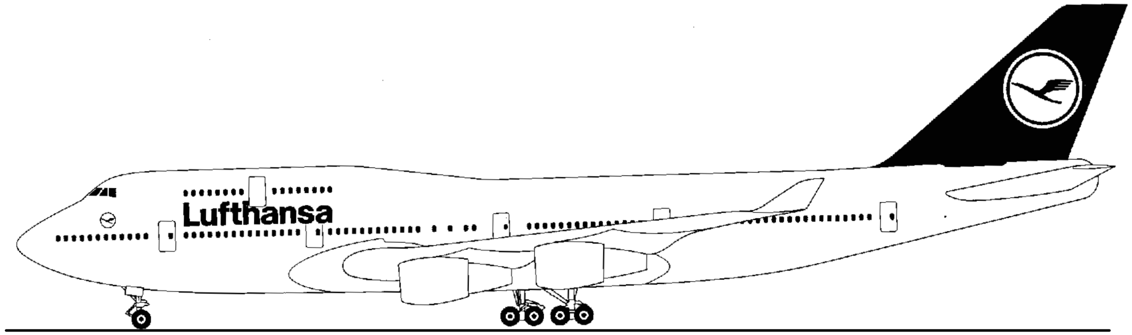
Lufthansa
Technical Training

Training Manual
B 747-400



ATA 34-58
GPS

Level III

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ATA 34-58 GLOBAL POSITIONING SYSTEM

GLOBAL POSITIONING SYSTEM INTRODUCTION

The global positioning system (GPS) is a satellite-based radio navigation system which uses navigation satellites to calculate accurate airplane position and time. This data goes to airplane systems and to displays for the flight crew.

The GPS system became fully operational in the early 1990's.

The GPS satellite system is designed to operate using 24 satellites; 21 primary and 3 spares. The actual number of satellites that are operational can vary. This is due to satellite failures and satellite replacement schedule.

Although designed as a military system, civil use of the system is an integral part of navigation systems.

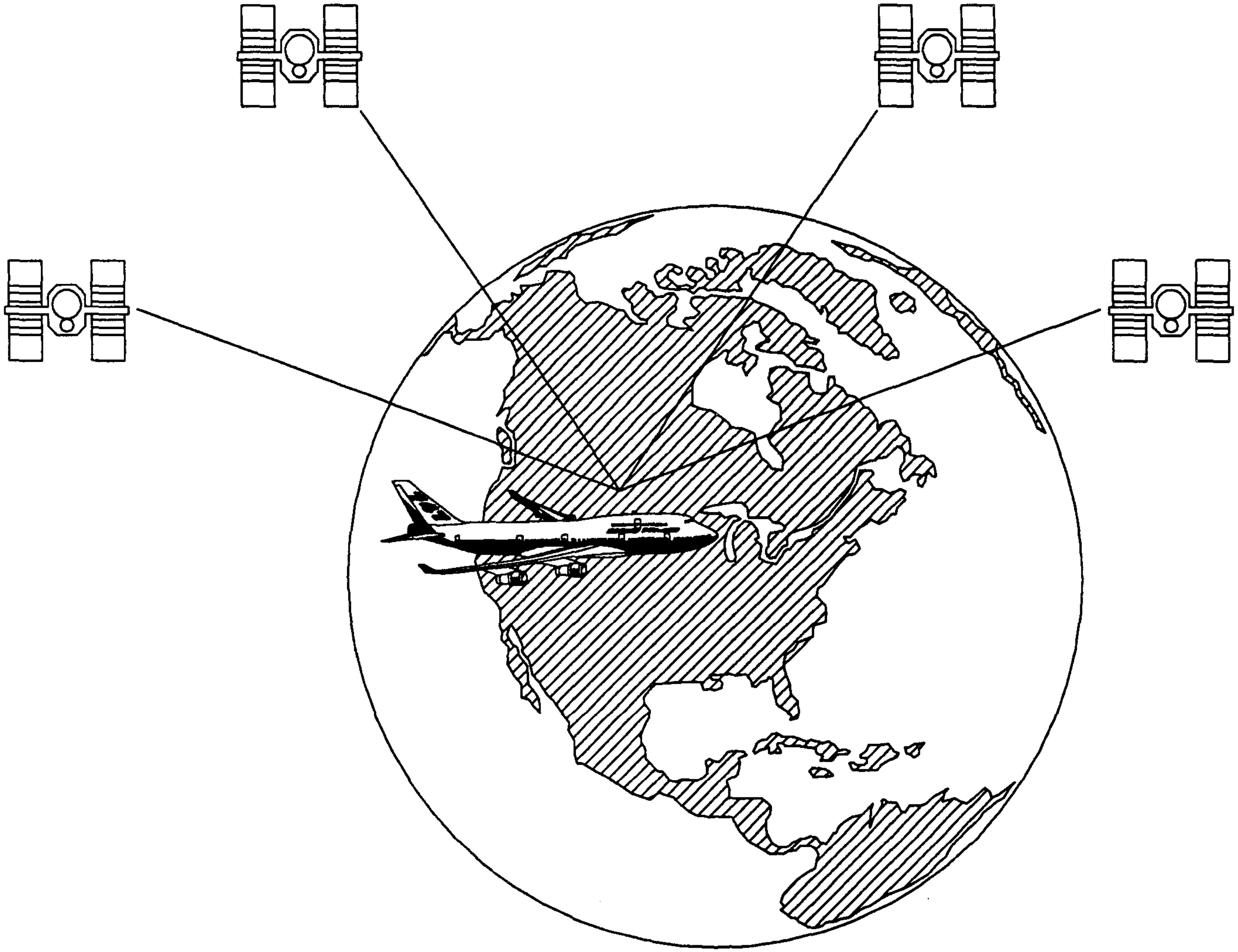


Figure 1 GLOBAL POSITIONING SYSTEM INTRODUCTION

GLOBAL POSITIONING SYSTEM

The global positioning system (GPS) calculates:

- Latitude
- Longitude
- Altitude
- Accurate time

There are two GPS antennas and two GPS multi mode receivers (GPS/MMR). The antennas connect to their respective GPS/MMR. The GPS/MMRs calculate the airplane position and update the GPS clock. This data goes to the flight management computer system (FMCS) and to the airplane condition monitoring system (ACMS) data management unit (DMU).

The navigation function in the FMCS uses GPS and other navigation sensors to calculate the airplane position. GPS position data is observed on the control and display unit (CDU). The FMCS uses universal coordinated time (UTC) from the GPS as a reference for calculations.

If the GPS/MMRs are not initialized with latitude and longitude, the first satellite position fix can take up to 10 minutes.

The inertial reference units (IRUs) send latitude and longitude to the GPS/MMRs for initialization. This allows the first satellite position fix to take place within 75 seconds from power-up. Short periods of adverse satellite coverage can occur. When this happens, the GPS/MMRs use IRU data to aid in continued calculation of airplane position when not enough satellites are in view. This IRU input also lets the GPS/MMRs reacquire the satellites needed to re-enter the navigate mode quickly.

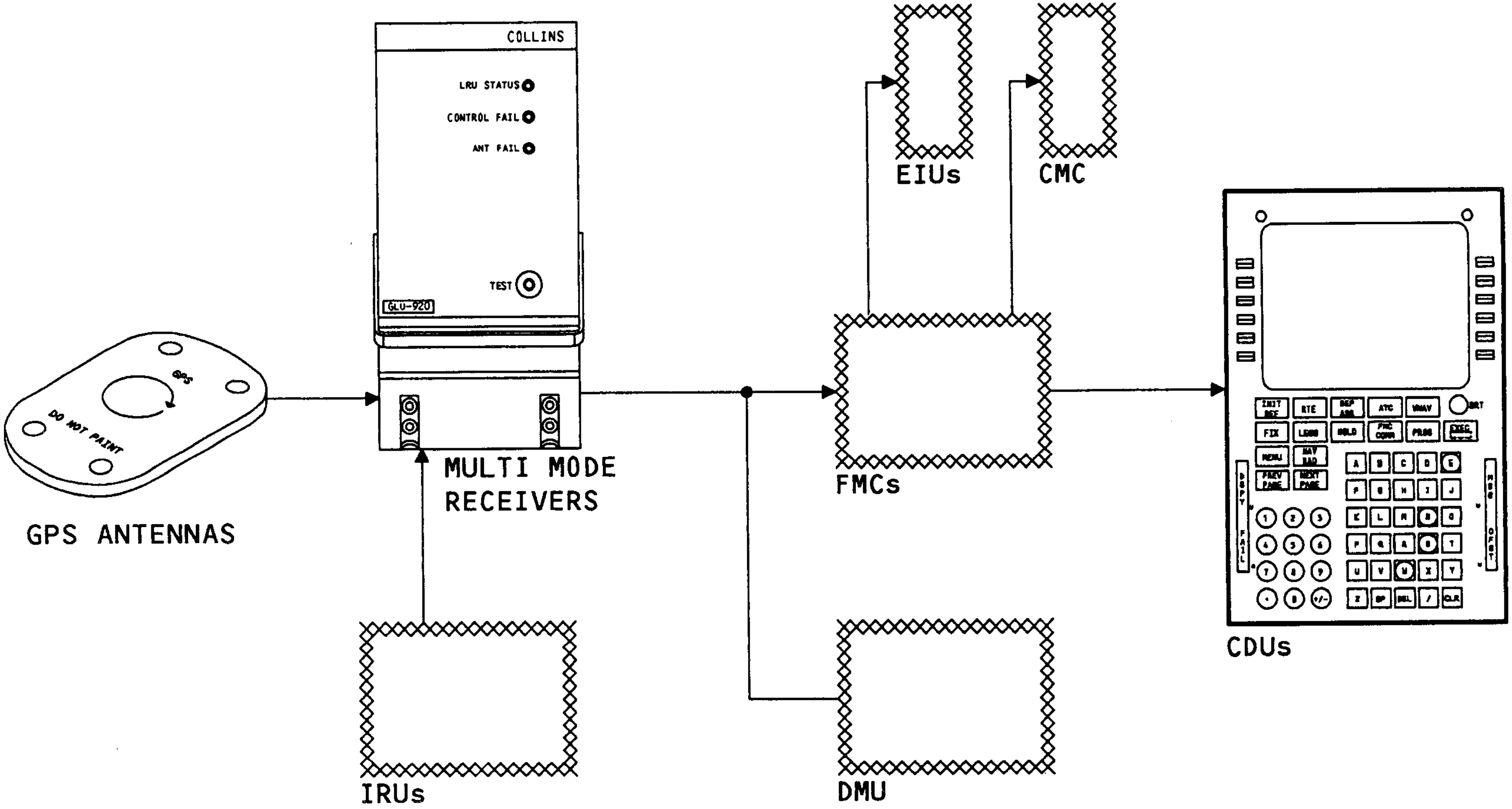


Figure 2 GLOBAL POSITIONING SYSTEM

COMPONENT LOCATIONS - FLIGHT DECK

The GPS interfacing components located in the flight deck are the:

- Left inboard IDU
- Left outboard IDU
- Lower IDU
- Upper IDU
- Right inboard IDU
- Right outboard IDU
- Right control display unit (CDU)
- Left CDU
- Center CDU
- Multi mode Receiver (MMR) circuit breakers

