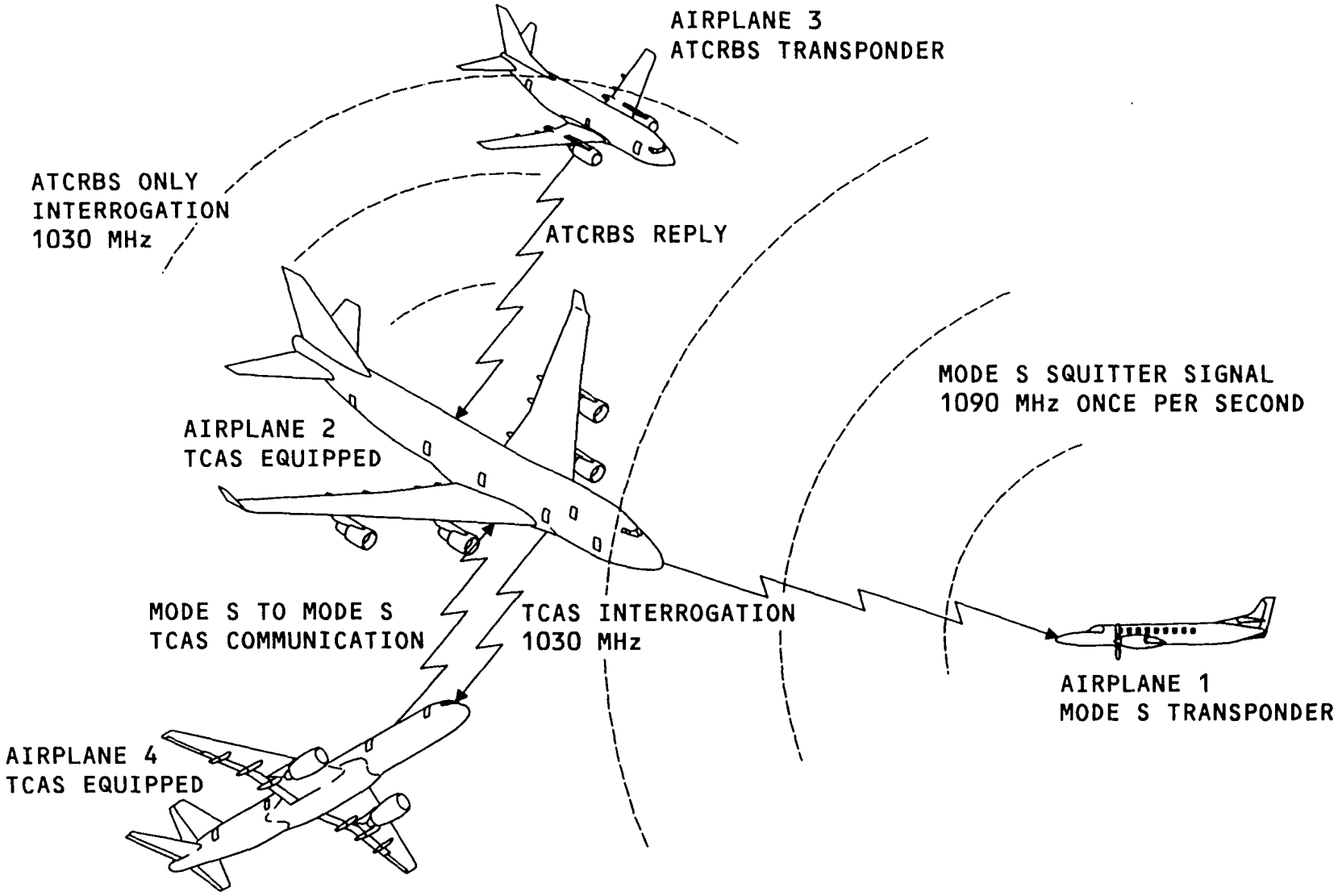


Figure 16 COMPUTER TRACKING SCENARIO

PRINCIPLES

TCAS Tau Areas

The WAS computer forms a protective area around the airplane as shown in the WAS protected areas. The dimensions of this protected area vary depending on the airspeed and altitude of the TCAS airplane, and the closure rates (range and altitude) of each intruder. This protected area represents the time until the intruder will be at the closest point of approach to own airplane. This time to endanger period is called tau. TAU is the minimum time the flight crew needs to learn of a collision threat and to take evasive action. The protected area is the tau area. A traffic advisory tau defines an area around the TCAS airplane. If this area is penetrated by an intruder, and the intruder meets the relative altitude restrictions, the WAS issues a traffic advisory alert. A resolution advisory tau is established for an RA warning in a similar manner.

TCAS Collision Calculations

The WAS computer predicts the relative altitude of the intruder at the closest point of approach. Based on own airplane radio or barometric altitude, there is a variable altitude restriction for advisory calculation as seen in the profile chart for WAS parameters.

TCAS Sensitivity Levels

The WAS computer has variable sensitivity levels (levels 2-7) as shown in the WAS parameters chart. The sensitivity level is selected by the WAS computer based on own airplane altitude. Level 2 is used from zero to 500 feet, and level 7 is used above 20,000 feet. Level 2 is the least sensitive and level 7 is the most sensitive. At level 2, no RA's can occur.

TCAS Sensitivity Levels (cont.)

The tau time in seconds varies with own airplane altitude from as little as 20 seconds to as much as 45 seconds. The vertical separation result of a resolution advisory also varies with own airplane altitude.

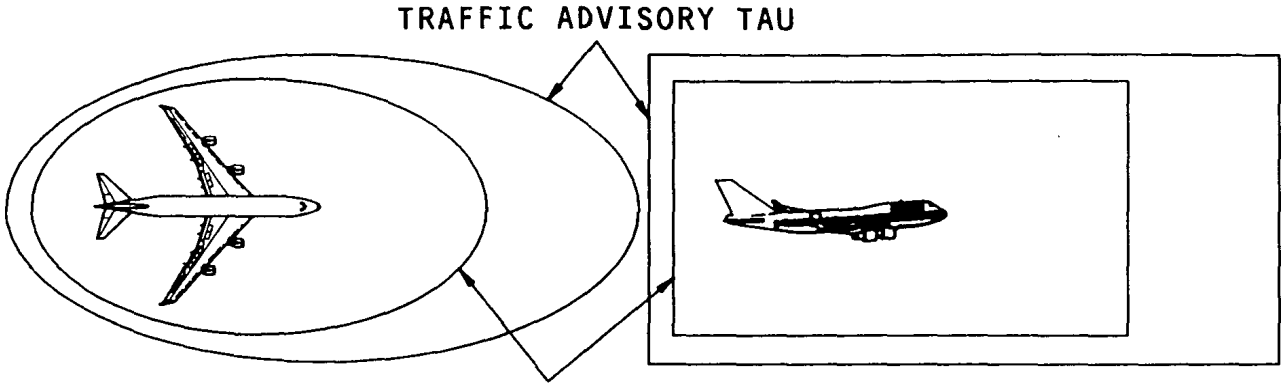
TCAS "DMOD"

A modification of a TCAS protected area called "DMOD" provides added TCAS protection against intruders with slow closure rates. DMOD keeps these intruders from getting too close. TA and RA ranges for various intruder closure rates are shown in the TCAS range vs closure rate chart.

