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TACAN OPERATIONAL DESCRIPTION FOR THE SPACE SHUTTLE
ORBITAL FLIGHT TEST PROGRAM

Job Order 16-609

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
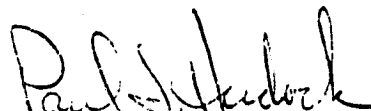
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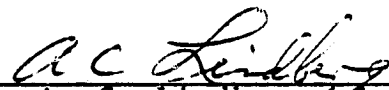
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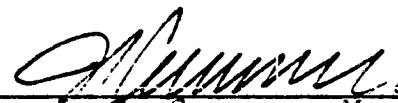
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CONTENTS

TABLES

FIGURES

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 (RTLS).

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 (RTLS). 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 RTLS 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

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

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

[3]See reference 2 for further information on TACAN stations that will be used in these landings.
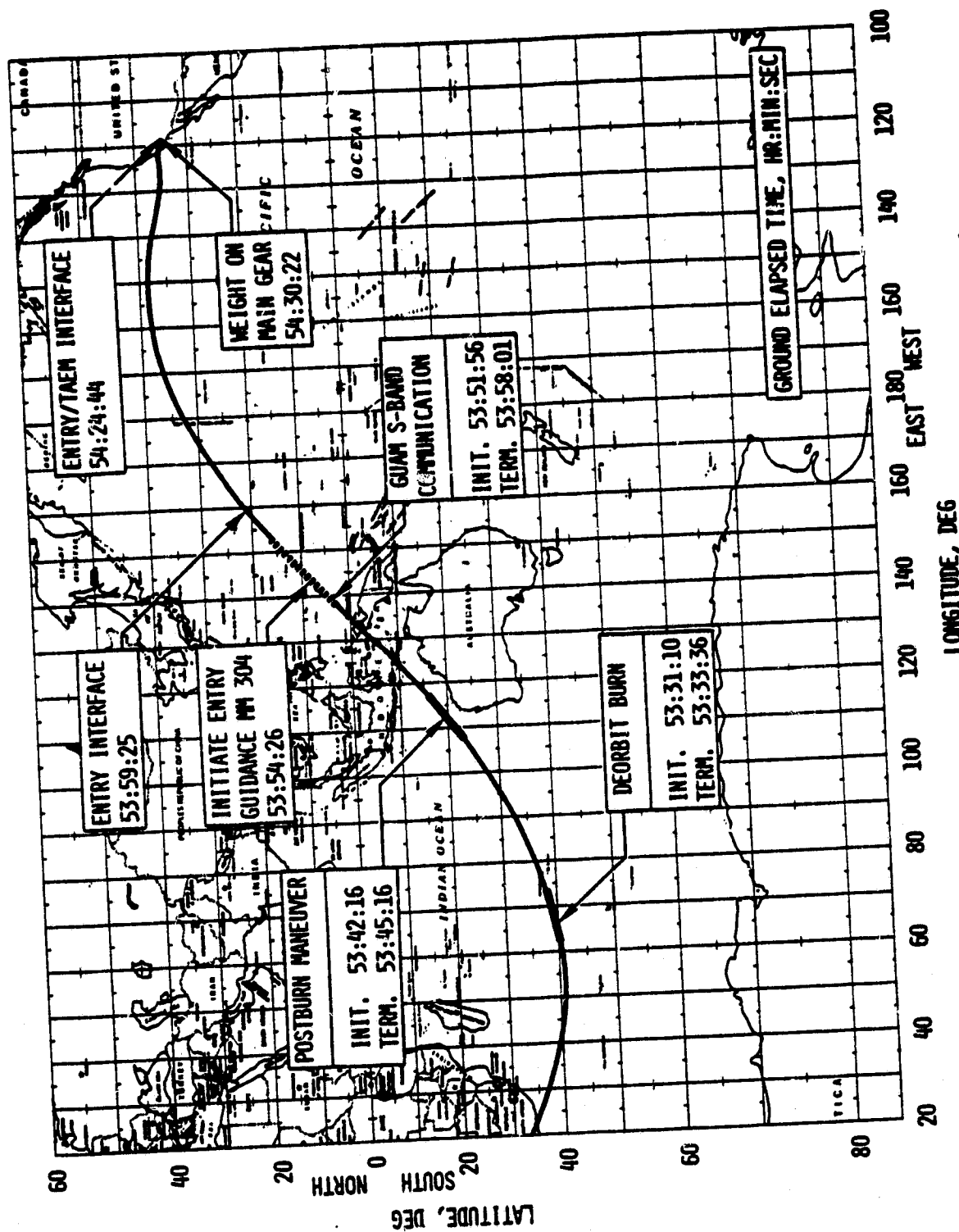
Figure 2-1.— STS-1 deorbit-through-landing groundtrack.

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

5
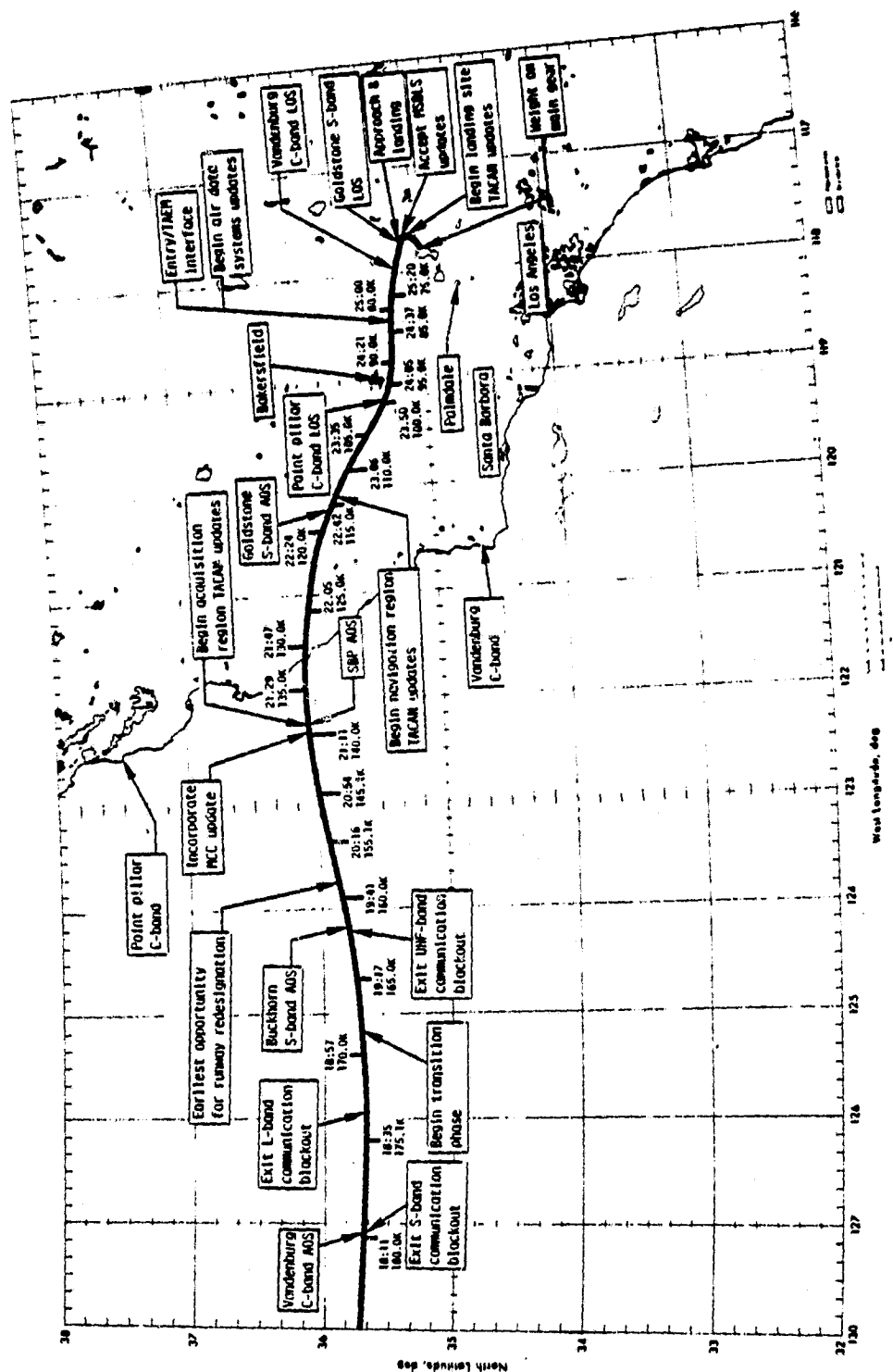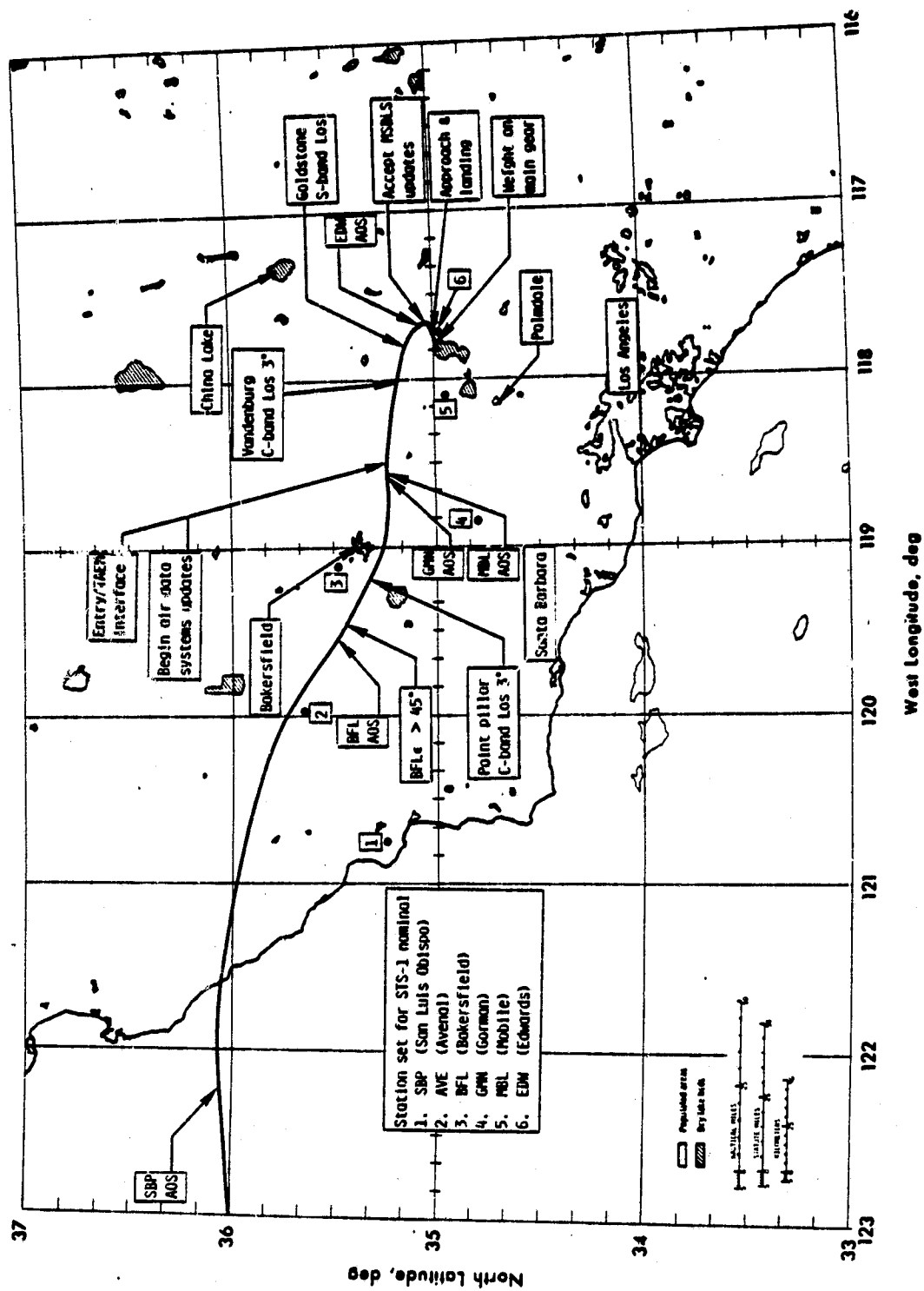
Figure 2-3.— STS-1 entry groundtrack and TACAN events.