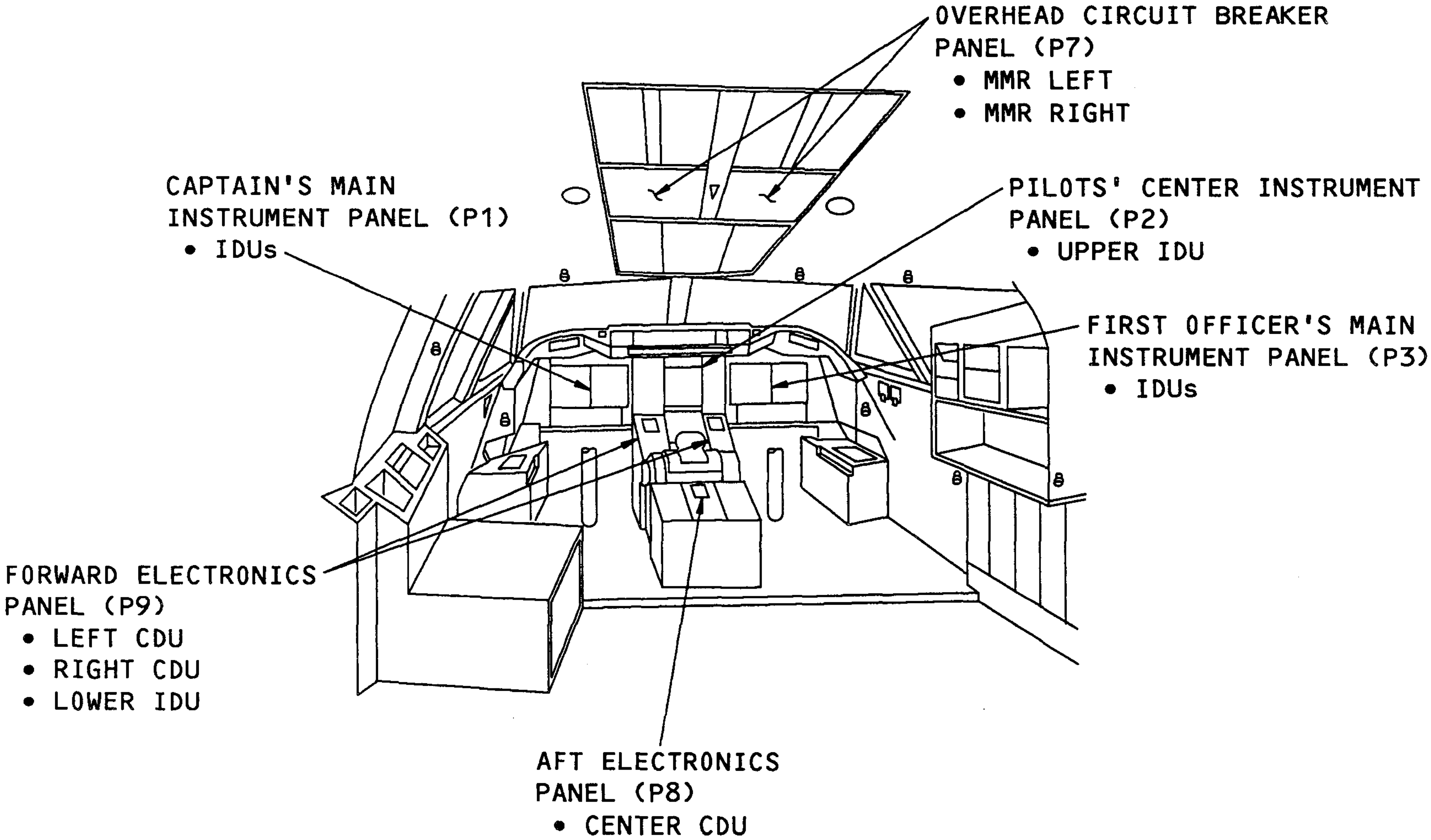


Figure 3 COMPONENT LOCATIONS - FLIGHT DECK

COMPONENT LOCATIONS - FUSELAGE

The two GPS antennas are installed on the top of the fuselage.

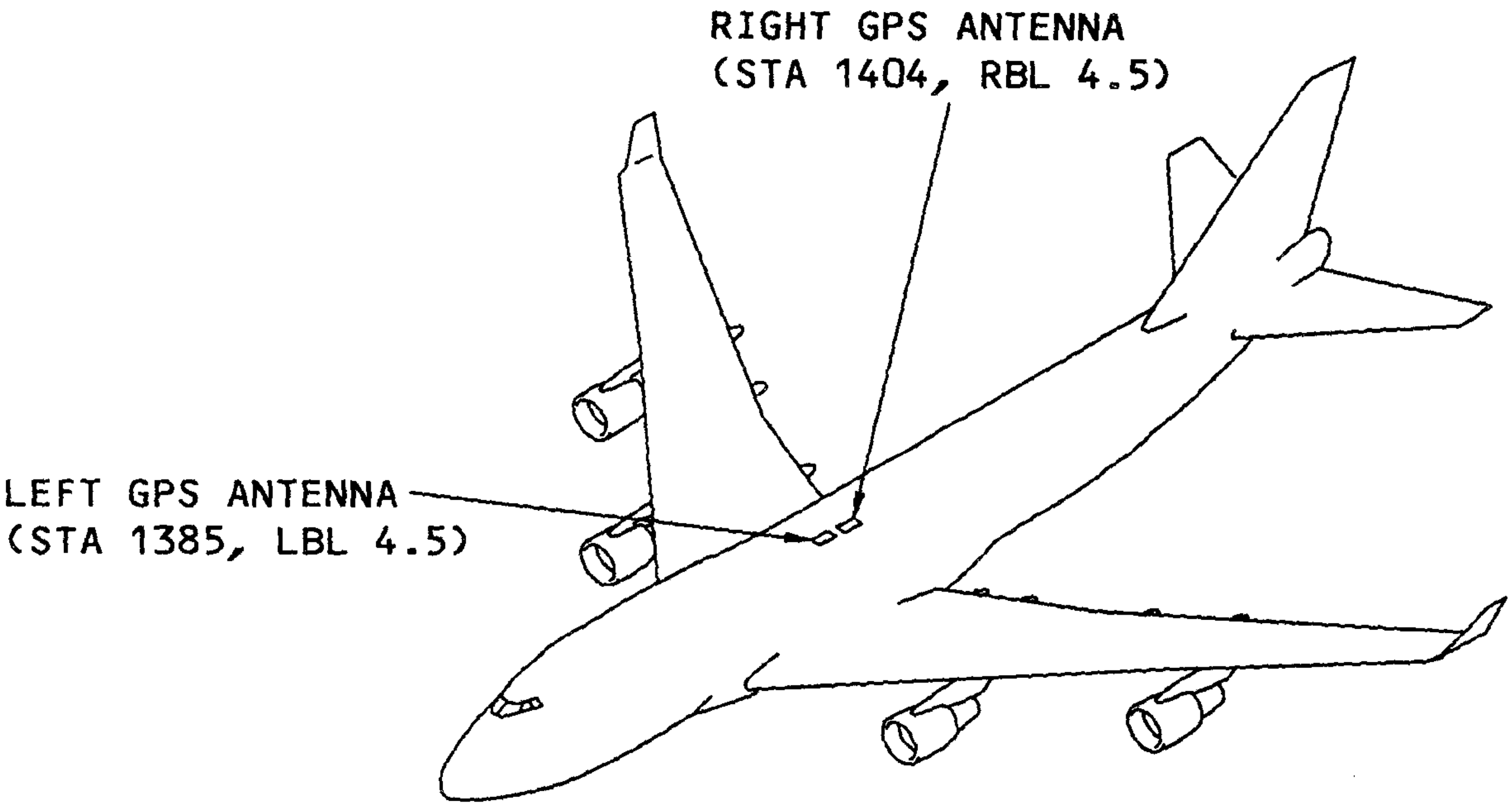


Figure 4 COMPONENT LOCATIONS - FUSELAGE

COMPONENT LOCATIONS - MEC

The left and right GPS Multi Mode Receivers (GPS/MMR) are installed in the Main Equipment Center (MEC) on the E1-2 and E1-4 equipment racks.

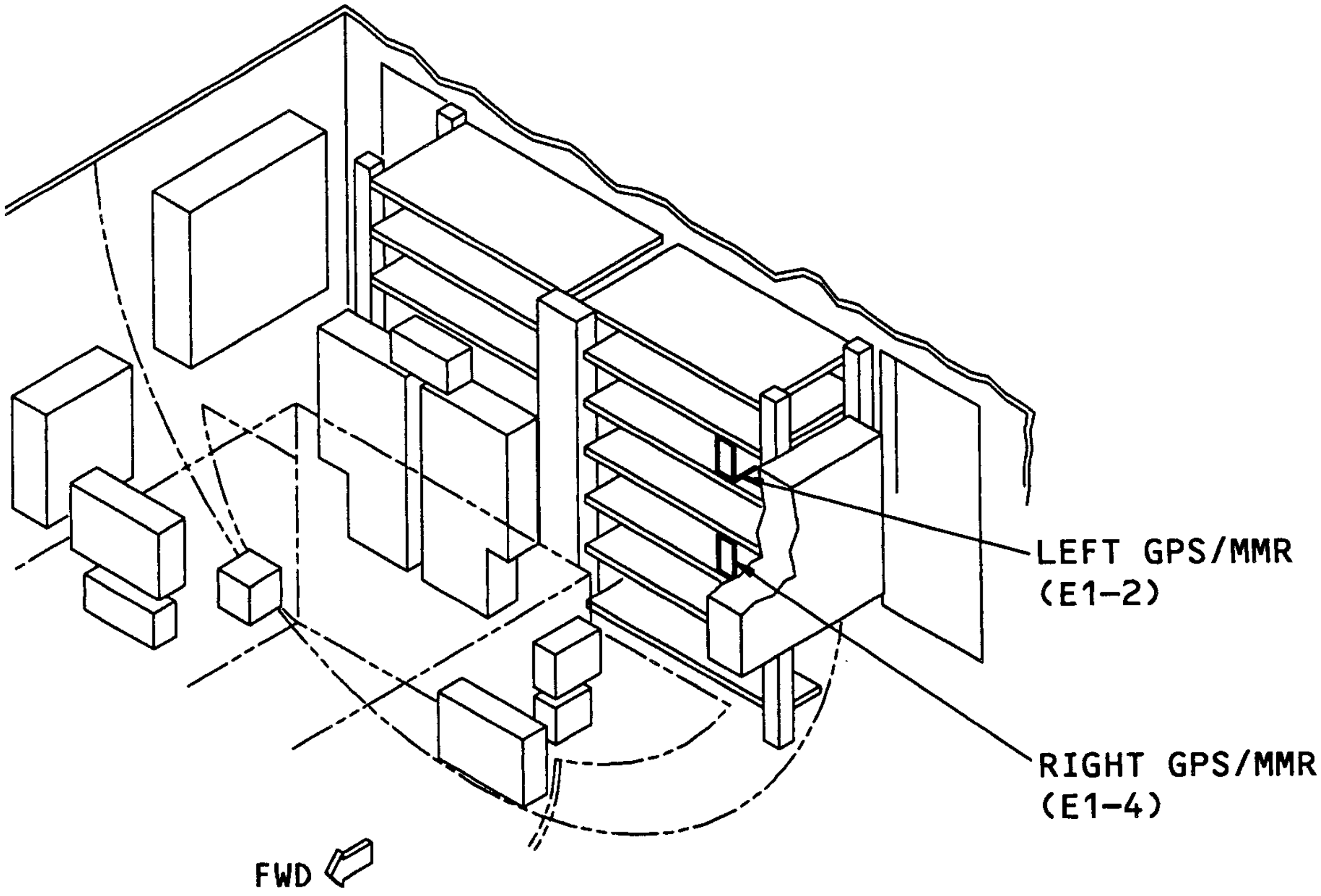


Figure 5 COMPONENT LOCATIONS - MEC

INTERFACE DIAGRAM

Power and Antenna Interface

Each GPS multi mode receiver (GPS/MMR) has its own circuit breaker. The 115V AC STBY BUS supplies power to the left GPS/MMR and the 115V AC BUS 2 supplies power to the right GPS/MMRs.

Each GPS/MMR receives radio frequency (RF) energy from its own GPS antenna.

IRU Data Bus

The GPS/MMR get inertial reference data from the IRUs. The left GPS/MMR receives data from either the left IRU or the center IRU. The right GPS/MMR receives data from the right IRU or the center IRU. Normally the onside input bus is used. If the onside bus is invalid the offside bus is used. The GPS/MMRs use this data for system initialization and to help operation during periods of low satellite coverage.

The IRU sends:

- Latitude
- Longitude
- True air speed
- Ground speed
- True and magnetic heading
- Track
- Inertial altitude
- Inertial vertical speed

GPS Data Output Bus

Each GPS/MMR sends GPS data to the FMCs and to the DMU. The GPS data includes:

- GPS position
- GPS time
- Horizontal figure of merit (HFOM)
- Horizontal integrity limit (HIL)
- Satellite coverage fail (SAT FAIL)
- Fault data

GPS fault data, for central maintenance computer (CMC) messages, are sent through the FMCs.

