



National Aeronautics and
Space Administration

JSC-16276

Lyndon B. Johnson Space Center
Houston, Texas 77058
September 1979

NASA CR-
160775

TACAN OPERATIONAL DESCRIPTION FOR THE SPACE SHUTTLE
ORBITAL FLIGHT TEST PROGRAM

Job Order 16-609

(NASA-CR-160775)	TACAN OPERATIONAL	N80-31439
DESCRIPTION FOR THE SPACE SHUTTLE ORBITAL		
FLIGHT TEST PROGRAM (Lockheed Electronics		
Co.) 90 p HC A05/MF A01	CSCL 17G	Unclas
		28520
		G3/16

Prepared By

Lockheed Electronics Company, Inc.
Systems and Services Division
Houston, Texas

Contract NAS 9-15800

For

Tracking Techniques Branch
Tracking and Communications Development Division




C-13790

Page intentionally left blank

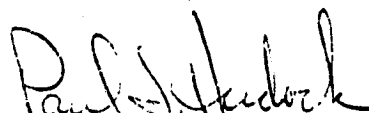
TACAN OPERATIONAL DESCRIPTION FOR THE SPACE SHUTTLE
ORBITAL FLIGHT TEST PROGRAM

Job Order 16-609

PREPARED BY

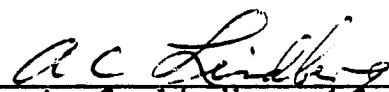


C. L. Hughes
Principal Engineer

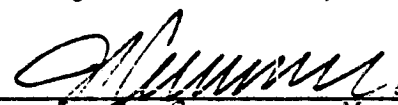


Paul J. Hudock
Senior Engineer

APPROVED BY



A. C. Lindberg, Supervisor
Tracking and Laser Systems Section



J. S. Creamer, Manager
Tracking and Communications Systems Department

Prepared By

Lockheed Electronics Company, Inc.

For

Tracking Techniques Branch
Tracking and Communications Development Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

November 1979

LEC-13790

CONTENTS

Section	Page
1. INTRODUCTION.	1
2. PLANNED USE OF TACAN DURING STS-1	3
3. TACAN HARDWARE DESCRIPTION.	13
4. HARDWARE/SOFTWARE INTERFACE	21
5. TACAN SOFTWARE.	25
5.1 <u>TACAN SOP</u>	25
5.1.1 FUNCTIONAL DESCRIPTION	25
5.1.2 SOP SOFTWARE DESCRIPTION	27
5.2 <u>REDUNDANCY MANAGEMENT (RM)</u>	30
5.2.1 SALIENT FEATURES	30
5.2.2 UNIT SELECTION AND PROCESSING.	37
6. TACAN SOFTWARE INTERFACES	49
7. SPACE SHUTTLE USAGE OF TACAN DATA	53
8. ANTICIPATED TACAN PERFORMANCE	57
9. REFERENCES.	61
 Appendix	
A. GNC OPERATIONAL SEQUENCES AND MAJOR MODES	A-3
B. COMPUTER INTERFACE WORDS BETWEEN THE MDM AND THE GPC	B-3
C. SIGNAL INTERFACE TABLES	C-3
D. I-LOADS	D-3
E. OPS 8 I-LOADS FOR SENSOR SELF TESTS (OPS 8)	E-3

PRECEDING PAGE BLANK NOT FILMED

TABLES

Table		Page
2-1	TACAN STATION LOCATIONS USED FOR STS-1	8
5-1	UNIT SELECTION IN CASES OF LRU FAILURE/DESELECT IN GPC OR MANUAL MODE.	45
5-2	PARAMETRIC SELECTION IN CASES OF FAILURE IN GPC OR MANUAL MODE	46
5-3	UNIT SELECTION IN CASES OF LRU FAILURE/DESELECT WHERE LRUs ARE IN MIXED CHANNEL MODE	47
A-1	OFT GNC OPERATIONAL SEQUENCES AND MAJOR MODES.	A-4
B-1	TACAN CONTROL REGISTER FORMAT.	B-8
B-2	TACAN DISCRETE WORD FORMAT	B-9
C-1	INPUT/OUTPUT FUNCTIONAL PARAMETERS FOR THE TACAN RM MODULE.	C-4
C-2	INPUT/OUTPUT FUNCTIONAL PARAMETERS FOR THE TACAN SOP MODULE	C-7
D-1	TACAN SOP I-LOAD PARAMETERS.	D-4
D-2	TACAN RM I-LOAD PARAMETERS	D-5

PRECEDING PAGE BLANK NOT FILLED

FIGURES

Figure		Page
2-1	STS-1 deorbit-through-landing groundtrack	4
2-2	Postblackout entry groundtrack for Orbiter STS-1	5
2-3	STS-1 entry groundtrack and TACAN events.	6
2-4	Approach and landing groundtrack.	7
2-5	Nominal Shuttle flight profile during STS-1 entry through final approach.	10
2-6	Range to runway threshold versus elapsed time from entry interface for a nominal Shuttle flight profile.	11
3-1	TACAN LRU used in the Space Shuttle	
3-2	Shuttle TACAN antenna locations	15
3-3	Cockpit layout showing components used in TACAN operations.	17
4-1	Hardware/software interface	22
5-1	TACAN SOP block diagram	26
5-2	TACAN RM processing block diagram	31
5-3	Overall view of TACAN status interfaces	36
5-4	TACAN control panel	38
5-5	On-orbit sensor self-test display	40
5-6	Horizontal Situation Display (HSD).	42
5-7	TACAN status logic for the HSD.	43
6-1	Overall signal interface of the TACAN SOP and RM unit	51
7-1	External navigation sensor availability	55
7-2	STS-1 flight profile.	56

Figure		Page
8-1	Navigated state vector performance – end of mission	
	(a) Altitude error.	58
	(b) Downrange error	59
	(c) Crossrange error.	60
B-1	MDM to GPC range words	B-4
B-2	MDM to GPC bearing words	B-5
B-3	TACAN to MDM range word.	B-6
B-4	TACAN to MDM bearing word.	B-7

ACRONYMS AND DEFINITIONS

ALT	Approach and Landing Test
AOA	abort once around
AOS	acquisition of signal
BITE	built-in test equipment
BFS	Backup Flight System
CMD	command
comfault	the detection and flagging of an error that occurs in data exchanges within the GPC software
concatenated	united in series
CR	change request
CRT	cathode-ray tube
C&W	caution & warning
DES	deselect
FCOS	Flight Computer Operating System
FDI	fault detection/identification
FDIR	fault detection, identification, and reconfiguration
GAX	GNC annunciation interface module
GNC or GN&C	guidance, navigation, and control
GPC	general-purpose computer
HSD	Horizontal Situation Display
HSI	Horizontal Situation Indicator
I-Load	initialization load
IOP	input/output processor
IMU	inertial measurement unit

KSC	Kennedy Space Center
KTS	knots
LOS	loss of signal
LRU	line replaceable unit
MDM	multiplexer/demultiplexer
MLS	Microwave Landing System
MSBLS	Microwave Scanning Beam Landing System
MCC	Mission Control Center
MIA	multiplexer interface adapter
MML	master measurement list
MVS	mid value select
NAVAID	navigation aid
OFT	Orbital Flight Test
OPS	operational sequence
RA	radar altimeter
RCS	Reaction Control System
RCV	receive
RM	redundancy management
RTLS	return to launch site
SOP	Subsystem Operating Program
SPEC	specialist
SM	system management
SEL	select
STS-1	Space Transportation System 1
TAC (TACAN)	Tactical Air Control Navigation
TAEM	terminal area energy management

T/R transmitted/receive
UHF ultra high frequency
VU vehicle utility

1. INTRODUCTION

The Tactical Air Navigation (TACAN) system is a military L-band air navigational system that provides slant range and magnetic bearing information to the user aircraft or spacecraft. Slant range is obtained by interrogation of the ground transponder, whereas magnetic bearing information is continually available. The Space Shuttle's Orbital Flight Test (OFT) program relies upon this navigational system to provide accurate positional information to the crew after reentry. The TACAN system, together with its onboard Shuttle software, is the subject of this document.

The Shuttle TACAN navigational system consists of three TACAN transponders, six antennas (three upper and three lower), a subsystem operating program (SOP), and redundancy management (RM) software. The objective and scope of this document are to present these TACAN subsystems in a tutorial form and identify the interaction between these subsystems and the Shuttle navigation system.

The presentation of these subsystems begins with a discussion of the use of TACAN during the first Space Transportation System (STS-1), is followed by a brief functional description of the TACAN hardware, then proceeds to cover the software units with a view to the STS-1, and ends with a discussion on the Shuttle usage of the TACAN data and anticipated performance.

2. PLANNED USE OF TACAN DURING STS-1

The Space Shuttle's TACAN subsystem will provide primary navigational data from post L-band blackout signal acquisition after deorbit to the Microwave Scanning Beam Landing System (MSBLS) signal acquisition. TACAN will also provide primary navigational data during a return to launch site (RTLIS).

There are two guidance, navigation, and control (GNC) operational sequences (OPS) in which landing can occur;¹ these are OPS3 (entry and landing after deorbit) and OPS6 (RTLIS). One additional landing that can occur during OPS3 will be abort once around (AOA). It is planned that the landing sites for the nominal mission will be Edwards Air Force Base, California; the AOA mission will be at the Northrup Strip, White Sands, New Mexico; and the RTLIS will be at Kennedy Space Center (KSC). The preliminary nominal entry-through-landing flight profile for Edwards Air Force Base, California, planned for STS-1 is illustrated in figures 2-1 through 2-4 (ref. 1).² (Other contingency landing sites that could be used are ROTA, Spain; Kadena Air Force Base, Okinawa; and Hickam Air Force Base, Hawaii.)³

In each of the landings at either Edwards Air Force Base, the Northrup Strip, or KSC, the TACAN acquisition logic will be based on the three-tier concept. Ten TACAN stations are used for navigation with acquisition and switching of these stations based on the arrangement within the three tiers or regions: the acquisition region, the navigation region, and the landing region. The 10 TACAN stations surrounding Edwards Air Force Base to be used are listed in table 2-1. The acquisition region is for ranges

¹See a list of operational sequences and major modes in appendix A.

²Figures 2-1 through 2-4 are reproduced from pages 84, 205, 206, and 166 of reference 1, respectively.

³See reference 2 for further information on TACAN stations that will be used in these landings.

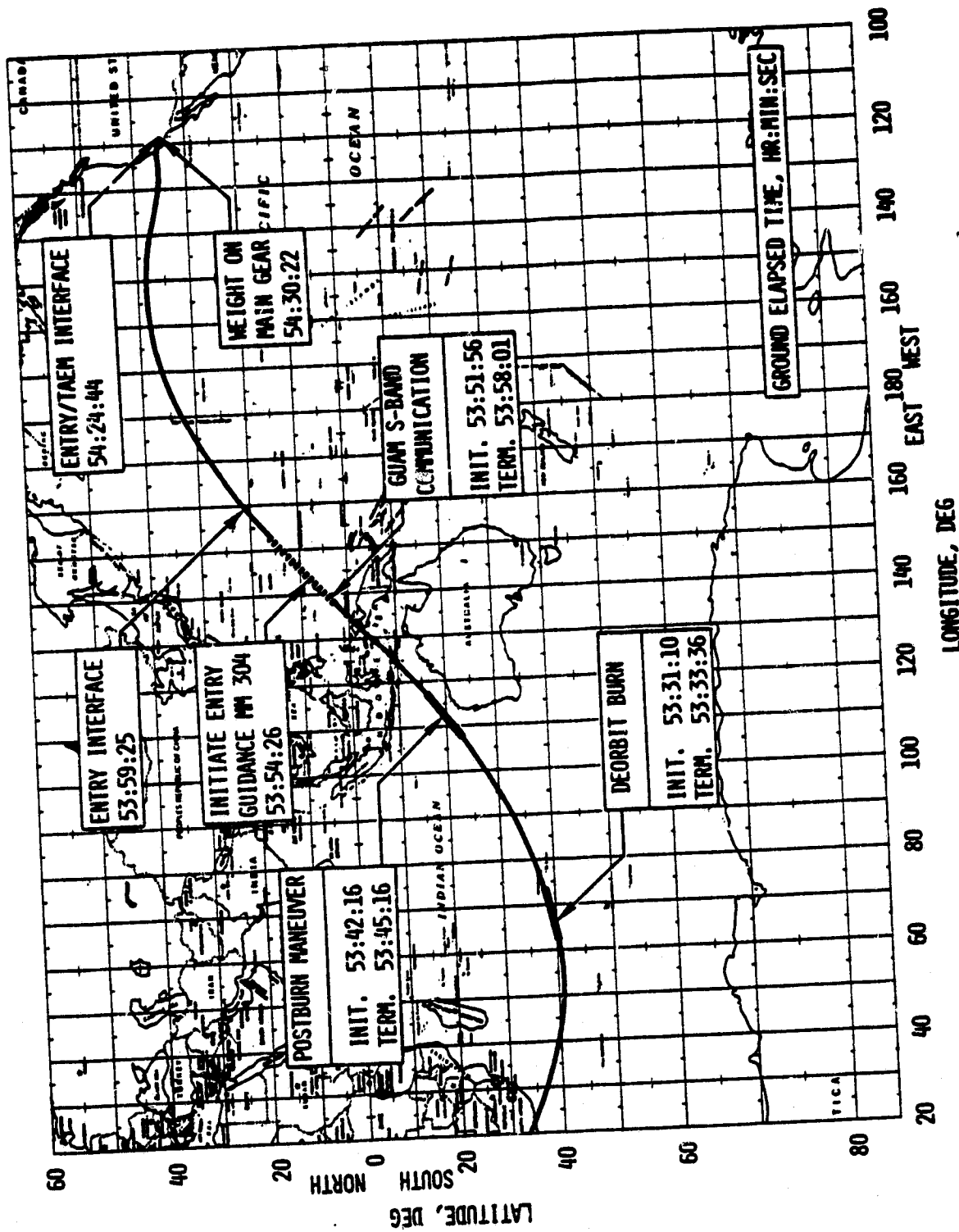


Figure 2-1.- STS-1 deorbit-through-landing groundtrack.

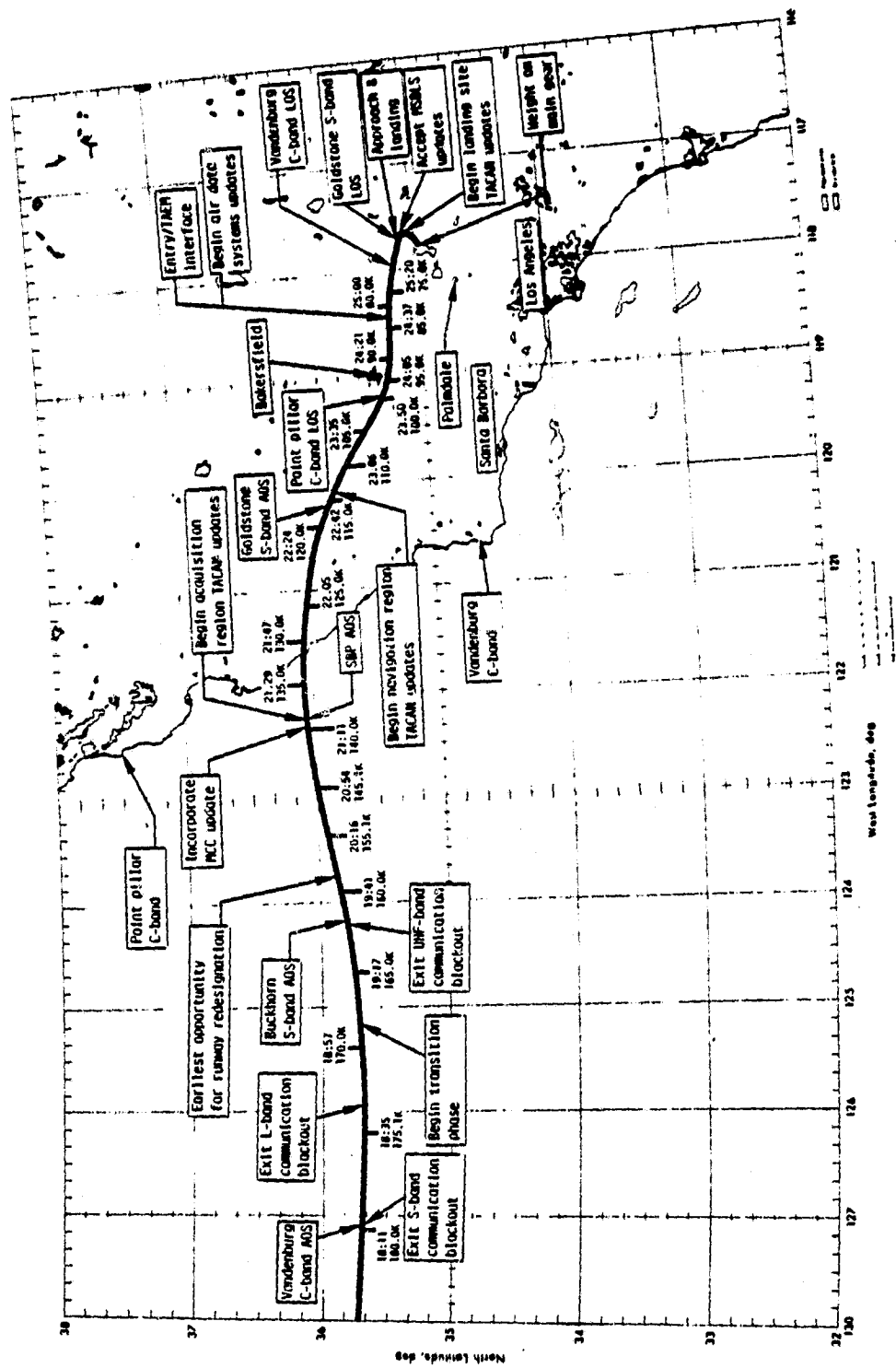


Figure 2-2.- Postblackout entry groundtrack for Orbiter STS-1.

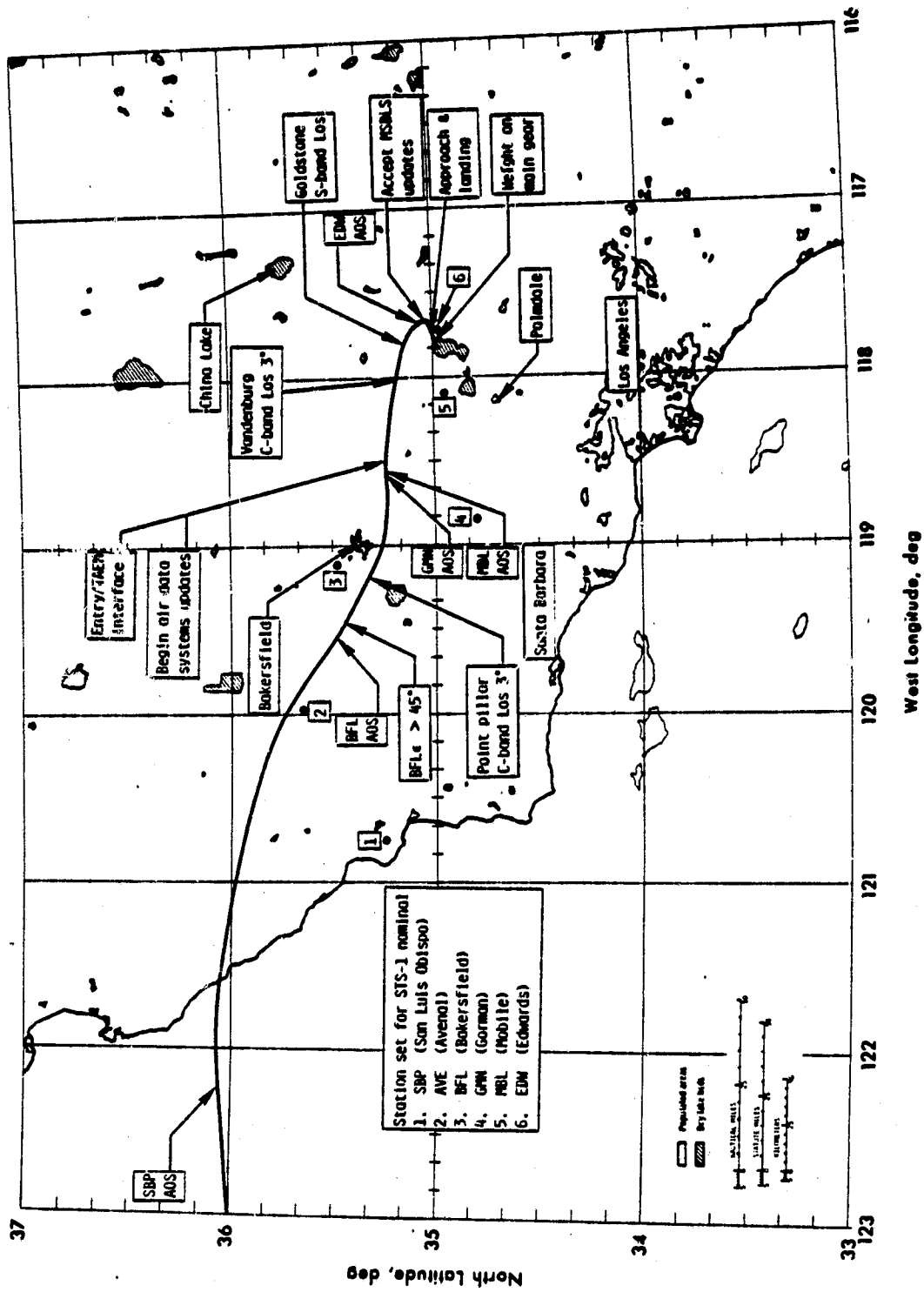


Figure 2-3.-- STS-1 entry groundtrack and TACAN events.