6
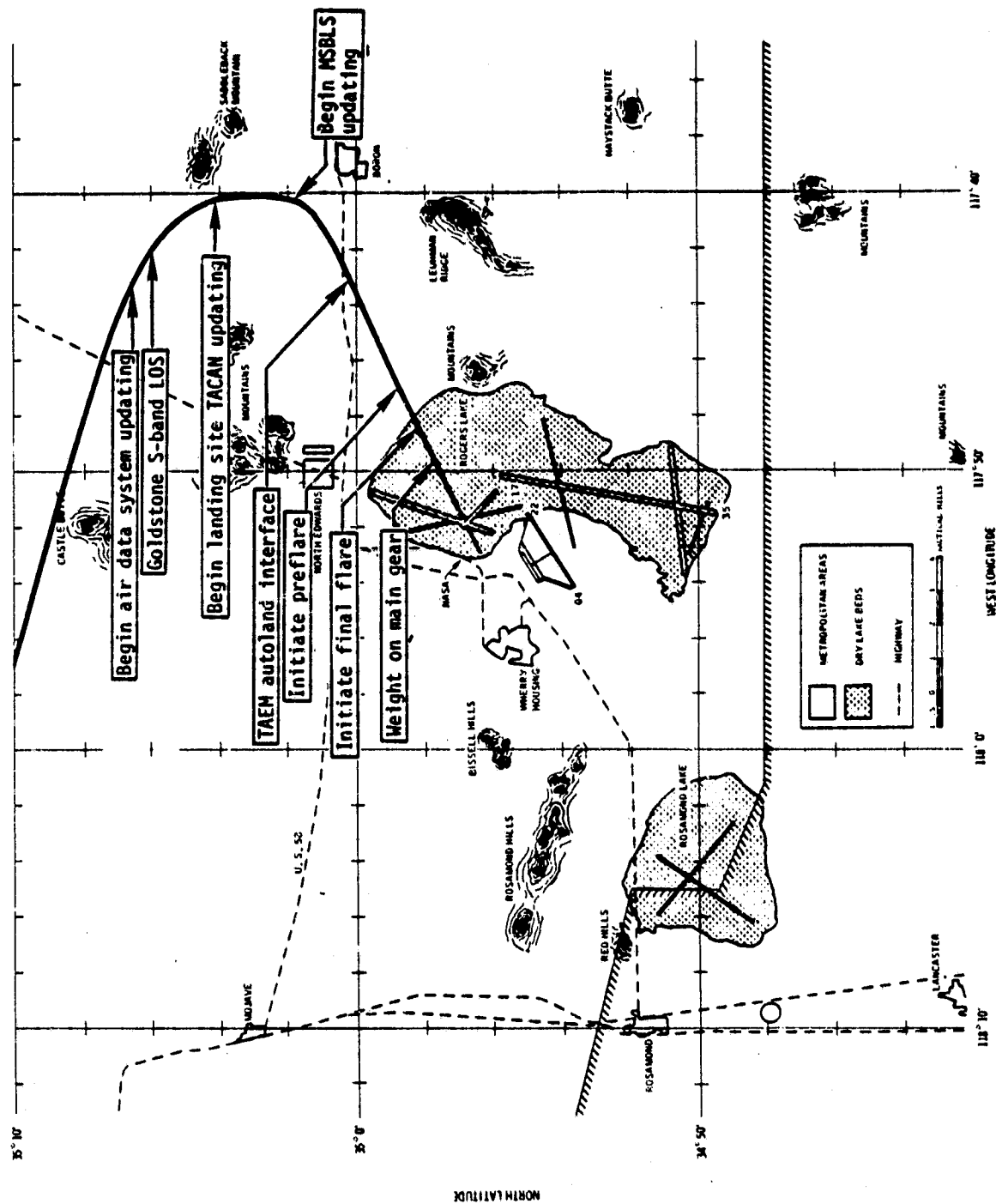
Figure 2-4.— Approach and landing groundtrack.

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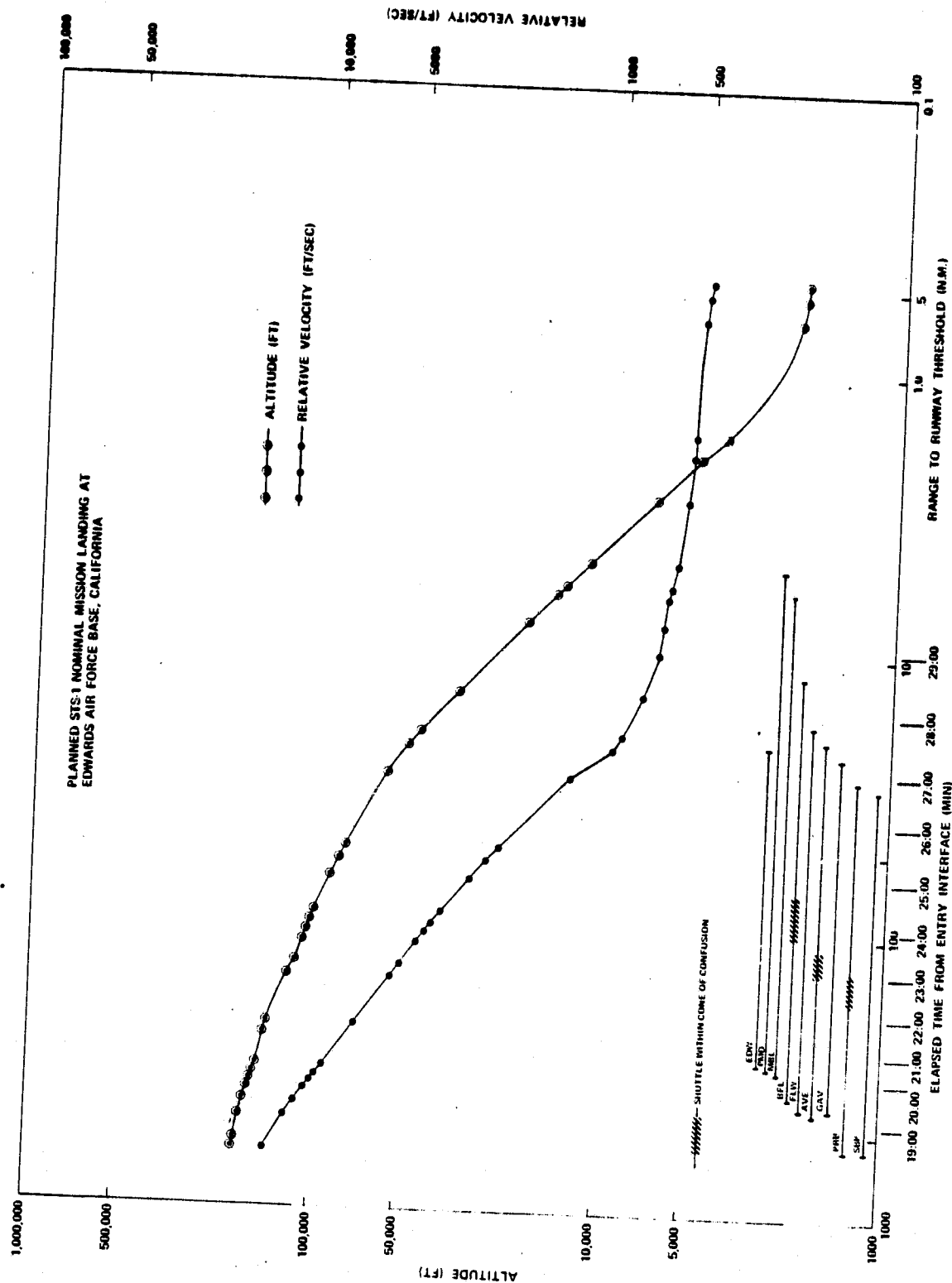
Figure 2-5.— Nominal Shuttle flight profile during STS-1: entry through final approach. TACAN station coverage versus elapsed time from entry interface is superimposed on flight profile. (This figure is extracted from page 58, ref. 1.)

RANGE TO RUNWAY THRESHOLD VS ELAPSED TIME FROM ENTRY INTERFACE
TACAN STATION COVERAGE
PLANNED STS-1 NOMINAL MISSION LANDING AT
EDWARDS AIR FORCE BASE, CALIFORNIA
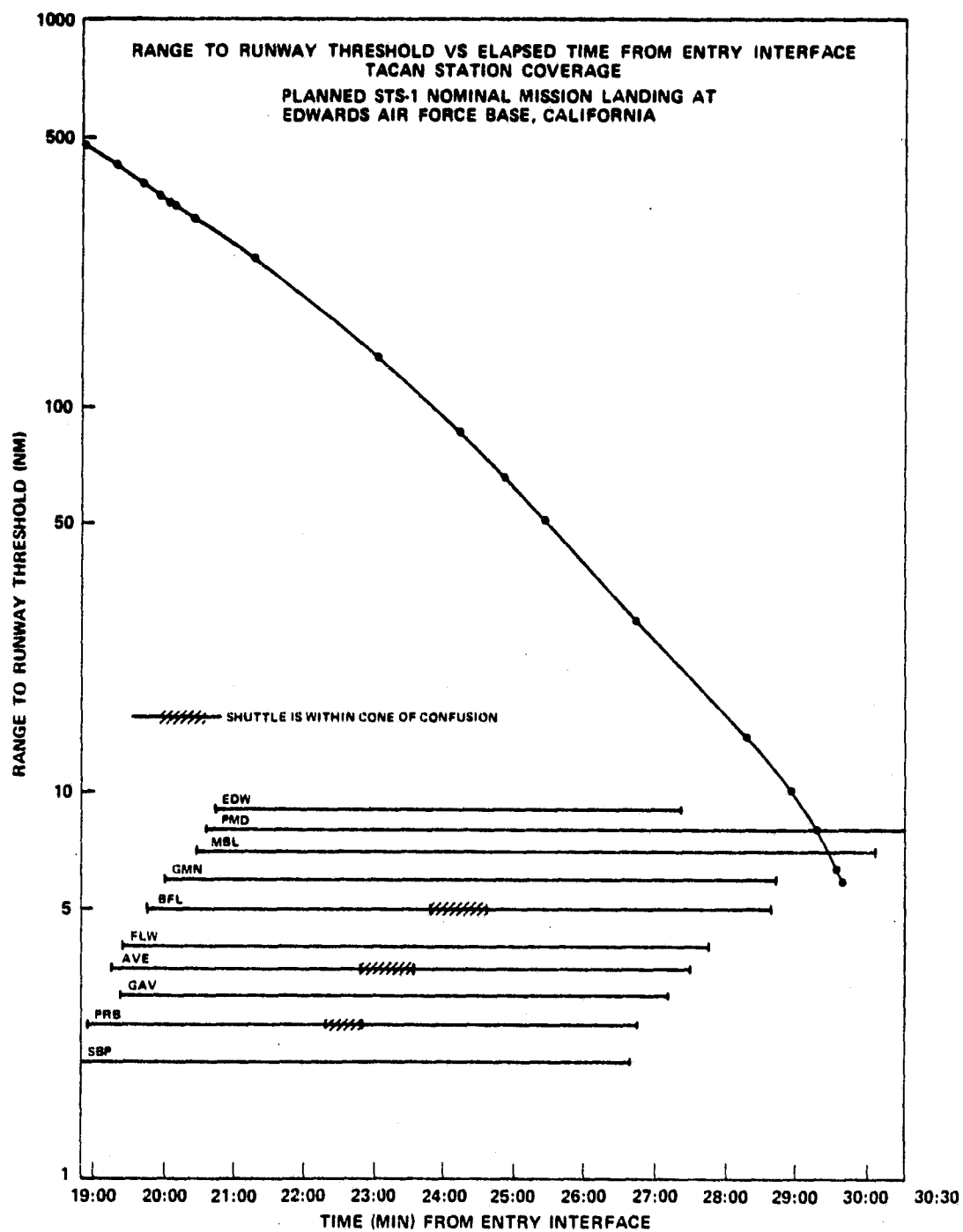
Figure 2-6.— Range to runway threshold versus elapsed time from entry interface for a nominal Shuttle flight profile. (TACAN station coverage is superimposed on time scale. This figure is extracted from page 58, ref. 1.)

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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.)