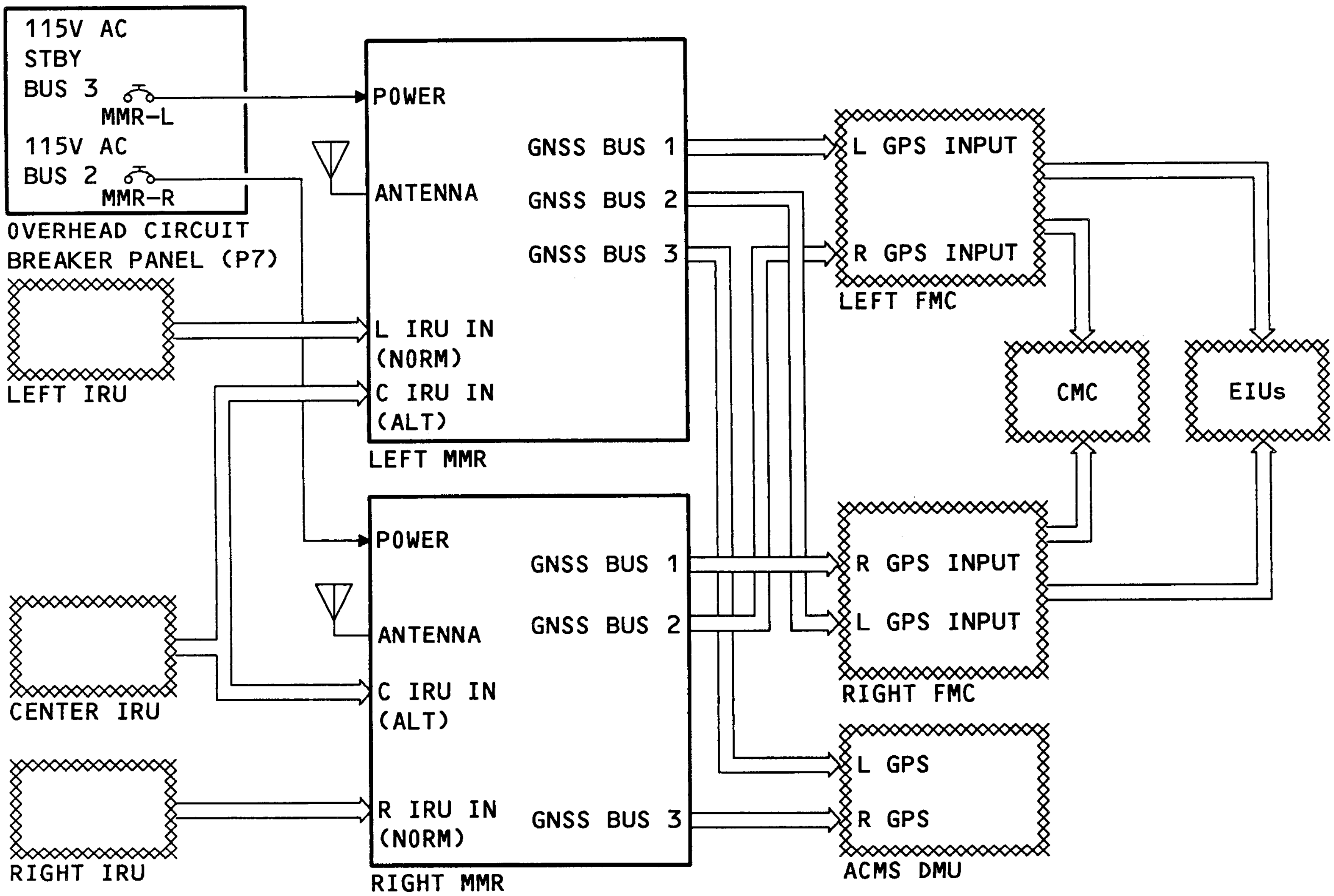


Figure 6 INTERFACE DIAGRAM

GPS MULTI MODE RECEIVER

Purpose

The multi mode receiver (MMR) is an LRU which combines the functions of an ILS receiver, a microwave landing system receiver, and a GPS receiver in a single unit. The GPS section of the MMR activates when installed in the left or right position. The GPS/MMR receives navigation satellite signals and calculates GPS data.

Physical Description

The GPS/MMR dimensions are 9.5 inches (24 cm) long, 8.5 inches (22 cm) wide, and 2.5 inches (6 cm) tall. The GPS/MMR is an Lband receiver and a computer in one unit. The GPS/MMR uses 115v ac for operation, and has passive cooling. The GPS/MMRs are located in the main equipment center.

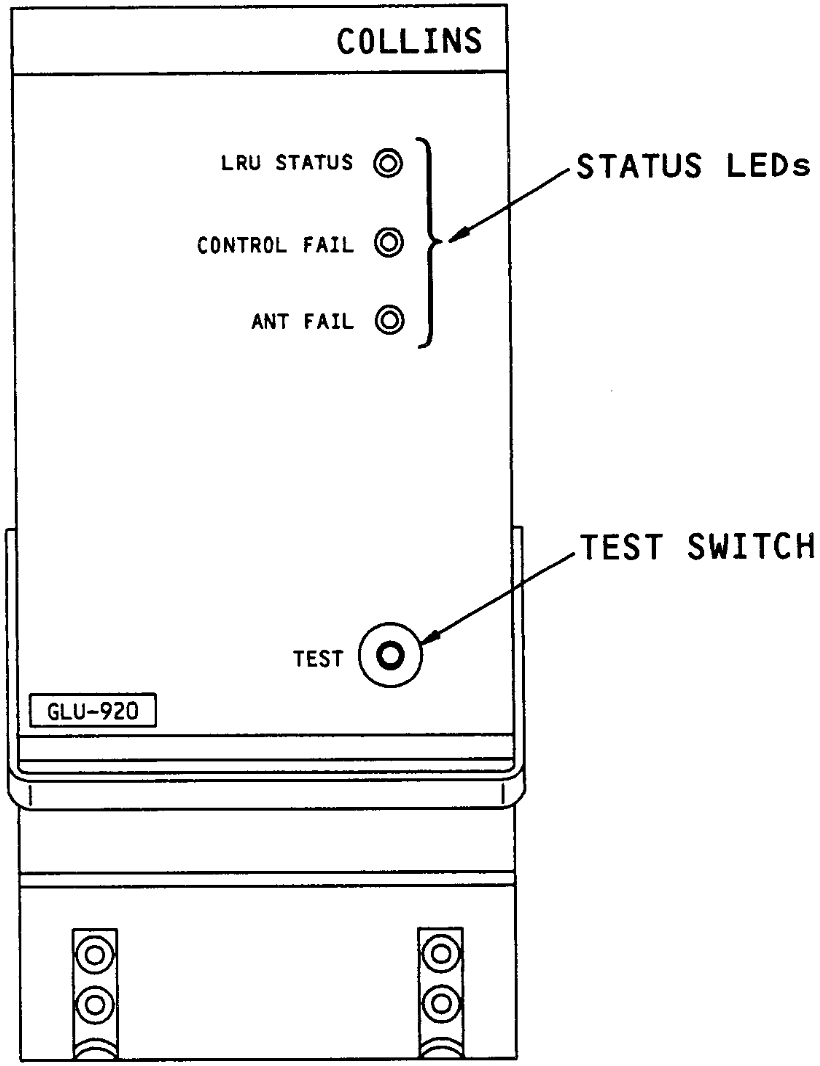


Figure 7 GPS MULTI MODE RECEIVER

GPS ANTENNA

The GPS antennas receive L-band frequency signals from navigation satellites and send them to the GPS/MMRs. The GPS antennas use built in preamplifiers to reduce RF signal loss. The antenna preamplifiers use 12v dc from the power supply in the MMR.

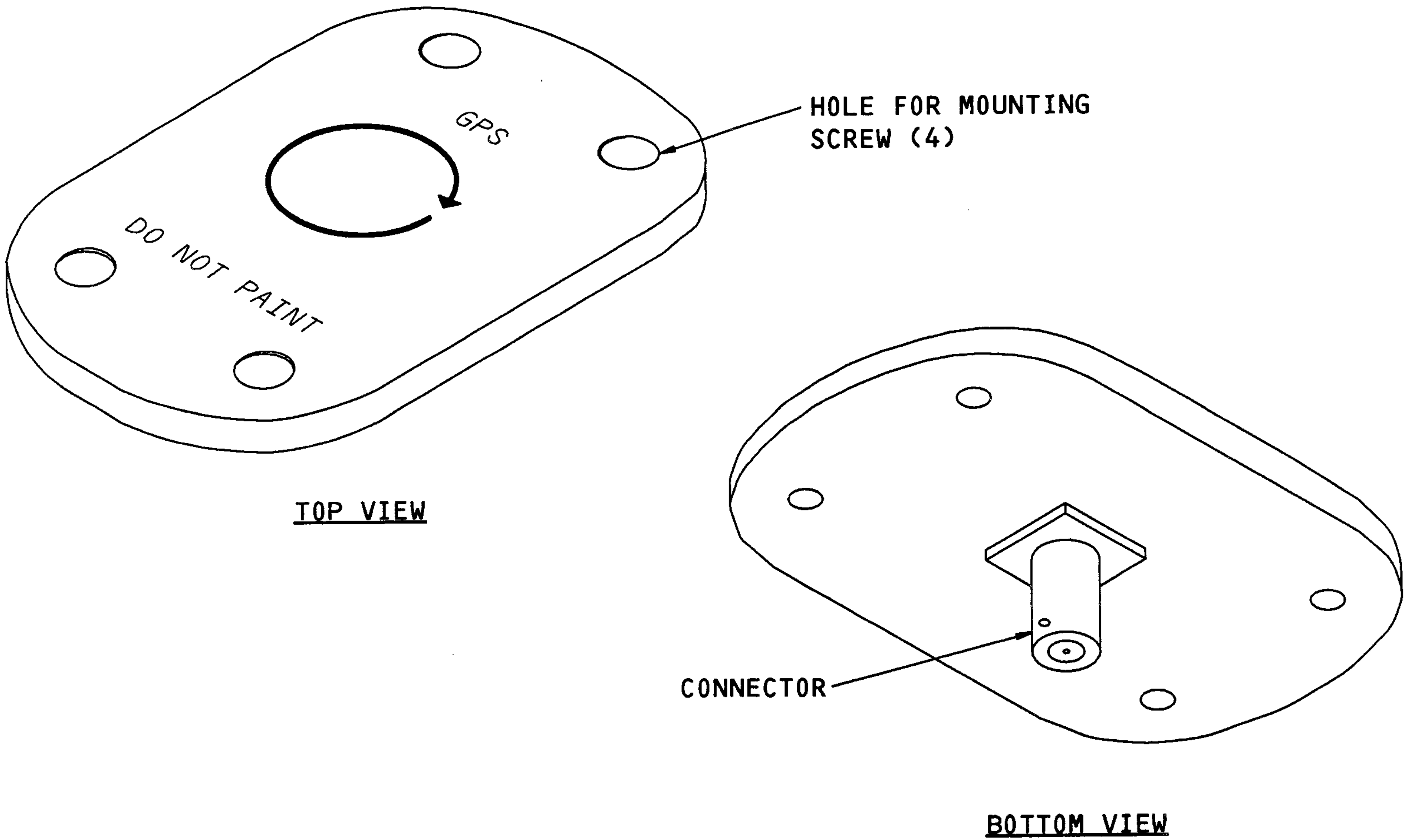


Figure 8 GPS ANTENNA

NAVIGATION DISPLAY

Position Display

The IRU, VOR/DME and GPS position indications show when the position (POS) display map data selector button, on the EFIS control panel is pushed.

The GPS position indicators (GPS symbols) show either the left, right, or left and right GPS positions. When the distance between GPS positions is small enough that one symbol's circle touches or overlaps the other symbol's circle, only one symbol shows.

The IRU position indicators (asterisks) show the left, center, and right IRU positions.

VOR/DME positions show as a bearing and distance line from the airplane symbol to the NAVAID on the map.

Radio Position Update Display

The FMC can use GPS alone or along with other navigation sensors. Radio position update mode shows on the navigation display in the MAP modes.