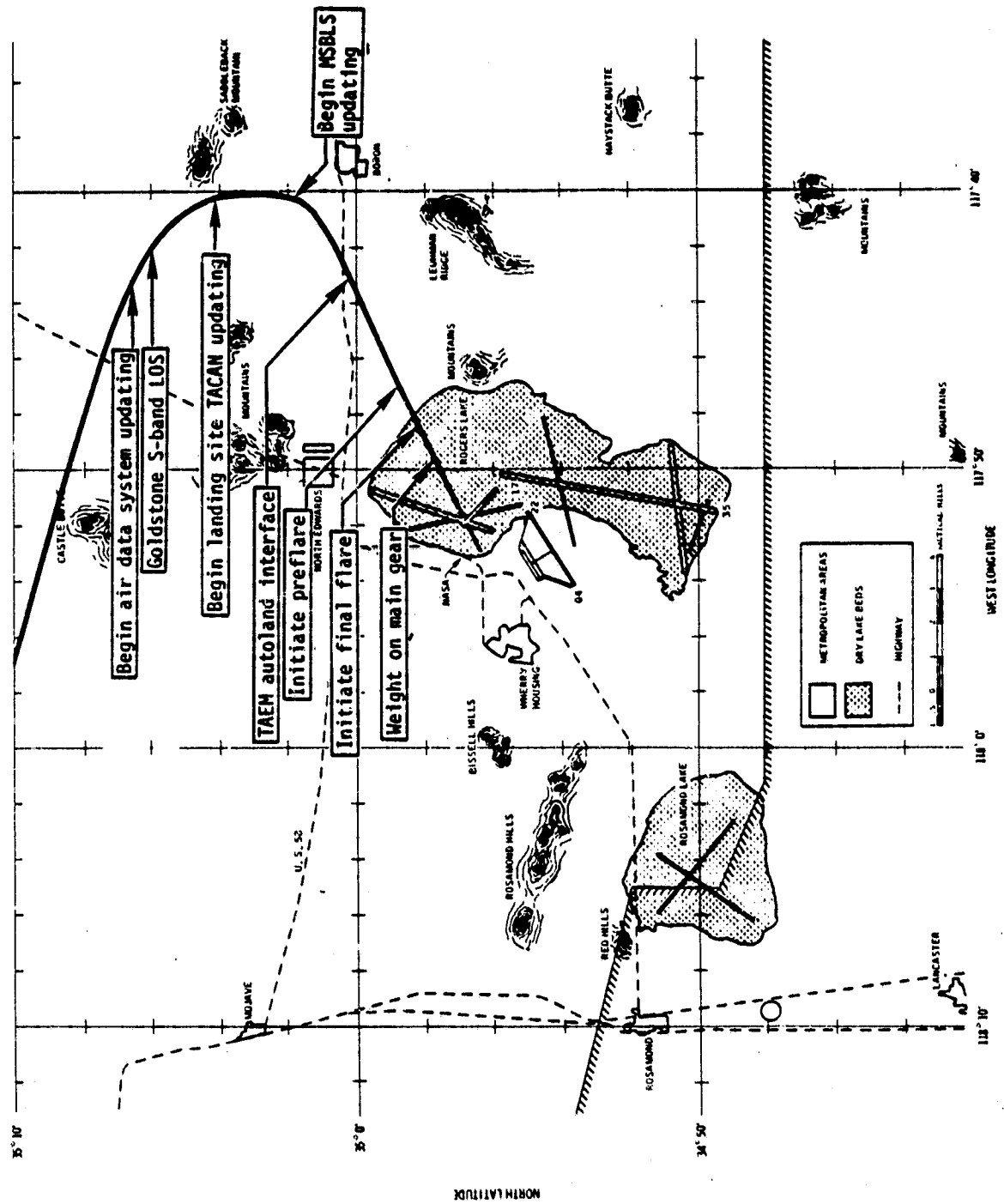


Figure 2-4.— Approach and landing groundtrack.

TABLE 2-1.- TACAN STATION LOCATIONS USED FOR STS-1

[From ref. 1, p. 59]

Designation	Station name	Latitude, deg	Longitude, deg	Altitude, ft	Channel no.
Acquisition region					
SBP	San Luis Obispo	35.252N	120.759W	1262	71
PRB	Paso Robles	35.672N	120.627W	618	90
GVO	Gaviota	34.531N	120.091W	2418	112
Navigation region					
AVE	Avenal	35.647N	119.978W	506	118
FLW	Fellows	35.093N	119.865W	3695	122
BFL	Bakersfield	35.485N	119.097W	359	101
GMN	Gorman	34.804N	118.861W	4714	108
MBL	Mobile Unit	34.938N	118.091W	2364	69
Landing region					
PMD	Palmdale	34.631N	118.064W	2314	92
EDW	Edwards	34.982N	117.732W	2127	111

greater than 120 nautical miles and includes the San Luis Obispo, Paso Robles, and Gaviota stations. The navigation region is for ranges between 120 to 7.5 nautical miles and includes the Fellows, Gorman, Bakersfield, and Avenal stations. A mobile TACAN station is also included in the navigation region. The landing region is for ranges less than 7.5 nautical miles and includes the Palmdale and Edwards stations.

The TACAN station coverage for a planned STS-1 landing at Edwards Air Force Base is illustrated in figures 2-5 and 2-6. Acquisition and lock-on by two TACAN line replaceable units (LRUs) should occur at approximately 148,510 feet. If the navigation state residuals are acceptable and the navigation filter is in the AUTO mode, incorporation of TACAN data that have passed the RM criteria will then occur with no verification from the Mission Control Center (MCC). Otherwise, crew action and MCC verification are required to incorporate the TACAN data into the navigation state.

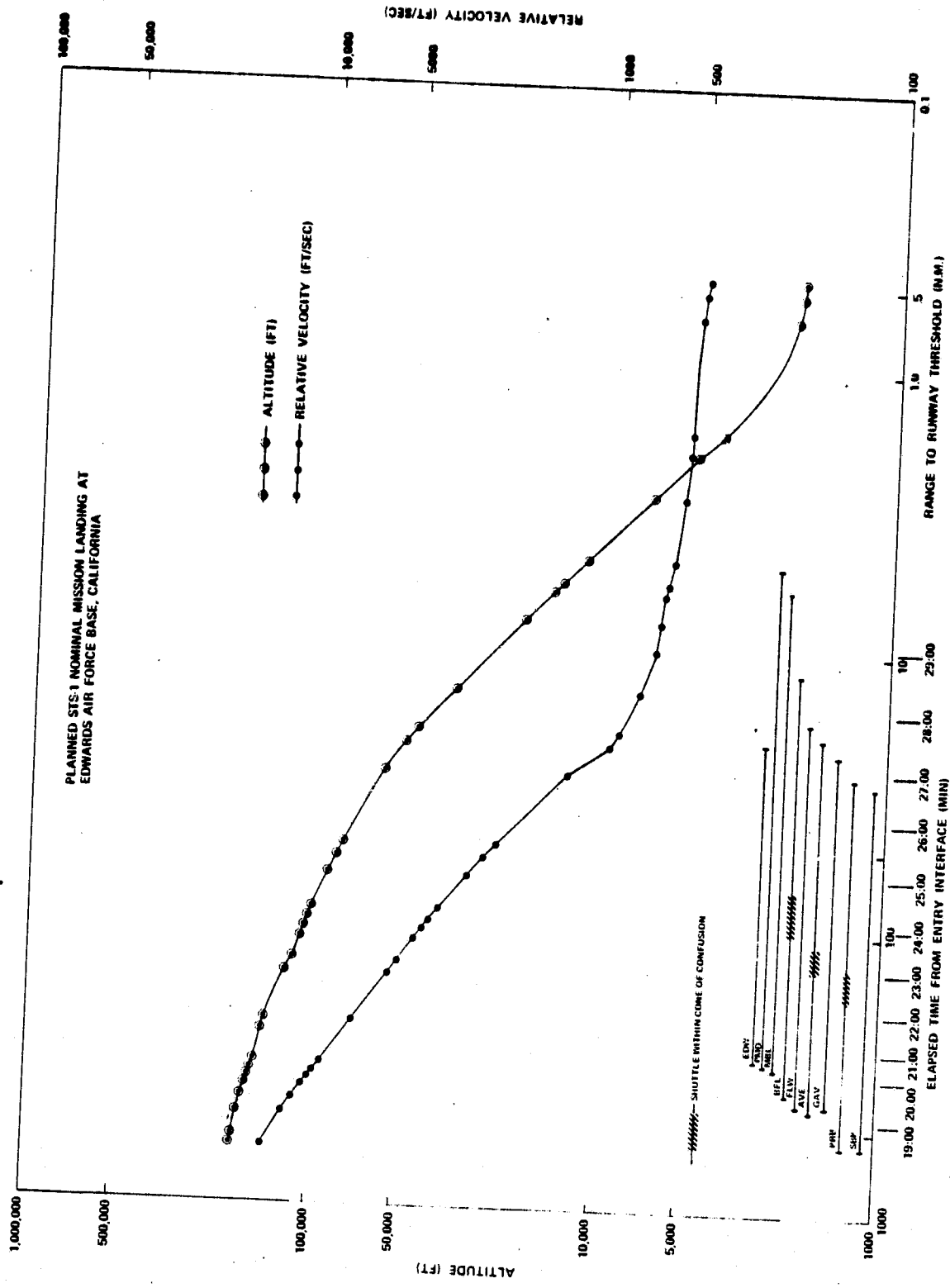


Figure 2-5.-- Nominal Shuttle flight profile during STS-1: entry through final approach. TACAN station coverage versus elapsed time from entry interface is superimposed on flight profile. (This figure is extracted from page 58, ref. 1.)

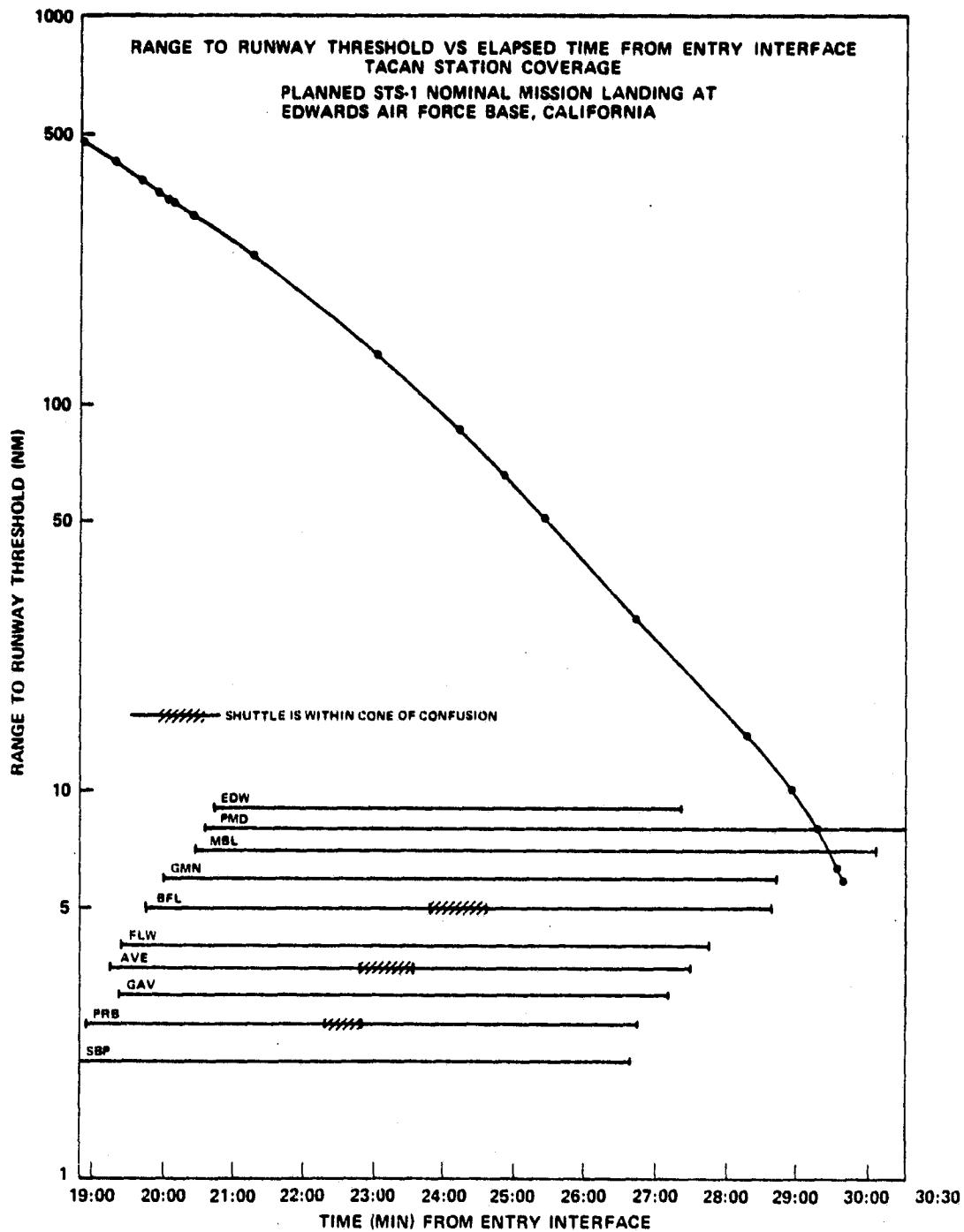


Figure 2-6.— Range to runway threshold versus elapsed time from entry interface for a nominal Shuttle flight profile. (TACAN station coverage is superimposed on time scale. This figure is extracted from page 58, ref. 1.)

3. TACAN HARDWARE DESCRIPTION

The TACAN L-band navigation system provides slant range and magnetic bearing to the user aircraft from a ground beacon. The ground-based transponder beacon can service a maximum of 100 aircraft simultaneously obtaining distance information, but an unlimited number of aircraft may obtain azimuth (bearing) information. The present TACAN system has the following limits: two modes of ground beacon operation (X or Y), 126 frequency channels (1 through 126), a specified range of 400 nautical miles, and an accuracy of 1.0 degree in azimuth and 0.1 nautical mile in range. The Y mode is presently not in use but would add another 126 channels (-1 through -126) if it were adopted.

The TACAN system for the Space Shuttle consists of three LRUs designated as a receiver-transmitter (R/T); and each LRU has an associated multiplexer/demultiplexer (MDM), an upper antenna, and a lower antenna. Other components completing the system are a control panel and the onboard or general-purpose computer (GPC). A keyboard and a display electronics unit are also required for TACAN self-test command and data monitoring.

An LRU is illustrated in figure 3-1. Figure 3-2 shows the locations of the Shuttle TACAN antennas. The cockpit layout identifying the keyboard, cathode-ray tube (CRT) displays, and the TACAN control panel is shown in figure 3-3. The three CRTs are available for presenting about 60 computer stored displays (ref. 3). These displays are called up on any of the three CRTs via the OPS/SPEC (operational sequence/specialist) request on the commander or pilot keyboards. The displays of importance to TACAN operation during the mission are as follows.

1. On-orbit sensor self-test; SPEC 040 keyboard entry (see ref. 4, sec. 4.5.4.)
2. Horizontal situation display (HDS); SPEC 050 keyboard entry (see ref. 4, sec. 4.2.9.)

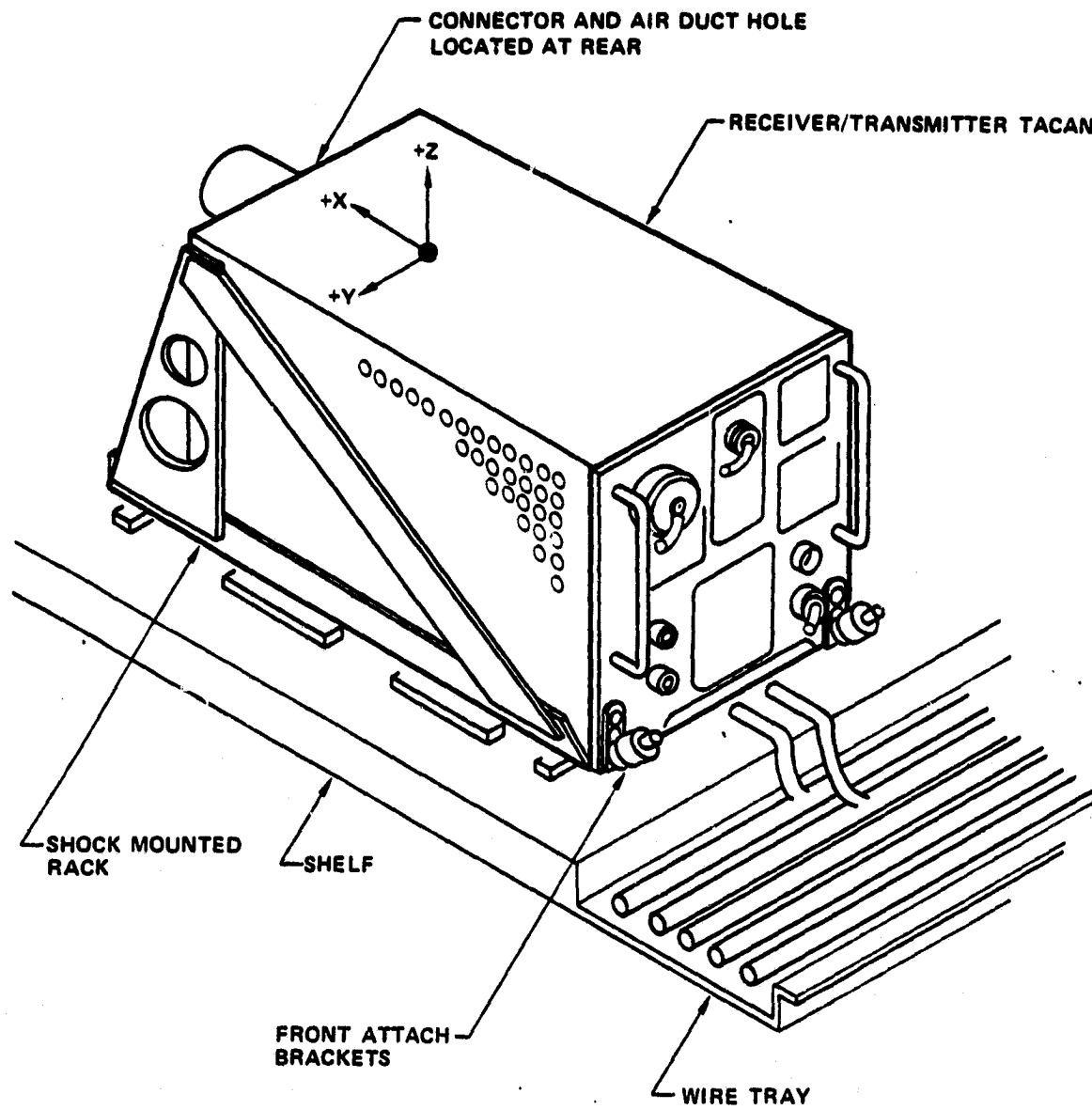


Figure 3-1.- TACAN LRU used in the Space Shuttle.