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CONNECTOR AND AIR DUCT HOLE
LOCATED AT REAR

RECEIVER/TRANSMITTER TACAN

+Z

+X

+Y

SHOCK MOUNTED
RACK

SHELF

FRONT ATTACH
BRACKETS

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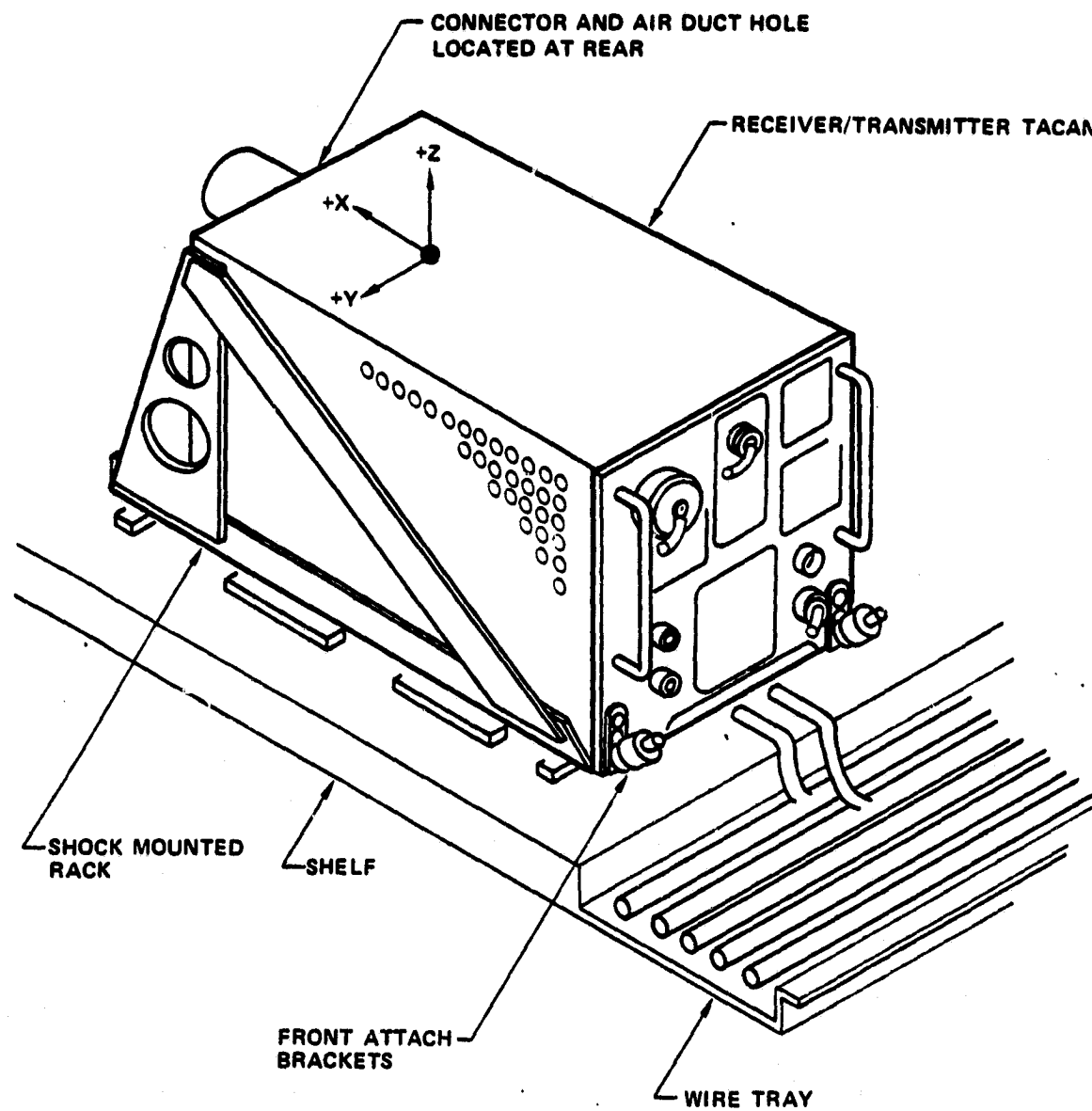
Figure 3-1.— TACAN LRU used in the Space Shuttle.

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ANTENNA LOCATIONS

L-BAND TACAN
(3 ANTENNAS)

L-BAND TACAN
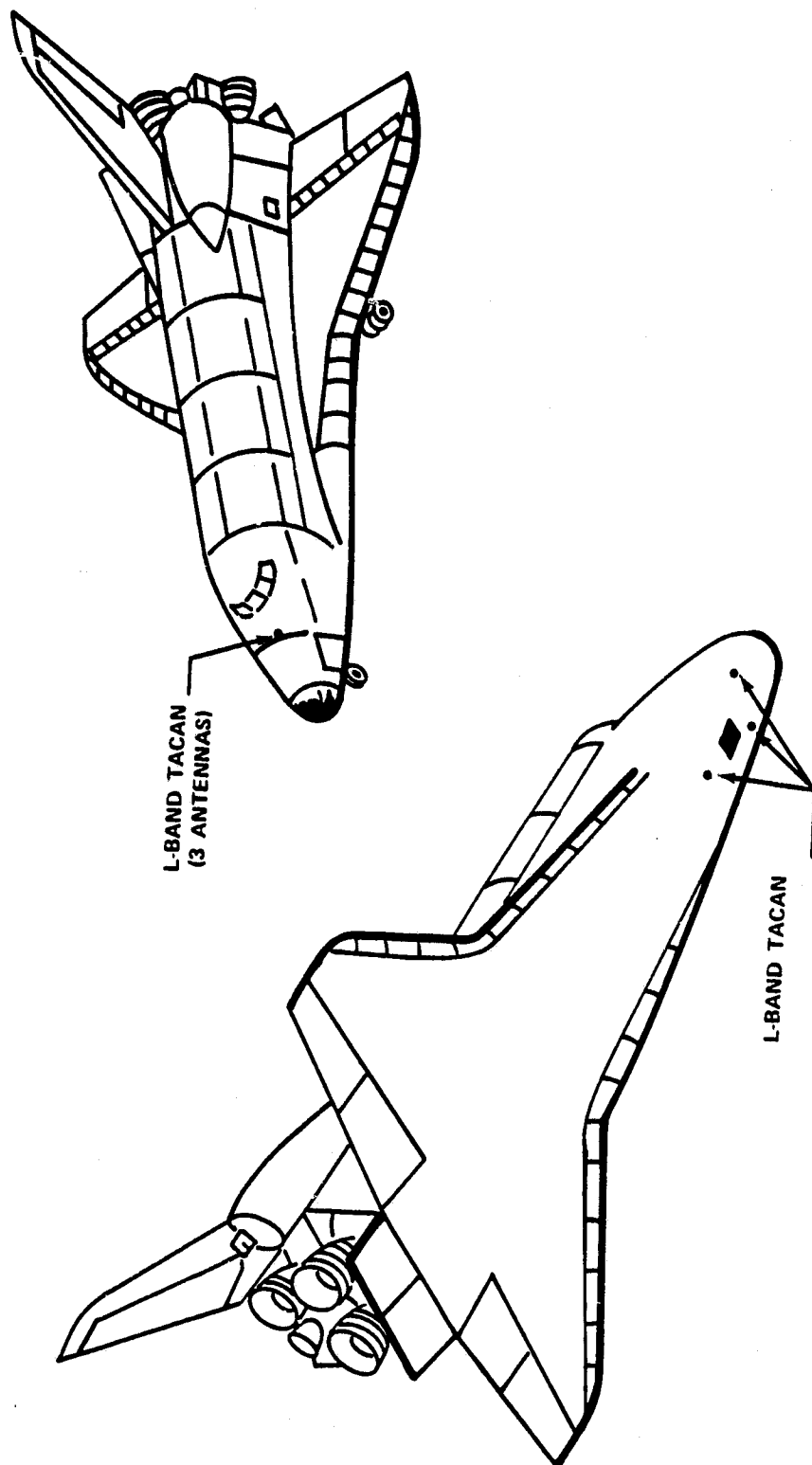
Figure 3-2.— Shuttle TACAN antenna locations.
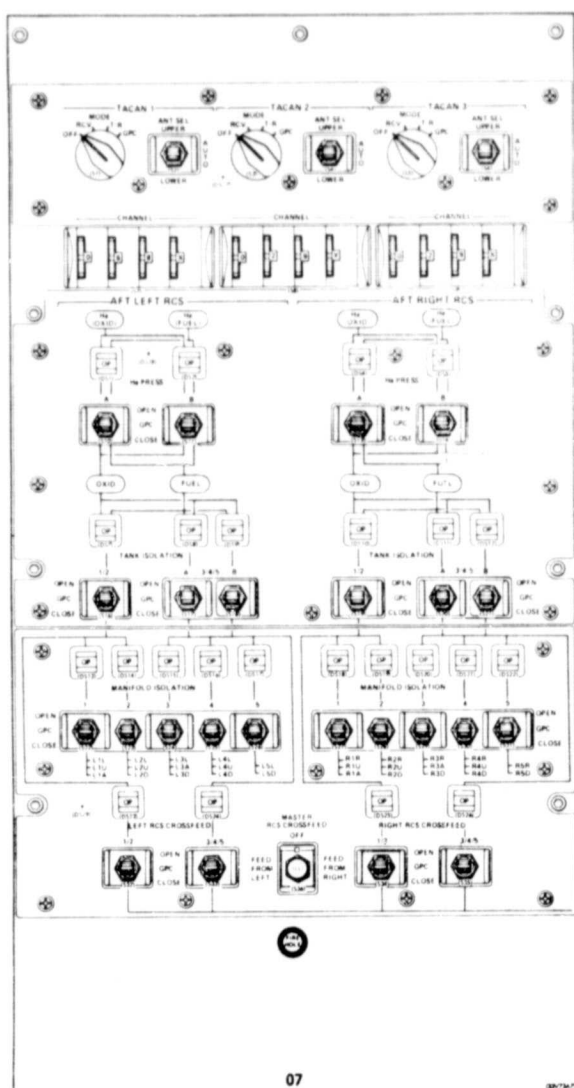
TACAN CONTROL PANEL

PANEL 07
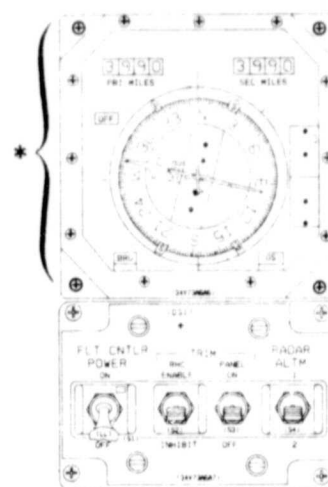
*HSI DISPLAY
[PANEL F6, A6]
[PANEL F8, A6]
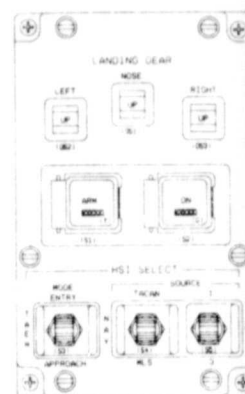
HSI SELECT
[PANEL F6, A5]
[PANEL F8, A5]

OVERHEAD PANELS
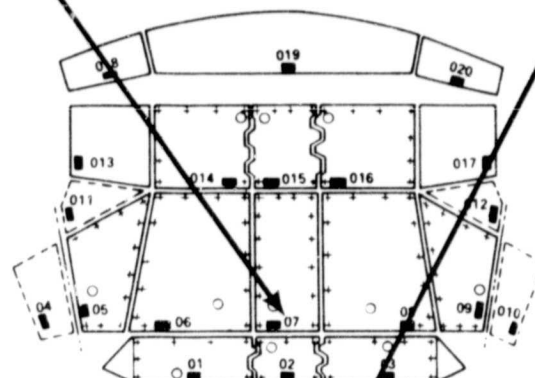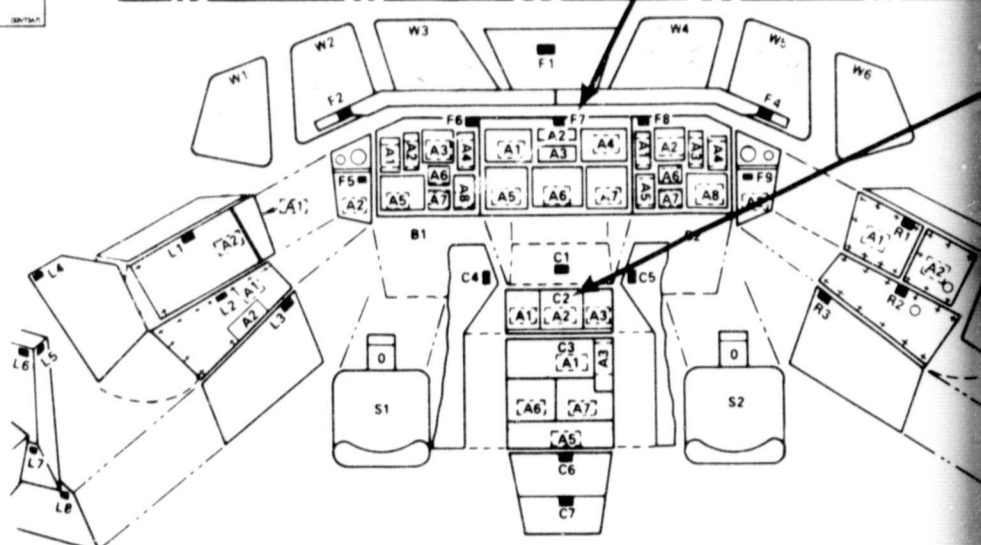
FLIGHT STATION
(COCKPIT LAYOUT)