TCAS Antenna Radiation Patterns

The TCAS computer transmits a variety of RF radiation patterns from both the top and bottom TCAS antennas. When TCAS is in communication with a mode S ATC transponder, the RF beam is transmitted in the direction of the intruder. This can be in any of the four transmit quadrants about the airplane.

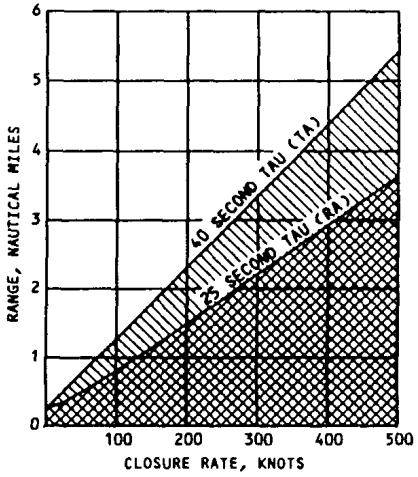
When TCAS transmits an ATCRBS only all call, the RF beam pattern is radiated on both the top and bottom antenna. The WAS favors the top antenna and the forward RF transmit quadrant for this type of transmission.



TCAS PROTECTED AREAS

OWN ALTITUDE (FEET)	RADIO ALTITUDE (FEET)		BAROMETRIC ALTITUDE (FEET)			
	UP TO 500	500-2500	UP TO 10,000	10,000-20,000	20,000-30,000	ABOVE 30,000
SENSITIVITY LEVEL	2	4	5	6	7	7
RESOLUTION ADVISORY TAU (SECONDS)	NA	20	25	30	35	35
TRAFFIC ADVISORY TAU (SECONDS)	20	35	40	45	45	45
TA RELATIVE ALTITUDE (FEET)	1200					
RA RELATIVE ALTITUDE (FEET)	NA	750			850	930
INCREMENTAL VOLUME (DMOD IN NAUTICAL MILES)	NA	0.1	0.3	1.0	1.0	1.0
RA MINIMUM RESULTANT VERTICAL SEPARATION	NA	400	400	500	640	740

TCAS PARAMETERS CHART



TCAS RANGE VS
CLOSURE RATE CHART
AT SENSITIVITY SETTING FIVE

Figure 17 PRINCIPLES

CONTROL AND DISPLAY MESSAGES

ATC/TCAS Control Panel

TCAS II is controlled by the ATC/TCAS function select switch.

If the ATC/TCAS functional select switch is not in TA or TA/RA, the message WAS OFF shows in yellow on the ND. This message shows in EFIS modes of MAP, EXP APP, or EXP VOR.

If WAS fails, a WAS FAIL message shows on the ND in yellow.

When TA is selected, WAS is enabled for traffic advisories only, and the message TA ONLY shows in cyan on the ND.

When TA/RA is selected, WAS is enabled for both traffic advisories and resolution advisories.

EFIS Control Panel

The EFIS mode control switch must be in either MAP, EXP APP, EXP VOR to show WAS symbols.

TCAS symbols show in any EFIS ranges, but show best in ranges of 40 nm or less.

When TCAS is tested the message TCAS TEST shows in cyan on the ND in any EFIS mode.

The TFC pushbutton on the range select knob turns WAS symbols on or off. When selected, the TFC message shows on the ND in cyan.

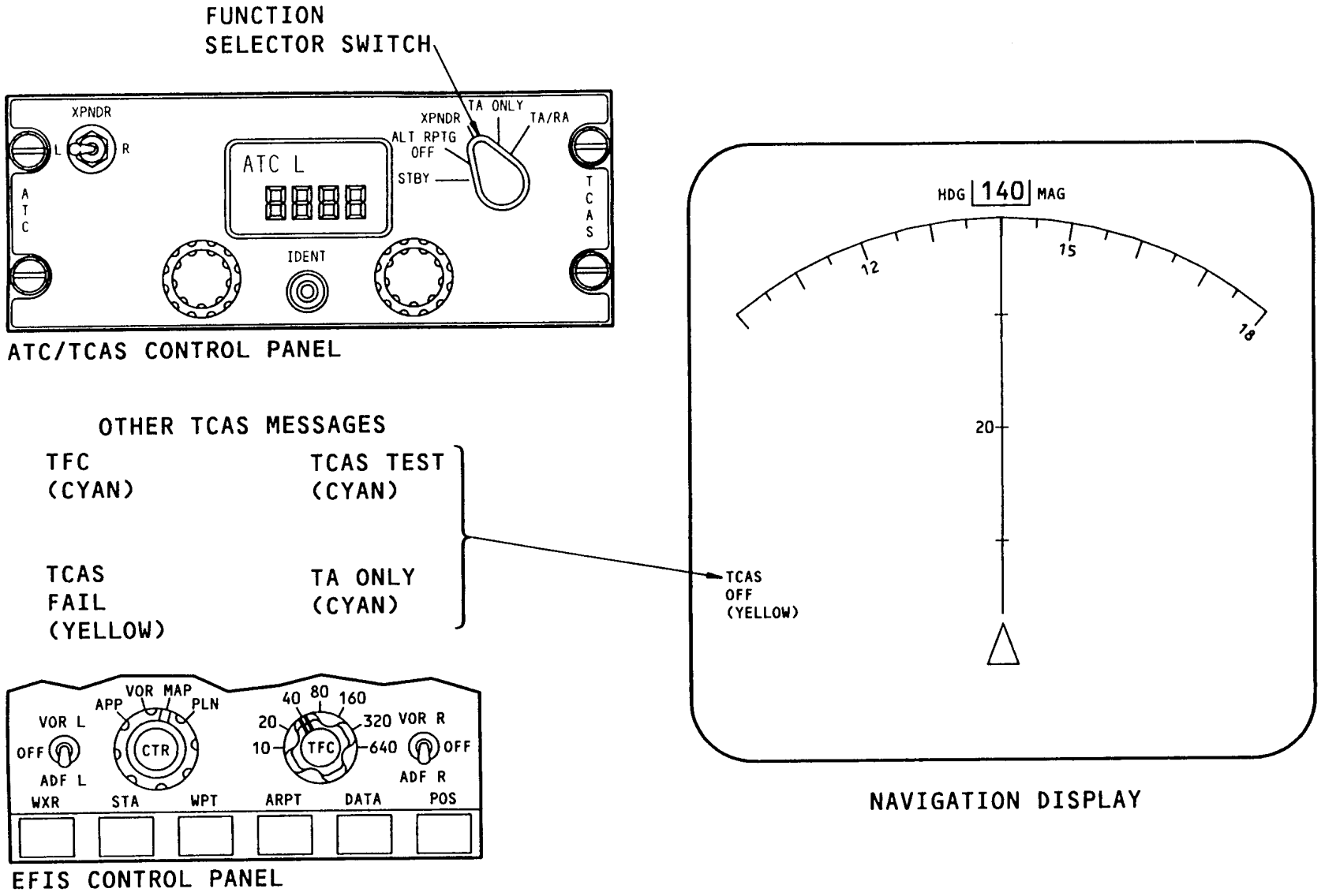


Figure 18 CONTROL AND DISPLAY MESSAGES

NAVIGATION DISPLAYS

General

TCAS II intruder display symbology is determined by several IDS software control laws and program pins. Target data is sent to the IDUs on two high speed ARINC 429 buses. Range, altitude, and bearing for up to 31 intruders are sent in each data file. For TCAS to show, the TFC button must be selected, the EFIS display range should be less than 40 nm, and the ND EFIS mode must be in either MAP, EXP APP, or EXP VOR.