ANTENNA LOCATIONS

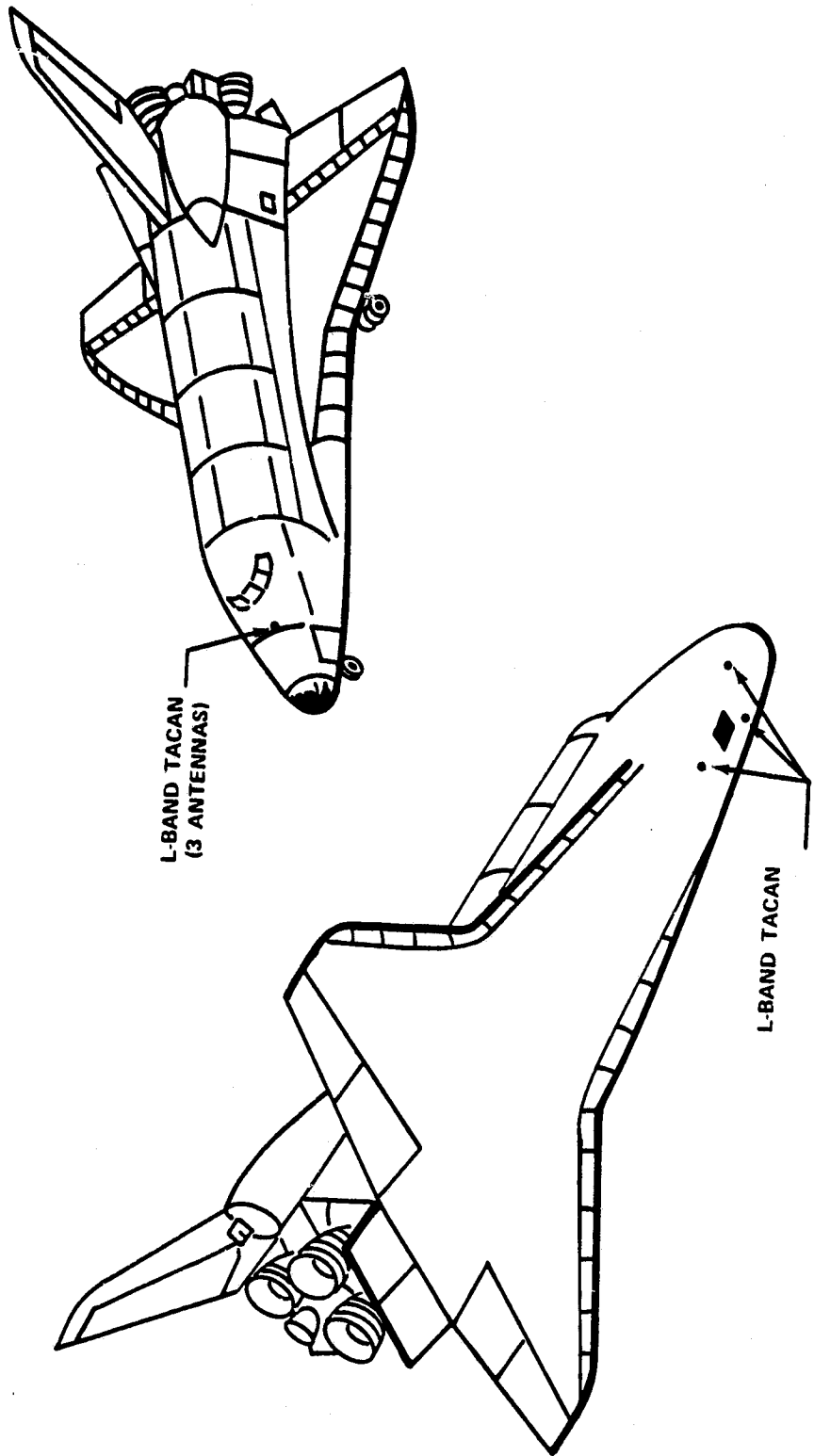
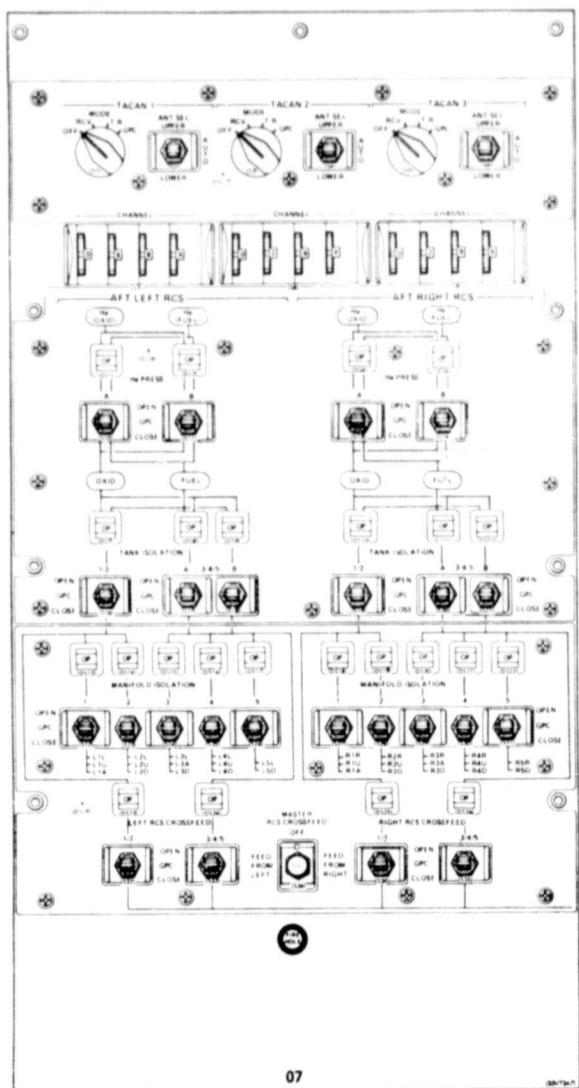
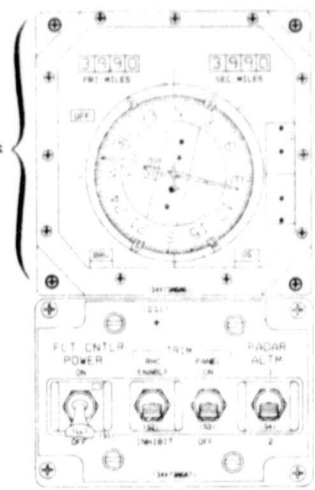


Figure 3-2.- Shuttle TACAN antenna locations.

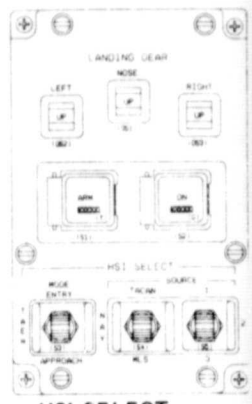


PANEL 07

TACAN CONTROL PANEL

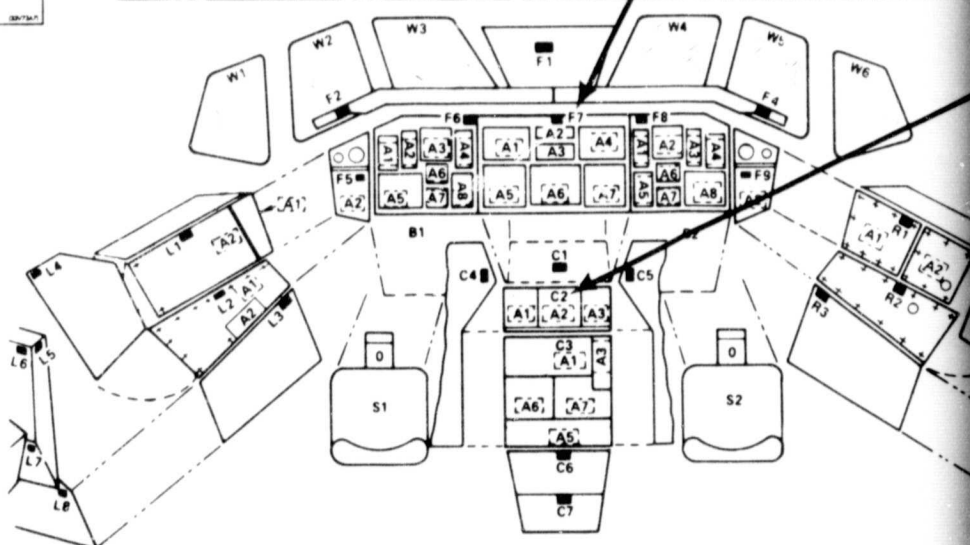
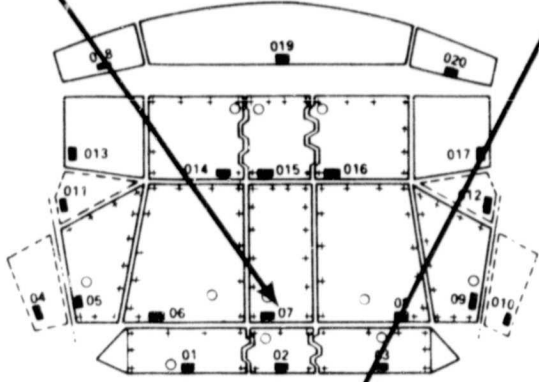


*HSI DISPLAY
PANEL F6, A6
PANEL F8, A6



HSI SELECT
PANEL F6, A5
PANEL F8, A5

OVERHEAD PANELS



FLIGHT STATION
(COCKPIT LAYOUT)

FOLDOUT FRAME

PRECEDING PAGE BLANK NOT FILMED

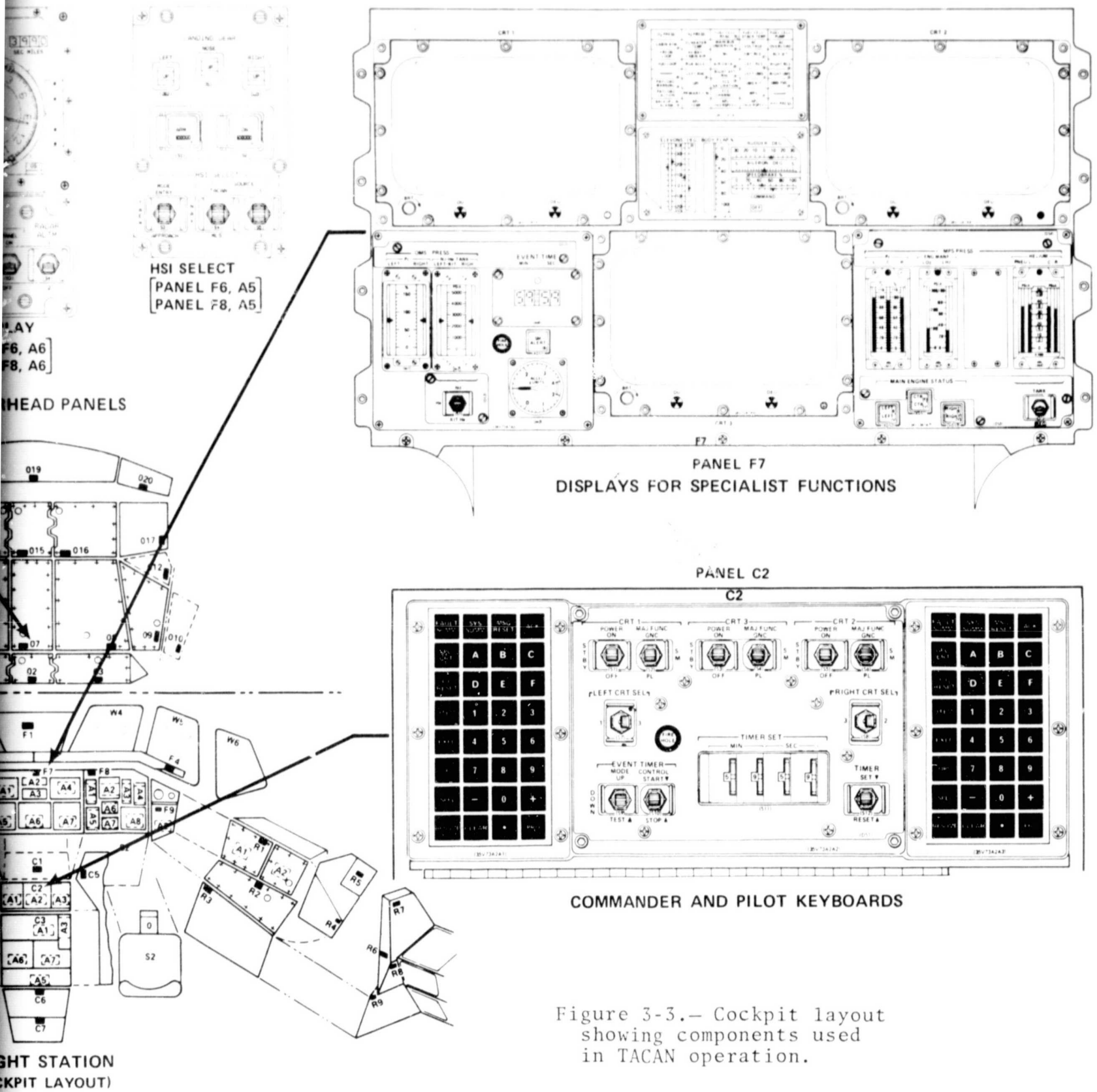


Figure 3-3.— Cockpit layout showing components used in TACAN operation.

3. GNC system summary 1; SPEC 018 keyboard entry or SYS SUMM key. (See ref. 4, section 4.2.15.) The GNC system summary 1 display only provides station monitoring on an LRU basis and is also further discussed in ref. 5, page 3-13.

The on-orbit sensor self test and HSD displays will be further discussed in section 5.2.2.2.

An additional non-CRT display that can utilize TACAN data indirectly is the Horizontal Situation Indicator (HSI). TACAN or Microwave Landing System (MLS) data must be operated upon by Area Navigation and the horizontal situation processor before being used by the HSI. An illustration of the HSI and its control panel is shown in figure 3-3.

One CRT display used prior to launch is the Preflight Sensor Self Test (SPEC 101 keyboard entry). This is further discussed in ref. 4, sec. 4.6.2, and ref. 5, page 3-1.

PRECEDING PAGE BLANK NOT FILMED

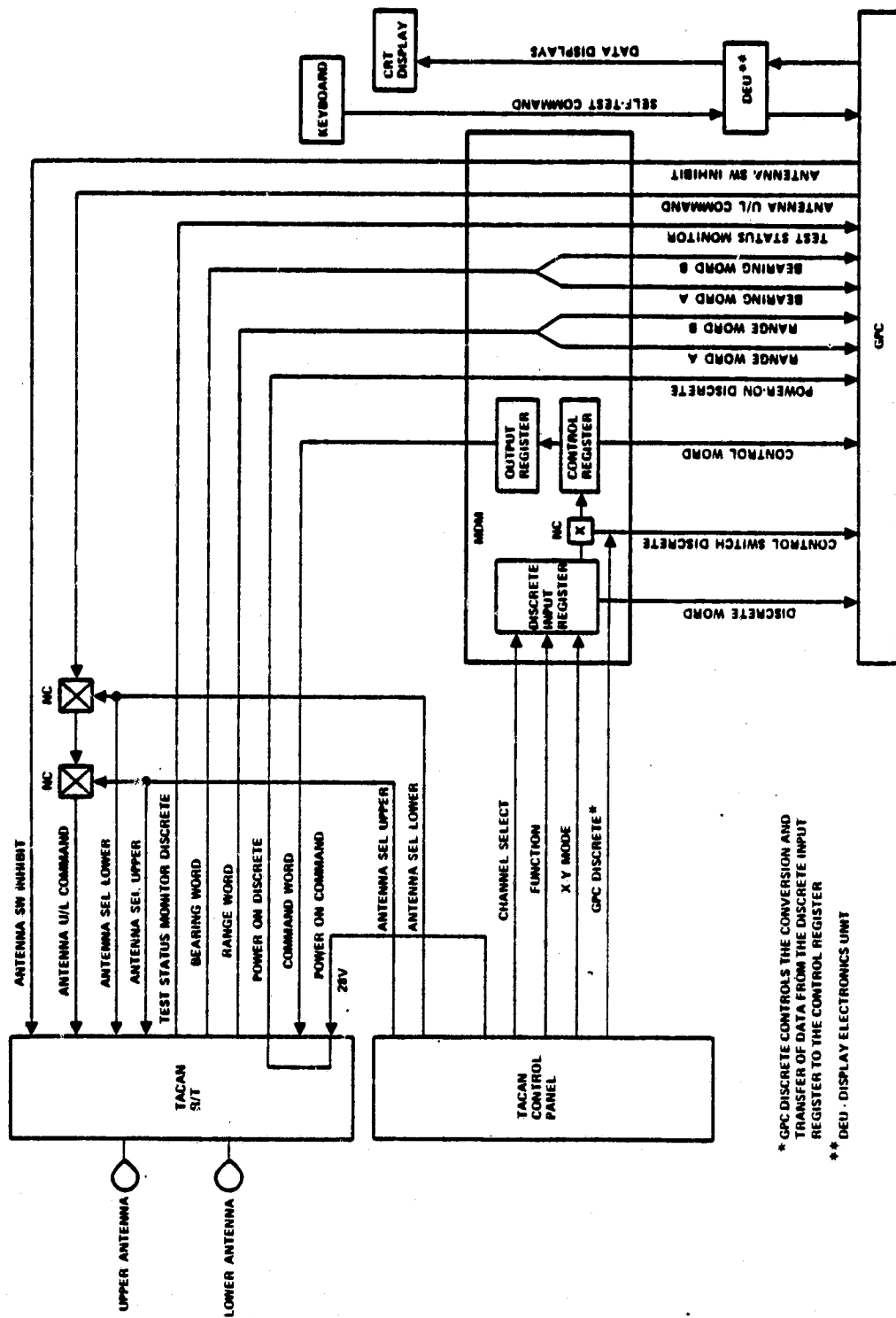
4. HARDWARE/SOFTWARE INTERFACE

A block diagram of the TACAN hardware/software interface is shown in figure 4-1. As previously stated, there are six major components required for each TACAN's performance; a control panel, an MDM that contains the TACAN control register, a receiver/transmitter (R/T), an upper antenna, a lower antenna, and an onboard GPC. In addition, a keyboard and a display electronics unit are required for on-orbit self test, for monitoring the health of the TACAN outputs, and for deselecting/reselecting units.

The control panel switch has four positions: OFF, RCV, T/R, and GPC [RCV (receive is not utilized in Space Shuttle operations)]. Power is applied to the TACAN R/T in all positions except OFF. From this control panel input, the TACAN R/T supplies a power-on discrete to the software for utilization in RM processing.

Four thumbwheels switches on the control panels provide a method of inputting channel numbers 1 through 126 and the mode of operation, X or Y. The channel number and the mode of operation are transferred to the discrete input register and on to the control register if the four-position switch is in the T/R or manual mode. If the switch is in the GPC mode, the control panel channel number and mode inputs are inhibited at the discrete input register; and selection of these two parameters is made by the GPC. The contents of the control register are supplied to the output register, and its contents are in turn made available to the TACAN R/T every 32 milliseconds. The control register format and the discrete input register format are shown in appendix B.

The range and bearing words output by the TACAN R/T are reformatted in the MDM. The TACAN-to-MDM and MDM-to-GPC bearing and range word formats are shown in appendix B. In addition to the bearing and range words, the TACAN R/T provides a test status



* GPC DISCRETE CONTROLS THE CONVERSION AND TRANSFER OF DATA FROM THE DISCRETE INPUT REGISTER TO THE CONTROL REGISTER

** DEU - DISPLAY ELECTRONICS UNIT

Figure 4-1.- Hardware/software interface.

monitor discrete to the GPC; this discrete checks on the health of the TACAN R/T. The following things are checked.

- Frequency synthesizer
- Power supply voltages
- RF power output
- Range self-test results
- Bearing self-test results

The state of the test status monitor discrete may change only when self test is active.

An antenna switch inhibit is set at all times during TACAN operation and inhibits the TACAN R/T from internally controlling antenna switching. The antenna switch has three settings: (1) antenna select upper, (2) auto, and (3) antenna select lower. The normal condition is AUTO, at which time the GPC controls the antenna switching. If the switch is in the antenna select upper or antenna select lower, the GPC selection is inhibited and the given antenna is selected.

The keyboard can be utilized during preflight or while on orbit to request self test. The results are displayed on the CRT display. During entry through landing, self test is under the control of the GPC. The self-test request from the GPC is sent to the TACAN R/T via the control register.

5. TACAN SOFTWARE⁴

The TACAN software consists of two separate units that provide TACAN hardware and data moding while evaluating the data for performance and reliability. The first software unit to be considered is the SOP. The second unit is designated the TACAN RM unit. Together, these units provide data quality assessment for range and bearing to Navigation. The internal and external interfaces to the units comprising the TACAN software are described in section 6, and the interface tables are given in appendix C.

5.1 TACAN SUBSYSTEM OPERATING PROGRAM (SOP)

5.1.1 FUNCTIONAL DESCRIPTION

The TACAN SOP controls and monitors the operation of the three TACAN systems and processes TACAN data for use by other program elements. The inputs and outputs from the TACAN SOP modules are stored in locations labeled according to parameter and transceiver.

A block diagram of the SOP operation is shown in figure 5-1. The TACAN SOP will process data at a 1.04-hertz rate to support the RM and provides the functions of valid range and bearing data computation, channel selection and verification, selection of the preferred station, and channel command and self-test processing to format the control word. The TACAN SOP will also process data at a 3.125-hertz rate in support of the HSI if the HSI control panel switches (right or left) are in the TACAN position. The TACAN SOP also calls the RM subprogram.

The TACAN SOP is functionally partitioned into four modules, which are as follows:

- TACAN self-test processing

⁴This is a description of Primary Avionics System Software (PASS) and does not cover Backup Flight System software.

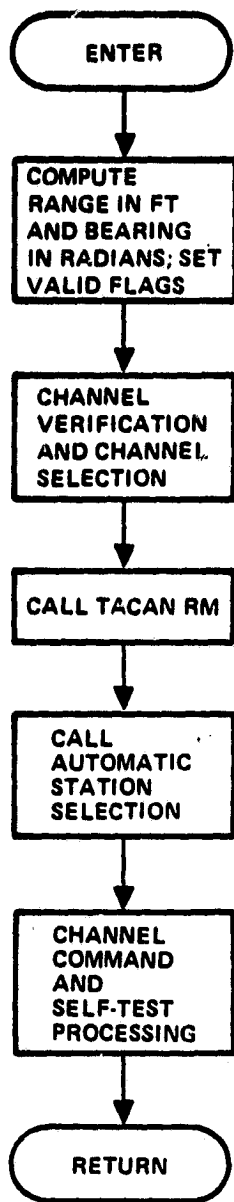


Figure 5-1.- TACAN SOP block diagram (from detailed design software, see ref. 6.)

- TACAN data processing
- TACAN antenna selection processing
- TACAN channel command processing

A detailed description of the TACAN SOP can be found in reference 7.

5.1.2 SOP SOFTWARE DESCRIPTION

5.1.2.1 TACAN Self-Test Processing

Self-test processing is initiated by the two-element processor in the RM. This occurs when the tolerance between two available LRUs is greater than an allowable limit.⁵ All LRUs must be in the GPC mode for self test to be completed. If self test is requested in the transmit/receive (T/R) mode, all requested TACANs are failed and the self test is terminated.