The radio position update mode display

can show one of these radio position update modes:

- LOC GPS (LOCALIZER GPS)
- LOC DD (LOCALIZER DME DME)
- LOC VD (LOCALIZER VOR DME)
- LOC (LOCALIZER)
- GPS (GLOBAL POSITIONING SYSTEM)
- DD (DME DME)
- VD (VOR DME)

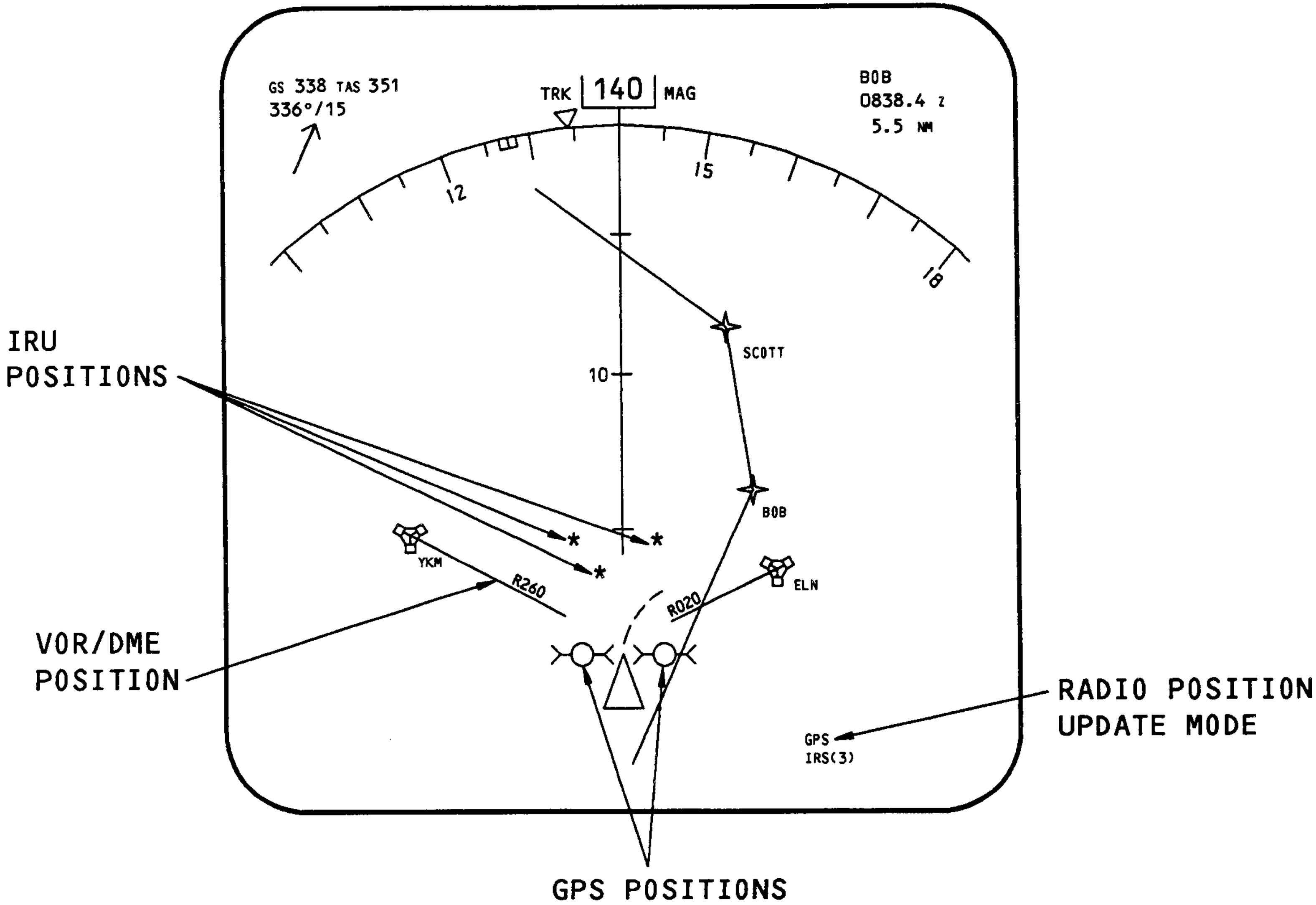


Figure 9 NAVIGATION DISPLAY

POSITION INITIALIZATION

General

The position initialization (POS INIT) page provides position initialization data to the inertial reference system (IRS) for alignment.

To show the position initialization page, push the INIT REF key on the CDU.

The GPSSUs send GPS latitude, longitude, ground speed, and time to the FMC. This data shows on the position initialization pages in the FMC menu.

GPS Time

(4L) UTC (GPS or MAN): GPS time shows on this line if the GPS time is valid from the left GPSSU. If the left GPSSU is not valid, time from the right GPSSU shows. If GPS time is not valid, time from the captain’s clock (MAN) shows. If time from the captain’s clock is not valid, time from the first officer’s clock shows.

GPS Position

(4R) GPS POS: This line shows the left GPSSU position if the GPSSU is reporting a valid position within a specific limit. If the left GPSSU exceeds this limit, data from the right GPSSU shows. This line is blank if neither GPSSU is valid.

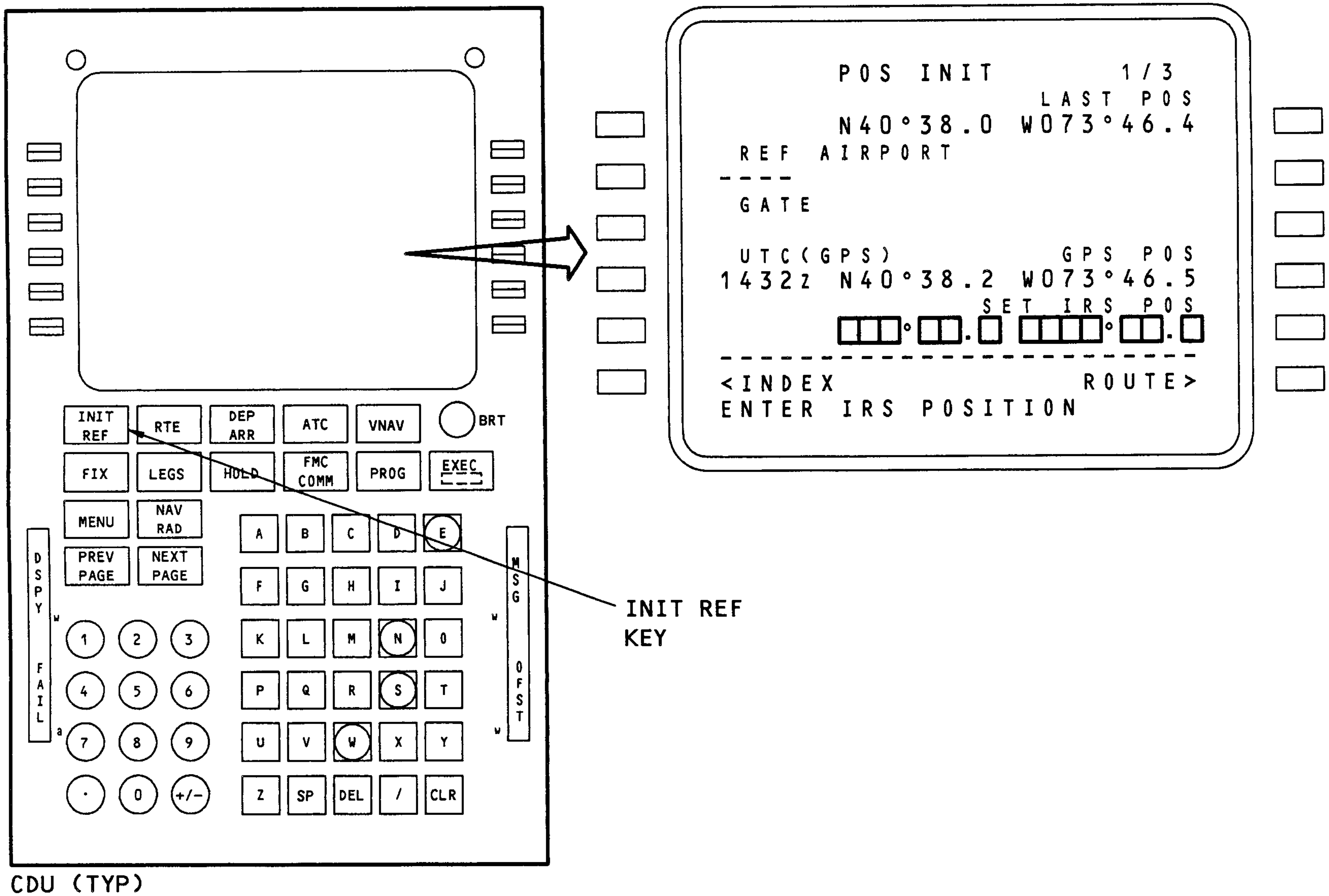


Figure 10 POSITION INITIALIZATION

POSITION REFERENCE - GPS ENABLE

General

The position reference (POS REF) page two, with GPS enabled, shows the current FMC position using the GPS to update that position. This page also provides the ability to cancel the GPS/radio update.

FMC Position

(IL) FMC POS (GPS L, GPS R, LOC GPS L, LOC GPS R, LOC DD, LOC VD, LOC, or RADIO): This line shows the current FMC computed airplane position and the update mode.

Required and Actual Navigation Performance

(3L) RNP/ACTUAL: This line shows the required navigation performance followed by the actual navigation performance (ANP). RNP and ANP are FMC functions.

Purging of Updates

(5L) PURGE: Selection of this line results in the dynamic display of the IRS position in line 1L. CONFIRM then shows on line 5L. Selection of CONFIRM causes the FMC position to revert to the IRS position.

GPS Update Inhibits

(5R) GPS NAV: Selection of this line inhibits the use of GPS data for position updating, and causes ENABLE to show. Selection of ENABLE will cause GPS updating to resume.

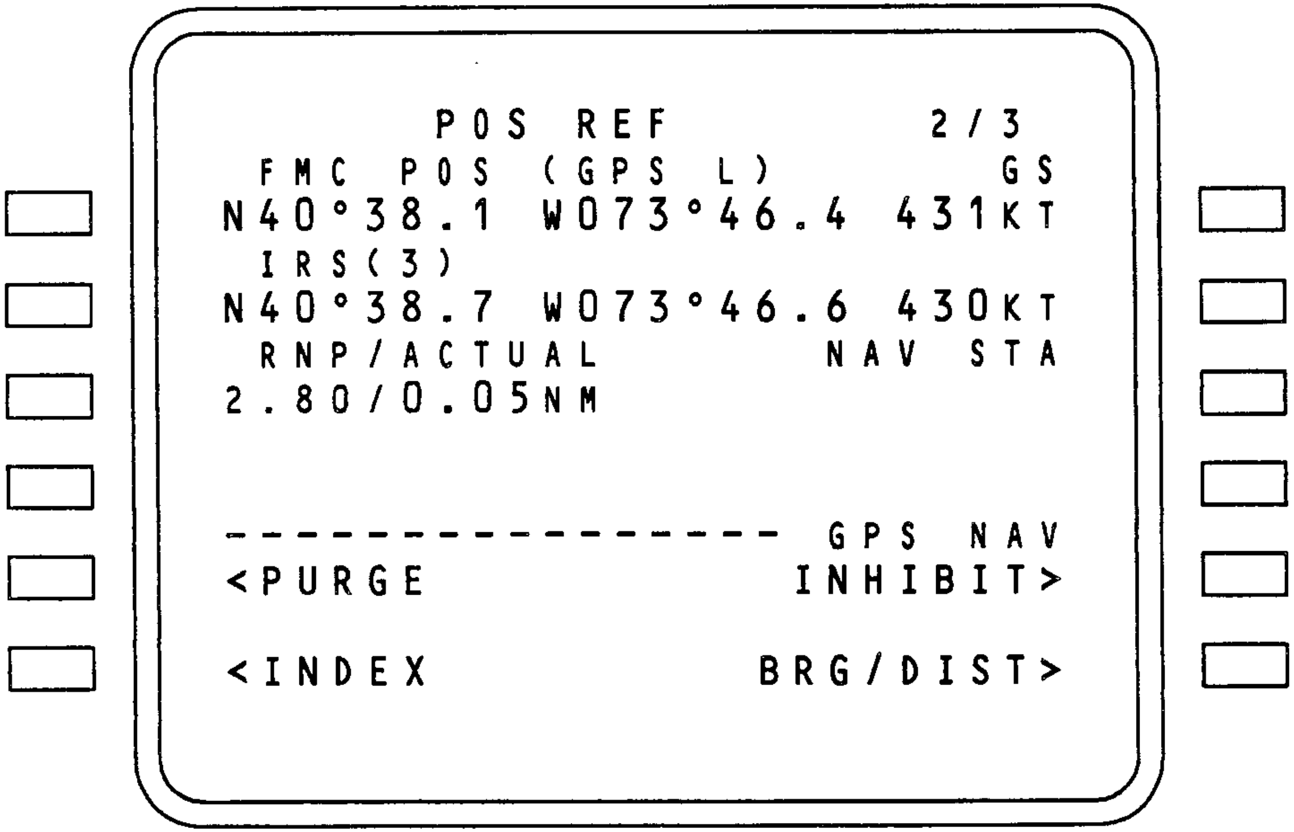


Figure 11 POSITION REFERENCE - GPS ENABLE

POSITION REFERENCE - LAT/LON

On position reference (POS REF) page three, the left GPSSU data shows in line 4 and the right GPSSU data shows in line 5. This data is latitude, longitude, and ground speed.