HSI SELECT
[PANEL F6, A5]
[PANEL F8, A5]

LAY
F6, A6]
F8, A6]

HEAD PANELS

PANEL F7

DISPLAYS FOR SPECIALIST FUNCTIONS

PANEL C2

COMMANDER AND PILOT KEYBOARDS
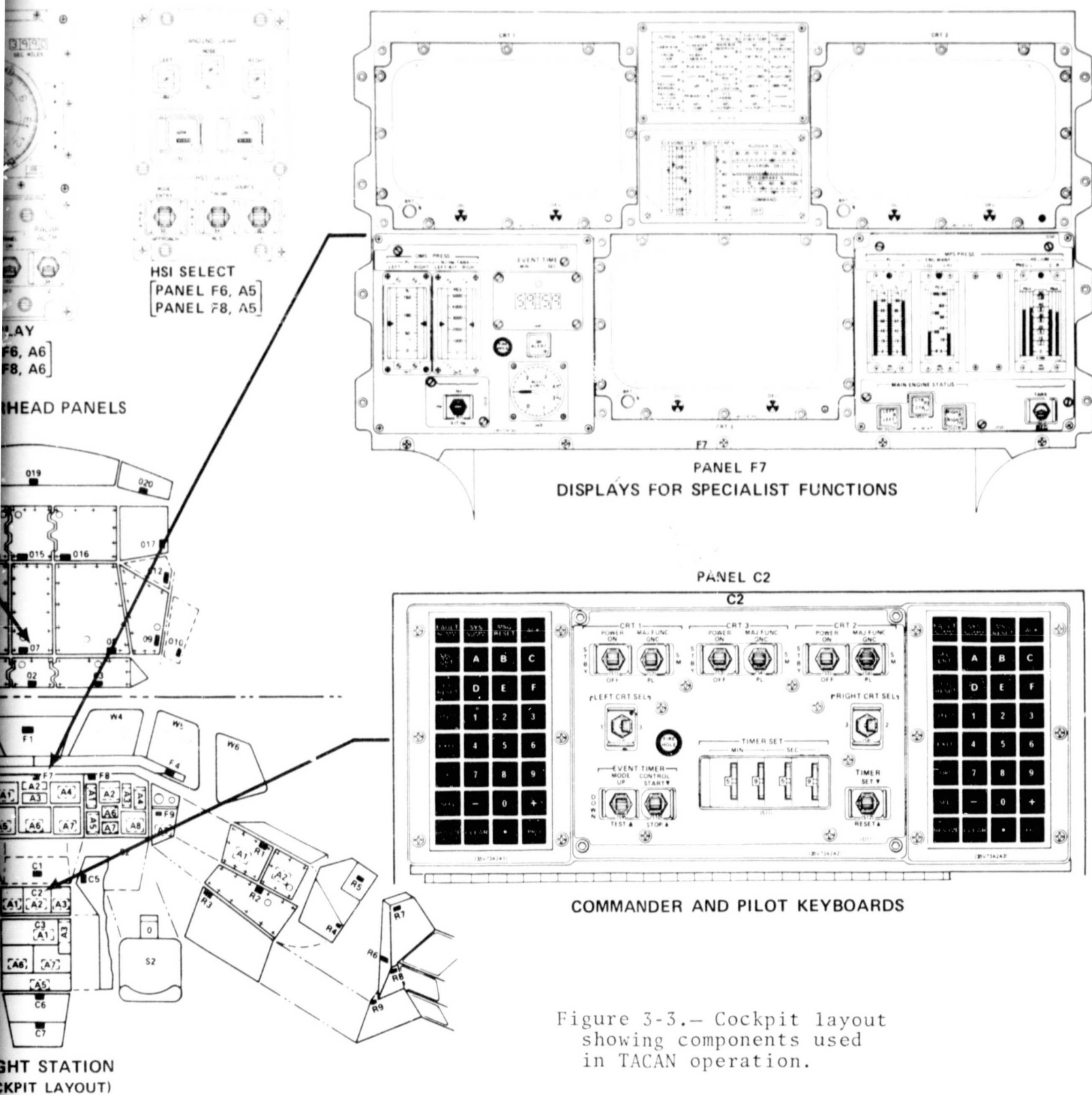
Figure 3-3.— Cockpit layout
showing components used
in TACAN operation.

GHT STATION
CKPIT LAYOUT)

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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 indi-
rectly 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.

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 compo-
nents required for each TACAN's performance; a control panel, an
MDM that contains the TACAN control register, a receiver/trans-
mitter (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 opera-
tion, 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 num-
ber 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 reg-
ister, 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 refor-
matted 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

21
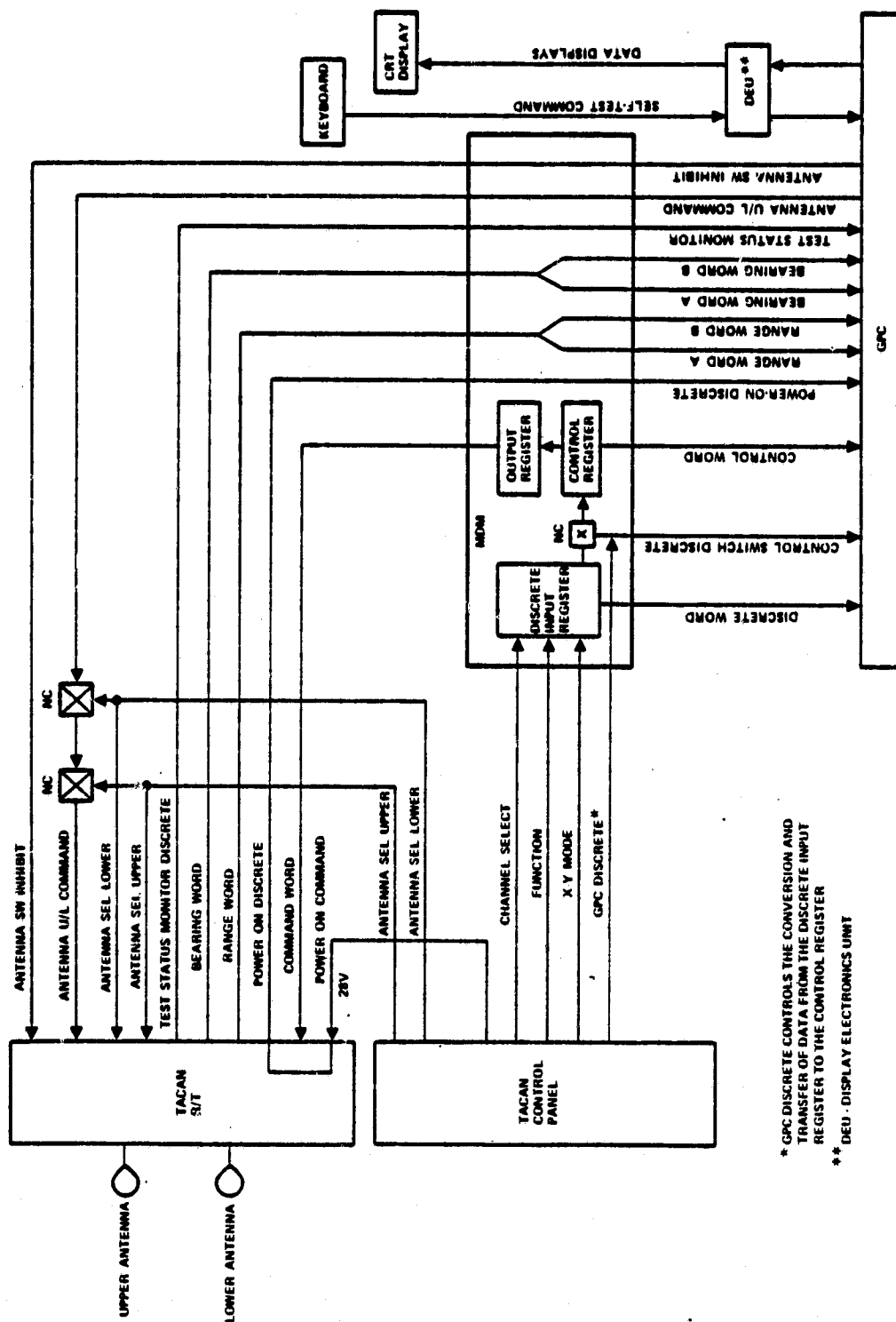
Figure 4-1.— Hardware/software interface.

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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 SOFTWARE[4]

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 con-
sidered 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 inter-
faces 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 trans-
ceiver.

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

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[4]This is a description of Primary Avionics System Software (PASS)
and does not cover Backup Flight System software.
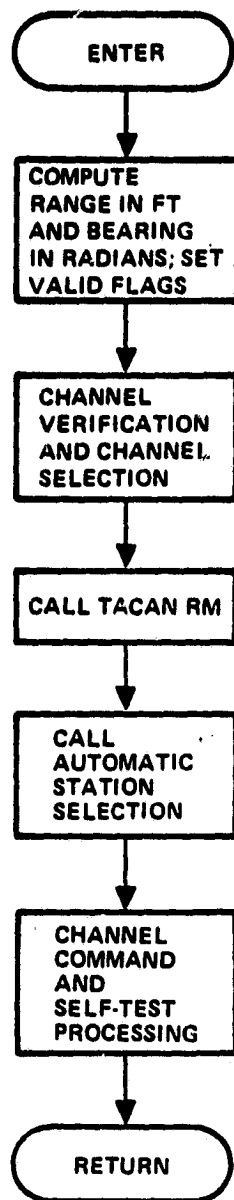
Figure 5-1.— TACAN SOP block diagram (from detailed design software, see ref. 6.)

- 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).

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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 posi-
tion by the crew. In these cases, this manual setting overrid·
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.

---

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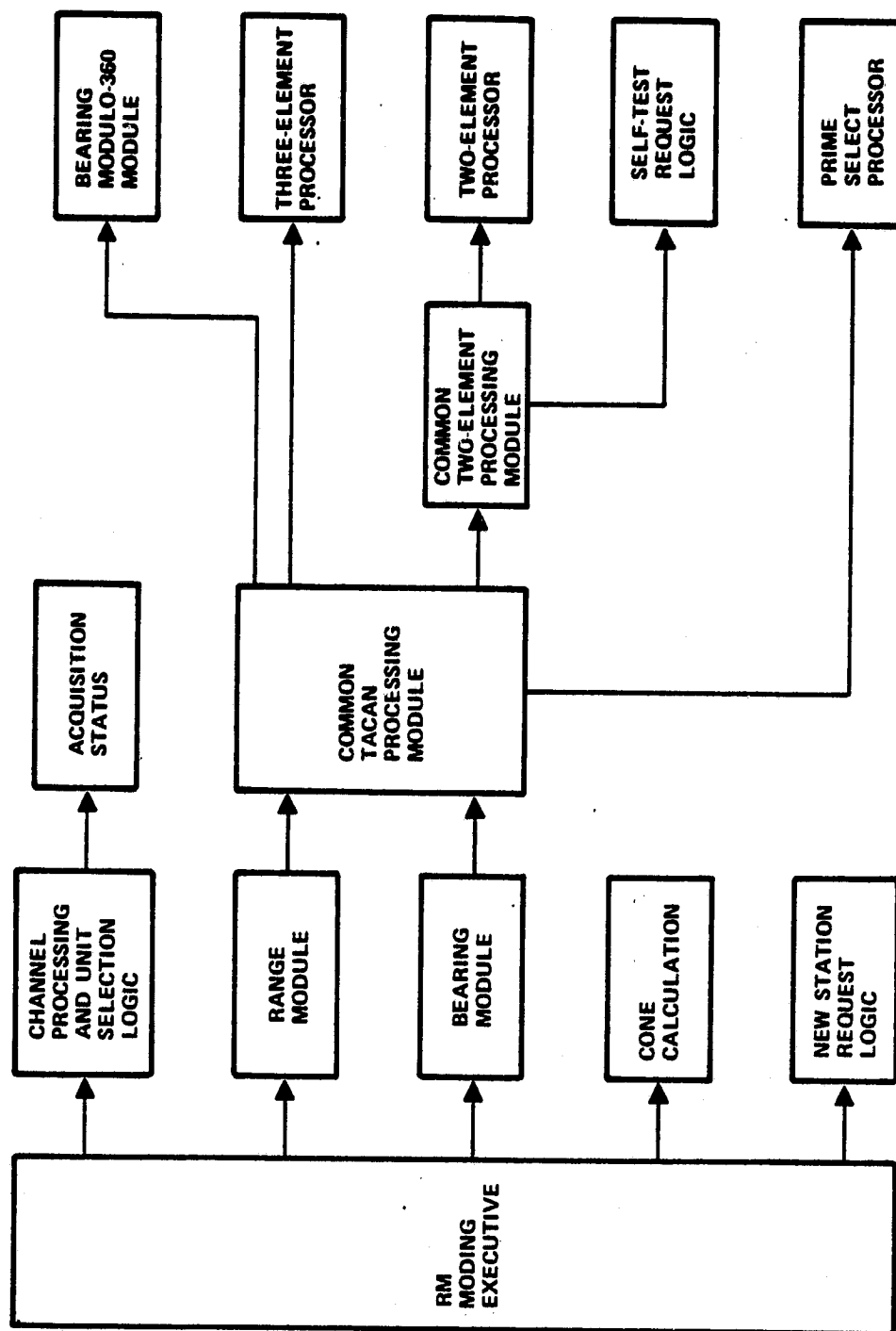
Figure 5-2.— TACAN RM processing block diagram. (Developed from the detailed design software, see ref. 6.)