When all applicable LRUs are in the GPC mode during a self-test request, then the TACAN LRU outputs calibrated range and bearing data which are tested by the software against high and low I-load limits.⁶ Any LRU parameter which does not pass these limit checks is failed. In addition, the LRU has to pass internal hardware checks indicated by the test status monitor. After a self test is completed, the TACAN parameters that pass the tests are returned to normal RM operation.

5.1.2.2 TACAN Data Processing

This module performs the following tasks:

1. Time-tags TACAN input data for use by navigation.

⁵ See Hal words BRG_TOL and RNG_TOL in appendix D.

⁶ See Hal words TAC_RNGLO, TAC_RNGHI, TAC_BEARLO, and TAC_BEARHI in appendix D.

2. Computes the TACAN range values by concatenating the two range words and performing the required scaling and conversion to obtain floating point data in units of feet.
3. Computes the TACAN bearing values by performing the required scaling and conversion to obtain floating point data in units of radians.
4. Sets the TACAN range and bearing lock-on flags and comfault/lock-on flags to the correct state.
5. Computes the current TACAN channel identification for use by other software functions.

The time tag is executed at the rate of 1.04 hertz unless the HSI selection switch is set in the "TACAN" mode; then processing is done at 3.125 hertz for the selected TACAN.

Both the range words A & B and bearing words A & B that are input to SOP from the MDM are concatenated (united in series) to form 32 bit words; these are scaled and converted to floating point. The range word is scaled to feet and the bearing word to radians. These words are identified in appendix B.

Both the range and bearing lock-on and comfault flags are set in the correct state in the SOP. In addition, the correct bits from the TACAN control word are extracted to form the TACAN channel number, which can have any value from 1 through 126.

Two modes of operation are also available, either X or Y. The X mode is the only one that is currently assigned to TACAN stations (+1 through +126) throughout the world. If the Y mode is ever adopted, it will give frequency assignments to 126 new channels (-1 through -126).

5.1.2.3 TACAN Antenna Selection Processing

When the TACAN antenna switch is in the "AUTO" position, the antenna position is determined by software logic in the SOP. The software initially selects the lower antenna, and then a test is made to determine whether TACAN range lock-on has been attained. If after a number of data passes equal to an I-Load,⁷ the TACAN has not accomplished range lock-on; then this module switches to the upper antenna, and the lock-on test begins anew. This switching process continues until lock-on is attained, and then further switching is inhibited. This condition continues until either lock-on is lost or navigation requests a new channel.

The TACAN antenna switch can also be set to lower or upper position by the crew. In these cases, this manual setting overrides the "AUTO" position and inhibits the switching module and selects the indicated antenna.

5.1.2.4 TACAN Channel Command Processing

This module is required to perform the following:

1. Convert the TACAN channel number selected by navigation into the required format for output to the TACAN control registers.
2. Format the TACAN control word to specify the proper channel, mode, and test condition and output the control word to the TACAN control registers.

The control register only accepts the TACAN SOP-produced control word if the TACAN is in the GPC mode. If in the T/R or RCV mode, the control word is sent directly from the discrete input register to the control register.

⁷See Hal word TAC-RLTIM appendix D.

5.2 REDUNDANCY MANAGEMENT (RM)

5.2.1 SALIENT FEATURES

The basic function of the RM unit is to select the best estimate of range and bearing of the Space Shuttle relative to a TACAN station from any combination of the three LRUs onboard the Space Shuttle and provide the data to Navigation. A detailed description of the TACAN RM can be found in reference 5.

A block diagram of RM operations is shown in figure 5-2. The program consists of a moding executive, which provides sequencing and control while determining dilemma status, self-test request status, and failure status; a fault detection/identification (FDI) module for both range and bearing, which provides postselection filtering; a unit and channel selection routine; a cone calculation routine; and a subroutine to determine whether or not a new station should be requested. The RM also includes a common TACAN processing module, which provides moding to the bearing modulo-360 module, and for both range and bearing provides moding to the three-element processor, the two-element processor with a self-test request logic routine, and the prime select processor.

The logic design of the software evolved from standard RM techniques and analysis of approach and landing test (ALT) data. This resulted in the incorporation of a number of features that are unique to the TACAN RM unit. These features include the following:

- a. Limit checks for TACAN operational regimes.
- b. Filters for data jumps and dropouts.
- c. Provisions to change channels automatically when RM range lock-on cannot be attained and when Navigation determines that a TACAN station is more appropriately located than the one currently being utilized.
- d. Accommodations for deselecting LRUs either through system failure or crew intervention via keyboards and CRT displays.

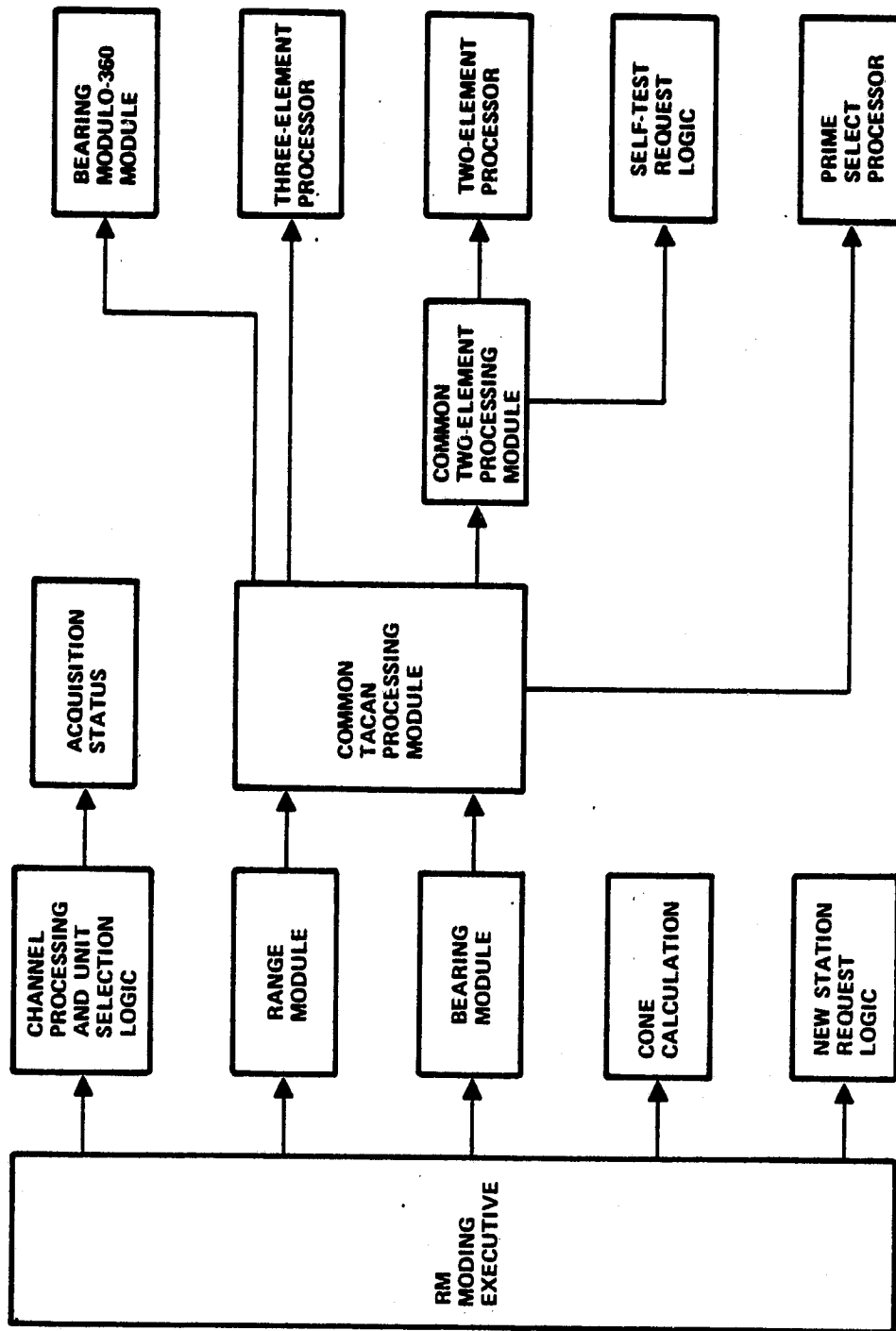


Figure 5-2.- TACAN RM processing block diagram. (Developed from the detailed design software, see ref. 6.)

- e. An interface with a navigation filter that requires two LRUs to lock on before passing data.
- f. Correction for modulo 360 effect in bearing data.
- g. The capability of prime selection through crew intervention or system failure.

In addition to these features, the TACAN system utilizes a standard RM technique to further pass on the data. This will be further discussed in section 5.2.2.3. Each of these features other than the standard RM will be discussed in the following paragraphs.

5.2.1.1 Limit Checks for TACAN RM Operational Regimes

Two distinct operational regimes of the TACAN are coded in the software. The criteria for these regimes are ground speed and altitude of the Space Shuttle. A third software check allows only bearing data below 45° elevation angle to be passed on to Navigation.

The RM ground speed regime utilizes a velocity threshold of 4500 knots to establish a two-to-one change in the number of RM cycles of continuous lock-on after range data acquisition. For a ground speed of less than 4500 knots, five continuous range data lock-ons per LRU are required before RM processing continues, whereas 10 lock-ons are required for greater speeds.⁸

At a Shuttle altitude of less than 1500 feet,⁹ the RM software is bypassed, and no TACAN data are passed to navigation because of multipath reflections of the signal between the TACAN station and the Space Shuttle.

⁸See Hal words R_ACQ_LIM_H, R_ACQ_LIM_L, B_ACQ_LIM_H, and B_ACQ_LIM_L in appendix D.

⁹See Hal words ALT_CUTOFF in appendix D.

A cone calculation routine performs an elevation angle comparison between the TACAN station in use and the computed position of the Space Shuttle. If the Space Shuttle's position is at an angle of 45° or greater relative to the 0° elevation reference angle of the TACAN station, an in-cone flag is set in the RM software which inhibits the bearing data from being used by Navigation.¹⁰

5.2.1.2 Filters for Smoothing Data Jumps and Dropouts

The bearing postselection filter and the range postselection filter smooth data wherever jumps or dropouts occur.

The range postselection filter tests the incoming range value against a range reference value which is the previous range value. If this difference is less than a jump limit,¹¹ then the data are passed on to Navigation; otherwise, they are inhibited. Failure of the range data to pass this limit test for the same reference value over five consecutive times causes the reference value to be updated to the last incoming range value and the jump limit checking to begin anew. All range data are failed until this filter is passed.

The bearing postselection filter tests the incoming bearing data in much the same manner as the range test, except that one other test is performed to eliminate problems associated with the modulo 360 effect. For example, one reading might be 1° and another 359°; this is less change than the (BRG_JMP_LIM) jump limit of 4.5°, but it would not pass a simple jump limit test. Therefore, the |current bearing minus reference bearing| must be greater than 360°-BRG_JMP_LIM to handle this situation. The bearing reference during cycles that pass this filter are the

¹⁰See Hal word ELEV_ANG_LIM in appendix D.

¹¹See Hal words RNG_JUMP_LIM and BRG_JUMP_LIM in appendix D.

previous incoming bearing data; but on continuous jump failure, the bearing reference is updated after 10 passes to the incoming bearing data.

5.2.1.3 Automatic Channel Identification (ID) Change

When the GPC mode of operation is in effect and channel lock-on cannot be attained over a continuous time limit as determined by the TWO_LOCK_COUNTER_LIMIT, then a request (ID_CHANGE_REQUEST) is made to Entry or Ascent Navigation for an AUTO_TACAN_SELECTION of a new channel. (See ref. 9, sec. 4.5.3, ref. 10, sec. 4.5.3.)

The design of the AUTO_TACAN_SELECTION algorithm imposes the following constraints upon the structure and composition of the TACAN site location data tables:

1. The first three entries (indices) in the TACAN site location data tables will be reserved for the early acquisition TACAN stations.
2. The last (tenth) entry will be reserved for the TACAN station associated with, or closest to, the landing site.
3. The ninth entry will be reserved for a contingency TACAN station that could be employed in the manual mode of TACAN selection as a backup or alternate for landing site TACAN station. During automatic TACAN selection, this TACAN station will be included in the middle region.

The remaining five stations will also be included in the middle region. The station coverage is illustrated in figures 2-5 and 2-6, and a listing of these stations for STS-1 is shown in table 2-1.

An ID_CHANGE_REQUEST can only be initiated by TACAN RM if all applicable LRUs are in the GPC mode.

The TWO_LOCK_COUNTER is updated by failure to obtain range lock-on only. Range is more difficult to acquire than bearing because it requires a transponded signal from the TACAN station, whereas bearing data only require a received signal by the LRU. The downlink signal from the spacecraft is 1 kilowatt, whereas a ground station transmits at 5 kilowatts. Navigation will also request a change in channel usage whenever it determines that another TACAN station is more appropriately located for good reception than the one currently being utilized.

5.2.1.4 Accommodations for Deselecting LRUs

LRUs may be deselected by the crew or by failure of data to pass the RM. The crew may also reselect either failed or deselected LRUs. (If the failed LRU does not pass the RM checks, then it will fail immediately after reselection). The crew can deselect/reselect LRUs while on orbit by utilizing the computer keyboard and calling the on-orbit sensor self test CRT display and during entry, ascent, or RTLS by calling the HSD and keying in the deselect. An overview of the interfaces of the possible TACAN deselections is shown in figure 5-3 and is further discussed in reference 5.

5.2.1.5 Navigation Filters

Navigation filters utilize TACAN and other sensor outputs to calculate residuals for range and bearing. These residuals must be less than 1; i.e., converging, in order to pass the navigation test. In addition, at least two TACAN LRUs must be locked on and tracking for this test to be performed. Two HAL words that limit operation in the RM are set to True if these residuals are less than 1; these are ONE_RNG_LOCK and ONE_BRG_LOCK; otherwise, they are set to False.

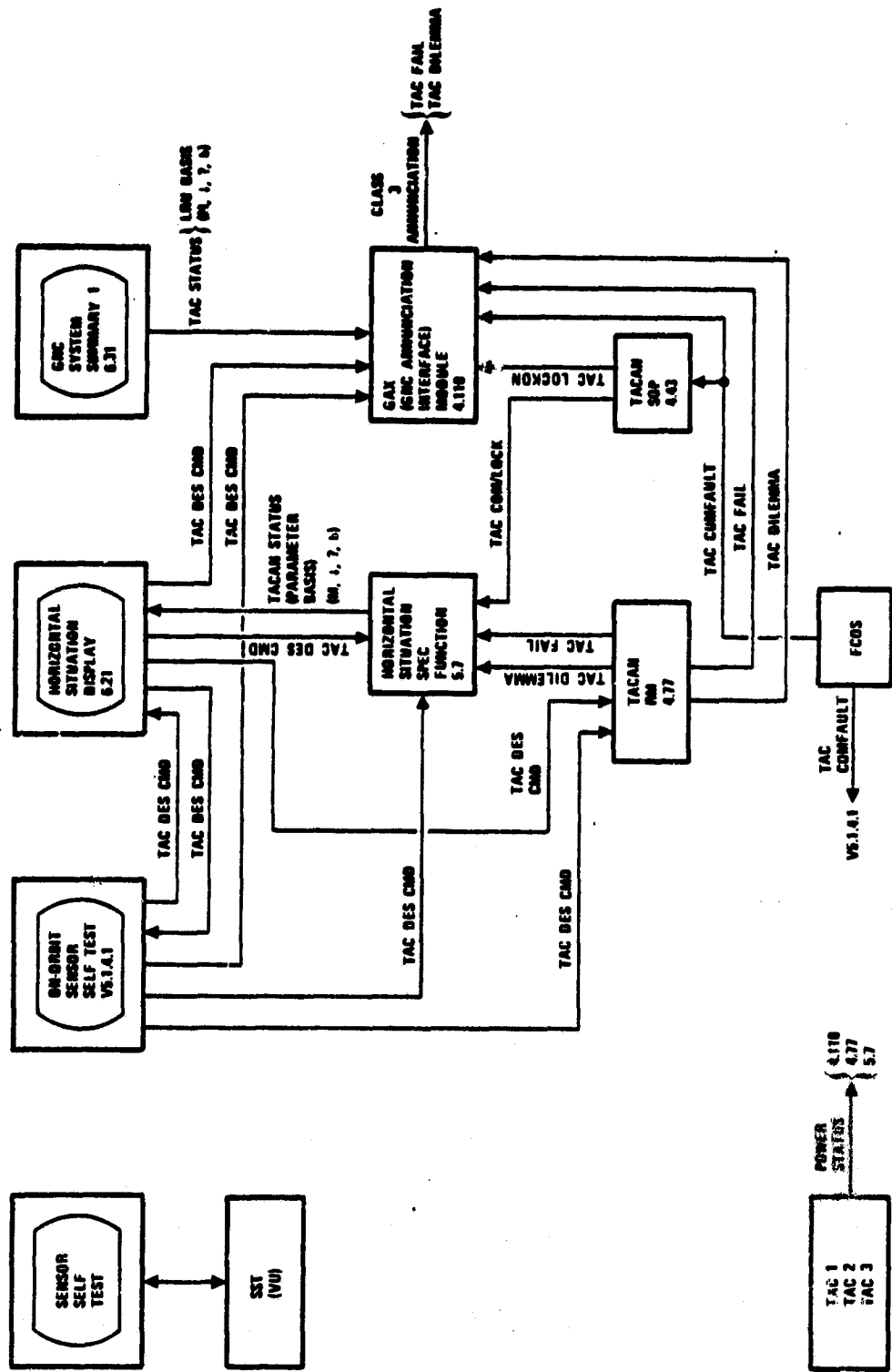


Figure 5-3.- Overall view of TACAN status interfaces.

5.2.1.6 Correction for Modulo 360 Effect in Bearing Data

When RM compares bearing data from more than one LRU, the possibility exists that readings will be very far apart if values are close to 360°; i.e., one value may be 359° and another 1°. To make comparisons in the RM, this effect is corrected by adding 360° to the smaller number(s) and subtracting 360° from the final composite output if it is greater than 360°.

5.2.1.7 Prime Select

Prime Select occurs whenever two LRUs are failed by RM or if two LRUs are deselected. Prime Select allows the crew to select one operating LRU to be used by Navigation. This is accomplished by "calling up" the HSD and keying in a deselect command to the unwanted LRUs. This process can be accomplished either with the LRUs in the manual (T/R) mode or in the GPC mode. Prime Select can also be implemented by the crew by turning two unwanted LRUs "OFF" on the control panel (see fig. 5-4).

5.2.2 UNIT SELECTION AND PROCESSING

Unit or LRU selection can be affected generally be one of three operations: comfaulting that occurs through signal structure testing in the Flight Computer Operating System (FCOS), crew selection or deselection, and RM testing and voting.

5.2.2.1 Comfaulting

Comfaulting occurs as a result of any errors detected through any of the many GPC internal software checks. These include checks in the multiplexer interface adapters (MIAs), input/output processors (IOPs), and host data bus terminals (see ref. 11, pp. 2.2-17 through 2.2-20). When an error occurs more than once in some internal GPC data exchange, then a comfault flag is set for that data string and valid data are no longer exchanged. This is usually a permanent failure; however, the crew can attempt an

I/O Reset (see ref. 12, p. 6-10, ref. 13, page 6-10) to clear this comfault. If the error has not cleared prior to this action, the data will continue to be comfaulted.

5.2.2.2 Crew Selection/Deselection

Unit or LRU selection can be characterized as manual or automatic. The manual or automatic mode can be selected on the four position TACAN switches as shown for each of the three TACAN LRUs in figure 5-4 (a part of the cockpit overhead display and control panel 07).

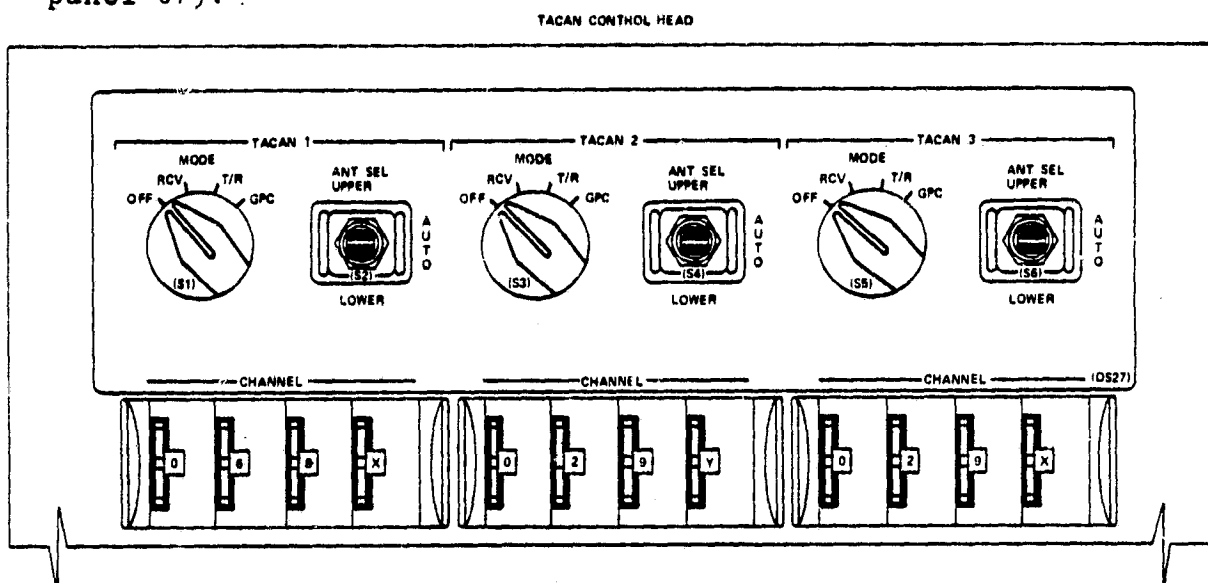


Figure 5-4.- TACAN control panel.