Intruder

An intruder is any airplane being processed by the TCAS II computer threat detection logic as a potential threat. Traffic advisories (TAs) are issued for intruders with active tranpsonders. WAS II shows TAs for all intruders evaluated as threats on the EFIS NDs.

TCAS II Advisories

TCAS classifies intruders into four categories. Four types of symbols,

with different shapes and colors, show traffic symbols. The different types of WAS II intruders are:

- Other traffic
- Proximate traffic
- Traffic advisory (TA)
- Resolution advisory (RA)

These symbols show the relative position (range and usually bearing) of all intruders that are, or could become collision threats. In addition, a TA also shows intruder relative altitude up to + 7000 feet, and if the intruder is ascending or descending.

Non-Threat Displays

Non-threat or other traffic shows as a white open diamond. These represent airplanes with a range greater than 6 nm or relative altitude greater than 1200 feet.

Proximate Traffic

Proximate traffic shows as a solid, white-filled diamond. These are airplanes within 6 nm range and + 1200 feet relative altitude. Proximate traffic is not considered a threat, but only shows to assist the flight crew in visually acquiring the intruder.

Traffic Advisory (TA) Traffic

TAs show as a solid, yellow-filled circle. These are intruders within a specified number of seconds to closest point of approach (CPA). This gives the flight crew time to visually acquire the intruder. No vertical collision avoidance maneuvers are commanded for a TA. The altitude and seconds to CPA are:

- 35 sec. between 500-2500 feet
- 40 sec. between 2500-10,000 feet
- 45 sec. above 10,000 feet

Resolution Advisory (RA) Traffic

RAs show as a solid, red square. RAs are issued only when the intruder has altitude reporting capability. This vertical resolution advisory warns the flight crew when a collision course is determined and provides vertical flight cues to avoid a collision. These intruders require a vertical flight maneuver to avoid a collision. The altitude and seconds to CPA to make the maneuver are:

- 20 sec. at 500-2500 feet
- 25 sec. at 2500-10,000 feet
- 30 sec. at 10,000-20,000 feet
- 35 sec. at 20,000 feet & ABOVE

For takeoff or landing, RAs are inhibited under 500 feet, and aural announcements are inhibited under 400 feet.

Altitude Readout

Intruder relative altitude shows as two digits that represents altitude in hundreds of feet. The color is the same as the traffic symbol. The size of the digits are small for other and proximate traffic, and medium double-stroke for TAs and RAs. If the intruders relative altitude is above you, the digits appear above the symbol with a plus sign. If the intruder is below you, the digits appear below the symbol with a minus sign. If the relative altitude is NCD, the altitude readout is not displayed.

Vertical Motion Arrow

An arrow pointing up or down, the same color as the traffic symbol, is placed on the right side of the symbol to show the intruder is either climbing or descending at a rate greater than 500 feet-per-minute.

No-Bearing Traffic

A no-bearing (bearing NCD) TA or RA symbol shows on the upper right side of the ND. Each no-bearing intruder shows on a single line with TA or RA on the left, followed by the range in miles and tenths of a mile, followed by relative altitude, and by a vertical motion arrow. This data is yellow for TAs and red for RAs. There is a maximum of two no-bearing symbols shown at a time. Priority is the closest RA and then TA intruders.

Traffic Message

A yellow TA or red RA TRAFFIC message shows at the right center in the expanded EFIS modes and on the upper right side of the ND for all full rose EFIS modes.

Off-Scale Traffic

off-scale traffic (TA or RA traffic only) shows as a yellow (TA) or a red (RA) OFF-SCALE message. The message shows on the right center of the ND in the expanded EFIS modes and on the upper right side of the ND for all full rose EFIS modes, when the intruder is out of EFIS display range.