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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 additon 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.

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[8]See Hal words R_ACQ_LIM_H, R_ACQ_LIM_L, B_ACQ_LIM_H, and B_ACQ_ LIM_L in appendix D.

[9]See Hal words ALT_CUTOFF in appendix D.

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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

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[10]See Hal word ELEV_ANG_LIM in appendix D.

[11]See 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 de-
select. An overview of the interfaces of the possible TACAN
deselects 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 naviga-
tion 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; other-
wise, they are set to False.
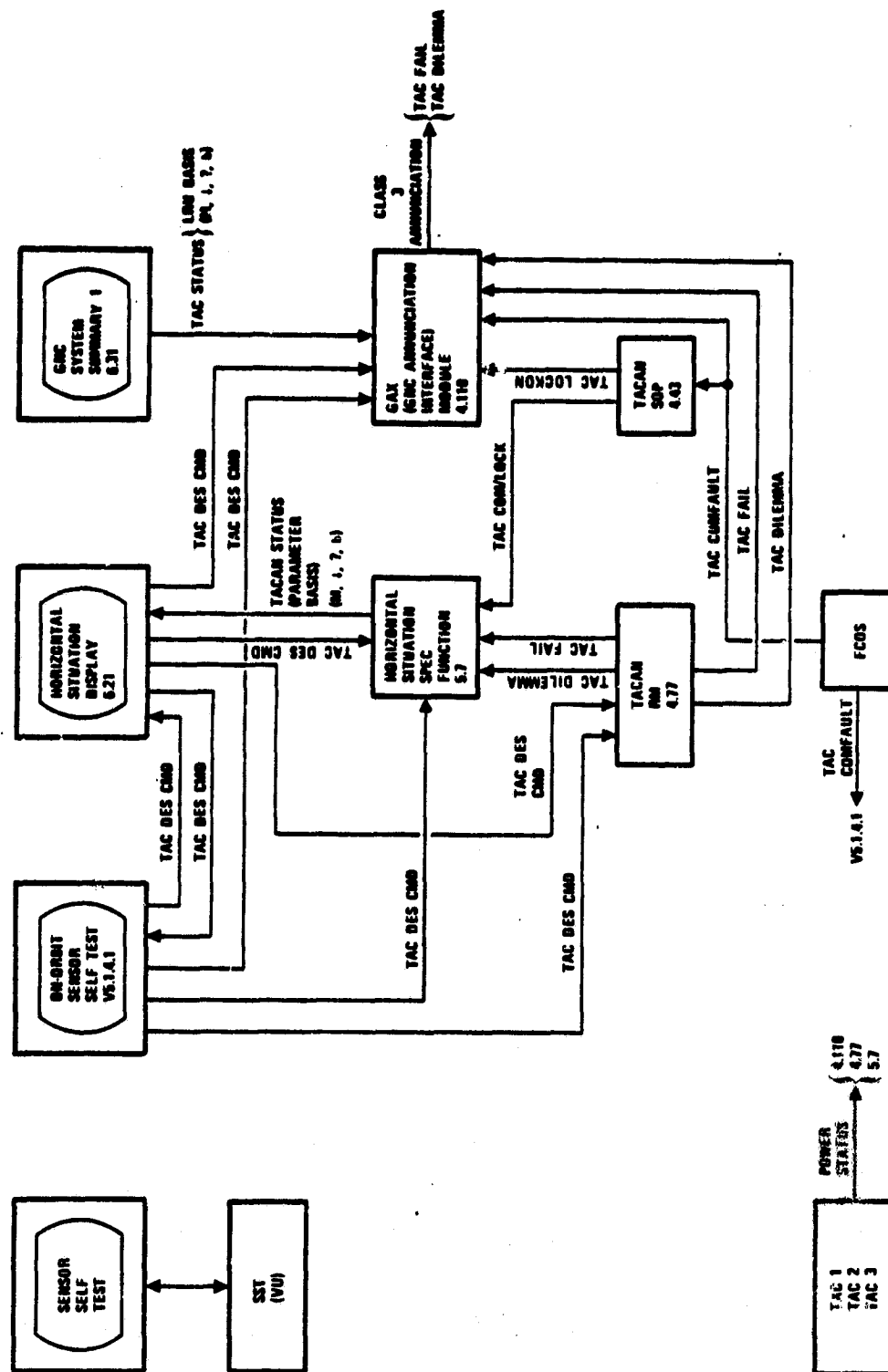
Figure 5-3.— Overall view of TACAN status interfaces.

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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 fig-
ure 5-4 (a part of the cockpit overhead display and control
panel 07). .
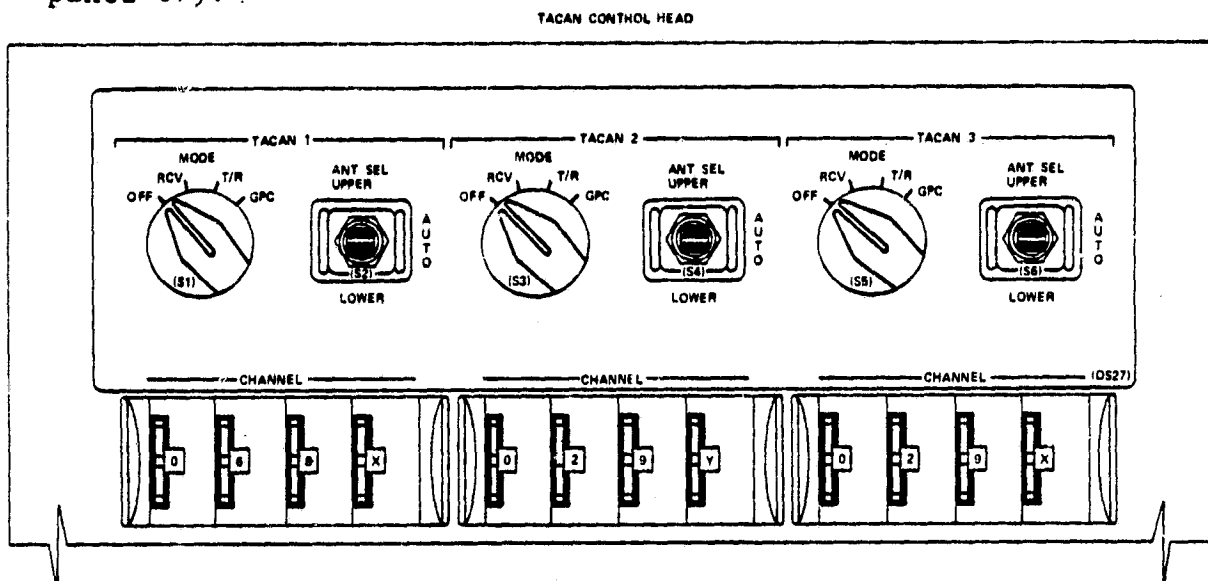
TACAN CONTROL HEAD

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 selec-
tion 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 selec-
tion 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
         1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 ( 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1

  1      X X X X / 0 4 0                  S E N S O R   T E S T     X X   X   D D D / H H : M M : S S
  2                                                                       D D D / H H : M M : S S
  3                      D E S   S T A T   R N G        A Z        E L
  4          M L S   1     1 X   X X X X   X X . X S    ± X . X X S   X . X X S
  5                  2     2 X   X X X X   X X . X S    ± X . X X S   X . X X S
  6                  3     3 X   X X X X   X X . X S    ± X . X X S   X . X X S

  8                      D E S   S T A T   R N G        A Z
  9          T A C   1     4 X   X X X X     X . X S   X X X . X X S
 10                  2     5 X   X X X X     X . X S   X X X . X X S
  1                  3     6 X   X X X X     X . X S   X X X . X X S

  3                      D E S   S T A T   A L T
  4          R A     1     7 X   X X X X   X X X X S
  5                  2     8 X   X X X X   X X X X S
  6

  7                      D E S             Y            Z
  8          A A     1     9 X           ± X X . X S   ± X X . X S
  9                  2   1 0 X           ± X X . X S   ± X X . X S
 20                  3   1 1 X           ± X X . X S   ± X X . X S
  1                  4   1 2 X           ± X X . X S   ± X X . X S