The positions are OFF, RCV (receive, not used in Space Shuttle operations), T/R (also known as the manual mode), and GPC (also known as the automatic mode). When in the T/R or manual mode, four thumbwheel switches for each TACAN LRU allow manual selection of channels 1 through 126 and the associated X or Y mode of operation. In the automatic mode (GPC setting), the thumbwheel channel selection outputs are bypassed and TACAN channel selection is provided by navigation software. This selection is based on the three-tier concept utilizing 10 channels whose stations are located close to the proposed Orbiter landing site (see table 2-1).

The GPC (automatic) mode (with all three LRUs operating) is preferred over the manual mode because

- a. Channel selection occurs automatically during critical phases of entry through landing.
- b. All LRUs are switched simultaneously, allowing for optimum use of the TACAN RM voting.
- c. The RM unit cannot resolve dilemmas between like LRU parameters in the manual mode.

There are three methods by which the crew can intervene in the operation of the TACAN and deselect/reselect LRUs in either the manual or automatic mode:

1. Use of the OFF switch on the panel as illustrated in figure 5-4.
2. Use of the on-orbit self-test display during OPS 8.
3. Use of the HSD during OPS 1, 3, and 6. (Appendix A lists the OPS and their major modes.)

The method of turning off an LRU on the overhead panel is undesirable because it takes approximately 1 minute for warmup if it is desired to reselect that LRU by turning either to the T/R or the GPC mode. Additionally, the suited commander and the pilot have difficulty in seeing and manipulating the switches on the overhead panel 07.

The on-orbit sensor self-test display is illustrated in figure 5-5. For the TACAN parameter status (S), an arrow (↑) indicates data too high, a down arrow (↓) indicates data too low, and a blank indicates data good. The I-loads for these self tests are shown in appendix E. An M can also appear in the status column; it indicates data missing. If any discrepancies appear during self

```

1 2 3 4 5
12345678901234567890123456789012345678901
1  XXXX/040          SENSOR TEST  XX X DDD/HH:MM:SS
2                               DDD/HH:MM:SS
3
4     DES STAT  RNG      AZ      EL
5     MLS 1  1X XXXX XX.XS  1X.XXS  X.XXS
6         2  2X XXXX XX.XS  2X.XXS  X.XXS
7         3  3X XXXX XX.XS  3X.XXS  X.XXS
8
9     DES STAT  RNG      AZ
10    TAC 1  4X XXXX  X.XS  XXX.XXS
11        2  5X XXXX  X.XS  XXX.XXS
12        3  6X XXXX  X.XS  XXX.XXS
13
14    DES STAT  ALT
15    RA  1  7X XXXX XXXXS
16        2  8X XXXX XXXXS
17
18    DES          Y          Z
19    AA  1  9X      1XX.XS  2XX.XS
20        2 10X      2XX.XS  3XX.XS
21        3 11X      3XX.XS  4XX.XS
22        4 12X      4XX.XS  5XX.XS
23
24                START 13X  STOP 14X
25
26                                (XX)

```

Figure 5-5.— On-orbit sensor self-test display.

test, the affected LRU(s) can be deselected by keying in 4 or 5 or 6 and depressing the EXECUTE key. An asterisk (*) appearing in the X column after the keyed-in number indicates deselection. The on-orbit sensor self test can only be called up during OPS 8. Both deselection and subsequent reselection (using the same procedure) of LRUs can be accomplished in OPS 8.

The primary method for the crew to monitor TACAN LRU and associated parameter status, determine channel selection, determine the LRU deselect status, and deselect/reselect LRUs is through utilization of the horizontal situation display (HSD). The HSD is used during the entry through landing phases of the Space Shuttle's flight and is illustrated in figure 5-6. Items 29, 30, and 31 are the deselects for each of the three LRUs. By depressing any one of these numbers on the keyboard and then the EXECUTE key, the crewmember can deselect the appropriate LRU. An asterisk indicates deselection; it appears after the number in the X position. Reselection can be accomplished by repeating the same procedure. The channel number selected either by the thumbwheel (T/R mode) or by navigation (GPC mode) will appear after the words TAC1, TAC2, and TAC3 in the XXX position.

The status position S after each of the LRU azimuth and range readings can have three characters or a blank indicated (M, †, ?, Ø). The meanings of these status indicators are shown in figure 5-7. The M means power off or a bad comfault/lock-on flag, a down arrow (†) indicates software fail or deselect, a question mark (?) indicates a dilemma, and blank indicates normal data. A fail or dilemma is developed through LRU output testing by the RM software.

The reselection of an LRU can be attempted on either a deselected LRU or one that has been RM-failed. A deselect LRU can be reselected if it continues to pass all RM tests. If reselection is

```

 1  XXXX/XXX/XXX  HDKZ BT  XX X 000/HH:MM:SS
 2  ALTM          NAV DELTA
 3  1 XX XX      0X 8
 4  Rwy          0XXX XXXX
 5  XXX XX 0X   AY 9
 6  XXX XX 0X   0XXX XXXX
 7  XXX XX 4X   LZ 10
 8  GLD SLOPE   0XXX XXXX
 9  LO WND 5X   AY 11
10  HI WND 6X   0XXX XX
11  XEP SW 7    LZ 12
12  XEP SW 7    0XXX XX
13  XEP SW 7    LOAD 14
14  XEP SW 7    LB AT 0XXX XX
15  RESID RATIO AUT TH FOR  TACI XXXTAC0 XXXTAC0 XXX
16  AC 0XXX.XX X.XS 17X 18X 19X  XXX.XXS:XXX.XXS:XXX.XXS
17  RNG 0XXX.XX X.XS        :XXX.XXS:XXX.XXS:XXX.XXS
18  DRAG 0XXX.XX X.XS 30X 31X 32X  DES 09X DES 30X DES 31X
19  AOTA 0XXX.XX X.XS 33X 34X 35X
20  AOTA TO GC  0XXX 30X 31X
21  AOTA TO GC  ABS 30X
22  AOTA TO GC  DELTA 33X
23  AOTA TO GC  XXXX  DELTA 33X

```

Figure 5-6.— Horizontal Situation Display (HSD).

O U T P U T	TACAN "X" "YYY" DISPLAY STATUS INDICATORS	M	↑	?	(BLANK)
I N P U T S	TAC "X" POWER DISCRETE	OFF (OR)	ON (AND)	ON (AND)	ON (AND)
	TAC "X" "YYY" COMFAULT/LOCKON FLG.	BAD	GOOD (AND)	GOOD (AND)	GOOD (AND)
		---	FAIL (OR)	GOOD (AND)	GOOD (AND)
	TAC "X" DESELECT	---	DESELECT	SELECT	SELECT (AND)
	TAC "YYY" DISAGREE	---	---	DISAGREE	AGREE (AND)

WHERE "X" = 1, 2, 3
 2ND "YYY" = BEARING, RANGE

Figure 5-7.— TACAN status logic for the HSD.

attempted on an LRU that has been RM-failed, the LRU must have corrected its fault or RM will again fail it; and none of its failed data will be available to navigation.

5.2.2.3 Selection by RM Voting

The RM unit can fail either complete LRUs or can fail individual parameters in a given unit. For example, if LRU_i and LRU_j are both good but LRU_k has an out-of-tolerance bearing reading, the RM will assume three good range data values (i, j, k) and two good bearing readings (i, j).

The things that act as complete LRU fails are comfaults and deselects. Deselects are not failures, but the RM treats them as such. In addition, individual RM failures of both bearing and range of an LRU will act as a complete LRU failure.

RM voting for different LRU failure configurations in a GPC or manual mode in which all LRUs are tuned to the same channel (A) is shown in table 5-1. Table 5-2 shows failures on a parameter basis in the GPC or manual mode in which all units are on the same channel (A). Table 5-3 shows the results of RM voting on several cases where channels are in a mixed mode of operation.

TABLE 5-1.1.- UNIT SELECTION IN CASES OF LRU FAILURE/
 DESELECT IN GPC OR MANUAL MODE

[All units on channel A]

Case	LRU _i	LRU _j	LRU _k	Results of RM voting on data sent to navigation
1	No failure	No failure	No failure	Mid-value select (MVS) of range and bearing data
2	Deselect and/or comfault	No failure	No failure	Average $\frac{LRU_j + LRU_k}{2}$ bearing and range data
3	Deselect and/or comfault	Deselect and/or comfault	No failure	Prime select LRU _k bearing and range data
4	Deselect and/or comfault	Deselect and/or comfault	Deselect and/or comfault	No data sent to navigation

TABLE 5-2.— PARAMETRIC SELECTION IN CASES OF FAILURE IN GPC OR MANUAL MODE

[All units on channel A]

Case	LRU _i bearing ^a	LRU _j bearing ^a	LRU _k bearing ^a	Results of RM voting on data sent to navigation
1	No failure	No failure	No failure	MVS of bearing data
2	Comfault and/or deselect and/or bearing fail and/or data good flag ^c is false	No failure	No failure	Average $\frac{LRU_i + LRU_j}{2}$ bearing data
3	Comfault and/or deselect and/or bearing fail and/or data good flag ^c is false	Comfault and/or deselect and/or bearing fail and/or data good flag is false	No failure	Prime select LRU _k bearing data
4	Comfault and/or deselect and/or bearing fail and/or data good flag is false	Comfault and/or deselect and/or bearing fail and/or data good flag is false	Comfault and/or deselect and/or bearing fail and/or data good flag is false	No bearing data sent to navigation
5	Comfault and/or deselect and/or bearing fail and/or data good flag is false	Bearing out of tolerance	Bearing out of tolerance	Bearing dilemma; ^b no bearing data sent to navigation until dilemma resolved

^aThe LRU_{i, j, k} range data have the same RM voting.

^bA self test would be requested by RM for the two LRU parameters out of tolerance. In the manual mode, self test cannot be completed. In the GPC mode, self test would be completed; and if one of the LRUs failed, then the remaining unit's data would be sent to navigation. If neither LRU passed self test or if both passed, then a dilemma would still exist.

^cIf the Shuttle is within the cone of confusion, the bearing data good flag will be set false.

TABLE 5-3.-- UNIT SELECTION IN CASES OF LRU FAILURE/DESELECT
WHERE LRUs ARE IN MIXED CHANNEL MODE

Case	LRU _i	LRU _j	LRU _k	Results of RM voting on data sent to Navigation
1	<ul style="list-style-type: none"> • Manual Mode • Channel "A" • No failures or comfault 	<ul style="list-style-type: none"> • Manual Mode • Channel "B" • No failures or comfault 	<ul style="list-style-type: none"> • Manual Mode • Channel "C" • No failures or comfault 	<p>No common channel</p> <p>No data sent to Navigation</p>
2	<ul style="list-style-type: none"> • Manual Mode • Channel A • Deselect 	<ul style="list-style-type: none"> • Manual Mode • Channel B • Deselect 	<ul style="list-style-type: none"> • Manual Mode • Channel C • No failures 	<p>Present RM software will not pass data to Navigation. CR19403A would allow LRU_k to be prime selected. (CR19403A will be implemented on STS-2 and possibly on STS-1.)</p>
3	<ul style="list-style-type: none"> • Manual or GPC • Channel "A" • No failures 	<ul style="list-style-type: none"> • Manual or GPC • Channel "A" • No failures 	<ul style="list-style-type: none"> • Manual • Channel "B" • No failures 	<p>Average $\frac{LRU_i + LRU_j}{2}$</p> <p>Bearing and range data</p>
4	<ul style="list-style-type: none"> • Manual or GPC • Channel A • Comfault or deselect 	<ul style="list-style-type: none"> • Manual or GPC • Channel A • No failures 	<ul style="list-style-type: none"> • Manual • Channel B • No failure 	<p>LRU_j bearing and range data will be prime selected</p>
5	<ul style="list-style-type: none"> • Manual or GPC • Channel "A" • Comfault 	<ul style="list-style-type: none"> • Manual or GPC • Channel "A" • Comfault 	<ul style="list-style-type: none"> • Manual • Channel "B" • No failures 	<p>RM software will not pass data to Navigation</p> <p>Common channels are failed</p>
6	<ul style="list-style-type: none"> • Manual or GPC • Channel "A" • Deselect 	<ul style="list-style-type: none"> • Manual or GPC • Channel "A" • Deselect 	<ul style="list-style-type: none"> • Manual • Channel "B" • No failures 	<p>Present RM software will pass no data to Navigation as both common channels have been deselected. CR19403A would allow LRU_k to be prime selected. (CR19403A will be implemented on STS-2 and possibly on STS-1.)</p>
7	<ul style="list-style-type: none"> • Channel A • OFF 	<ul style="list-style-type: none"> • GPC or Manual Mode • Channel B • No failures 	<ul style="list-style-type: none"> • GPC or Manual Mode • Channel B • No failures 	<p>Average $\frac{LRU_i + LRU_k}{2}$</p> <p>Bearing and range data</p>
8	<ul style="list-style-type: none"> • Channel A • OFF 	<ul style="list-style-type: none"> • Channel B • OFF 	<ul style="list-style-type: none"> • GPC or Manual Mode • Channel B • No failures 	<p>Prime select LRU_k</p>
9	<ul style="list-style-type: none"> • Channel A • OFF 	<ul style="list-style-type: none"> • Channel B • OFF 	<ul style="list-style-type: none"> • GPC or Manual Mode • Channel C • No failures 	<p>Prime select LRU_k</p>

6. TACAN SOFTWARE INTERFACES

An overall signal interface diagram of the TACAN SOP and the RM is shown in figure 6-1. Tables from which this figure was derived are given in appendix C.

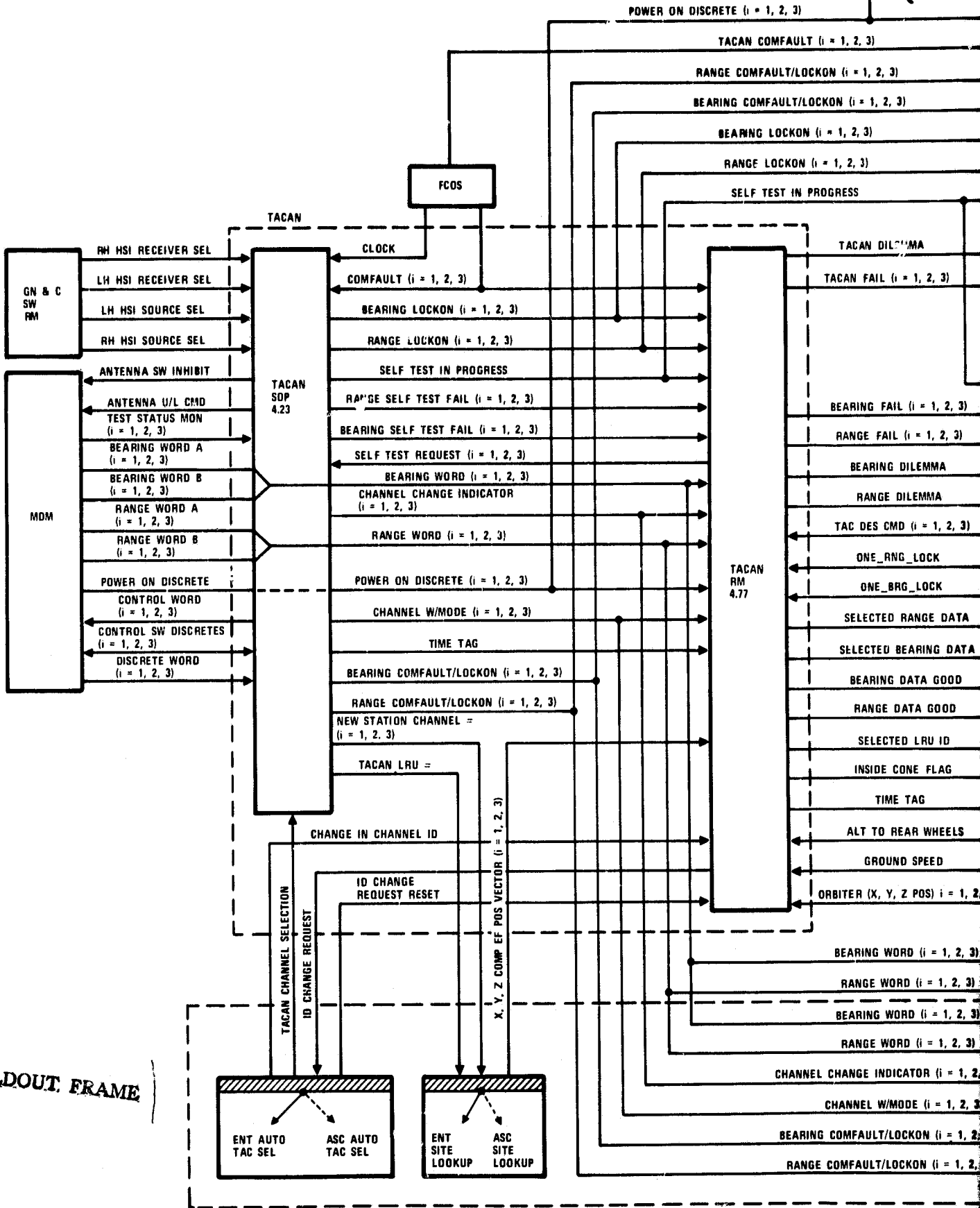
TACAN primarily interfaces with navigation, where its output of range and bearing is utilized to calculate the Space Shuttle's state vector. Navigation provides automatic site selection and identification to the TACAN when it is in the GPC mode.

Three displays can also be interfaced to the TACAN during flight operations: These are the GNC system summary 1, HSD, and on-orbit sensor self test. These displays allow the crew to determine the status and health of the TACAN LRUs and to select/deselect LRUs. An annunciation module is interfaced to TACAN outputs, and it warns the crew of TACAN failures and dilemmas.

The FCOS provides a testing of the signal structure to each LRU and fails that LRU through comfaulting when the signal structure is bad.

One display, the HSI, can utilize TACAN data indirectly through Area Navigation.

REPRODUCTION OF THIS DOCUMENT IS PROHIBITED



FOLDOUT FRAME

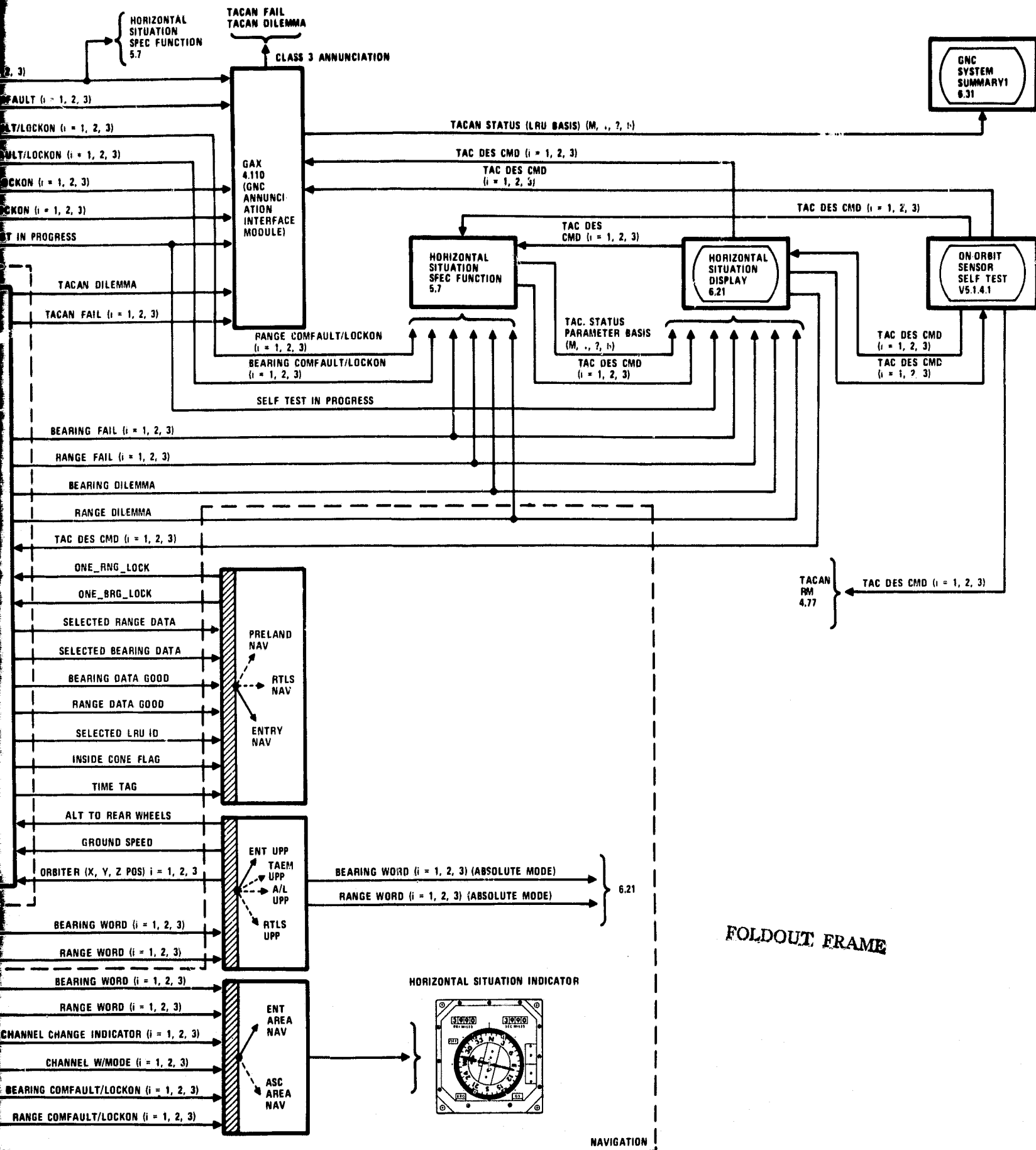


Figure 6-1.— Overall signal interface diagram of the TACAN SOP and RM unit.