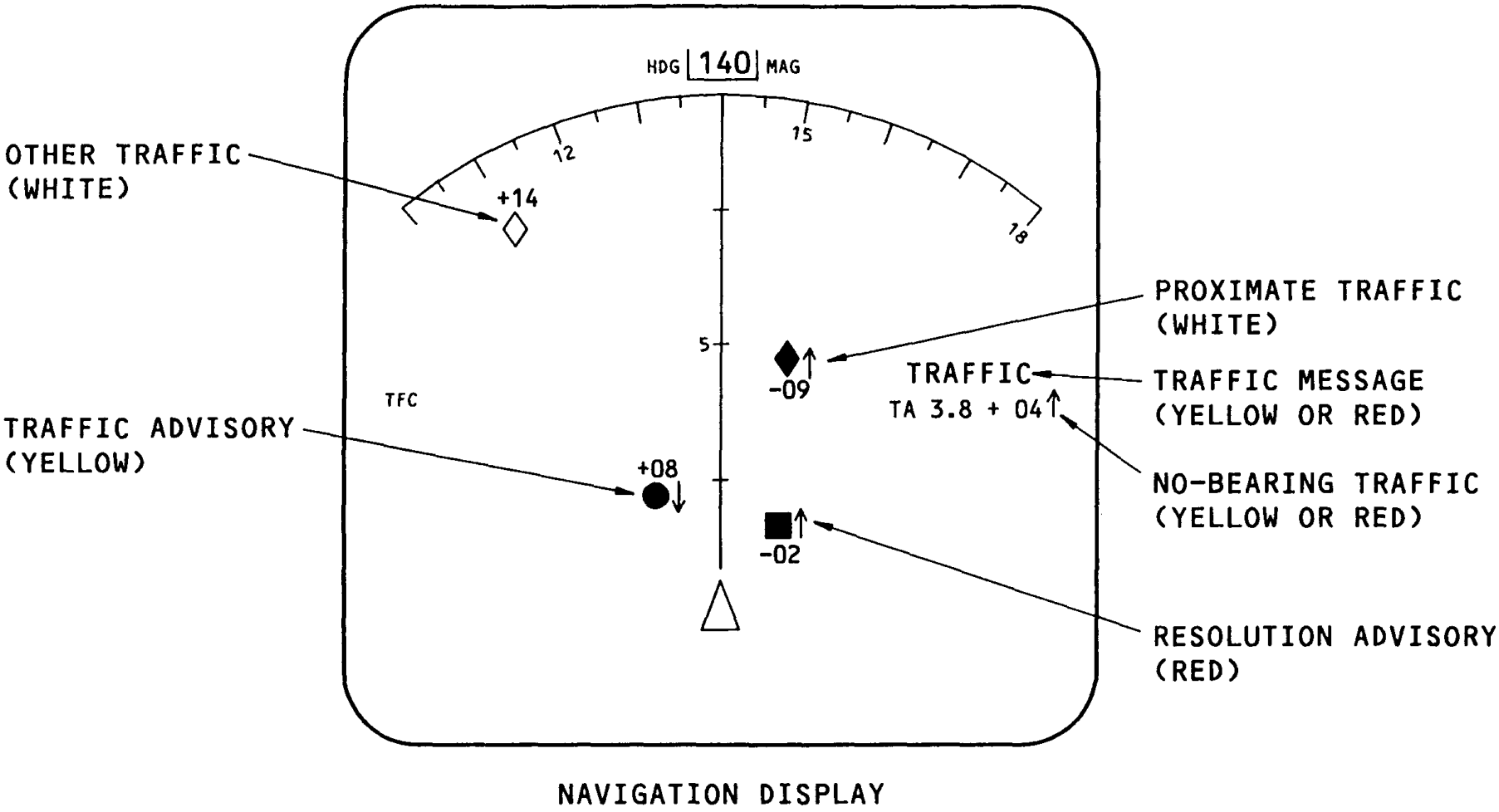


Figure 19 NAVIGATION DISPLAYS

PRIMARY FLIGHT DISPLAY

General

The primary flight display (PFD) shows an RA pitch maneuver symbol on the attitude display. This symbol is activated by IDU program pins. The symbol shows the flight crew vertical avoidance maneuver cues in response to a WAS resolution advisory (RA).

Vertical Position Display

An up or down vertical pitch advisory is generated for one or multiple RAs. The position of this TCAS symbol is a function of the TCAS resolution advisory, ADC true airspeed, IRU current vertical speed and pitch data. Display range of this WAS symbol is limited by the current position of the pitch limit indicator (PLI) symbol. Provisions are made to ensure this TCAS symbol is always in view relative to the display range of the PFD attitude background raster area.

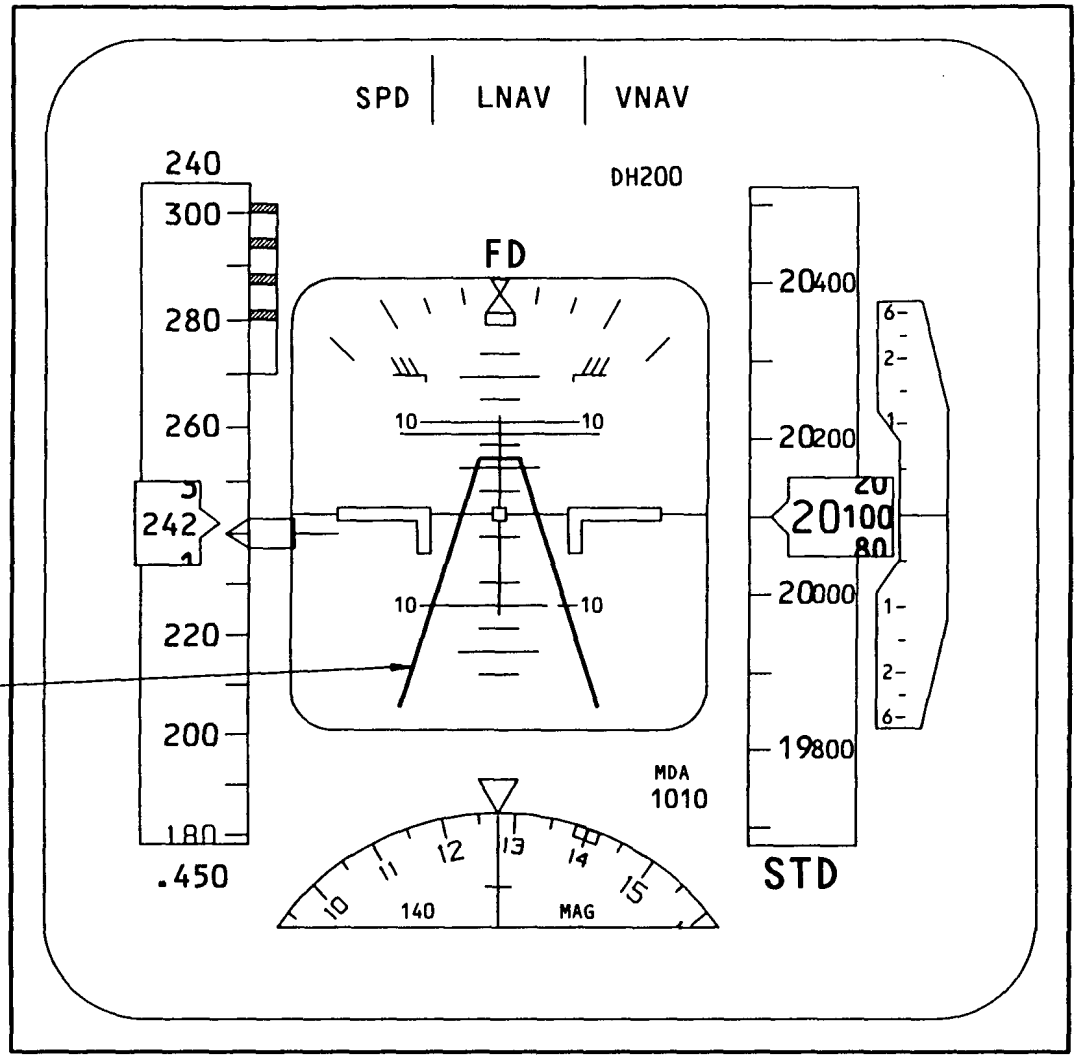


Figure 20 PRIMARY FLIGHT DISPLAY

AURAL MESSAGES

General

Traffic advisories (TAs), resolution advisories (RAs) and WAS self-test are announced with computer-generated aural voice messages.

Traffic Advisory Aural

For each traffic advisory, the aural 'TRAFFIC, TRAFFIC" is announced. This announcement directs the flight crew to monitor the ND to help visually acquire the intruder. The TA may be a new intruder, proximity, or other traffic which has been upgraded. A TA normally precedes an RA by 15 or more seconds.

Resolution Advisory Aurals

Resolution advisory aurals are announced with all RAs. These announcements are either preventive or corrective types.

Preventive RA aural advisories are announced when the airplane symbol is not inside the resolution advisory pitch cue. An example of a preventive aural is:

- "MONITOR VERTICAL SPEED - MONITOR VERTICAL SPEED": This message tells the flight crew to maintain the current vertical speed rate. The airplane symbol cannot cross the RA pitch command cue. If an earlier corrective resolution advisory is changed to a preventive advisory, the aural is only announced once.

Corrective type advisory aurals are either initial action or increased action types. Examples of initial action corrective RA aurals when the airplane symbol is inside the RA pitch cue are:

- "CLIMB, CLIMB, CLIMB (or DESCEND)" requires a maneuver at the rate indicated by the pitch cue on the PFD, nominal 1500 feet-per-minute.
- "CLIMB, CROSSING CLIMB - CLIMB, CROSSING CLIMB (or DESCEND)" requires a maneuver at the rate indicated by the pitch cue on the PFD and shows the airplane flight path will cross the intruder's flight path.
- "REDUCE CLIMB - REDUCE CLIMB (or DESCENT)" tells the flight crew to reduce the rate of vertical speed to that shown on the PFD.