  3                      S T A R T   1 3 X     S T O P   1 4 X

  5                                                                      ( X X )
  6
```

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

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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, ↓, ?, ∅). 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

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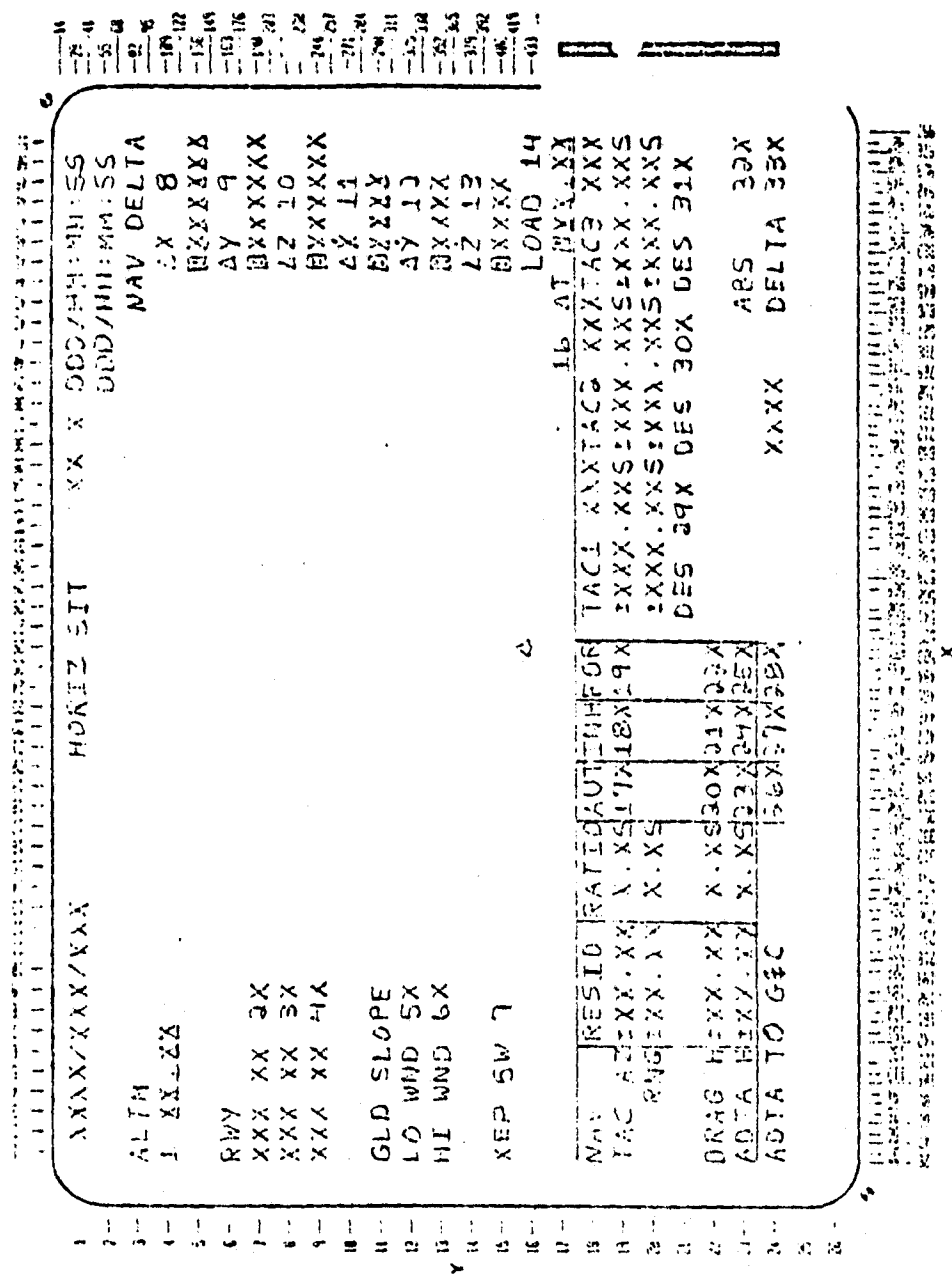
Figure 5-6.— Horizontal Situation Display (HSD).

	TACAN "X" "YYY" DISPLAY STATUS INDICATORS			
	M	→	?	(BLANK)
TAC "X" POWER DISCRETE	OFF (OR)	ON (AND)	ON (AND)	ON (AND)
TAC "X" "YYY" COMFAULT/LOCKON FLG.	BAD	GOOD	GOOD	GOOD
TAC "X" "YYY" FAIL	– –	FAIL (AND) (OR)	GOOD (AND)	GOOD (AND)
TAC "X" DESELECT	– –	DESELECT	SELECT	SELECT
TAC "YYY" DISAGREE	– –	– –	DISAGREE	AGREE

O U T P U T — I, N, P, U, T, S

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

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

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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.— 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 $\dfrac{LRU_j + LRU_k}{2}$ 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

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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 $\dfrac{\text{LRU}_i + \text{LRU}_j}{2}$ 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

[a] The LRU$_{i,j,k}$ range data have the same RM voting.

[b] A 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.

[c] If 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	• Manual Mode • Channel "A" • No failures or comfault	• Manual Mode • Channel "B" • No failures or comfault	• Manual Mode • Channel "C" • No failures or comfault	No common channel No data sent to Navigation
2	• Manual Mode • Channel A • Deselect	• Manual Mode • Channel B • Deselect	• Manual Mode • Channel C • No failures	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.)
3	• Manual or GPC • Channel "A" • No failures	• Manual or GPC • Channel "A" • No failures	• Manual • Channel "B" • No failures	Average $\dfrac{LRU_i + LRU_j}{2}$ Bearing and range data
4	• Manual or GPC • Channel A • Comfault or deselect	• Manual or GPC • Channel A • No failures	• Manual • Channel B • No failure	LRU$_j$ bearing and range data will be prime selected
5	• Manual or GPC • Channel "A" • Comfault	• Manual or GPC • Channel "A" • Comfault	• Manual • Channel "B" • No failures	RM software will not pass data to Navigation Common channels are failed
6	• Manual or GPC • Channel "A" • Deselect	• Manual or GPC • Channel "A" • Deselect	• Manual • Channel "B" • No failures	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.)
7	• Channel A • OFF	• GPC or Manual Mode • Channel B • No failures	• GPC or Manual Mode • Channel B • No failures	Average $\dfrac{LRU_j + LRU_k}{2}$ Bearing and range data
8	• Channel A • OFF	• Channel B • OFF	• GPC or Manual Mode • Channel B • No failures	Prime select LRU$_k$
9	• Channel A • OFF	• Channel C • OFF	• GPC or Manual Mode • Channel C • No failures	Prime select LRU$_k$