7. SPACE SHUTTLE USAGE OF TACAN DATA

The primary use of TACAN data by the Space Shuttle is navigation. Navigation normally uses inertial measurement units (IMUs) in developing position and velocity (state vectors) and then updates the Space Shuttle state vector. Unfortunately, errors in position grow exponentially with time if this is the only means of updating measurements. For this reason, several sensors that obtain external data are utilized to refine this update of the state vector to obtain the accuracies required for safe operation of the Space Shuttle.

The sensors utilized for these updates obtain drag measurements, barometric measurements, TACAN, MSBLS, and radar altimeter data. Each of these measurements can provide one or more of three parameters necessary for a complete update of the state vector. A table of these update systems and the measurements that they provide is as follows.

Measurement		
Range	Azimuth	Altitude
		Drag
		Barometer
TACAN	TACAN	TACAN*
MSBLS	MSBLS	MSBLS
		Radar altimeter

*The altitude of the Shuttle can be estimated if the spacecraft directly overflies the TACAN station; the range measurement then becomes altitude.

MSBLS data are the primary sensor data desired because they provide data to calculate a complete update to the state vector. Unfortunately, the data are only available on final approach.

Sensors such as TACAN must be utilized with other sensors for a complete state vector update. The combinations of usage by navigation for each of these external sensors with respect to the Space Shuttle's altitude is shown in figure 7-1. A typical flight profile identifying how navigation utilizes these sensors is shown in figure 7-2.

Figure 7-2 shows the importance of TACAN data's availability to navigation after blackout to remove large down-track position errors. TACAN data and either drag or barometric measurements are used thereafter by navigation for state vector updates until about 20,000 feet. At this range, the MSBLS begins to acquire its ground station.

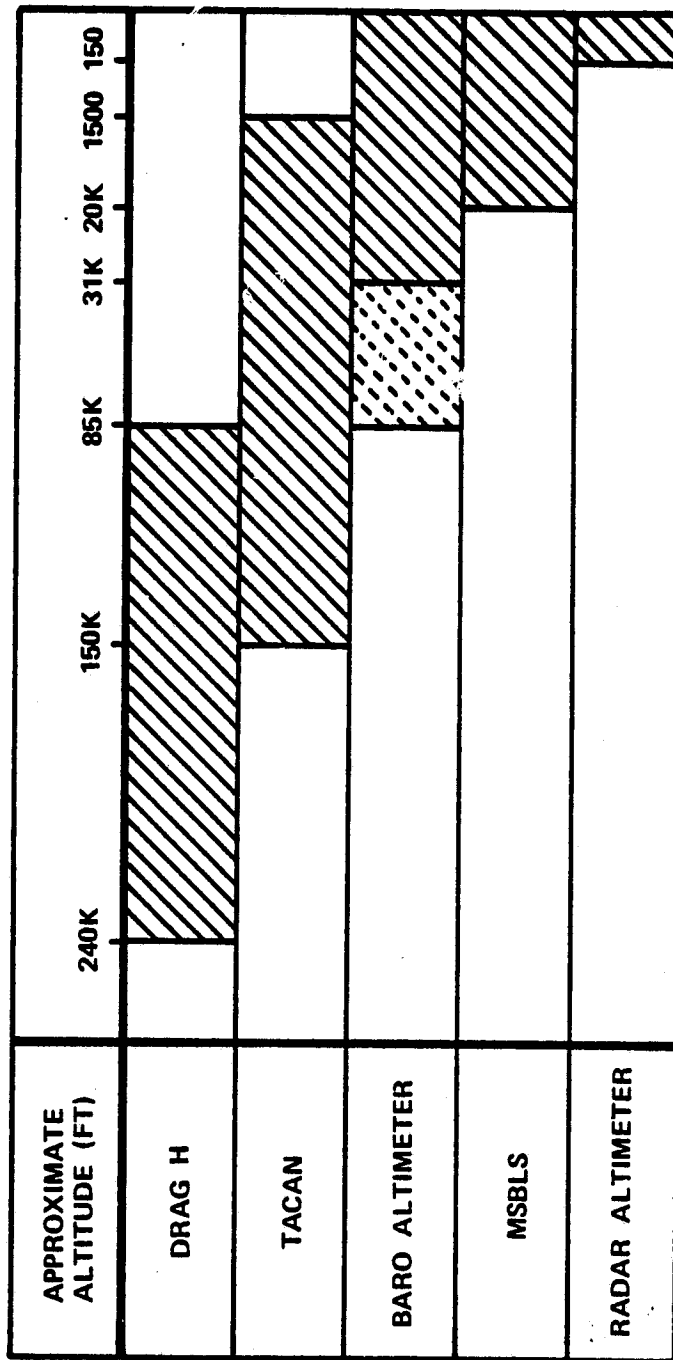


Figure 7-1.- External navigation sensor availability (from ref. 14).

STS-1 FLIGHT PROFILE OVERVIEW

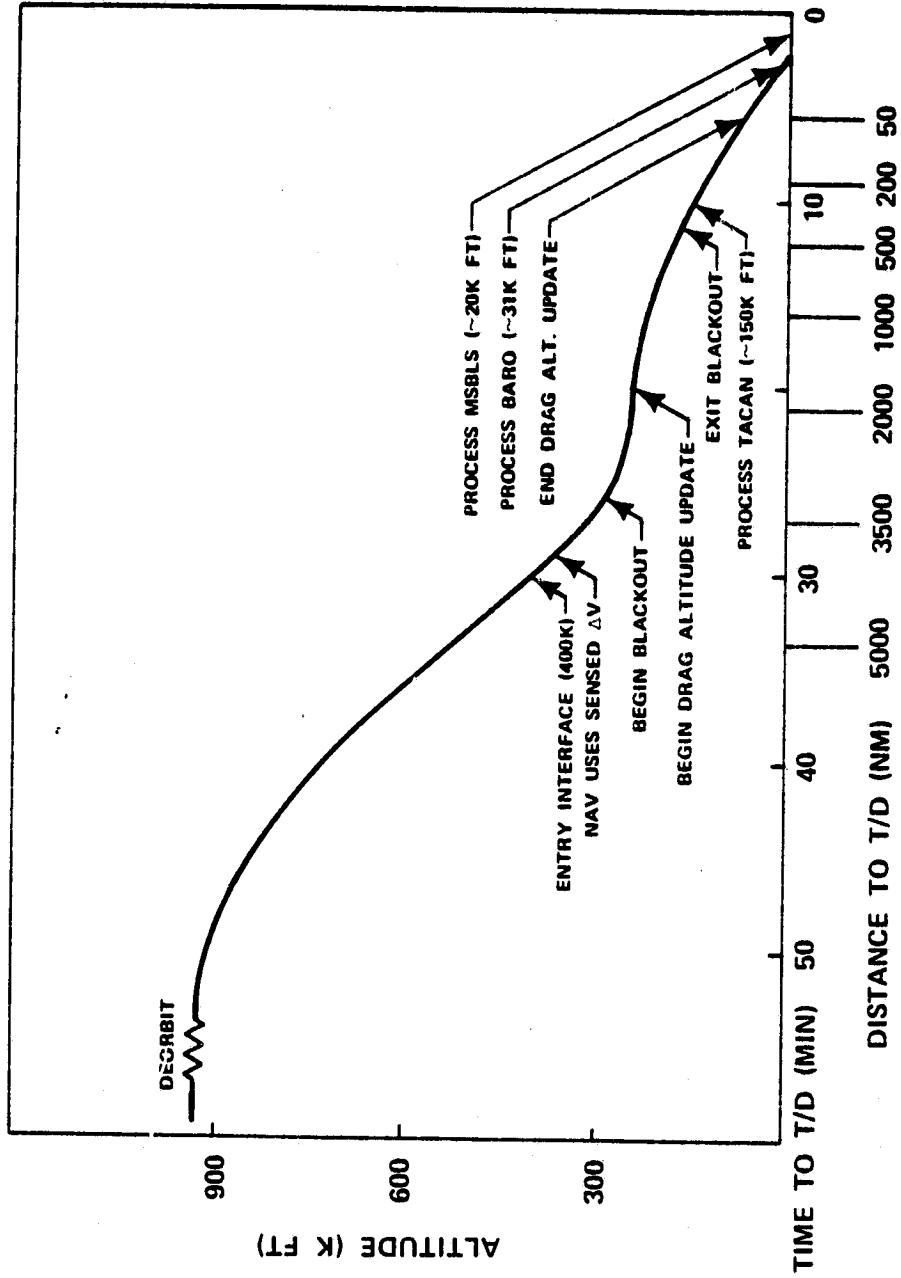


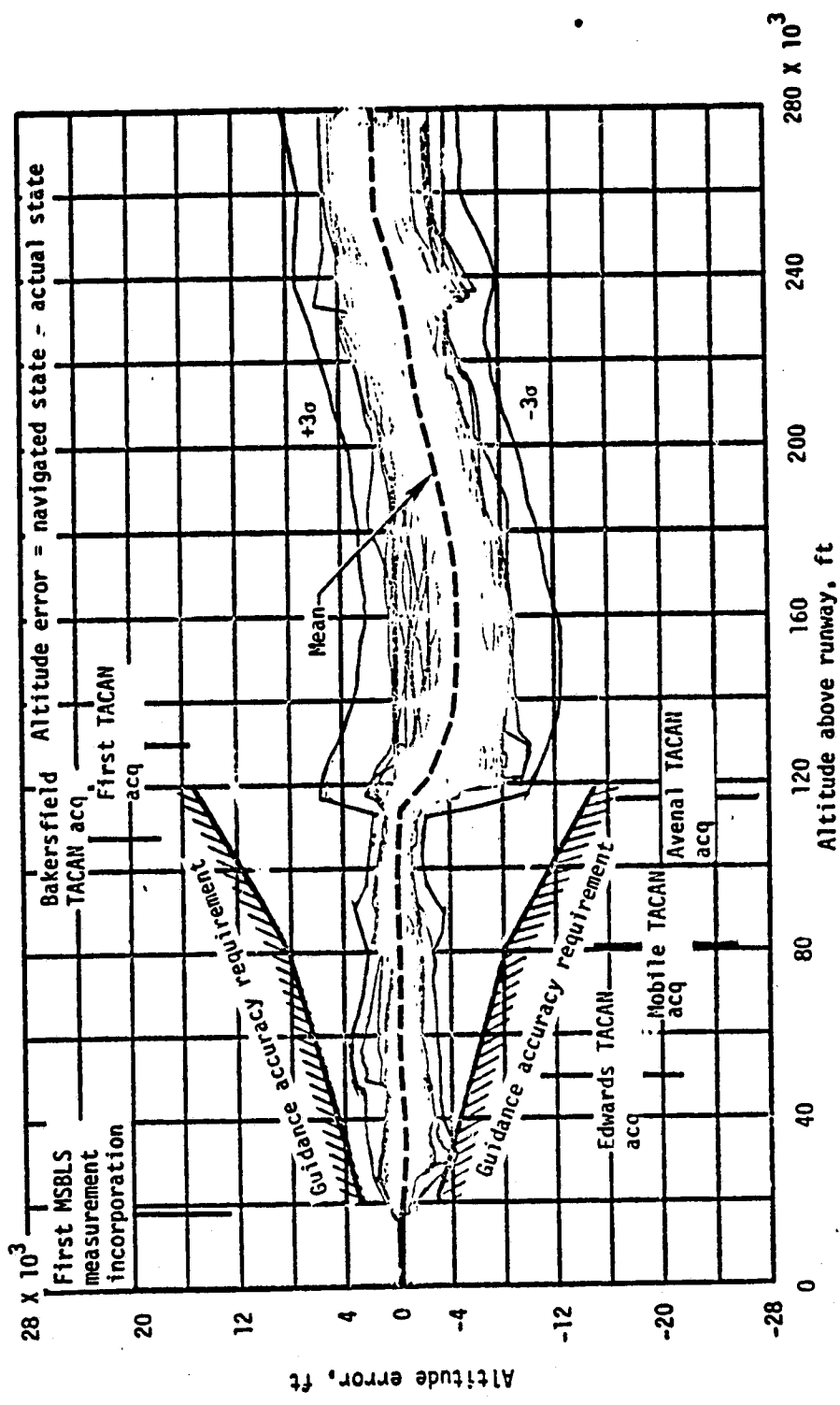
Figure 7-2.- STS-1 flight profile. (From ref. 14)

8. ANTICIPATED TACAN PERFORMANCE

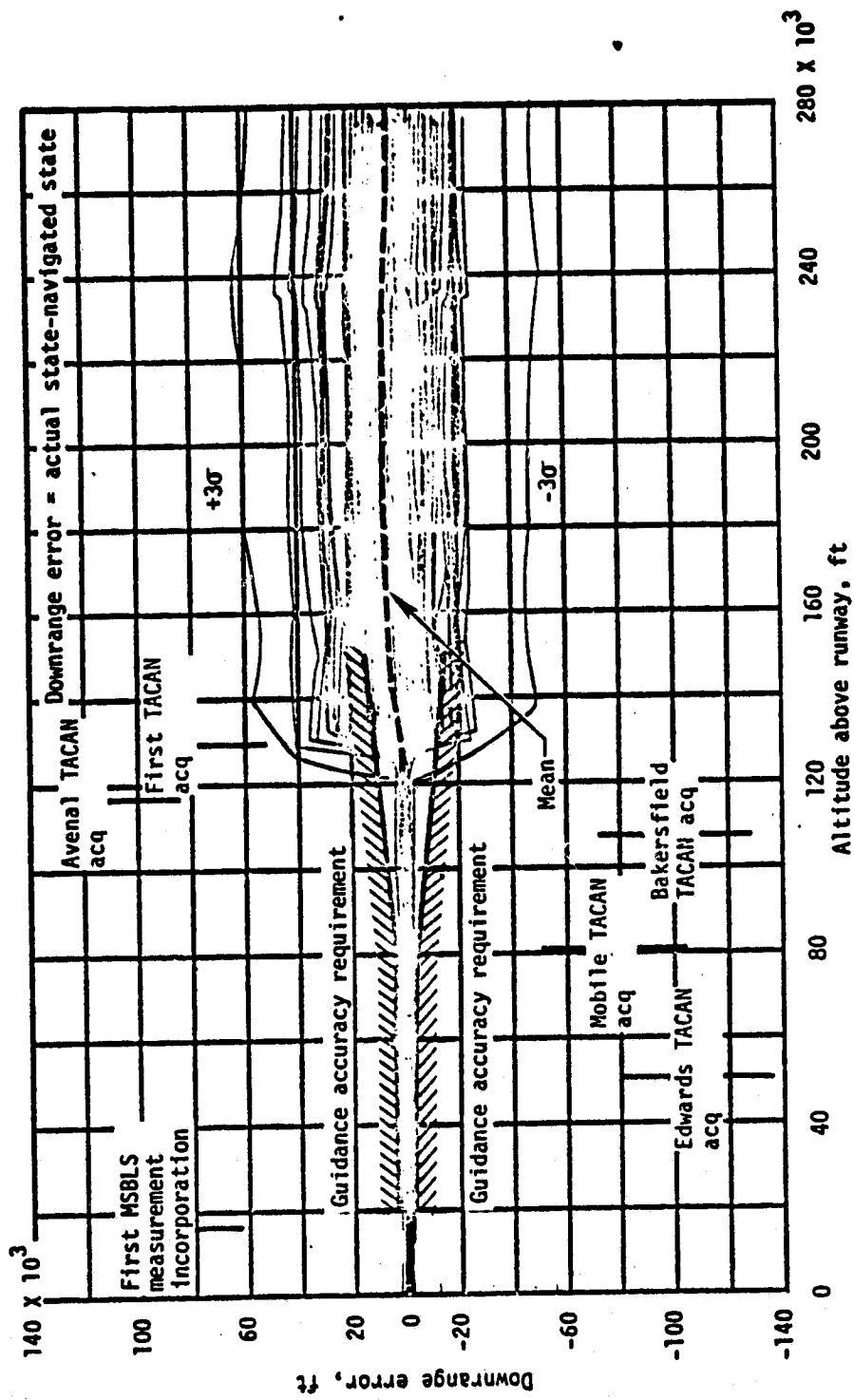
It is anticipated that the two LRU lock-on requirements will be met and data passed from the TACAN software to Space Shuttle navigation by 150,000 feet. From the time of initial lock-on until acquisition of MSBLS data, losses will occur when changing stations and when in the cone of confusion for a particular TACAN station. Only very limited data losses are expected to occur as a result of low signal levels.

In most cases, the data passed to Navigation are expected to be the result of a two-LRU average. This results because the two-unit case is the most probable for the greatest portion of the TACAN coverage region.

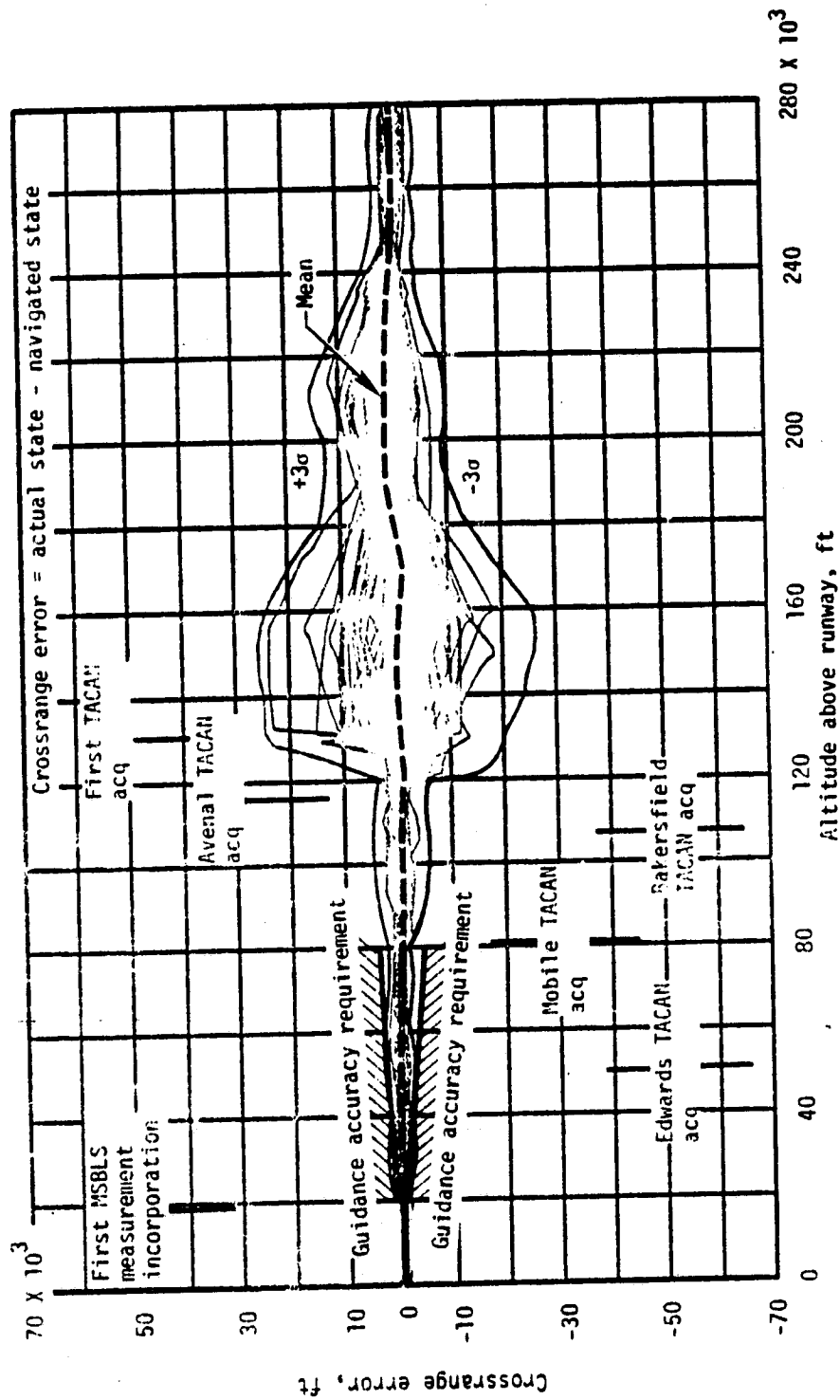
The anticipated improvement in the navigated state vector performance for a normal end-of-mission trajectory with landing at Edwards Air Base, California is shown in figure 8-1 (ref. 15, pages 45-47). These curves are based on a nonlinear Monte Carlo dispersion analysis for the STS-1 Orbiter Descent Operational Flight Profile, Cycle 2. Fifty randomly selected simulations for the end-of-mission descent were utilized. These curves show that immediate improvement occurs in navigational estimates after first TACAN acquisition and the continued use of TACAN until MSBLS acquisition is essential to final mission success.



(a) Altitude error.
 Figure 8-1.- Navigated state vector performance - end of mission.



(b) Downrange error.
Figure 8-1.- Continued.



(c) Crossrange error.
Figure 8-1.- Concluded.