(6R) BRG/DIST: Selection of this line causes the positions on lines 1L through 5L and 2L on POS REF page 2, to show in a bearing distance format relative to the FMC position.

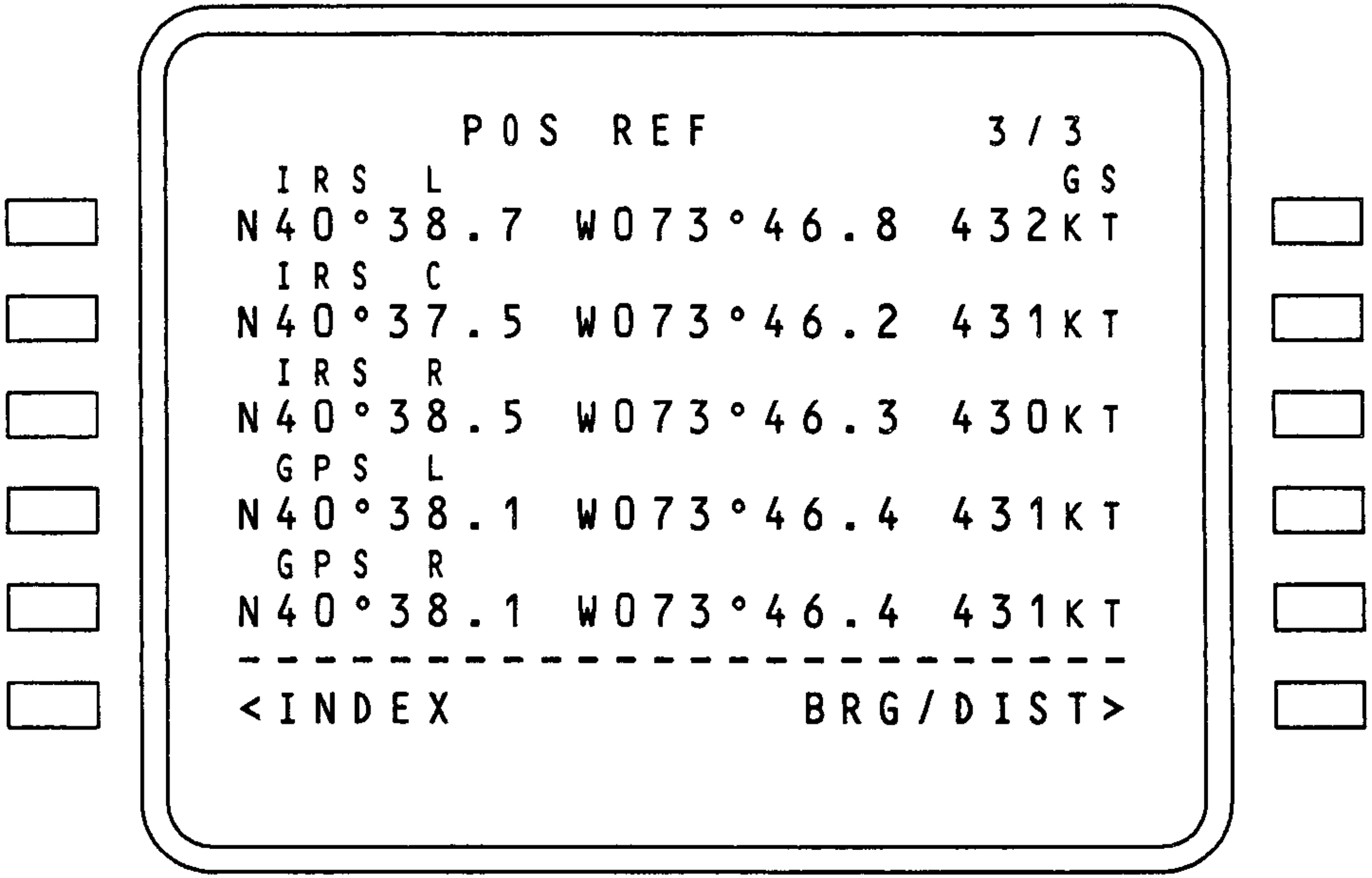


Figure 12 POSITION REFERENCE - LAT/LON

POSITION REFERENCE - BRG/DIST

On position reference (POS REF) page three, the left GPSSU data shows in line 4 and the right GPSSU data shown in line 5. This data is bearing and distance to the FMC position.

- (6R) LAT/LON: Selection of this line causes the positions on lines 1L through 5L and 2L on POS REF page 2, to show in a latitude and longitude format.

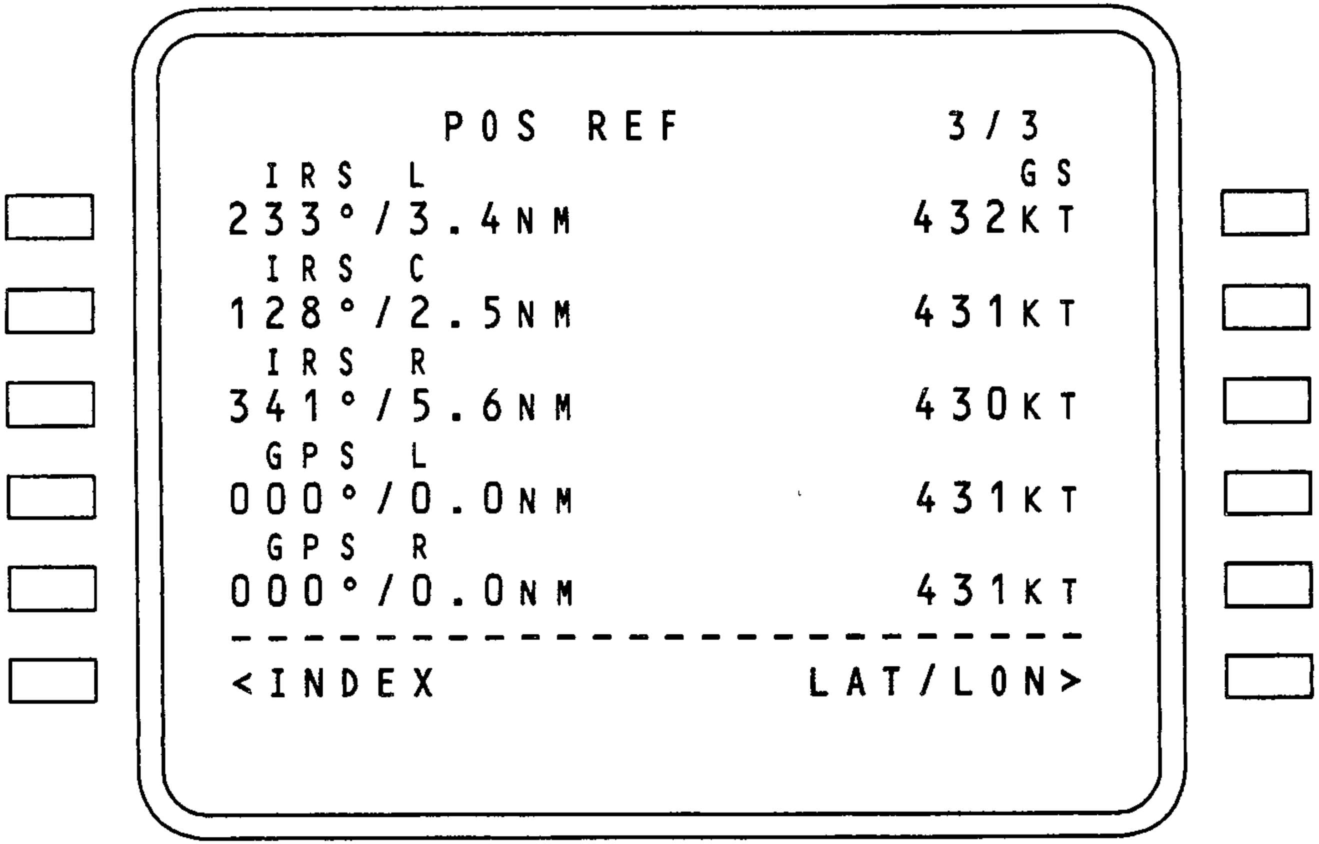


Figure 13 POSITION REFERENCE - BRG/DIST

GPS - SATELLITE OPERATION

GPS Segments

The GPS has three segments:

- Satellite
- User
- Control

Satellite Segment

The satellite segment is a group of satellites that orbit approximately 10,900 nautical miles above the earth. Each satellite completes an orbit once every 12 hours.

A full group of operational satellites is now in orbit. There are 21 primary satellites and 3 spares.

User Segment

The user segment is the GPS sensor unit (GPSSU) on the airplane. It receives the satellite signals. The GPSSU uses the satellite data to calculate the airplane position.

Control Segment

The control segment has control and monitor stations on earth that continuously monitor and track the satellites. The purpose of the control segment is to:

- Monitor and correct satellite orbits and clocks.
- Calculate and format a satellite navigation message. This message has up-todate descriptions of the satellites' future positions, and a collection of the latest data on all GPS satellites.
- Update the satellite navigation message regularly.

The control segment has one master control station and five monitor stations. Three of the monitor stations are also upload stations.

The master control station is in Colorado Springs, Colorado (USA). The master control station is the operational center of the GPS. The master control station controls all operations in the control segment. The master control station has an atomic clock. This clock is the reference for the GPS.

The monitor stations track the satellites 24 hours a day. The master control station remotely controls the monitor stations through on-line connections. The monitor stations are in:

- Ascension Island
- Colorado Springs
- Diego Garcia Island
- Hawaii
- Kwajalein Island

The monitor stations receive the same information from the satellites that the GPSSUs receive. The monitor stations:

- Record the accuracy of the satellite clocks
- Collect and relay to the control station meteorological data, such as barometric pressure, temperature, and dew point. The master control station uses this data to calculate the satellites' tropospheric signal delay.
- Continuously measure the ranges to all visible satellites. The master control station uses this data to calculate and predict the satellite orbits.

The master control station uses the upload stations to send:

- Orbit correction commands to the satellites. The satellites use control rockets to correct their orbits.
- The navigation message to the satellites.

The upload stations are in Ascension Island, Diego Garcia Island, and Kwajalein Island.

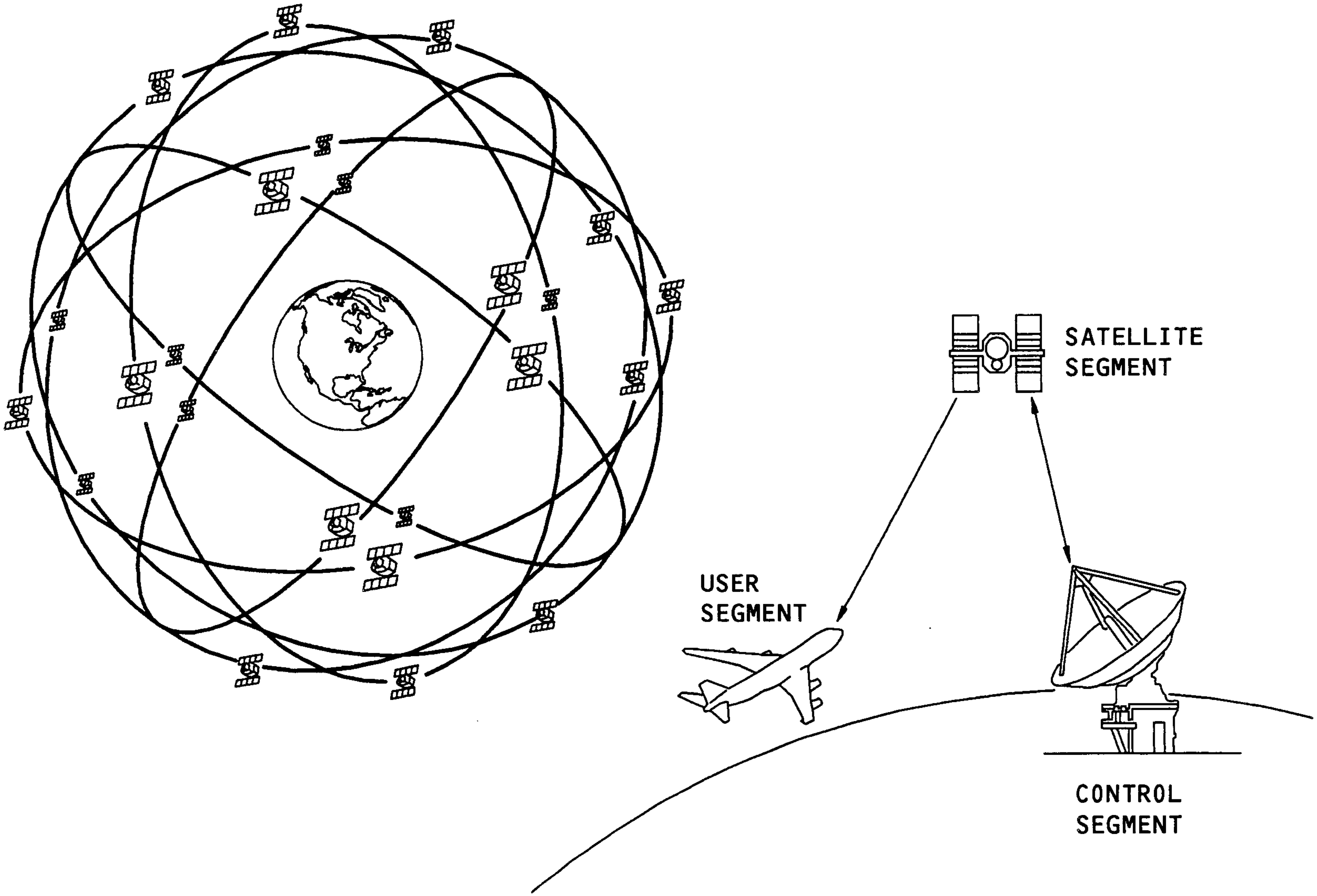


Figure 14 GPS - SATELLITE OPERATION

GPS/MMR CALCULATIONS

Values Calculated by the GPS/MMR

These are the values that the GPS/MMR calculates:

- Latitude
- Longitude
- Altitude
- Universal coordinated time (UTC)
- Date
- North/south velocity
- East/west velocity
- Accelerations
- Track angle
- Satellite position
- Accuracy
- GPS/MMR status.