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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.

HORIZONTAL
SITUATION
SPEC FUNCT
5.7

POWER ON DISCRETE (i = 1, 2, 3)

TACAN COMFAULT (i = 1, 2, 3)

RANGE COMFAULT/LOCKON (i = 1, 2, 3)

BEARING COMFAULT/LOCKON (i = 1, 2, 3)

BEARING LOCKON (i = 1, 2, 3)

RANGE LOCKON (i = 1, 2, 3)

SELF TEST IN PROGRESS

FCOS

TACAN

CLOCK

TACAN DILEMMA

RH HSI RECEIVER SEL

TACAN FAIL (i = 1, 2, 3)

COMFAULT (i = 1, 2, 3)

LH HSI RECEIVER SEL

BEARING LOCKON (i = 1, 2, 3)

GN & C
SW
RM

LH HSI SOURCE SEL

RANGE LOCKON (i = 1, 2, 3)

RH HSI SOURCE SEL

ANTENNA SW INHIBIT

SELF TEST IN PROGRESS

ANTENNA U/L CMD

RANGE SELF TEST FAIL (i = 1, 2, 3)

TACAN
SOP
4.23

TEST STATUS MON
(i = 1, 2, 3)

BEARING SELF TEST FAIL (i = 1, 2, 3)

BEARING FAIL (i = 1, 2, 3)

BEARING WORD A
(i = 1, 2, 3)

SELF TEST REQUEST (i = 1, 2, 3)

RANGE FAIL (i = 1, 2, 3)

BEARING WORD B
(i = 1, 2, 3)

BEARING WORD (i = 1, 2, 3)

BEARING DILEMMA

RANGE WORD A
(i = 1, 2, 3)

CHANNEL CHANGE INDICATOR
(i = 1, 2, 3)

RANGE DILEMMA

MDM

RANGE WORD B
(i = 1, 2, 3)

RANGE WORD (i = 1, 2, 3)

TAC DES CMD (i = 1, 2, 3)

ONE_RNG_LOCK

POWER ON DISCRETE

POWER ON DISCRETE (i = 1, 2, 3)

TACAN
RM
4.77

ONE_BRG_LOCK

CONTROL WORD
(i = 1, 2, 3)

CHANNEL W/MODE (i = 1, 2, 3)

SELECTED RANGE DATA

CONTROL SW DISCRETES
(i = 1, 2, 3)

TIME TAG

SELECTED BEARING DATA

DISCRETE WORD
(i = 1, 2, 3)

BEARING COMFAULT/LOCKON (i = 1, 2, 3)

BEARING DATA GOOD

RANGE COMFAULT/LOCKON (i = 1, 2, 3)

RANGE DATA GOOD

NEW STATION CHANNEL =
(i = 1, 2, 3)

SELECTED LRU ID

TACAN LRU =

INSIDE CONE FLAG

TIME TAG

CHANGE IN CHANNEL ID

ALT TO REAR WHEELS

GROUND SPEED

ID CHANGE
REQUEST RESET

ORBITER (X, Y, Z POS) i = 1, 2,

TACAN CHANNEL SELECTION

ID CHANGE REQUEST

X, Y, Z COMP EF POS VECTOR (i = 1, 2, 3)

BEARING WORD (i = 1, 2, 3)

RANGE WORD (i = 1, 2, 3)

BEARING WORD (i = 1, 2, 3)

RANGE WORD (i = 1, 2, 3)

CHANNEL CHANGE INDICATOR (i = 1, 2,

CHANNEL W/MODE (i = 1, 2, 3

BEARING COMFAULT/LOCKON (i = 1, 2,

RANGE COMFAULT/LOCKON (i = 1, 2,

FOLDOUT FRAME

ENT AUTO
TAC SEL

ASC AUTO
TAC SEL

ENT
SITE
LOOKUP

ASC
SITE
LOOKUP

PRECEDING PAGE BLANK NOT FILMED

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 pro-
vide 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 navi-
gation 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.
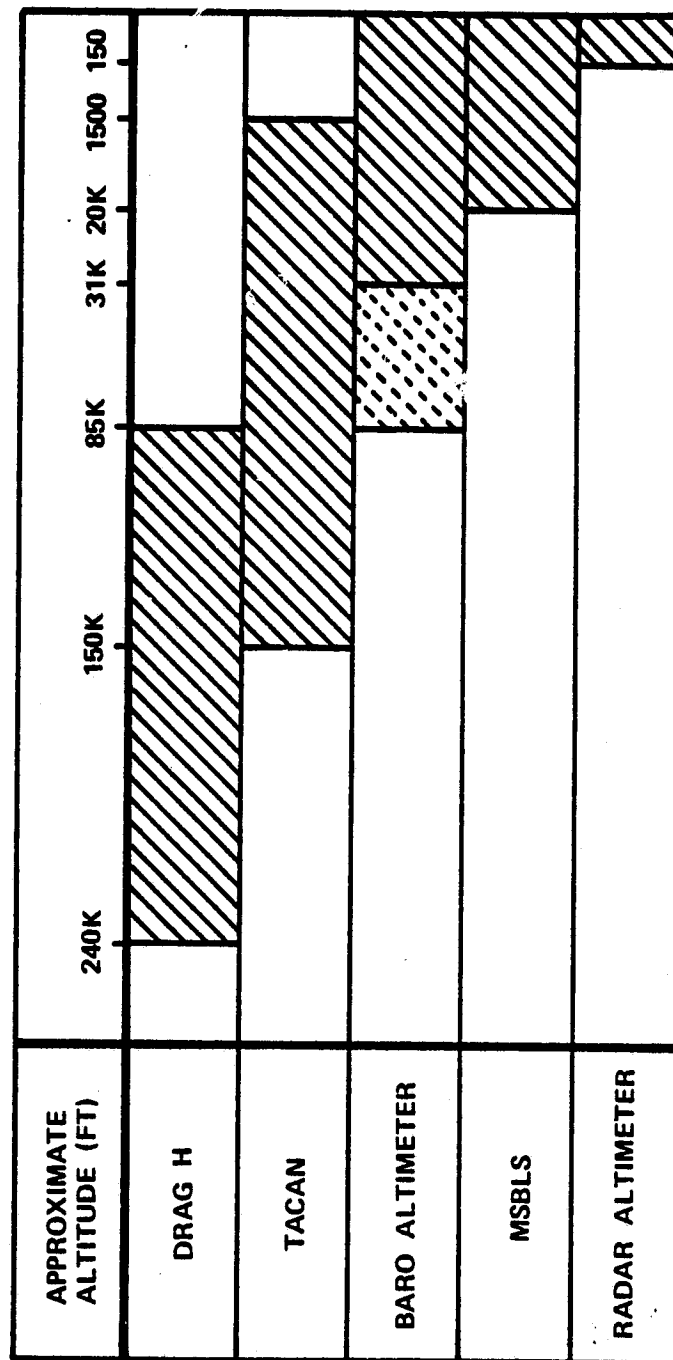
Figure 7-1.— External navigation sensor availability (from ref. 14).

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

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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.
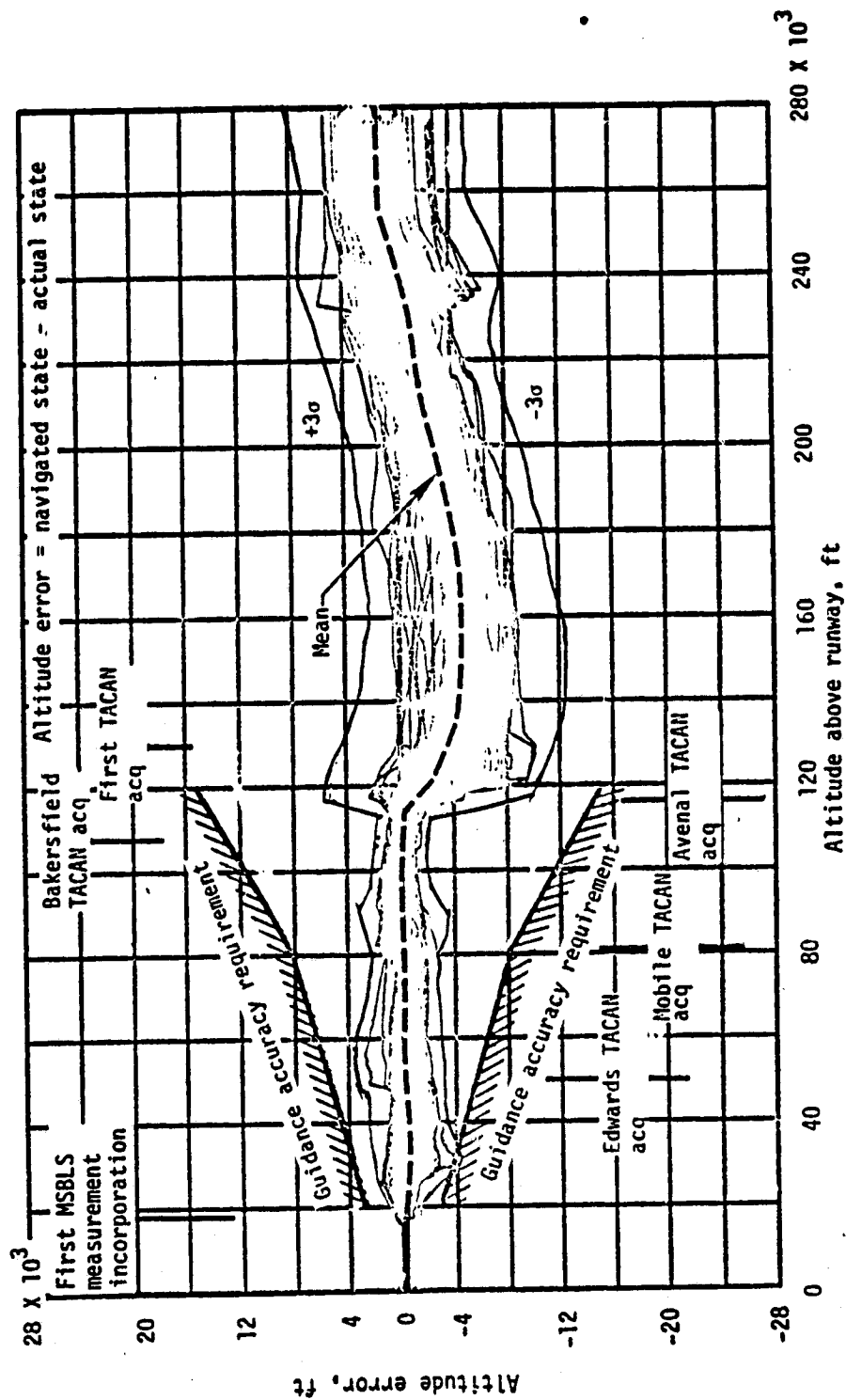
(a) Altitude error.

Figure 8-1.– Navigated state vector performance – end of mission.
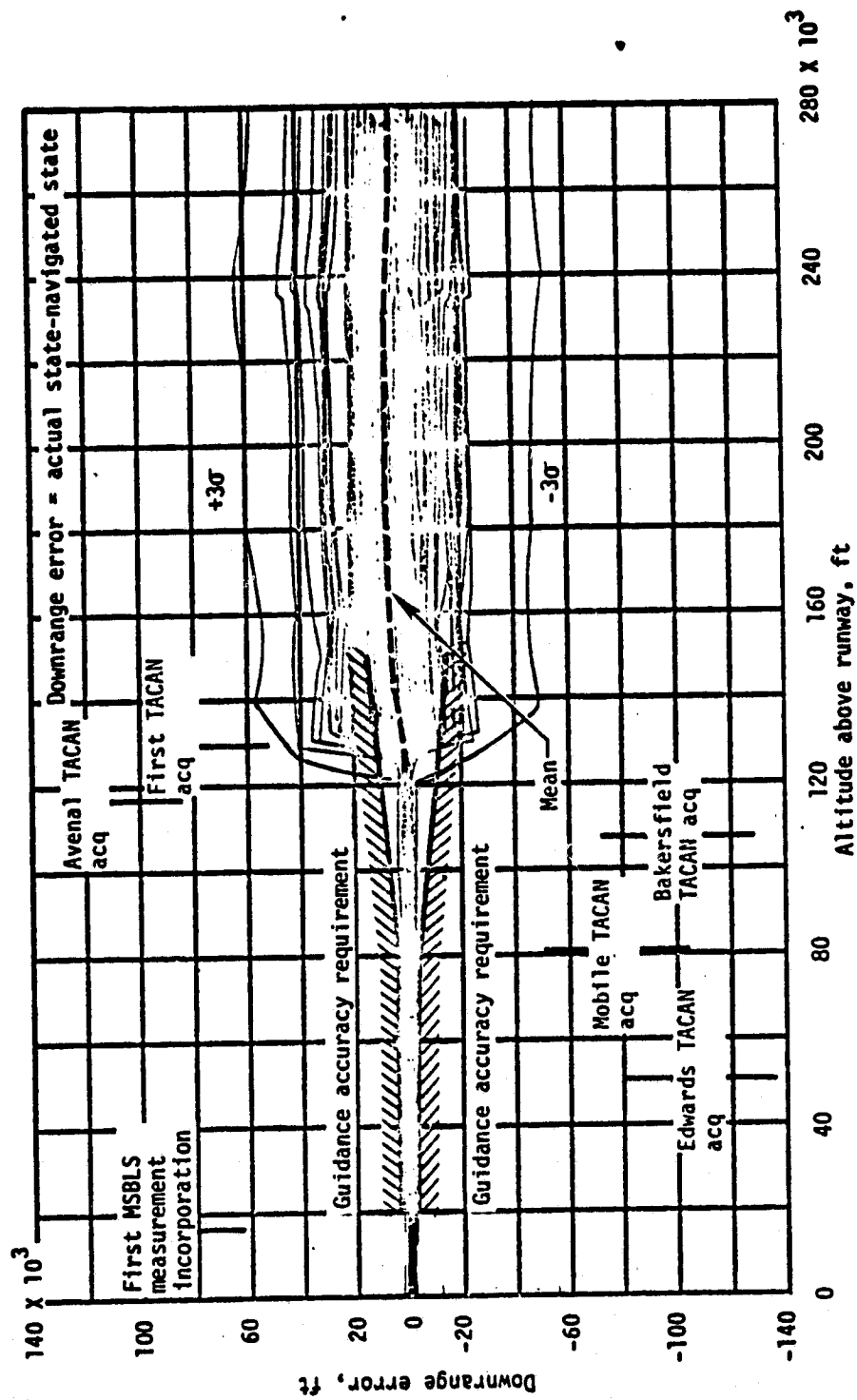
(b) Downrange error.

Figure 8-1.— Continued.

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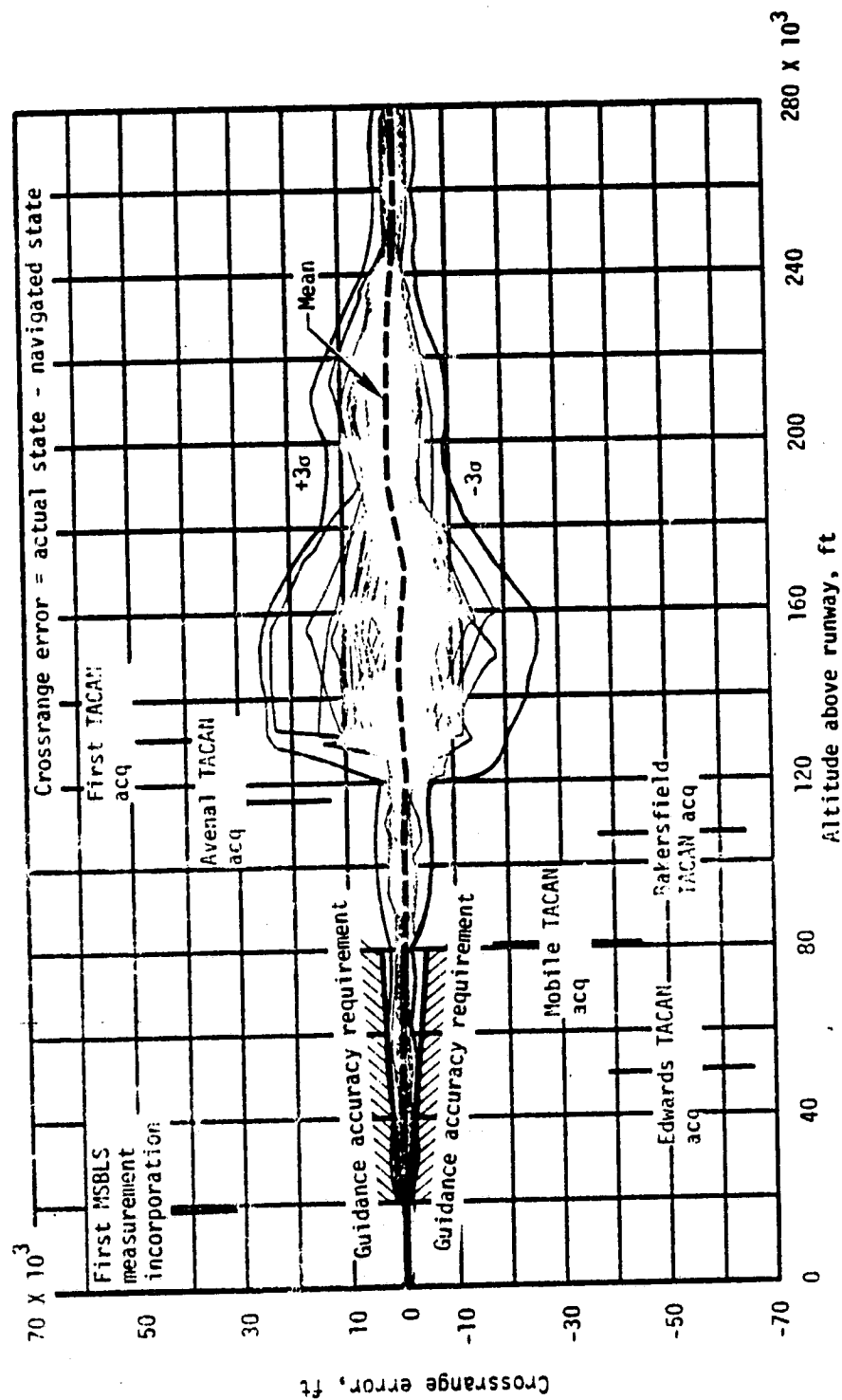
(c) Crossrange error.

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, Apprendix 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.

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.

RANGEWORD

TACRANGA