9. REFERENCES

1. Heath, David; Hansen, J. Ann; Moore, Richard; et al.: STS-1 Operational Flight Profile. Vol. V, Descent-Cycle 2. JSC-14483, Feb. 1979.
2. STS-2 Conceptual Flight Profile, Mission Planning and Analysis Division, National Aeronautics and Space Administration, 79-FM-18, June 1979.
3. OFT User's Guide, IBM Federal Systems Division, 78-SS-4042, IRD # 209, December 11, 1978 (Revision 18 dated July 10, 1979).
4. SD76-SH0020C, Level C FSSR, Display and Controls (Dec. 15, 1978 with change notices 1 & 2 through Apr. 13, 1979).
5. Hughes, C. L.: NAVAID/Display Interfaces, Lockheed Electronics Company, LEC-13168, Feb. 1979.
6. Orbital Flight Test (OFT) Detailed Design Specifications, Volume III - Applications: Guidance, Navigation and Control, Prepared by IBM under NAS 9-14444, Dec. 11, 1978.
7. Level C Functional Subsystem Software Requirements Document: Guidance, Navigation, and Control. Part E, Navigation Aids Subsystem Operating Program. SD76-SH-0014A, Mar. 1979 (change notice dated Apr. 15, 1979).
8. SD76-SH-0010D, Level C FSSR, GN&C (Part D), Redundancy Management (Dec. 15, 1978 with change notice Mar. 1, 1979).
9. SD76-SH-0004D, Level C FSSR, GN&C (Part B) Entry Through Landing Navigation (Dec. 15, 1979 with change notices 1 & 2 through Apr. 15, 1979).
10. SD76-SH-0005C, Level C FSSR, GN&C (Part B) Navigation: Ascent/RTLS (Nov. 15, 1978 with change notices 1 & 2 through Apr. 15, 1979).
11. SD 74-SH-0230C, Data Processing Subsystem Principles of Operation, Apr. 1978.
12. STS-1 Entry Pocket Checklist, JSC-14893, Preliminary, Revision C, Sept. 26, 1979.
13. STS Ascent Pocket Checklist, JSC-14891, Preliminary, Revision B, July 10, 1979.

14. Heck, M. L.: MPAD Entry Navigation Presentation to D. Slayton, FM83(78-274) July 6, 1978.
15. Montez, Moises M.: STS-1 Operational Flight Profile, Vol. V, Descent-Cycle 2, Appendix C, Monte Carlo Dispersion Analysis, JSC-14483, May 1979.

APPENDIX A
GNC OPERATIONAL SEQUENCES AND MAJOR MODES

APPENDIX A

GNC OPERATIONAL SEQUENCES AND MAJOR MODES

Combinations of operational sequences, major modes, and functions completely specify the GNC software configuration and processing at a given time. Only certain combinations and transitions are allowed by the GNC software.

REVERSE PAGE BLANK NOT FILMED

TABLE A-1.- OFT GNC OPERATIONAL SEQUENCES AND MAJOR MODES

OPS 1. ASCENT OPERATIONS

101 TERMINAL COUNT
102 FIRST STAGE
103 SECOND STAGE
104 CMS 1 INSERTION
105 CMS 2 INSERTION
106 INSERTION COAST

OPS 2. ORBIT OPERATIONS

201 ORBIT COAST
202/212 MANEUVER EXECUTE
211 RENDEZVOUS NAVIGATION
213 TPF/STATION KEEPING

OPS 3. ENTRY OPERATIONS

301 PREDEORBIT COAST
302 DEORBIT EXECUTE
303 PRE-ENTRY MONITOR
304 ENTRY
305 TAEM

OPS 5. DELETED

OPS 6. RETURN TO LAUNCH SITE (RTLS) OPERATIONS

601 RTLS SECOND STAGE
602 RTLS ENTRY
603 RTLS TAEM

OPS 8. ORBIT CHECKOUT OPERATIONS

OPS 9. GROUND CHECKOUT OPERATIONS

APPENDIX B
COMPUTER INTERFACE WORDS BETWEEN THE MDM AND THE GPC

APPENDIX B

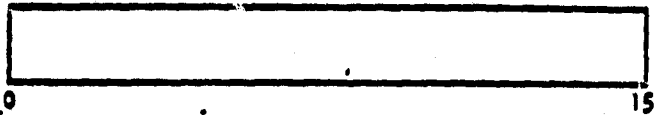
COMPUTER INTERFACE WORDS BETWEEN THE MDM AND THE GPC

The computer interface words between the MDM and the GPC are given in figures B-1 (MDM to GPC range words), B-2 (MDM to GPC bearing words), B-3 (TACAN to MDM range word), and B-4 (TACAN to MDM bearing word). The TACAN control register format (table B-1) and the TACAN discrete word format (table B-2) are also presented.

PRECEDING PAGE BLANK ~~AND~~ NOT FILMED

RANGEWORD

TACRANGA



TACRANGB



BITS

- 0 & 1
 - = "00" VALID DATA
 - = "01" SELF-TEST FAILURE
 - = "10" NO COMPUTED DATA
 - = "11" NOT USED
- 2 & 3 100'S N. MILES
- 4 THRU 7 10'S N. MILES
- 8 THRU 11 1'S N. MILES
- 12 THRU 15 1/10'S N. MILES
- 16 THRU 19 1/100'S N. MILES
- 20 *
- 21 & 22
 - = "00" NOT IN SELF-TEST
 - = "11" IN SELF-TEST
 - = "10" NOT USED
 - = "01" NOT USED
- 23 *
- 24 THRU 31 LABEL = 10001001

*DON'T CARE BITS IN R/W

Figure B-1.- MDM to GPC range words. (From ref. 7.)

BEARING WORD

TACBEARA



0

15

TACSEARB



16

31

BITS

0 - PARITY

1 & 2 = '00' LESS THAN 180 DEGREES
- '01' SELF-TEST FAILURE
- '10' NO COMPUTED DATA
- '11' 180 DEGREES OR GREATER

3 - 90.0000°

4 - 45.0000°

5 - 22.5000°

6 - 11.2500°

7 - 5.6250°

8 - 2.8125°

9 - 1.40625°

10 - 0.703125°

11 - 0.3515625°

12 - 0.1757812°

13 - 0.0878956°

14 - 0.0439453°

15 THRU 20*

21 & 22 = '00' NOT IN SELF-TEST

- '11' IN SELF-TEST

- '10' NOT USED

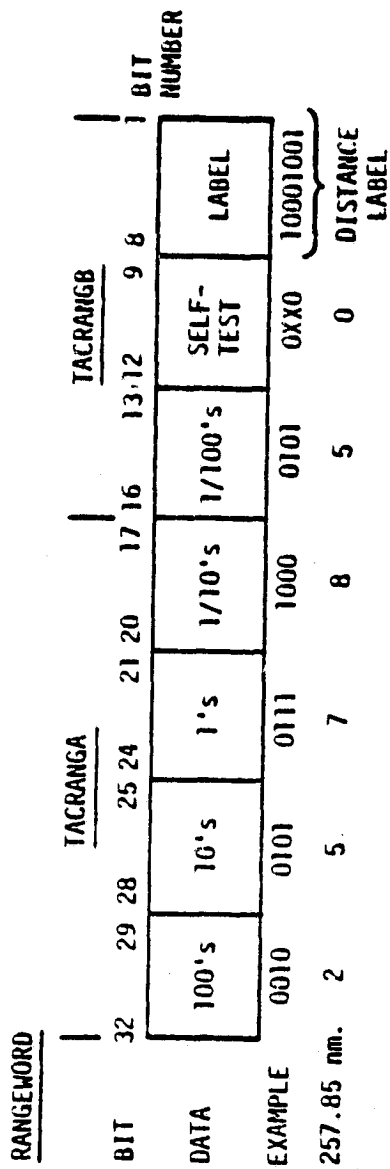
- '01' NOT USED

23 *

24 THRU 31 LABEL = 0000 0001

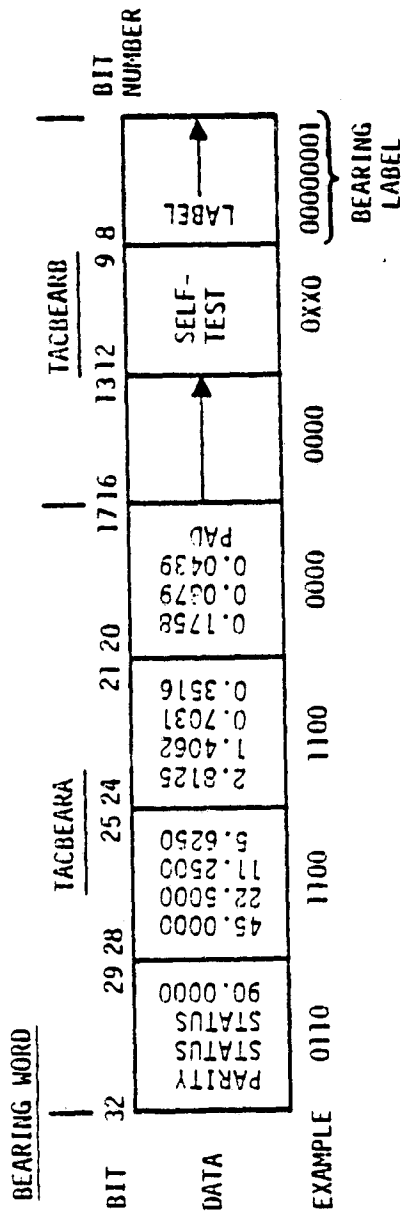
*DON'T CARE BITS IN H/W

Figure B-2.— MDM to GPC bearing words. (From ref. 7.)



32	31	11	10	BIT
0	0	-	-	VALID DATA (TRACK OR SHORT-TERM MEMORY)
0	1	-	-	SELF-TEST FAILURE
1	0	-	-	NO COMPUTED DATA (SEARCH OR LONG-TERM MEMORY)
1	1	-	-	NOT USED
-	-	0	0	NOT IN SELF-TEST
-	-	1	1	IN SELF-TEST
-	-	0	1	NOT DEFINED
-	-	1	0	NOT DEFINED

Figure B-3.- TACAN to MDM range word.



1251.7187

31	30	11	10	BIT
0	0	-	-	LESS THAN 180 DEGREES (TRACK OR SHORT-TERM MEMORY)
0	1	-	-	SELF-TEST FAILURE
1	0	-	-	NO COMPUTED DATA (NO OR UNUSEABLE SIGNAL)
1	1	-	-	180 DEGREES OR GREATER (TRACK OR SHORT-TERM MEMORY)
-	-	0	0	NOT IN SELF-TEST
-	-	1	1	IN SELF-TEST
-	-	0	1	NOT DEFINED
-	-	1	0	NOT DEFINED

NOTE: BIT 32 IS ALWAYS SET FOR ODD PARITY
BINARY VALUES ROUNDED

Figure B-4.— TACAN to MDM bearing word.

TABLE B-1.- TACAN CONTROL REGISTER FORMAT

[From ref. 7]

Bit no.	Function	Comment
0	Sync	Always 1
1	Spare	*
2	X/Y mode	1 = Y, 0 = X
3	A/A	0 = not air to air
4	T/R, R	1 = T/R, 0 = R
5	Spare	*
6	Spare	*
7	Channel selection	1 units
8	Channel selection	2 units
9	Channel selection	4 units
10	Channel selection	8 units
11	Channel selection	10 tens
12	Channel selection	20 tens
13	Channel selection	40 tens
14	Channel selection	80 tens
15	Self test	1 = test
16-31	Set to 0 by MDM	

*"Don't-care" bits in hardware.

TABLE B-2.- TACAN DISCRETE WORD FORMAT^a

[From ref. 7]

Bit no.	Function	Comment
0	Channel selection	100 hundreds
1	Power on discrete	1 = Power On
2	X/Y mode	1 = Y, 0 = X
3	Test status monitor	1 = Good
4	T/R, R	1 = T/R, 0 = R
5	Radar altimeter	
6	Radar altimeter	
7	Channel selection	1 units
8	Channel selection	2 units
9	Channel selection	4 units
10	Channel selection	8 units
11	Channel selection	10 tens
12	Channel selection	20 tens
13	Channel selection	40 tens
14	Channel selection	80 tens
15	Spare	

^aFor TACAN channel numbers >100, bits 11 to 14 of the control word differ from bits 11 to 14 and 0 of the discrete word.

APPENDIX C
SIGNAL INTERFACE TABLES

APPENDIX C
SIGNAL INTERFACE TABLES

The input functional parameters for the TACAN RM module (table C-1) and for the TACAN SOP module (table C-2) are presented on the following pages.

PRECEDING PAGE BLANK NOT FILMED

TABLE C-1.- INPUT/OUTPUT FUNCTIONAL PARAMETERS FOR THE TACAN RM MODULE

M/S ID	INPUT FUNCTIONAL PARAMETERS FOR THE TACTICAL AIR NAVIGATION RM MODULE (TACAN RM.4.77)	SYMBOL	UNITS
V55H0165CA	ALT TO REAR WHEELS/NAV BASE(ENTRY)	RTLS UP	FT
V55L0178CA	GROUND SPEED	RTLS UP	FT
V55H0155CB	ORBITER X POSITION EF(100)	RTLS UP	FT
V55H0156CB	ORBITER Y POSITION EF(100)	RTLS UP	FT
V55H0157CB	ORBITER Z POSITION EF(100)	RTLS UP	FT
V55H0155CA	ORBITER X POSITION EF(100)	ENT UP	FT
V55H0156CA	ORBITER Y POSITION EF(100)	ENT UP	FT
V55H0157CA	ORBITER Z POSITION EF(100)	ENT UP	FT
V55L0178CA	ALT TO REAR WHEELS/NAV BASE(ENTRY)	ENT UP	FT
V55L0178CA	GROUND SPEED	ENT UP	FT
V55H0155CC	GROUND SPEED	TAEM UP	FT/S
V55H0155CC	ALT TO REAR WHEELS/NAV BASE(ENTRY)	TAEM UP	FT
V55H0155CC	ORBITER X POSITION EF(100)	TAEM UP	FT
V55H0155CC	ORBITER Y POSITION EF(100)	TAEM UP	FT
V55H0155CC	ORBITER Z POSITION EF(100)	TAEM UP	FT
V55L0178CC	GROUND SPEED	TAEM UP	FT/S
V55L0178CC	ALT TO REAR WHEELS/NAV BASE(ENTRY)	A/L UP	FT
V55L0178CC	ORBITER X POSITION EF(100)	A/L UP	FT
V55L0178CC	ORBITER Y POSITION EF(100)	A/L UP	FT
V55L0178CC	ORBITER Z POSITION EF(100)	A/L UP	FT
V55L0178CC	TACAN TIME TAG	TACAN SOP	FT
G04203	TACAN NO 1 RANGE OUT	TACAN SOP	0. 2432000 FT
G04208	TACAN NO 1 BEARING OUT	TACAN SOP	0. 1
G46579	TACAN NO 1 BEARING LOCKED ON	TACAN SOP	0. 6.28
G46580	TACAN NO 1 CHANNEL W/NODE	TACAN SOP	0. 1
G46581	TACAN NO 2 RANGE OUT	TACAN SOP	0. 2432000 FT
G46582	TACAN NO 2 BEARING OUT	TACAN SOP	0. 1
G46583	TACAN NO 2 BEARING LOCKED ON	TACAN SOP	0. 6.28
G46584	TACAN NO 2 CHANNEL W/NODE	TACAN SOP	0. 1
G46585	TACAN NO 3 RANGE OUT	TACAN SOP	0. 2432000 FT
G46586	TACAN NO 3 BEARING OUT	TACAN SOP	0. 1
G46587	TACAN NO 3 BEARING LOCKED ON	TACAN SOP	0. 6.28
G46588	TACAN NO 3 CHANNEL W/NODE	TACAN SOP	0. 1
G46589	TACAN 1 CHANNEL CHANGE INDICATOR	TACAN SCP	0. 1
G46590	TACAN 2 CHANNEL CHANGE INDICATOR	TACAN SCP	0. 1
G46591	TACAN 3 CHANNEL CHANGE INDICATOR	TACAN SCP	0. 1
G46592	TACAN NO 1 BEARING SELF TEST FAIL	TACAN SCP	0. 1
G46593	TACAN NO 2 BEARING SELF TEST FAIL	TACAN SCP	0. 1
G46594	TACAN NO 3 BEARING SELF TEST FAIL	TACAN SCP	0. 1
G46595	TACAN NO 1 RANGE SELF TEST FAIL	TACAN SCP	0. 1
G46596	TACAN NO 2 RANGE SELF TEST FAIL	TACAN SCP	0. 1
G46597	TACAN NO 3 RANGE SELF TEST FAIL	TACAN SCP	0. 1
G46598	TACAN SELF TEST IN PROGRESS	TACAN SCP	0. 1
G25804	X-COMP EF POS VECTOR OF TACAN 1	ENT SITE LOOKUP	FT
G25805	Y-COMP EF POS VECTOR OF TACAN 1	ENT SITE LOOKUP	FT
G25806	Z-COMP EF POS VECTOR OF TACAN 1	ENT SITE LOOKUP	FT
V55H0183CA	X-COMP EF POS VECTOR OF TACAN 2	ENT SITE LOOKUP	FT
V55H0183CA	Y-COMP EF POS VECTOR OF TACAN 2	ENT SITE LOOKUP	FT
V55H0183CA	Z-COMP EF POS VECTOR OF TACAN 2	ENT SITE LOOKUP	FT

TABLE C-1.- Concluded.

M.S. ID		INPUT FUNCTIONAL PARAMETERS FOR THE TACTICAL AIR NAVIGATION RM MODULE (TACAN RM.4.77)		RANGE		UNITS	
LEVEL	NO.	SYMBOL	DESCRIPTION	SOURCE			
V001839C	G25900	R_TACAN_EF_SL(3)	Z-COMP EF POS VECTOR OF TACAN 2	ENT SITE LOOKUP		FT	
V001840C	G25910	X-COMP EF POS VECTOR OF TACAN 3	X-COMP EF POS VECTOR OF TACAN 3	ENT SITE LOOKUP		FT	
V001841C	G25911	Y-COMP EF POS VECTOR OF TACAN 3	Y-COMP EF POS VECTOR OF TACAN 3	ENT SITE LOOKUP		FT	
V001842C	G25912	Z-COMP EF POS VECTOR OF TACAN 3	Z-COMP EF POS VECTOR OF TACAN 3	ENT SITE LOOKUP		FT	
V001843C	G25913	ONE_RANGE_LOCK	TACAN RM 1 LRU RING LOCKON RQMT FLG	ENT NAV	0.1		
V001844C	G25914	ONE_DRG_LOCK	TACAN RM 1 LRU DRG LOCKON RQMT FLG	ENT NAV	0.1		
V001845C	G25915	ONE_IRS_LOCK	TACAN RM 1 LRU IRS LOCKON RQMT FLG	PRELMD NAV	0.1		
V001846C	G25916	ONE_RNG_LOCK	TACAN RM 1 LRU RNG LOCKON RQMT FLG	PRELMD NAV	0.1		
V001847C	G25917	ONE_ID_LOCK	TACAN RM 1 LRU ID LOCKON RQMT FLG	PRELMD NAV	0.1		
V001848C	G25918	AUTO_ID_CHANGED	CHANGE IN CHANNEL ID	ASC AUTO TAC SEL	0.1		
V001849C	G25919	ID_CHANGE_REQUEST	ID CHANGE REQUEST RESET	ASC AUTO TAC SEL	0.1		
V001850C	G25920	R_TACAN_EF_SL(1)	X-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP		FT	
V001851C	G25921	Y-COMP EF POS VECTOR OF TACAN 1	Y-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP		FT	
V001852C	G25922	Z-COMP EF POS VECTOR OF TACAN 1	Z-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP		FT	
V001853C	G25923	R_TACAN_EF_SL(2)	X-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP		FT	
V001854C	G25924	Y-COMP EF POS VECTOR OF TACAN 2	Y-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP		FT	
V001855C	G25925	Z-COMP EF POS VECTOR OF TACAN 2	Z-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP		FT	
V001856C	G25926	R_TACAN_EF_SL(3)	X-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP		FT	
V001857C	G25927	Y-COMP EF POS VECTOR OF TACAN 3	Y-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP		FT	
V001858C	G25928	Z-COMP EF POS VECTOR OF TACAN 3	Z-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP		FT	
V001859C	G25929	AUTO_ID_CHANGED	CHANGE IN CHANNEL ID	ENT AUTO TAC SEL			
V001860C	G25930	ID_CHANGE_REQUEST	ID CHANGE REQUEST RESET	ENT AUTO TAC SEL			
V001861C	G25931	TACAN 1 DES CMD	TACAN 1 DES CMD	6.21	0.1		
V001862C	G25932	TACAN 2 DES CMD	TACAN 2 DES CMD	6.21	0.1		
V001863C	G25933	TACAN 3 DES CMD	TACAN 3 DES CMD	6.21	0.1		
V001864C	G25934	TACAN 1 COMM FAULT	TACAN 1 COMM FAULT	FCUS	0.1		
V001865C	G25935	TACAN 2 COMM FAULT	TACAN 2 COMM FAULT	FCUS	0.1		
V001866C	G25936	TACAN 3 COMM FAULT	TACAN 3 COMM FAULT	FCUS	0.1		
V001867C	G25937	TACAN 1 DES CMD	TACAN 1 DES CMD	V5.1.4	0.1		
V001868C	G25938	TACAN 2 DES CMD	TACAN 2 DES CMD	V5.1.4	0.1		
V001869C	G25939	TACAN 3 DES CMD	TACAN 3 DES CMD	V5.1.4	0.1		
V001870C	G25940	TACPOD(1)	TACAN NO 1 POWER STATUS	TACAN 1	0.1		
V001871C	G25941	TACPOD(2)	TACAN NO 2 POWER STATUS	TACAN 2	0.1		
V001872C	G25942	TACPOD(3)	TACAN NO 3 POWER STATUS	TACAN 3	0.1		

TABLE C-1.- Continued.