Ranging

The GPS/MMR use the principle of ranging to measure the distance between the GPSSU and the satellites. The GPS/MMR has in memory an almanac of the location of the satellites in their orbits at any time.

The GPS/MMR measures the time it takes for a radio signal to go from a satellite to the airplane. Since the GPS/MMR knows the location of the

satellite and that the radio signal travels at the speed of light, it can calculate the distance to the satellite.

Since this is one way ranging, the GPS/MMR must know exactly at what time the satellite sent the radio signal. The GPS/MMR compares the satellite signal to a signal that the GPS/MMR generates at the same time as the satellite. The difference between the two signals, called delta t, is the time the signal took to get to the GPS/MMR.

Each satellite has atomic clocks to keep accurate time to within 100 nanoseconds. All the satellites have precisely the same time. The GPS/MMR in the airplane has an internal clock but it is not atomic and it is not as accurate. Thus, it is not possible for the GPS/MMR to have precisely the same time as the satellite.

The GPS/MMR assumes that its internal clock is off by some clock bias, called the delta t-BIAS. This delta t-BIAS is an unknown that the GPS/MMR must calculate. The delta t-BIAS represents the difference between the GPS/MMR time and the satellite time. The range calculations for each satellite include the delta t-BIAS.

To calculate the airplane position, and the delta t-BIAS, the GPS/MMR must range at least four satellites. The GPS/MMR measures the distances to all the satellites at the same time, and solves for the four unknowns, latitude, longitude, altitude, and delta t-BIAS with four range equations.

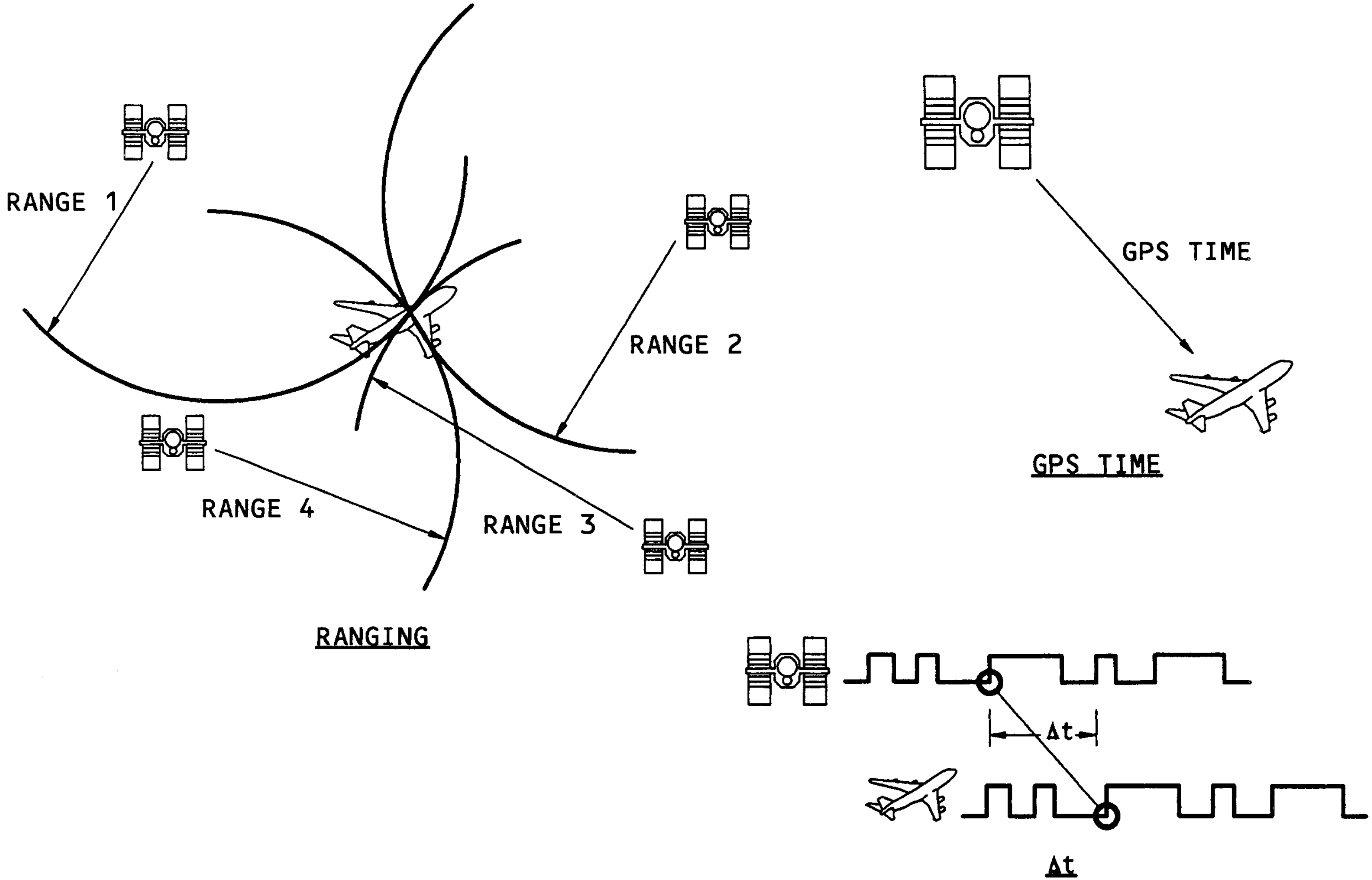


Figure 15 GPS - GPS/MMR CALCULATIONS

GPS - OPERATING MODES

GPS Modes of Operation

The GPS multi mode receiver (GPS/MMR) operates in these modes:

- Self-test mode
- Initialization mode
- Acquisition mode
- Navigation mode
- Altitude aiding mode
- Aided mode
- Fault mode.

Self-Test Mode

During the self-test mode, the GPS/MMR tests its circuits to verify proper operation. If the self-test passes, the GPS/MMR enters the initialization mode. If the self-test fails, the GPS/MMR enters the fault mode.

Initialization Mode

The GPS/MMR enters the initialization mode after power-up has occurred and the selftest passes. This mode lasts about 30 seconds while the signal processing sections are initialized with values of latitude, longitude, and altitude. During this mode there are no navigation or measurement outputs. Once the initialization is complete, the GPS/MMR enters the acquisition mode.

Acquisition Mode

The GPS/MMR looks for and locks on to the satellite signals. The GPS/MMR must find at least 4 satellites before it starts to calculate GPS data. The GPS/MMR accepts position and altitude from the IRUs if available. The GPS/MMR uses the inertial data to calculate which satellites are in view, at the present airplane position.

If the inertial data or clock data is not available, the GPS/MMR can still acquire satellite signals. However, the GPS/MMR takes longer to acquire the satellite signals because it has to look for all the satellites. When the GPS/MMR finds the satellites, it calculates which ones to track.

Without a valid initialization, the time to the first fix is approximately 10 minutes. A valid initialization requires position and time.

Navigation Modes

The GPS/MMR enters the navigation mode after it acquires and locks on to at least 4 satellites. When the GPS/MMR is in the navigation mode it updates positions, velocities, accelerations, and time.

If the GPS/MMR is unable to track at least four or more satellites, the GPS/MMR enters the altitude-aided mode.

Altitude-Aided Mode

With four satellites in view, the GPS/MMR stores the difference between the inertial altitude and the GPS altitude. With only three satellites in view it can estimate the GPS altitude.

In the altitude - aided mode, the GPS/MMR uses the inertial altitude and the length of the earth's radius as the fourth range.

The GPS/MMR re-enters the navigation mode when four satellites are acquired.

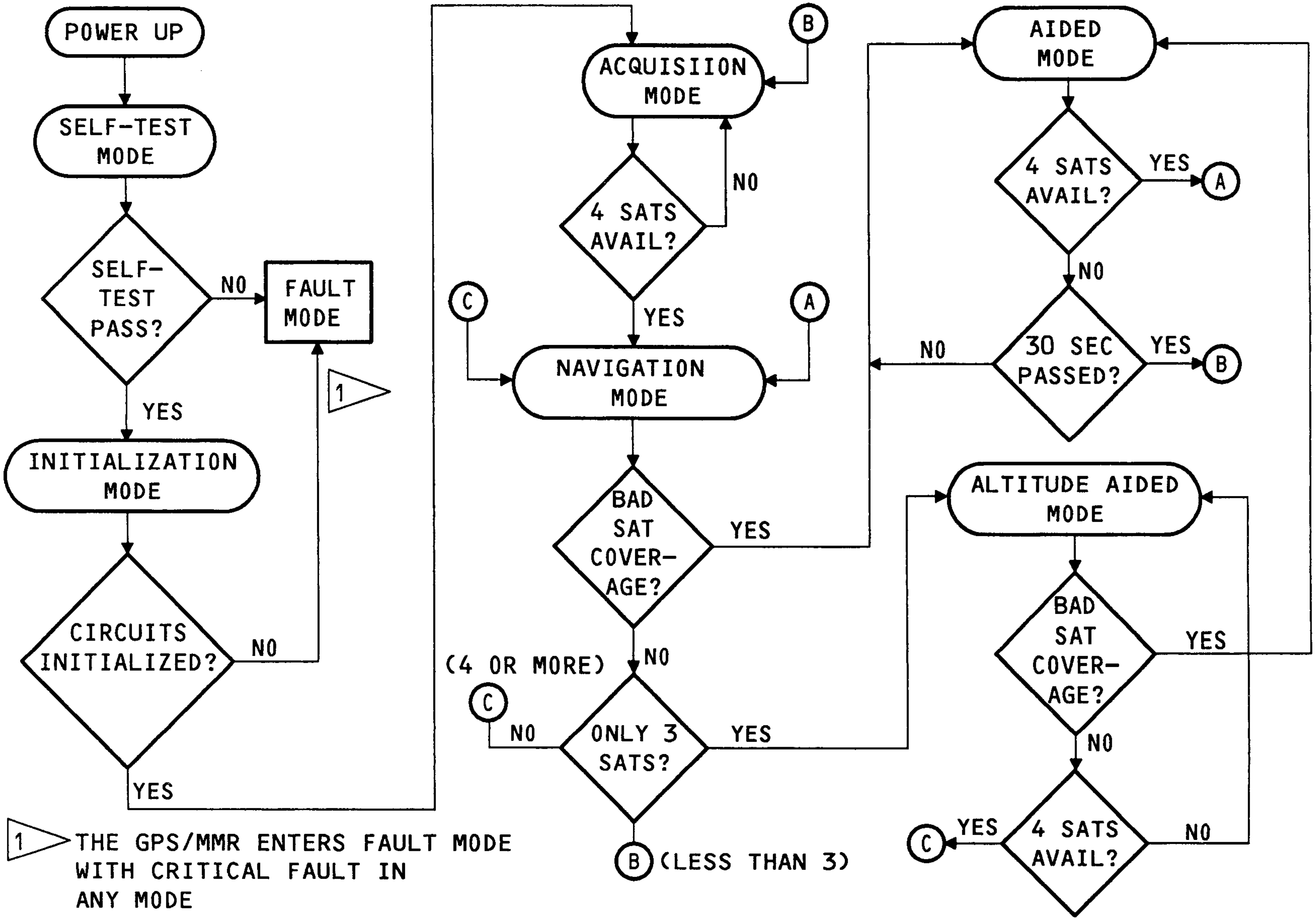
Aided Mode

The GPS/MMR enters the aided mode during short periods (less than 30 seconds) of bad satellite coverage. In the aided mode, the GPS/MMR receives altitude, track, and ground speed from the IRU. The GPS/MMR uses the inertial data to go back quickly to the navigation mode, when there is good satellite coverage again.