Increased action corrective RA aurals change from initial action to an increased action command and require immediate crew action. Examples of increased action corrective RA aurals are:

- "CLIMB, CLIMB NOW - CLIMB, CLIMB NOW (or DESCEND)" follows a descend or climb advisory, after it has been determined that a quick reversal of a current vertical pitch maneuver is necessary to provide adequate airplane separation.
- "INCREASE CLIMB - INCREASE CLIMB (or DESCENT)" alerts the flight crew to increase the vertical pitch maneuver to a nominal 2500 feet-per-minute rate.

An end-of-threat aural announcement is made when the intruder range starts to increase and there is no longer danger of a collision:

- "CLEAR OF CONFLICT" tells the flight crew that the TCAS intruder encounter has ended. The flight crew should return to the previous flight level clearance.

TCAS self-test aurals are announced upon completion of the TCAS self-test, examples are:

- "TCAS TEST PASS" announced for a pass of the TCAS system test
- "TCAS TEST FAIL" announced when the TCAS system fails the test

AURAL MESSAGE	MESSAGE TYPE
TRAFFIC, TRAFFIC	TRAFFIC ADVISORY
MONITOR VERTICAL SPEED, MONITOR VERTICAL SPEED (1)	RESOLUTION ADVISORY (PREVENTIVE)
CLIMB, CLIMB, CLIMB	RESOLUTION ADVISORY (CORRECTIVE)
DESCEND, DESCEND, DESCEND	
CLIMB, CROSSING CLIMB CLIMB, CROSSING CLIMB	
DESCEND, CROSSING DESCEND DESCEND, CROSSING DESCEND	
REDUCE CLIMB, REDUCE CLIMB	
REDUCE DESCENT, REDUCE DESCENT	
CLIMB, CLIMB NOW CLIMB, CLIMB NOW	
DESCEND, DESCEND NOW DESCEND, DESCEND NOW	
INCREASE CLIMB, INCREASE CLIMB	
INCREASE DESCENT, INCREASE DESCENT	
CLEAR OF CONFLICT (3)	CLEARED RESOLUTION ADVISORY
TCAS TEST PASS	SELF-TEST RESULTS
TCAS TEST FAIL	

(1) "MONITOR VERTICAL SPEED" IS ANNOUNCED ONLY ONCE IF RESOLUTION ADVISORY IS BEING DOWNGRADED FROM A CORRECTIVE ADVISORY TO PREVENTIVE ADVISORY

(2) INCREASED ACTION RESOLUTION ADVISORY - CHANGES FROM PREVIOUSLY ISSUED CORRECTIVE ADVISORIES

(3) INDICATES ENCOUNTER HAS ENDED (RANGE HAS STARTED TO INCREASE)

Figure 21 AURAL MESSAGES

SYSTEM INPUTS / OUTPUTS

General

The TCAS computer gets a variety of sensor and airplane system inputs. The CPU uses these inputs to produce the traffic and resolution advisories. The input/output (1/0) section has an interface with the TCAS central processor. ARINC 429 data and digital discretes come into the WAS computer.

I / O Discretes and Program Pins

The 1/0 section gets airplane system and sensor discretes along with WAS system program pin settings. The CPU gets this data from internal ARINC data buses. These 1/0 signals are:

- IRU data which comes from the IRU selected by the First Officer. WAS presently does not use the IRU inputs, these are reserved for future WAS applications.
- The GPWC sends three discretes that inhibit RAs during ground prox warnings. These are: windshear, pull up, and ground prox alerts.

The landing gear controls module sends and up/down discrete that tells the WAS processor the position of the landing gear control lever. This sets the bottom WAS antenna in the omnidirectional mode when the landing gear is down.

The air/ground relay sends an air/ground discrete that inhibits RA traffic on the ground. In the air WAS test are inhibited. If the CMC fails, the air/ground discrete increments the Flight Leg in non-volatile memory.

The left, center and right EIU sends RA status discretes to tell the WAS if the IDS system can show an RA.

Four program pins set the selection of the airplane altitude performance capability, self-test and audio level parameters.

Input / Output Section

The input/output section of the TCAS computer interfaces a variety of airplane systems with the WAS CPU. Input/output systems include:

- The selected air traffic control (ATC) transponder sends the control panel WAS mode, own airplane Mode S ID address, and the barometric altitude to the WAS CPU. The WAS processor sends real-time and periodic data to the selected transponder. This is the type of equipment and WAS coordination update data from other intruder WAS equipped airplanes.
- The left and right radio altimeters (RAs) sends radio altitude data to the TCAS computer. Only one RA is needed for WAS operation.
- The central maintenance computer (CMC) communicates with TCAS for ground test and fault monitor.
- The software data loader control panel is used to load the latest TCAS computer software into the CPU.
- An ARINC data buffer is used as an interface between the CPU and the 1/0 sections.

Mutual Suppression Generator

A suppression pulse is generated each time the WAS computer transmits an interrogation and suppresses the active ATC and both DME's. The TCAS computer receiver is suppressed when the active ATC or either of the DME's transmit.

Voice Output

The MAWEA aural synthesizer cards get TCAS voice announcements from the speech prom for TA and RA advisories and for test audio.