M/S ID		OUTPUT FUNCTIONAL PARAMETERS FROM THE TACTICAL AIR NAVIGATION MM MODULE (TACAN MM, 4.771)		SIS-2 REV300		PAGE 70	
LEVEL & NO.		DESCRIPTION		RANGE		UNITS	
V90J3501X	G15901	TACAN 1 FAIL	GAK	0.1			
V90J3701X	G15902	TACAN 2 FAIL	GAK	0.1			
V90J3801X	G15903	TACAN 3 FAIL	GAK	0.1			
V90J3602C	TAC STGEO	TACAN SELF TEST REQUEST	TACAN SGP	0.3			BITS
V90J3592C	OUT_SEL_RNG	SELECTED RANGE DATA	ENT NAV, PRELAND NAV, RTLS NAV.				FT
V90J3596C	OUT_SEL_BRG	SELECTED BEARING DATA	ENT NAV, PRELAND NAV, RTLS NAV.	0.360			DEG
V90J3591X	G50307	BEARING DATA GOOD	ENT NAV, PRELAND NAV, RTLS NAV.	0.1			
V90J3593X	G50306	RANGE DATA GOOD	ENT NAV, PRELAND NAV, RTLS NAV.	0.1			
V90J3600X	G50991	TACAN BEARING 1 FAIL	TLM	0.1			
V90J3700X	G50992	TACAN BEARING 2 FAIL	TLM	0.1			
V90J3608X	G50993	TACAN BEARING 3 FAIL	TLM	0.1			
V90J3711X	G50994	TACAN RANGE 1 FAIL	TLM	0.1			
V90J3811X	G50995	TACAN RANGE 2 FAIL	TLM	0.1			
V90J3911X	G50996	TACAN RANGE 3 FAIL	TLM	0.1			
V90J3604X	G50997	TACAN BEARING DILEMMA FLAG	TLM	0.1			
V90J3605X	G50998	TACAN RANGE DILEMMA FLAG	TLM	0.1			
V90J3599X	G50999	TACAN DILEMMA	TLM	0.1			
V90J3598X	G14426	INSIDE CONE FLAG	ENT AUTO TAC SEL	0.1			
V90J3595C	T_TACAN	SELECTED LRU ID	ASC AUTO TAC SEL, TLM	0.1			
V90J3596C	T_TACAN	TACAN TIME TAG	ENT NAV, PRELAND NAV, RTLS NAV.	1.3			
V90J0720CD	G50935	TACAN/SHUTTLE ELEV ANG	TLM	0.90			CEG

TABLE C-2.- INPUT/OUTPUT FUNCTIONAL PARAMETERS FOR THE TACAN SOP MODULE

JULY 16, 1979		SIS-2 REV300		PAGE 349	
R/S ID	INPUT FUNCTIONAL PARAMETERS FOR THE TACAN SOP MODULE (TACAN SOP.4.43)	DESCRIPTION	SOURCE	RANGE	UNITS
V90J3602C	TAC_STREQ	TACAN SELF TEST REQUEST	TACAN RW	0. 2	BITS
V95N2111X	SOURCE_LEFT	LH HSI SOURCE SELECT	GNSC SM RM	0. 1	
V96A2111X	SOURCE_RIGHT	RH HSI SOURCE SELECT	GNSC SM RM	0. 1	
V96J2105C	RCVR_LEFT	LH HSI RECEIVER SELECT	GNSC SM RM	1. 3	
V99J265C	RCVR_RIGHT	RH HSI RECEIVER SELECT	GNSC SM RM	1. 3	
V99J1242A	AUTO_CHANNEL_ID	TACAN CHANNEL SELECTION	ASC AUTO TAC SEL	1. 126	
V99J1242B	AUTO_CHANNEL_ID	TACAN CHANNEL SELECTION	ERT AUTO TAC SEL	1. 126	
V91X3502A	TAC_CF(1)	TACAN 1 COMB FAULT	FC05	0. 1	
V91X3510A	TAC_CF(2)	TACAN 2 COMB FAULT	FC05	0. 1	
V91X3520X	TAC_CF(3)	TACAN 3 COMB FAULT	FC05	0. 1	
V91X500C	CLOCK	CLOCK-COMPUTER(GMT)	FC05	0. 1	S
V72M1530P	TACBEAR(1)	TACAN 1 BEARING WORD A	ND1 TACAN 1	0. 360	DEG
V72M1531P	TACBEAR(1)	TACAN 1 BEARING WORD B	WD2 TACAN 1	0. 360	DEG
V72M1550P	TACRANG(1)	TACAN 1 RANGE WORD A	ND1 TACAN 1	0. 400	MM
V72M1551P	TACRANG(1)	TACAN 1 RANGE WORD B	WD2 TACAN 1	0. 400	MM
V72M1630P	TAC_T5(1)	TACAN NO 1 TEST STATUS MONITOR	ND1 TACAN 1	0. 1	
V72M1631P	TACBEAR(2)	TACAN 2 BEARING WORD A	ND1 TACAN 2	0. 360	DEG
V72M1632P	TACBEAR(2)	TACAN 2 BEARING WORD B	WD2 TACAN 2	0. 360	DEG
V72M1650P	TACRANG(2)	TACAN 2 RANGE WORD A	ND1 TACAN 2	0. 400	MM
V72M1651P	TACRANG(2)	TACAN 2 RANGE WORD B	WD2 TACAN 2	0. 400	MM
V72M1730P	TAC_TSM(2)	TACAN NO 2 TEST STATUS MONITOR	ND1 TACAN 2	0. 1	
V72M1731P	TACBEAR(3)	TACAN 3 BEARING WORD A	ND1 TACAN 3	0. 360	DEG
V72M1732P	TACBEAR(3)	TACAN 3 BEARING WORD B	WD2 TACAN 3	0. 360	DEG
V72M1750P	TACRANG(3)	TACAN 3 RANGE WORD A	ND1 TACAN 3	0. 400	MM
V72M1751P	TACRANG(3)	TACAN 3 RANGE WORD B	WD2 TACAN 3	0. 400	MM
V72M2000X	TAC_TSM(3)	TACAN NO 3 TEST STATUS MONITOR	ND1 TACAN 3	0. 1	
V72M2102A		TACAN NO 1 CONTROL WORD	DSC PNL		
V72M2103A		TACAN NO 2 CONTROL WORD	DSC PNL		
V72M2110PA		TACAN NO 3 CONTROL WORD	DSC PNL		
V72M2557P		MCM FF01 DSCR IN CD 09 CH 02	MDWR		
V72M2607P		MCM FF02 DSCR IN CD 09 CH 02	MDWR		
V72M2659P		MCM FF03 DSCR IN CD 00 CH 02	MDWR		
V72M2640P		MCM FF04 DSCR IN CD 00 CH 5	MDWR		
V72M2650P		MCM FF05 DSCR IN CD 00 CH 5	MDWR		
V72M26410X	TAC_GPC(1)	TACAN NO 1 AUTO DISCRETE(1) (COMPUTER)	MDWR	0. 1	
V72M26420X	TAC_GPC(2)	TACAN NO 2 AUTO DISCRETE(2) (COMPUTER)	MDWR	0. 1	
V72M26430X	TAC_GPC(3)	TACAN NO 3 AUTO DISCRETE(3) (COMPUTER)	MDWR	0. 1	

TABLE C-2. -- Continued.

M/S ID	OUTPUT FUNCTIONAL PARAMETERS FROM THE TACAN SOP MODULE (TACAN SOP 4.43)	SYMBOLIC NAME	DESCRIPTION	RANGE	UNITS
V9545001C	G07824 TAC_TLM TAG	TACAN TIME TAG	TACAN RW TLM		S
V9545102C	G07807 TAC_RANGE(1)	TACAN NO 1 RANGE OUT	ENT AREA NAV, ASC AREA NAV, TACAN RW TLM, ENT UP, TAEM UP, A/L UP, RTLS UP	0, 2432000	FT
V9545104X	G07815 TAC_RANGE(1)	TACAN NO 1 RANGE LOCKED ON	GAR, TACAN RW, TLM	0, 1	
V9545122C	G07811 TAC_BEARD(1)	TACAN NO 1 BEARING OUT	ENT AREA NAV, ASC AREA NAV, TACAN RW TLM, ENT UP, TAEM UP, A/L UP, RTLS UP	0, 6.28	RAD
V9545124X	G07818 TAC_BEARD(1)	TACAN NO 1 BEARING LOCKED ON	GAR, TACAN RW, TLM	0, 1	
V9545130C	G07821 TAC_CHAN(1)	TACAN NO 1 CHANNEL W/MODE	ASC AREA NAV, ENT AREA NAV, TACAN RW TLM	+/-126	
V9545202C	G07808 TAC_RANGE(2)	TACAN NO 2 RANGE OUT	ENT AREA NAV, ASC AREA NAV, TACAN RW TLM, ENT UP, TAEM UP, A/L UP, RTLS UP	0, 2432000	FT
V9545204X	G07816 TAC_RANGE(2)	TACAN NO 2 RANGE LOCKED ON	GAR, TACAN RW, TLM	0, 1	
V9545222C	G07812 TAC_BEARD(2)	TACAN NO 2 BEARING OUT	ENT AREA NAV, ASC AREA NAV, TACAN RW TLM, ENT UP, TAEM UP, A/L UP, RTLS UP	0, 6.28	RAD
V9545224X	G07819 TAC_BEARD(2)	TACAN NO 2 BEARING LOCKED ON	GAR, TACAN RW, TLM	0, 1	
V9545230C	G07822 TAC_CHAN(2)	TACAN NO 2 CHANNEL W/MODE	ASC AREA NAV, ENT AREA NAV, TACAN RW TLM	+/-126	
V9545302C	G07809 TAC_RANGE(3)	TACAN NO 3 RANGE OUT	ENT AREA NAV, ASC AREA NAV, TACAN RW TLM, ENT UP, TAEM UP, A/L UP, RTLS UP	0, 2432000	FT
V9545304X	G07817 TAC_RANGE(3)	TACAN NO 3 RANGE LOCKED ON	GAR, TACAN RW, TLM	0, 1	
V9545322C	G07813 TAC_BEARD(3)	TACAN NO 3 BEARING OUT	ENT AREA NAV, ASC AREA NAV, TACAN RW TLM, ENT UP, TAEM UP, A/L UP, RTLS UP	0, 6.28	RAD
V9545324X	G07820 TAC_BEARD(3)	TACAN NO 3 BEARING LOCKED ON	GAR, TACAN RW, TLM	0, 1	
V9545330C	G07823 TAC_CHAN(3)	TACAN NO 3 CHANNEL W/MODE	ASC AREA NAV, ENT AREA NAV, TACAN RW TLM	+/-126	
V9545140X	G51002 TRNG_CMLK(1)	TACAN 1 RANGE COMFAULT/LOCKON FLAG	ENT AREA NAV, ASC AREA NAV, S.7, TLM	0, 1	
V9545240X	G51003 TRNG_CMLK(2)	TACAN 2 RANGE COMFAULT/LOCKON FLAG	ENT AREA NAV, ASC AREA NAV, S.7, TLM	0, 1	
V9545340X	G51004 TRNG_CMLK(3)	TACAN 3 RANGE COMFAULT/LOCKON FLAG	ENT AREA NAV, ASC AREA NAV, S.7, TLM	0, 1	
V9545141X	G50999 TRBG_CMLK(1)	TACAN 1 BEAR COMFAULT/LOCKON FLAG	ENT AREA NAV, ASC AREA NAV, S.7, TLM	0, 1	
V9545241X	G51000 TRBG_CMLK(2)	TACAN 2 BEAR COMFAULT/LOCKON FLAG	ENT AREA NAV, ASC AREA NAV, S.7, TLM	0, 1	
V9545341X	G51001 TRBG_CMLK(3)	TACAN 3 BEAR COMFAULT/LOCKON FLAG	ENT AREA NAV, ASC AREA NAV, S.7, TLM	0, 1	
V9545146X	TCH_CHNG(1)	TACAN 1 CHANNEL CHANGE INDICATOR	ENT AREA NAV, ASC AREA NAV, S.7, TLM	0, 1	
V9545246X	TCH_CHNG(2)	TACAN 2 CHANNEL CHANGE INDICATOR	ENT AREA NAV, ASC AREA NAV, S.7, TLM	0, 1	
V9545346X	TCH_CHNG(3)	TACAN 3 CHANNEL CHANGE INDICATOR	ENT AREA NAV, ASC AREA NAV, S.7, TLM	0, 1	
V9545143X	TAC_BRGFL(1)	TACAN NO 1 BEARING SELF TEST FAIL	TACAN RW	0, 1	
V9545243X	TAC_BRGFL(2)	TACAN NO 2 BEARING SELF TEST FAIL	TACAN RW	0, 1	

TABLE C-2.- Concluded.

M/S ID	OUTPUT FUNCTION... LEVEL B NO.	PARAMETERS FROM THE TACAN SOP MODULE (TACAN SOP, 4-43)	DESTINATION	RANGE	UNITS
V09K5343X	TAC_RNGFL(1)	TACAN NO 3 BEARING SELF TEST FAIL	TACAN RW	0.1	
V09K5343X	TAC_RNGFL(1)	TACAN NO 1 RANGE SELF TEST FAIL	TACAN RW	0.1	
V09K5343X	TAC_RNGFL(2)	TACAN NO 2 RANGE SELF TEST FAIL	TACAN RW	0.1	
V09K5343X	TAC_STIP	TACAN SELF TEST IN PROGRESS	TACAN RW	0.1	
V09K5343X	HEX_STATION_ID	TACAN 1, 2, OR 3 NEW STATION CHAN NO	TACAN RW, GAX, 6.28	0.1	
V09K5343X	LRJ_ID	TACAN LRU NUMBER	ENT SITE LOOKUP, ASC SITE LOOKUP +/-128	0.1	
V74K1510P8	TAC_CNTRL(1)	TACAN NO 1 CONTROL WORD	TACAN 1, TLM	0.1	
V74K1510P8	TAC_CNTRL(2)	TACAN NO 2 CONTROL WORD	TACAN 2, TLM	0.1	
V74K1510P8	TAC_CNTRL(3)	TACAN NO 3 CONTROL WORD	TACAN 3, TLM	0.1	
V74K1510P8	TACANTSEL(1)	TACAN NO 1 UPPER/LOWER ANT LOCK	TACAN 1, TLM	0.1	
V74K1510P8	TACANTSEL(2)	TACAN NO 2 UPPER/LOWER ANT LOCK	TACAN 2, TLM	0.1	
V74K1510P8	TACANTSEL(3)	TACAN NO 3 UPPER/LOWER ANT LOCK	TACAN 3, TLM	0.1	
V74K1510P8	TACANTINH(1)	TACAN NO 1 ANTENNA SELECT INHIBIT	TACAN 1, TLM	0.1	
V74K1510P8	TACANTINH(2)	TACAN NO 2 ANTENNA SELECT INHIBIT	TACAN 2, TLM	0.1	
V74K1510P8	TACANTINH(3)	TACAN NO 3 ANTENNA SELECT INHIBIT	TACAN 3, TLM	0.1	
V74K1510P8		MODE FFO1 DSCR OUT SET CD 00 CH 7	TACAN 1, TLM	0.1	
V74K1510P8		MODE FFO2 DSCR OUT SET CD 00 CH 7	TACAN 2, TLM	0.1	
V74K1510P8		MODE FFO3 DSCR OUT SET CD 00 CH 7	TACAN 3, TLM	0.1	
V74K1510P8		TACAN NO 1 MODE X/Y	TACAN 1, TLM	0.1	
V74K1510P8		TACAN NO 2 MODE X/Y	TACAN 2, TLM	0.1	
V74K1510P8		TACAN NO 3 MODE X/Y	TACAN 3, TLM	0.1	
V74K1510P8		TACAN NO 1 A/A	TACAN 1, TLM	0.1	
V74K1510P8		TACAN NO 2 A/A	TACAN 2, TLM	0.1	
V74K1510P8		TACAN NO 3 A/A	TACAN 3, TLM	0.1	
V74K1510P8		TACAN NO 1 T/R+RCV ONLY	TACAN 1, TLM	0.1	
V74K1510P8		TACAN NO 2 T/R+RCV ONLY	TACAN 2, TLM	0.1	
V74K1510P8		TACAN NO 3 T/R+RCV ONLY	TACAN 3, TLM	0.1	
V74K1510P8		TACAN NO 1 CHANNEL SELECT	TACAN 1, TLM	0.1	
V74K1510P8		TACAN NO 2 CHANNEL SELECT	TACAN 2, TLM	0.1	
V74K1510P8		TACAN NO 3 CHANNEL SELECT	TACAN 3, TLM	0.1	

ORIGINAL PAGE IS OF POOR QUALITY

APPENDIX D

I-LOADS

APPENDIX D

I-LOADS

The I-load parameters for the TACAN SOP (table D-1) and for the TACAN RM (table D-2) are defined on the following pages.

PRECEDING PAGE BLANK NOT FILMED

TABLE D-1.- TACAN SOP I-LOAD PARAMETERS

[From ref. 7]

Name	MML no.	Description	Constant (a)	Type	Value	Units
TAC_RNGLO	V99U5718C	TACAN range low limit	SX	Scalar	0.0	n. mi.
TAC_RNGHI	V99U5717C	TACAN range high limit	SX	Scalar	0.5	n. mi.
TAC_BEARLO	V99U5716C	TACAN bearing low limit	SX	Scalar	177.5	deg
TAC_BEARHI	V99U5715C	TACAN bearing high limit	SX	Scalar	182.5	deg
TNM_FT	V99U5522C	TACAN n. mi. to feet conversion factor	X	Scalar	6077.6248	ft/n. mi.
TAC_RLTIM	V99U5520C	TACAN range lock time limit	SX	Scalar	10	sec
TAC_STTIM	V99U5521C	TACAN self test time	SX	Scalar	19	sec

^aThe codes for this column are as follows: SX indicates a soft constant that may change as the software is refined and X indicates a hard constant that will probably not change.

TABLE D-2.-- TACAN RM I-LOAD PARAMETERS

MSID	REQUIREMENTS SYMBOLIC NAME	UNIT	VALUE	UNITS	MAXIMUM	MINIMUM	CR NUM
V9703004C	*ALT_CUTOFF	E+03 FEET	*01+11.5000000 *03+11.5000000	E+03			*12266A
V9703013C	*ATTITUDE CUTOFF	ND	*01+110 *03+110	ND			*12266A
V9703015C	*BRG_COUNT_LIM	E+00 DEG	*01+14.5000000 *03+14.5000000	E+00			*12266A
V9703016C	*BRG_JUMP_LIM	E+00 DEG	*01+16.0000000 *03+16.0000000	E+00			*12266A
V9703029C	*BEARING TOLERANCE	E+01 DEG	*03+14.5000000	E+01			*12443
V9703234C	*ELEVATION ANGLE LIMIT	ND	*01+5 *03+5	ND			*12266A
V9703236C	*RNG_TOL	E+03 FT	*01+13.0000000 *03+13.0000000	E+03			*12266A
V9703250C	*RANGE TOLERANCE	ND	*01+20 *03+20	ND			*19387
V9703291C	*TWO LOCK COUNTER LIMIT	E+04 FT	*01+11.0000000 *03+11.0000000	E+04			*12266A
V9703292C	*RNG_K	E+00 SEC	*01+10.0 *03+10.0	E+00			*12266A
V9809722C	*RNG_JUMP_CTR_LIM	E+00 ND	*01+15.0000000 *03+15.0000000	E+00			*19065
V9809723C	*V_RNG_LIM	E+03 KNOTS	*01+14.5000000 *03+14.5000000	E+03			*19065
V9809724C	*R_ACO_LIM_H	ND	*01+110 *03+110	ND			*19065
V9809726C	*R_ACO_LIM_L	ND	*01+5 *03+5	ND			*19065

TABLE D-2.- Concluded.

MSID	PRINCIPAL FUNCTION WITH ALPHABETIC SYMBOLIC NAME	DOC. NUMBER	PARAGRAPH	CA. 77	UNIT	MAXIMUM	MINIMUM	CB NUM.
V90U9726C	*BRG_JUMP_CTR_LIM	*01*+1.0000000	E+01*MO					*19065
V90U9727C	*V_WRC_LIM	*03*+1.0000000	E+01*					
V90U9728C	*B_ACO_LIM_H	*01*+12	*MO					*19307
V90U9729C	*B_ACO_LIM_L	*03*+12	*MO					*19307

APPENDIX E

OPS 8 I-LOADS FOR SENSOR SELF TESTS (OPS 8)

APPENDIX E

OPS 8 I-LOADS FOR SENSOR SELF TESTS (OPS 8)

System	Value
1. MSBLS:	
Range, n. mi.	15.2 ± 0.2
Azimuth, deg	±3.0 ± 0.1
Elevation, deg.	6.0 ± 0.1
2. TAC:	
Range, n. mi.	0.0 + 0.5, -0.0
Bearing, deg	180.0 ± 2.5
3. Radar altimeter, ft. . . .	1000 ± 100

PRECEDING PAGE BLANK NOT TO BE