If the GPS/MMR cannot aquire four satellites in 30 seconds, the GPS/MMR goes back to the acquisition mode.

Fault Mode

The GPS/MMR enters the fault mode if a critical fault is detected. In this mode the normal ARINC 429 outputs are invalid.



1 THE GPS/MMR ENTERS FAULT MODE WITH CRITICAL FAULT IN ANY MODE

Figure 16 GPS - OPERATING MODES

ALTITUDE-AIDED MODE

In the altitude-aided mode, the GPS/MMR uses the inertial altitude and the length of the earth radius as the fourth pseudo range. This mode is used when the GPS/MMR is unable to track four or more satellites.

To enter the altitude - aided mode, three conditions must be true:

- The GPS/MMR was in the navigation mode.
- There are 3 satellites available with good geometry for fixes
- The GPS/MMR has previously stored the difference between inertial and GPS altitude.

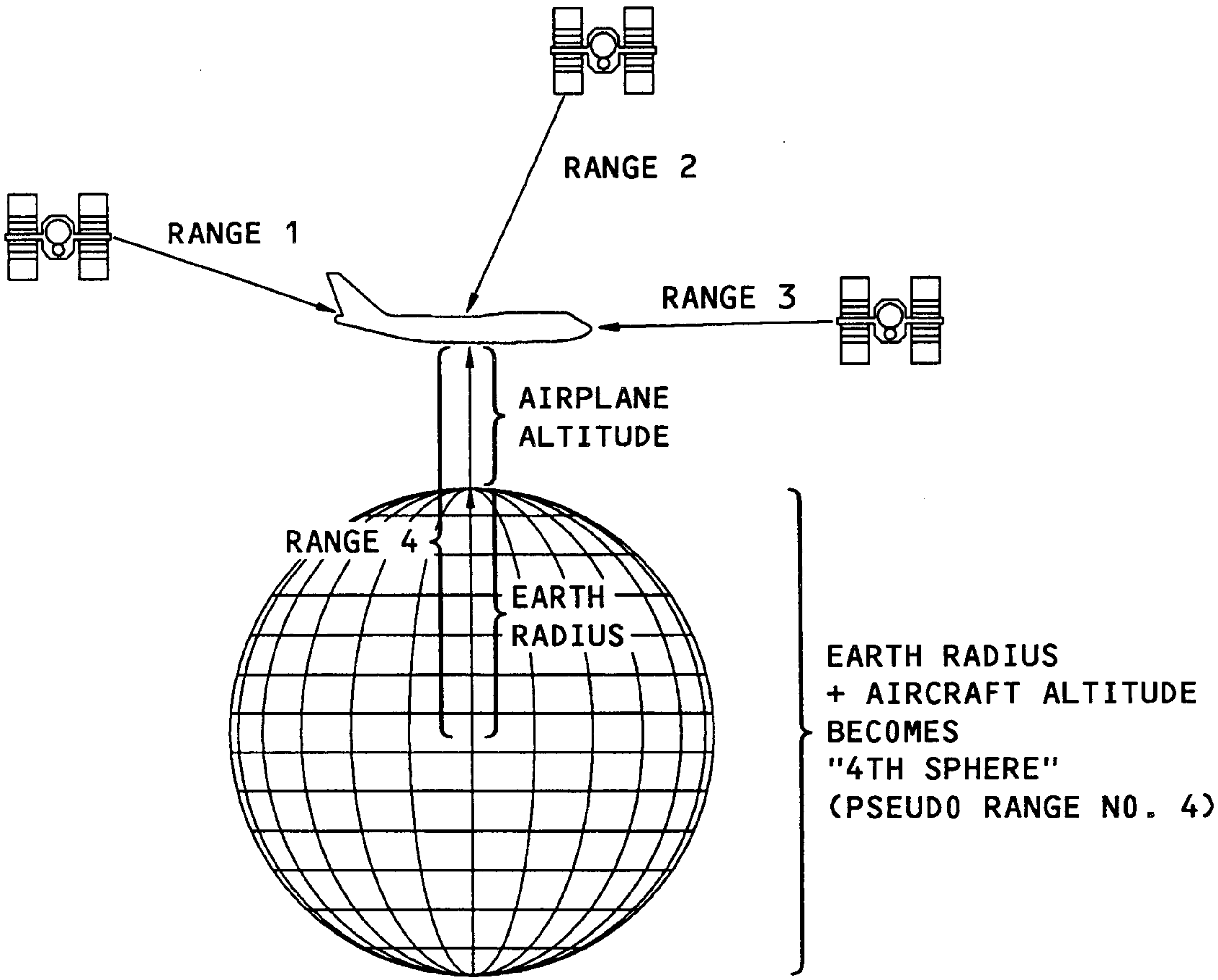


Figure 17 ALTITUDE-AIDED MODE

GPS INTERNAL PROCESSING

Power

The MMRs get 115v ac power from the airplane buses.

RF Section

The RF section receives the satellite signals from the GPS antenna. The signals are filtered and amplified. They are then sent to an analog to digital (A/D) converter.

A/D Conversion

The A/D converter changes the analog signal to digital data, which is used by the digital signal processor computer.

Micro Processor

The signal processor controls tracking, measures time from the satellite signals, determines signal validity, and decodes the satellite data.

The processor has 12 channels and can handle up to 12 satellites at the same time. Some of the channels are processing data from a set of tracked satellites and others are processing data to be used in searching for and aquiring new satellites.

The processor uses a twelve-state

Kalman filter. The filter states are: three positions, three velocities, three accelerations, an altitude bias error, user clock phase error, and user clock frequency error.

Measurements obtained from the satellite signals are compared with estimates computed in a previous filter update. The resulting differences are used for updates. These updates occur in the navigation mode. At least four GPS satellites are tracked in the navigation mode.

Inputs to the processor are navigation data from the ARINC 429 receivers and satellite data from the software data load. These inputs are used to determine satellite position and velocity.

ARINC 429 Receivers

The IRU initiation data is used during the initialization mode, after power-up.

IRU navigation data is used when less than 4 satellites are being tracked. This data is used in the aided mode.

Navigation Calculations

Navigation position calculations use the position updates from the Kalman filter, from each of the four satellites being tracked, to determine the user's location.

GPS Clock

The GPS Clock is updated by the navigation solutions. A clock bias is then calculated.

ARINC 429 Transmitters

Satellite measurements and navigation data are used to update the GPS position, velocity, and clock. This

information also goes to the flight management computer (FMC) and to the data management unit (DMU).

Continuous BITE Monitor

Fault monitoring of the GPS processor, satellite data, A/D conversion, and RF signal integrity is continuous. When a critical fault is detected the GPS fault mode begins. In this mode all ARINC 429 outputs are invalid.

NVM

When a fault is detected, the GPS records the fault in non-volatile memory (NVM). This is used to aid shop maintenance. When the NVM is full, the recording of the present fault replaces the recording of the oldest fault.

RAIM

The receiver autonomous integrity monitor (RAIM) is used to detect and isolate errors in satellite measurements.

Measurements from five satellites provide redundancy and an integrity check on the entire constellation being used. The RAIM algorithm sends an integrity figure of merit to the FMC. The figure of merit is called the horizontal integrity limit (HIL). The FMC determines if it can use the GPS data based on the HIL.

If measurements from six satellites are available, the faulty satellite can be identified. That satellite is eliminated from the navigation calculations.

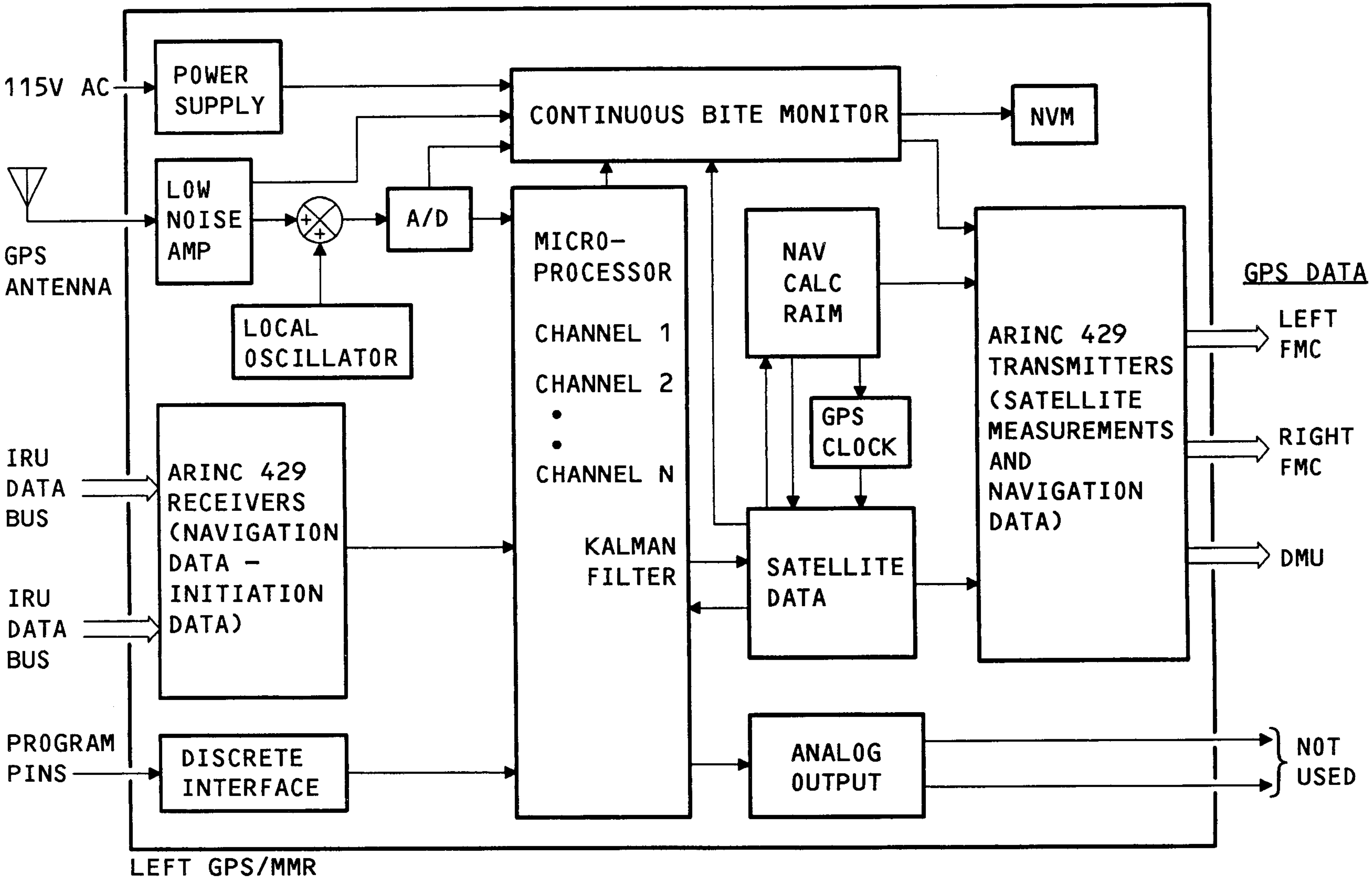


Figure 18 GPS INTERNAL PROCESSING

SYSTEM TEST

General

The system test procedure uses one of the CDUs to make sure the global positioning system operation is satisfactory.

The GPS system is initialized, with the airplane in a position where the GPS antennas have a clear view of the sky. The GPS position and time to first fix results are monitored.

Position Initialization

Establish electrical power, turn on, and initialize the IRUs. Use the keyboard to enter the airplane present position.

Monitoring of Results

Display the POS REF (Position Reference) page 3 of 3 and make sure the left GPS and right GPS latitudes and longitudes show.

The TTFF (Time to First Fix) is approximately 5 to 6 minutes and the GPS positions will not show until this

first fix occurs. The maximum TTFF should be less than 10 minutes.