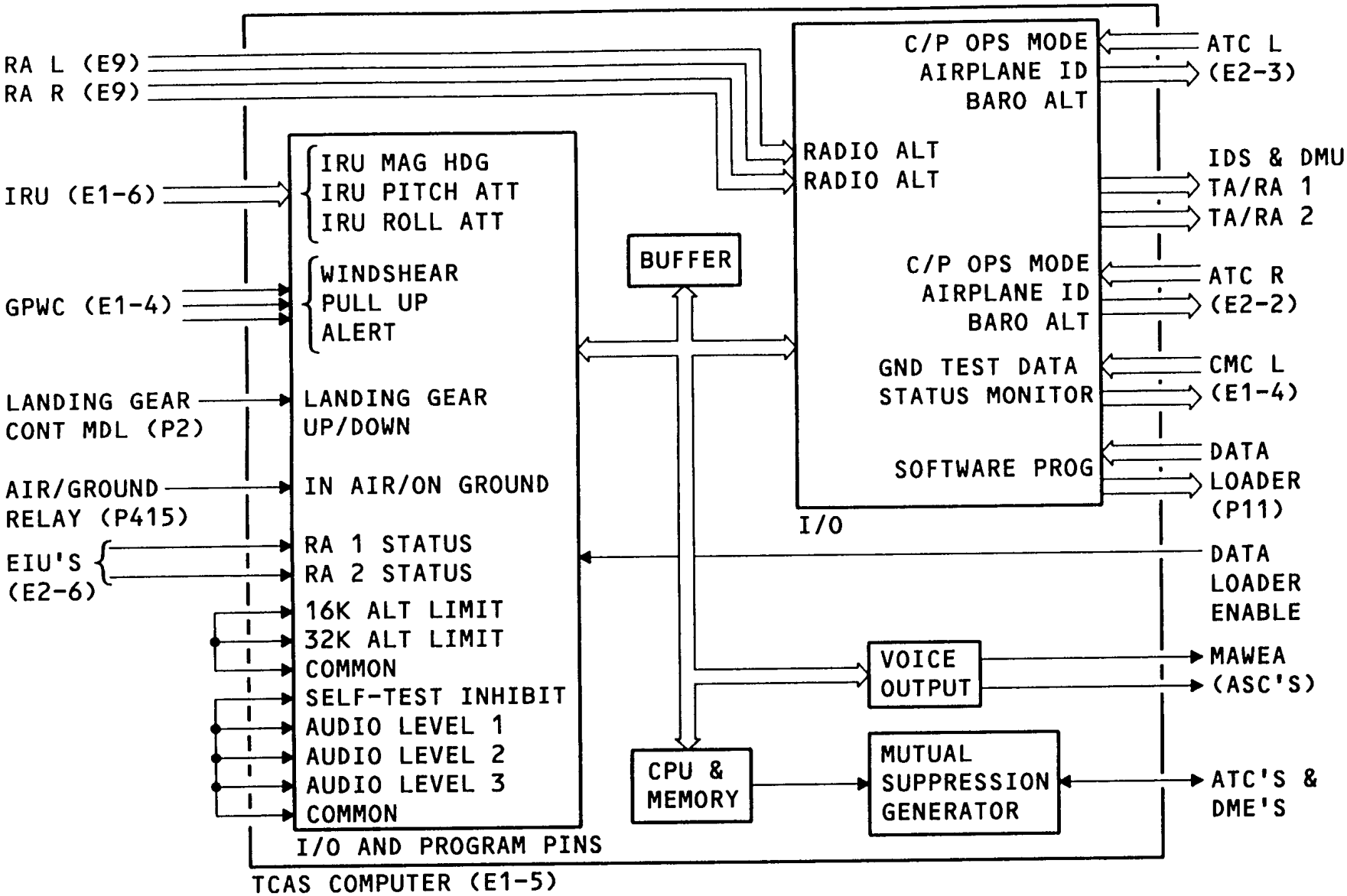


Figure 22 SYSTEM INPUTS / OUTPUTS

MICROPROCESSOR OPERATION

General

The microprocessor based WAS processor is the master control unit in the WAS II system. It has a combined computerized control system and an L-band receiver/transmitter. Operation of the WAS system is controlled by WAS software in the CPU (central processor unit) and memory section. The WAS CPU routinely reads and stores own airplane input data.

Microprocessor Functions

The WAS processor coordinates the data from the 1/0 sections and uses it along with received signals from other airplane transponders to compute traffic solutions and set transmission levels. The CPU is really three separate microprocessors that work together to process all traffic. The processor interfaces with global data and address buses through an ARINC transceiver and a buffer.

Signal Processor Functions

The primary purpose of the signal processor section is as a pre-processor of data that is transferred between the R/T section, the CPU, and 1/0 cards. The signal processor generates all timing signals necessary to receive and transmit mode S and mode C interrogations through the RF assembly. The signal processor operates under command of system software.

Receiver/Transmitter Functions

The R/T section links the TCAS II computer to other airplanes that may represent a collision threat. The R/T has four separate receivers that receive rf from other transponders on 1090 MHz from both the top and bottom TCAS directional antennas. This rf goes to the I/F video processor where it is converted to digital signals for computation in the signal processor. The signal processor sends signals to the modulator where it is formatted for use by the transmitter to interrogate ATC transponders on 1030 MHz.

Top and Bottom TCAS Antennas

These directional antennas are electronically steerable phased arrays with four beam forming elements. These antennas both transmit and receive rf for communication with any ATC transponders within range of the TCAS airplane.

During TCAS transmission, the top or bottom directional antenna radiates the 1030 MHz on a main beam pattern or an omni beam pattern. Beam pattern is under control of the four antenna element drive signals from the WAS processor. The landing gear discrete causes the bottom antenna to radiate in an omnidirectional pattern when the gear is down. TCAS mode S and ATCRBS interrogations are normally transmitted using the directional main beam, while the ATCRBS suppression pulse (P2) is transmitted in an omni pattern.

During TCAS receptions, each of the four directional antenna elements receives any 1090 MHz signals from other airplane transponders. The phasing of these signals is determined by the direction the rf energy is received. This direction data goes to the WAS receiver section for analysis in the WAS signal processor.

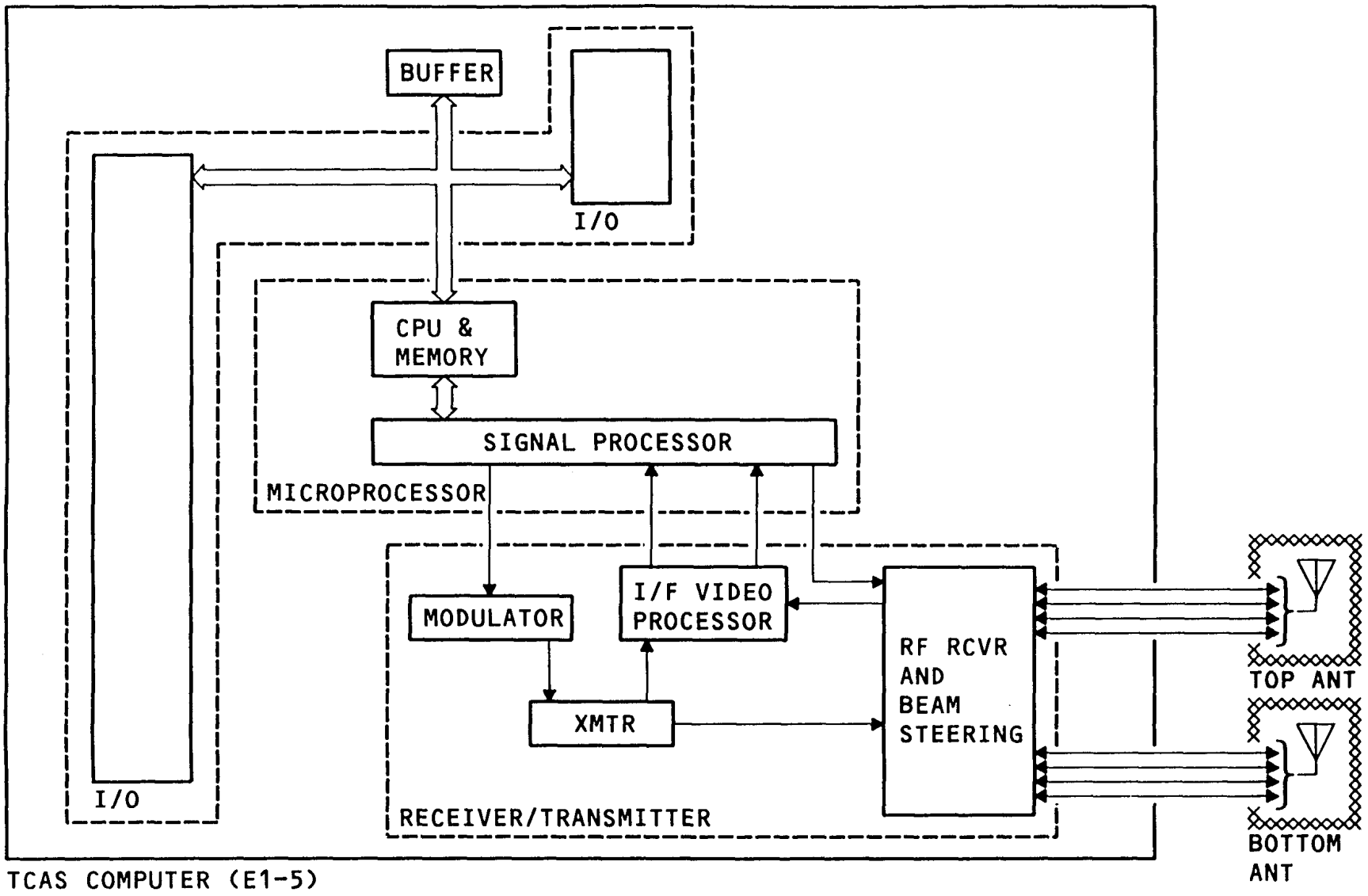


Figure 23 MICROPROCESSOR OPERATION

MANUAL SELF - TEST

General

The TCAS processor can detect any malfunctions of TCAS components that degrade or prevent possible collision avoidance protection. The processor has a full-time TCAS Built-In-Test Equipment (BITE) that monitors and initiates failure annunciations. A push-button on the front panel of the TCAS computer allows a manual self-test of TCAS.

Fault isolation is done only on the ground, using either the manual self test or the CMC ground test menu. A failure of either the mode S transponder or TCAS system during normal operation, causes the TCAS system to report a fail status to the CMC.

ATC/TCAS Manual Self-Test

When the manual self-test is started, a cyan message TCAS TEST shows on the ND with a test pattern that shows a sample of all the types of TCAS intruder symbols. The symbols show in this format:

- RA symbol is 3 o'clock relative, 2.0 nm distance, no vertical rate arrow, +200 ft. relative altitude.
- TA symbol is 9 o'clock relative, 2.0 nm distance, climbing vertical rate arrow, -200 ft. relative altitude.
- Proximity traffic symbol is at 1 o'clock relative, 3.6 nm distance descending vertical rate arrow, -1000 ft. relative altitude.
- Non-threat traffic symbol is at 11 o'clock relative, 3.6 nm distance no vertical rate arrow, +1000 ft. relative altitude.

During the self-test the PFD shows the do not descend and do not climb RA pitch cues on the attitude display in red.

TCAS Computer Front Panel Self-Test Indications

A pushbutton on the lower right corner of the WAS computer starts a manual self-test from the main equipment center.

When this button is pushed and held, the test sequence starts. The test begins with the illumination of all LED's for 3 seconds. The test pushbutton is released as soon as the LED's light and the test sequence continues until completion. Then all LED's go off for 3 seconds. If no faults exists, the green LED "TCAS PASS" lights. If there is a fault, the red LED for that fault comes on. The eleven LEDs are:

LED	MEANING
WAS PASS	- No Failure
TCAS FAIL	- TCAS Computer fail
TOP ANT	- Upper TCAS antenna fault
BOTTOM ANT	- Lower WAS antenna fault
HDG	- Not used
RA Log	- Not used
RA Display	- RA indicator fault
TA Display	- TA indicator fault
RAD ALT	- Radio altitude input fault
XPDR Bus	- Transponder bus fail
ATT	- Not used

Upon successful completion of the self-test, the aural message WAS TEST PASS is announced. If the self-test fails, the aural message WAS TEST FAIL is announced and the message TCAS FAIL shows on the ND.

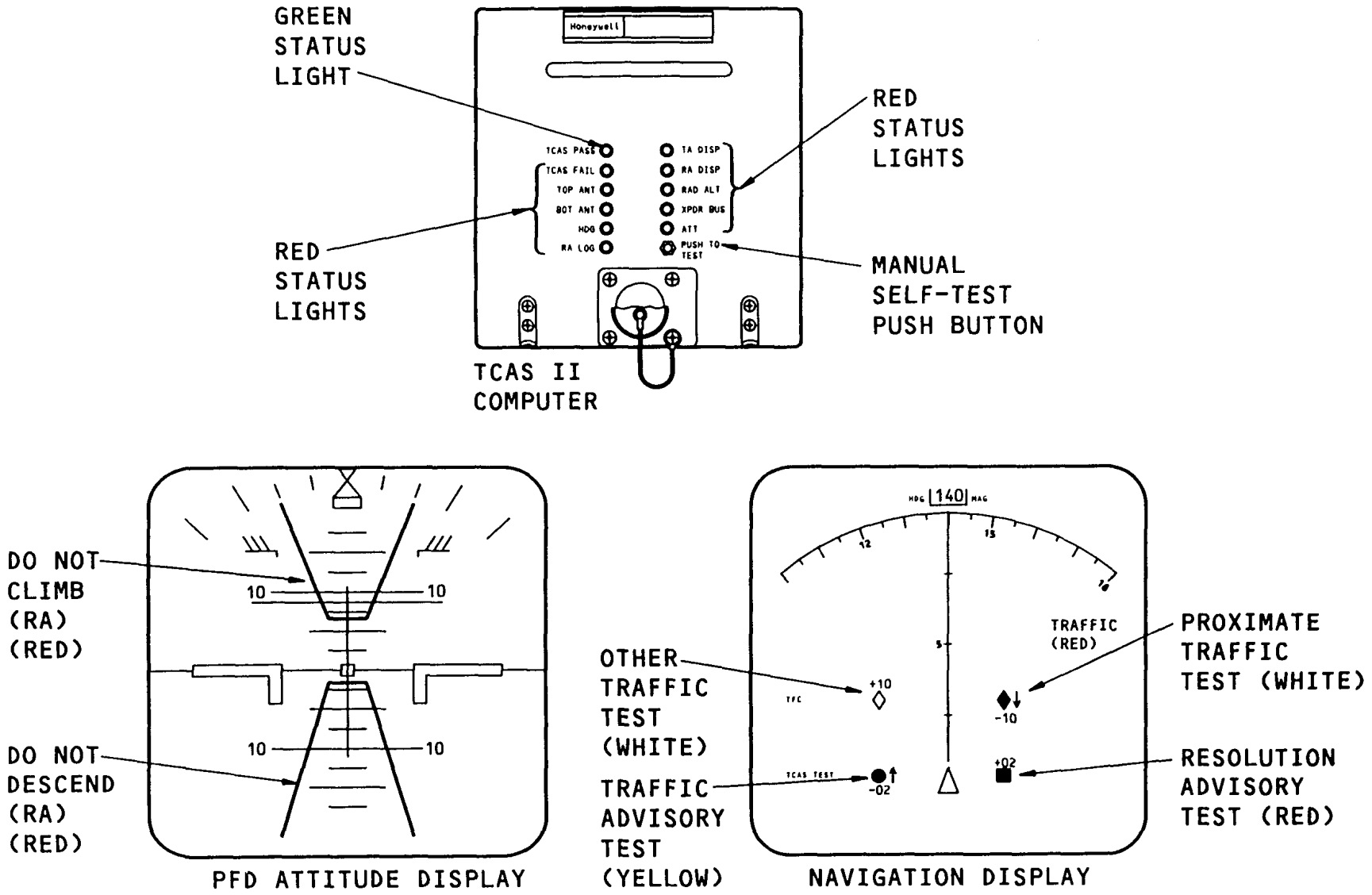


Figure 24 MANUAL SELF-TEST

CMC GROUND TEST

General

A TCAS CMC ground test is available from any CDU in the flight deck.