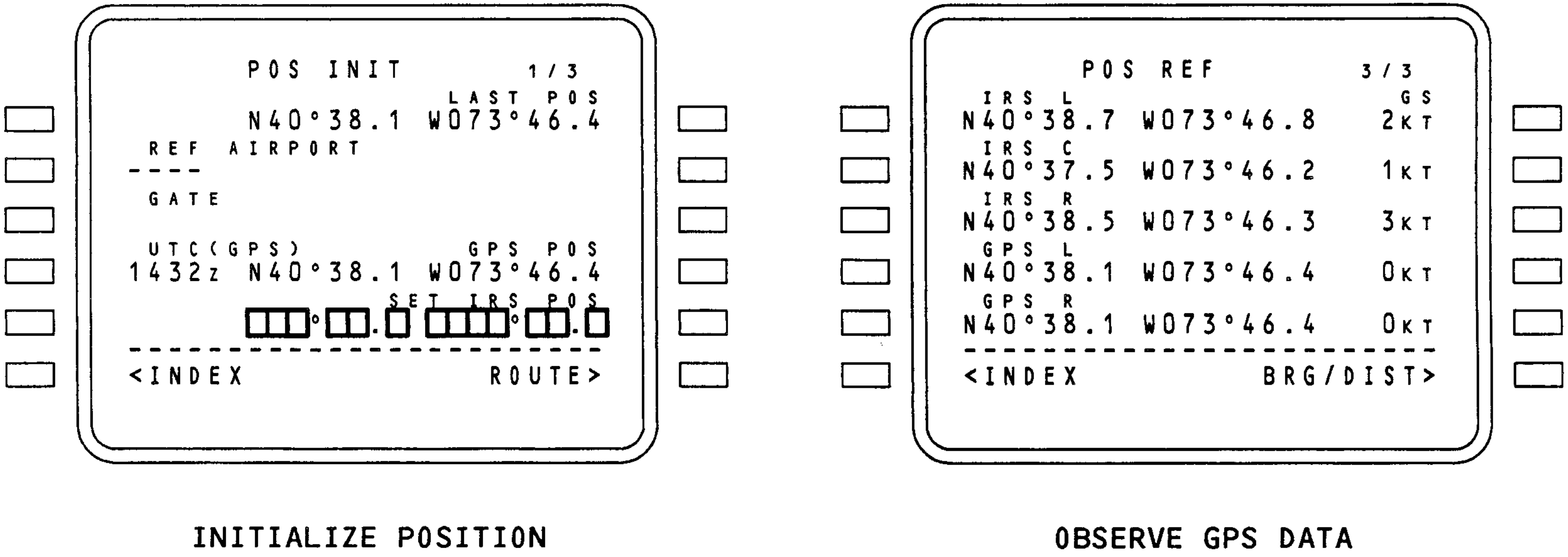


Figure 19 SYSTEM TEST

MMR BITE

Front Panel Self-Test

When you push the test switch, the MMR does a check of the internal operation and its interface with the GPS antenna. The test takes approximately 36 seconds. This is the test sequence that shows on the status LEDs during the test:

- 0 to 2 seconds, the LRU STATUS and the CONTROL FAIL LEDs are red
- 2 to 4 seconds, the LRU STATUS LED is green and the CONTROL FAIL LED is red
- 4 to 6 seconds, all LEDs go off
- 6 to 36 seconds, test status shows.

NOTE: THE ANT FAIL LED IS NOT USED AT THIS TIME.

The LRU STATUS LED shows red when there is an internal failure in the MMR. A green LED shows that the MMR is normal.

The CONTROL FAIL LED shows red when an interface to the MMR has a failure.

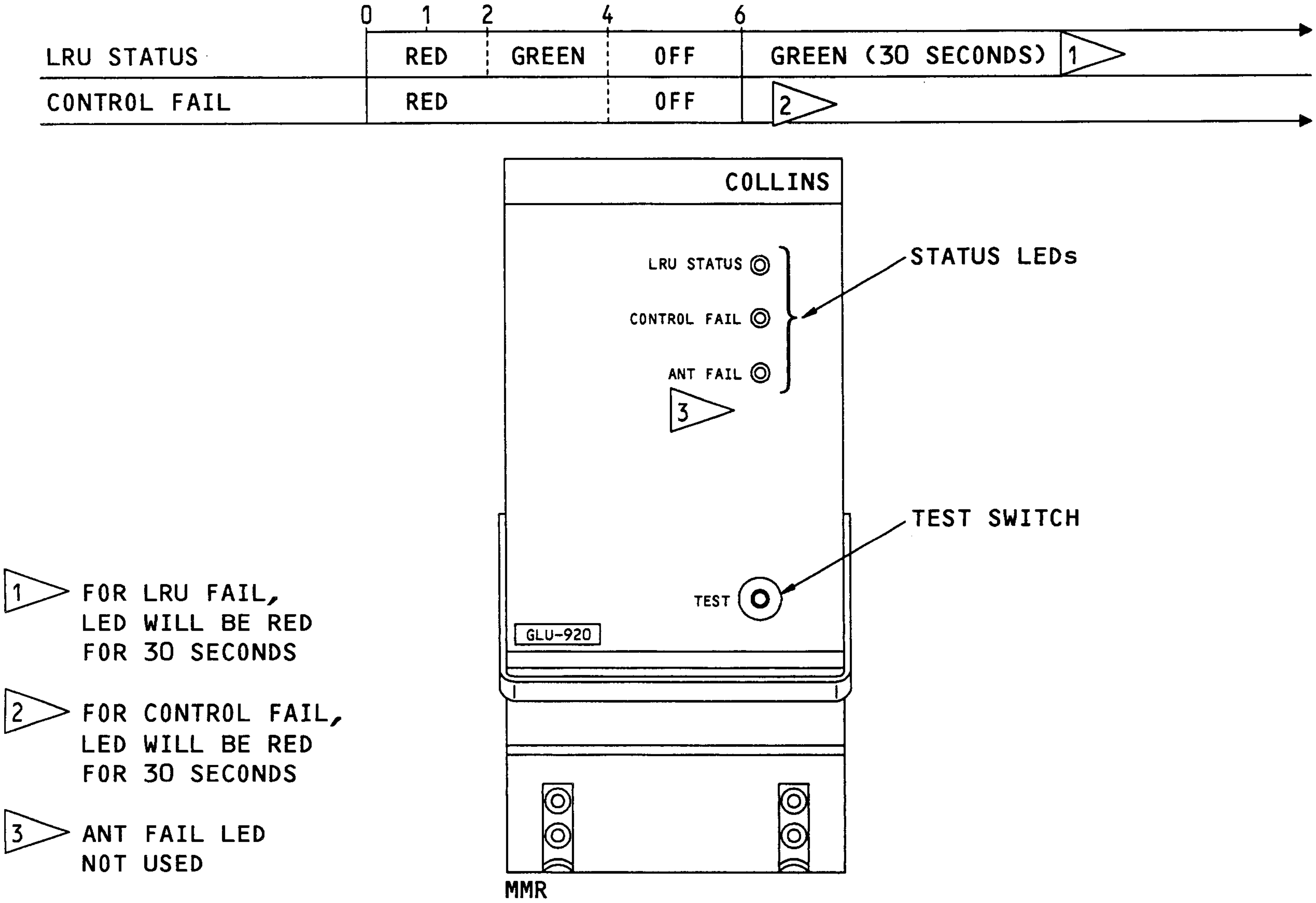


Figure 20 MMR BITE

FLIGHT DECK EFFECTS

General

This is a summary of the GPS flight deck effects.

FLIGHT DECK EFFECT	TYPE	DESCRIPTION
>GPS	ADVISORY	LEFT GPS SENSOR UNIT OR ANTENNA OR RF OR RF PATH FAILURE AND RIGHT GPS SENSOR UNIT OR ANTENNA OR RF OR RF PATH FAILURE
>GPS LEFT	ADVISORY	LEFT GPS SENSOR UNIT OR ANTENNA OR RF OR RF PATH FAILURE
>GPS RIGHT	ADVISORY	RIGHT GPS SENSOR UNIT OR ANTENNA OR RF OR RF PATH FAILURE

Figure 21 FLIGHT DECK EFFECTS

GPS - GLOSSARY OF TERMS

Appendix - A

Acquisition - The act of acquiring. A GPS operating mode used to look for and find the satellites needed for position determination. The satellite signals are acquired and then the signals are locked-on to and tracked.

A/D - Analog to Digital - The process of converting an analog signal to a digital signal.

Almanac - An overview of data for all the satellites, including the satellite identity and location, satellite health, clock corrections and atmospheric delays. The almanac is necessary for satellite visibility calculations, to select the group of satellites offering the best geometry.

Altitude aiding - A GPS operating mode used when the GPSSU is unable to track four or more satellites. In this mode inertial altitude inputs are used along with the earth's radius as the fourth range.

Algorithm - A step-by-step procedure for solving a problem; e.g. the procedure for finding the square root

of a number.

Autonomous - Independent or self-governing. An autonomous GPS system is one which stands alone and is NOT part of another system, like a GPS/IRS system.

Clock bias - The difference between a true universal time and the time of the clock.

Control segment - The GPS system is divided into segments. one of these is the control segment, which includes the control and monitor stations (one master station and five monitor stations.

Constellation - A number of satellites considered as a group.

Critical - The conditions which cause a fault to be declared. Conditions which are absolutely necessary for operation.

Earth-centered coordinates Coordinates of an earth-centered coordinate system, with the origin at the earth's center of mass (a WGS-84 system (World Geodetic System. 1984}). The z-axis is the rotation axis of the earth, the x-axis is the intersection of the WGS 84 reference meridian plane and the plane of the equator (parallel to the zero meridian), and the y-axis is measured in the plane of the equator 90 degrees east of the axis, completing a right-handed, earth-centered coordinate system.

Estimate - To calculate the approximate value of a quantity. A Kalman filter estimates the position error of the GPS, by always using the difference between the last estimate and the last measurement to make a new estimate.

GPS - Global Positioning System - A radio navigation system which uses a group of satellites orbiting the earth. The system is intended to provide highly accurate position and velocity in three dimensions and precise time on a global basis continuously.

GPSSU - GPS Sensor Unit - A unit which receives radio navigation signals from satellites and calculates GPS position and time data.

HIL - Horizontal Integrity Limit - An estimating term indicating what kind of accuracy the GPS is achieving, with a 99.9% confidence level. The integrity limit estimate is used when the GPS is not updating the GPS navigation position. It is a function of the time elapsed since the last GPS position update. It is a dynamic term.

Ionosphere - A region above the earth's surface, in which solar radiation causes an ionized layer of charged particles to exist. This causes some delay in the transmission of radio signals from the satellites to user.

Isolated - Set aside or apart from others. The GPS integrity monitor can isolate or exclude a failed satellite from the Kalman filter algorithm for determining position.

Kalman filter - An algorithm (data processing scheme) used to make estimates of systems performance. It uses statistical techniques of estimation, weighting, and makes correction. The filter is initialized and continuously computes the differences between the current measurement and the current estimate (based on the last measurement). These differences are referred to as residuals. The process is recursive, using the previous estimates and measurements to predict the current estimate.

MMR - multi mode receiver - A LRU which provides lateral and vertical landing guidance by means of either ILS, MLS, or GPS AND enroute GPS position and velocity information. ARINC 755 defines the standards for the MMR.

Nanoseconds - One billion nanoseconds equal one second - not a lot of time.

orbit - The path of a natural or man-made body (satellite) that resolves around another body; e.g., the earth.

Appendix - A (cont)

RAIM - Receiver autonomous integrity monitor - A monitoring process used to detect and isolate errors in satellite measurements. This process uses Kalman filter measurement residuals

(difference between the measured and estimated pseudo range) to determine which satellite has failed.

Ranging - The basic principle in GPS radio navigation is called ranging.

The range or distance to a number of satellites determines the airplane's position. Four satellites in good

geometry give a good position fix and solve for a time or clock bias.

SPS - Standard Positioning Service The service which is provided to all civilian users, with degraded

navigation information. It has an accuarcy of 100 m with a 95%

probability.

Space or satellite segment - The GPS system is divided into segments. One of these is the satellite segment,

which includes the group of satellites that orbit above the earth.

Synchronize - To cause events to occur at the same time. The GPS receives a coded radio signal from the satellite which is matched in time with a copy of the coded signal, generated in the GPSSU. The signals are synchronized.

User segment - The GPS system is divided into segements. One of these is the user segment, which includes the user antennas and sensor units.

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