Ground Test Operation

To start a TCAS CMC ground test, first access the CMC Chapter 34 Navigation Radios Ground Test pages on the CDU. Push the LSK next to TCAS. Push the start test LSK next to TCAS and the TCAS pre-condition screen appears. If these pre-conditions are met, push the start test LSK to complete the test. If the system passes the test the word PASS shows on the right side of the screen. If the system fails the test the word FAIL shows. Push the LSK next to the fail message to show the CMC ground test message page where the CMC lists the fail message.

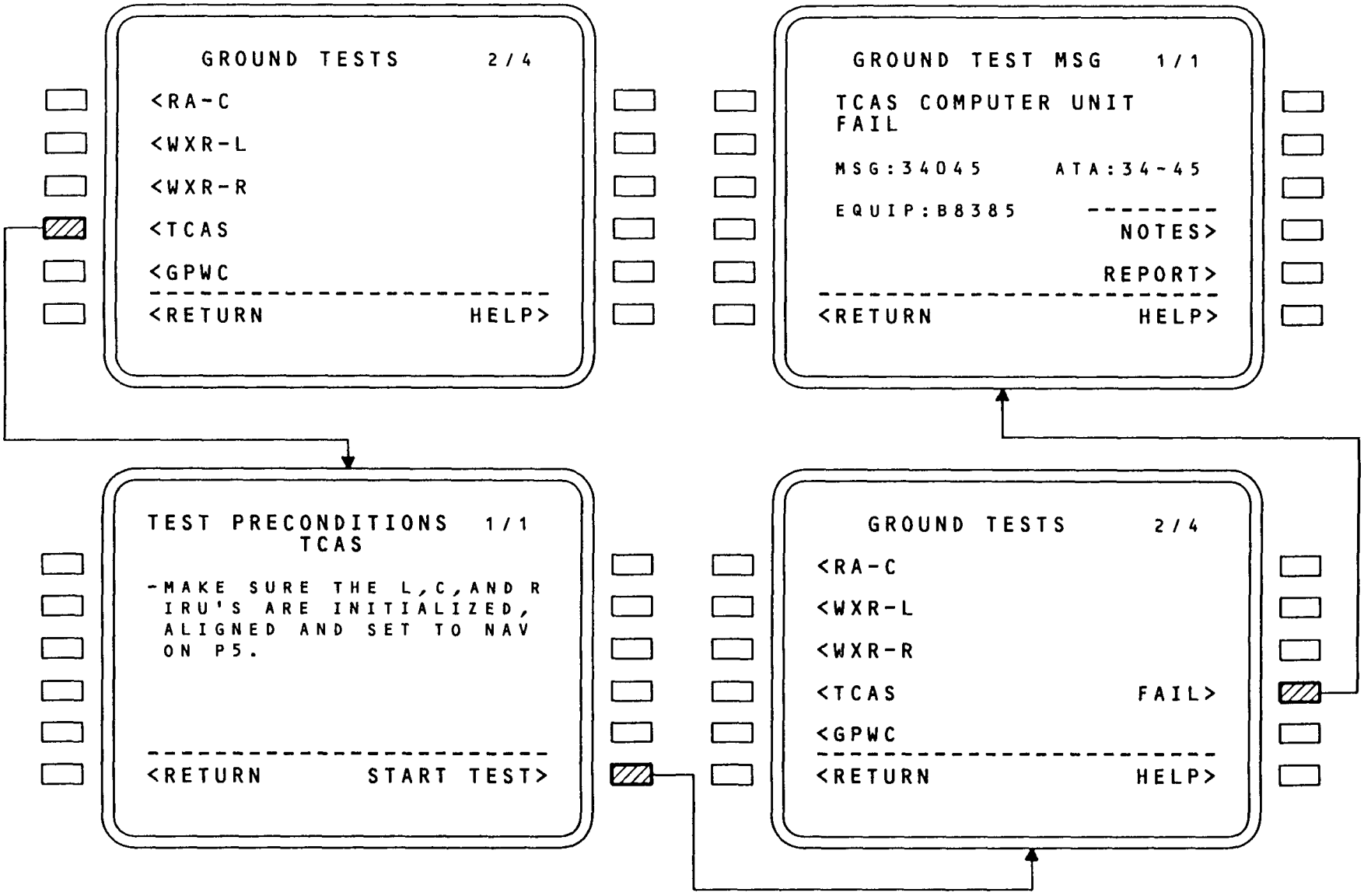


Figure 25 CMC GROUND TEST

FLIGHT DECK EFFECTS AND CMC MESSAGES

Flight Deck Effects

A TCAS II failure causes the message TCAS FAIL to show on both NDs.

Advisory EICAS messages include:

- >TCAS SYSTEM means data is not displayable on IDS
- >TCAS RA CAPT means resolution advisories cannot be displayed on the Captain's PFD
- >TCAS RA F/O means resolution advisories cannot be displayed on the F/O's PFD
- >TCAS OFF means the TCAS system is off

The status message TCAS SYSTEM appears for a fault in the TCAS display signal.

CMC Messages

Fifteen CMC messages show for faults that are reported to the CMC by TCAS. These messages assist in troubleshooting TCAS.

FLIGHT DECK EFFECTS	TYPE	DESCRIPTION
>TCAS SYSTEM	ADVISORY MESSAGE	TCAS DATA IS NOT DISPLAYABLE ON IDS
>TCAS RA CAPT	ADVISORY MESSAGE	TCAS RESOLUTION ADVISORIES CANNOT BE DISPLAYED ON THE CAPTAIN'S PFD
>TCAS RA F/O	ADVISORY MESSAGE	TCAS RESOLUTION ADVISORIES CANNOT BE DISPLAYED ON THE F/O'S PFD
>TCAS OFF	ADVISORY MESSAGE	TCAS SYSTEM OFF, OR INHIBITED BY ">TCAS SYSTEM"
TCAS SYSTEM	STATUS MESSAGE	TCAS SYSTEM DISPLAY FAULT

CMC MESSAGES

TCAS FAIL OR CMC-TCAS BUS FAIL
TCAS ~ CMC BUS FAIL
TCAS ~ CMC-R BUS FAIL
TCAS NO TEST RESPONSE
TCAS SYSTEM FAIL
TCAS COMPUTER UNIT FAIL
TCAS UPPER ANTENNA FAIL
TCAS LOWER ANTENNA FAIL
TCAS FAIL OR RA-L-TCAS BUS FAIL
TCAS FAIL OR RA-R-TCAS BUS FAIL
ATC-L ~ TCAS BUS FAIL
ATC-R ~ TCAS BUS FAIL
IRU ~ TCAS BUS FAIL
TCAS DISPLAY FAIL
TCAS FAIL (NO BUS OUTPUTS)

Figure 26 FLIGHT DECK EFFECTS AND CMC MESSAGES

TABLE OF CONTENTS

TABLE OF FIGURES