```
┌──────────────────────────────────────────┐
│                                          │
│                                          │
└──────────────────────────────────────────┘
 0                                        15
```

TACRANGB

```
┌──────────────────────────────────────────┐
│                                          │
│                                          │
└──────────────────────────────────────────┘
 16                                       31
```
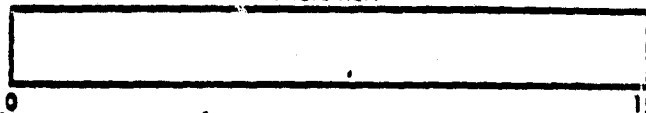
BITS

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 H/W

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

BEARING WORD

TACBEARA

0   15

TACBEARB

16   31.
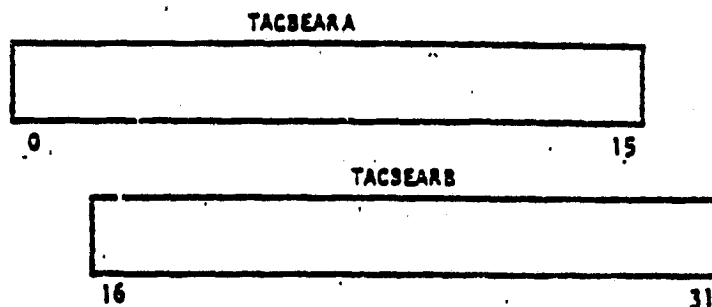
BITS

0   = PARITY

1 & 2 = 'CO'   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   = 2.3125°
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.)

RANGEWORD

	TACRANGA				TACRANGB		
BIT	32 29	28 25	24 21	20 17	16 13	12 9	8 1
DATA	100's	16's	1's	1/10's	1/100's	SELF-TEST	LABEL
EXAMPLE	0010	0101	0111	1000	0101	0XX0	10001001
257.85 nm.	2	5	7	8	5	0	DISTANCE LABEL

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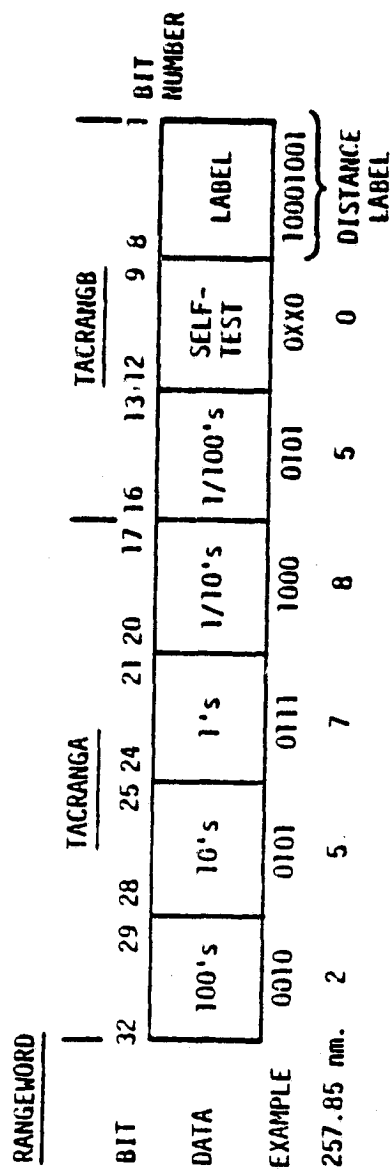
32	31	11	10	BIT
0	0	-	-	VALID DATA (TRACK OR SHORT-TERM MEMORY)
0	1	-	-	SELF-TEST FAILURE
1	0	-	-	NO COMPUTED DATA (SEARCH OR LONG-TERM MEMORY)
1	1	-	-	NOT USED
-	-	0	0	NOT IN SELF-TEST
-	-	1	1	IN SELF-TEST
-	-	0	1	NOT DEFINED
-	-	1	0	NOT DEFINED

Figure B-3.— TACAN to MDM range word.

BEARING WORD

BIT	32	29 28	25 24	21 20	17 16	13 12	9 8		BIT NUMBER

TACBEARA   TACBEARB

	PARITY STATUS STATUS			PAD		SELF-TEST	LABEL	

DATA (values shown):
90.0000
45.0000 22.5000 11.2500 5.6250
2.8125 1.4062 0.7031 0.3516
0.1758 0.0879 0.0439 PAD

EXAMPLE: 0110 1100 1100 0000 0000 0XX0 00000001

BEARING LABEL
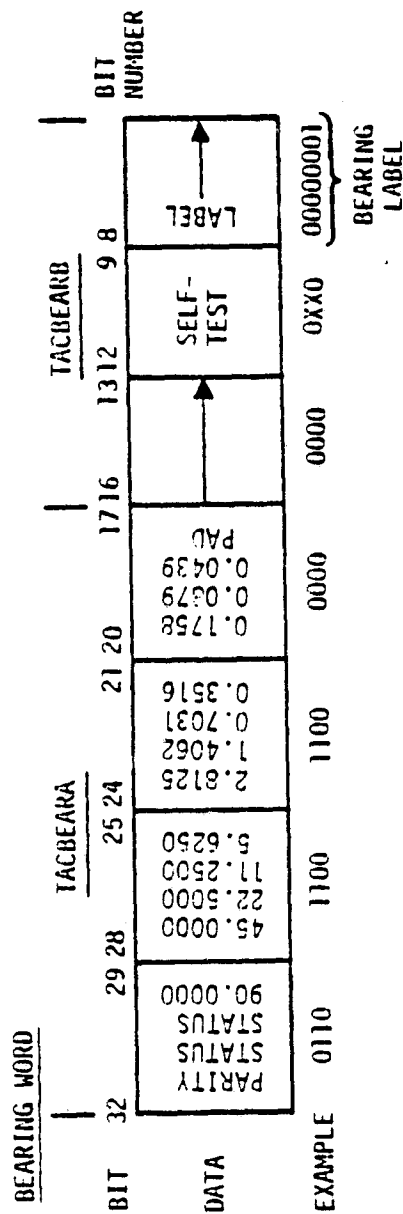
1251.7187

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.

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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	

[a]For TACAN channel numbers >100, bits 11 to 14
of the control word differ from bits 11 to 14
and 0 of the discrete word.

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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 fol-
lowing pages.

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

INPUT FUNCTIONAL PARAMETERS FOR THE TACTICAL AIR NAVIGATION RM MODULE (TACAN RM.4.77)

M/S ID	LEVEL B NO.	NOMENCLATURE	SOURCE	RANGE	UNITS
V95H016ECA	G04203	ALT WHEELS — ALT TO REAR WHEELS/NAV BASE(ENTRY)	RTLS UPP		FT
V95L017BCA	G04208	V_GROUNDSPEED — GROUNDSPEED	RTLS UPP		
V95H0155CD	G46580	R_EF — ORBITER X POSITION EF(TOD)	RTLS UPP		FT
V95H0156CB	G46580	ORBITER Y POSITION EF(TOD)	RTLS UPP		FT
V95H01572B	G46581	ORBITER Z POSITION EF(TOD)	RTLS UPP		FT
V95H0155CA	G46579	R_EF(1) — ORBITER X POSITION EF(TOD)	ENT UPP		FT
V95H016ECA	G46580	R_EF(2) — ORBITER Y POSITION EF(TOD)	ENT UPP		FT
V95H01572	G46581	R_EF(3) — ORBITER Z POSITION EF(TOD)	ENT UPP		FT
V95H016ECA	G04203	ALT_WHEELS — ALT TO REAR WHEELS/NAV BASE(ENTRY)	ENT UPP		FT/S
V95L017EC	G04208	V_GROUNDSPEED — GROUNDSPEED	ENT UPP		FT/S
V95H016ECA	G04203	ALT_WHEELS — ALT TO REAR WHEELS/NAV BASE(ENTRY)	TAEM UPP		FT
V95H0156CC	G46579	R_EF(1) — ORBITER X POSITION EF(TOD)	TAEM UPP		FT
V95H0156CB	G46580	R_EF(2) — ORBITER Y POSITION EF(TOD)	TAEM UPP		FT
V95H0157CC	G46581	R_EF(3) — ORBITER Z POSITION EF(TOD)	TAEM UPP		FT
V95L017EC	G04203	V_GROUNDSPEED — GROUNDSPEED	A/L UPP		FT/S
V95H016EC	G04203	ALT_WHEELS — ALT TO REAR WHEELS/NAV BASE(ENTRY)	A/L UPP		FT
V95H0156CD	G46579	R_EF(1) — ORBITER X POSITION EF(TOD)	A/L UPP		FT
V95H0156CB	G46580	R_EF(2) — ORBITER Y POSITION EF(TOD)	A/L UPP		FT
V95H0157CB	G46581	R_EF(3) — ORBITER Z POSITION EF(TOD)	A/L UPP		FT
V95H501C	G07024	TAC_TIM_TAG — TACAN TIME TAG	TACAN SOP	0.	S
V95H5102C	G07807	TACRANGE0(1) — TACAN NO 1 RANGE OUT	TACAN SOP	0. 2432000	FT
V95K510XA	G07815	TAC1RANGD0(1) — TACAN NO 1 RANGE LOCKED ON	TACAN SOP	0. 1	
V95H5122C	G07811	TAC1BEAR0(1) — TACAN NO 1 BEARING OUT	TACAN SOP	0. 6.28	RAD
V95K5124X	G07810	TAC1BEAR0G(1) — TACAN NO 1 BEARING LOCKED ON	TACAN SOP	0. 1	
V95H5130C	G07021	TAC1CHAN(1) — TACAN NO 1 CHANNEL W/MODE	TACAN SOP	+/-126	
V95H52020	G07000	TAC1RANGE0(2) — TACAN NO 2 RANGE OUT	TACAN SOP	0. 2432000	FT
V95K5204X	G07816	TAC2RANG00G(2) — TACAN NO 2 RANGE LOCKED ON	TACAN SOP	0. 1	
V95H5222C	G07812	TAC2BEAR0(2) — TACAN NO 2 BEARING OUT	TACAN SOP	0. 6.28	RAD
V95K5224X	G07819	TAC2BEAR0DG(2) — TACAN NO 2 BEARING LOCKED ON	TACAN SOP	0. 1	
V95H5230C	G07022	TAC2CHAN(2) — TACAN NO 2 CHANNEL W/MODE	TACAN SOP	+/-126	
V95H5302C	G07009	TAC3RANGE0(3) — TACAN NO 3 RANGE OUT	TACAN SOP	0. 2432000	FT
V95K5304X	G07817	TAC3RANG0G(3) — TACAN NO 3 RANGE LOCKED ON	TACAN SOP	0. 1	
V95H5322C	G07813	TAC3BEAR0(3) — TACAN NO 3 BEARING OUT	TACAN SOP	0. 6.28	RAD
V95K5324X	G07820	TAC3BEAR0G(3) — TACAN NO 3 BEARING LOCKED ON	TACAN SOP	0. 1	
V95H5330C	G07023	TAC3CHAN(3) — TACAN NO 3 CHANNEL W/MODE	TACAN SOP	+/-126	
V95K5146X		TCH_CPSG(1) — TACAN 1 CHANNEL CHANGE INDICATOR	TACAN SOP	0. 1	
V95K5246X		TCH_CHSG(2) — TACAN 2 CHANNEL CHANGE INDICATOR	TACAN SOP	0. 1	
V95K5346X		TCH_CHSG(3) — TACAN 3 CHANNEL CHANGE INDICATOR	TACAN SOP	0. 1	
V95K5143X		TAC_BRGFL(1) — TACAN NO 1 BEARING SELF TEST FAIL	TACAN SOP	0. 1	
V95K5243X		TAC_BRGFL(2) — TACAN NO 2 BEARING SELF TEST FAIL	TACAN SOP	0. 1	
V95K5343X		TAC_BRGFL(3) — TACAN NO 3 BEARING SELF TEST FAIL	TACAN SOP	0. 1	
V95K5144X		TAC_RNGFL(1) — TACAN NO 1 RANGE SELF TEST FAIL	TACAN SOP	0. 1	
V95K5244X		TAC_RNGFL(2) — TACAN NO 2 RANGE SELF TEST FAIL	TACAN SOP	0. 1	
V95K5344X		TAC_RNGFL(3) — TACAN NO 3 RANGE SELF TEST FAIL	TACAN SOP	0. 1	
V95K500GX		TAC_STIP — TACAN SELF TEST IN PROGRESS	TACAN SOP	0. 1	
V95H103ECA	G25904	R_TACAN_EF_SL(1) — X-COMP EF POS VECTOR OF TACAN 1	ENT SITE LOOKUP		FT
V95H1035CA	G25905	Y-COMP EF POS VECTOR OF TACAN 1	ENT SITE LOOKUP		FT
V95H103ECA	G25906	Z-COMP EF POS VECTOR OF TACAN 1	ENT SITE LOOKUP		FT
V95H1037CA	G25907	R_TACAN_EF_SL(2) — X-COMP EF POS VECTOR OF TACAN 2	ENT SITE LOOKUP		FT
V95H103ECA	G25900	Y-COMP EF POS VECTOR OF TACAN 2	ENT SITE LOOKUP		FT

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TABLE C-1.— Concluded.

INPUT FUNCTIONAL PARAMETERS FOR THE TACTICAL AIR NAVIGATION RM MODULE (TACAN RM,4.77)

M/S ID	LEVEL B NO.	NOMENCLATURE		SOURCE	RANGE	UNITS
V90H1839C∷	G25909		Z-COMP EF POS VECTOR OF TACAN 2	ENT SITE LOOKUP		FT
V90H1840C∷	G25910	R_TACAN_EF_SL(3)	X-COMP EF POS VECTOR OF TACAN 3	ENT SITE LOOKUP		FT
V90H1841C∷	G25911		Y-COMP EF POS VECTOR OF TACAN 3	ENT SITE LOOKUP		FT
V90H1842C∷	G25912		Z-COMP EF POS VECTOR OF TACAN 3	ENT SITE LOOKUP		FT
V90A0760A∷		ONE_RANGE_LOCK	TACAN RM 1 LRU RNG LOCKON RQST FLG	ENT NAV	0.1	
V90N0769A∷		ONE_BRG_LOCK	TACAN RM 1 LRU BRG LOCKON RQST FLG	ENT NAV	0.1	
V93X0760C∷		ONE_RANGE_LOCK	TACAN RM 1 LRU RNG LOCKON RQMT FLG	PRELAND NAV	0.1	
V90A0769A∷		ONE_BRG_LOCK	TACAN RM 1 LRU BRG LOCKON RQMT FLG	PRELAND NAV	0.1	
V90X0760C∷C		ONE_RNG_LOCK	TACAN RM 1 LRU RNC LOCKON RQST FLG	RTLS NAV	0.1	
V90N0769∷		ONE_BRG_LOCK	TACAN RM 1 LRJ BRG LOCKON RQST FLG	RTLS NAV	0.1	
V90N0121 ∷	G50318	AUTO_ID_CHANGED	CHANGE IN CHANNEL ID	ASC AUTO TAC SEL	0.1	
V93X0120L∷A	G50320	ID_CHANGE_REQUEST	ID CHANGE REQUEST RESET	ASC AUTO TAC SEL	0.1	
V90H1803∷C	G25904	R_TACAN_EF_SL(1)	X-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP		FT
V90H1803C∷	G25905		Y-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP		FT
V90H1803C∷)	G25906		Z-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP		FT
V90H1803∷3	G25907	R_TACAN_EF_SL(2)	X-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP		FT
V90H1803F	G25908		Y-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP		FT
V90H1839∷	G25909		Z-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP		FT
V90H1840C∷	G25910	R_TACAN_EF_SL(3)	X-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP		FT
V90H1841C∷	G25911		Y-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP		FT
V90H1842C∷	G25912		Z-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP		FT
V90N0125∷∷	G50318	AUTO_ID_CHANGED	CHANGE IN CHANNEL ID	ENT AUTO TAC SEL	0.1	
V90N0120CA∷	G50320	ID_CHANGE_REQUEST	ID CHANGE REQUEST RESET	ENT AUTO TAC SEL	0.1	
V93K4041A∷	C03034		TACAN 1 DES CMD	G.21		
V93K4035∷	C03035		TACAN 2 DES CMD	G.21		
V93K4036∷A	C03036		TACAN 3 DES CMD	G.21		
V91K3506∷	G46254	TAC_CF(1)	TACAN 1 COMM FAULT	FCOS	0.1	
V91K3516A	G46255	TAC_CF(2)	TACAN 2 COMM FAULT	FCOS	0.1	
V91K3526	G46256	TAC_CF(3)	TACAN 3 COMM FAULT	FCOS	0.1	
V93K4041∷∷A	C03034		TACAN 1 DES CMD	V5.1.4	0.1	
V93K4045∷∷	C03035		TACAN 2 DES CMD	V5.1.4	0.1	
V93K4415∷∷	C03036		TACAN 3 DES CMD	V5.1.4	0.1	
V71K3071∷	G07001	TACPOD(1)	TACAN NO 1 POWER STATUS	TACAN 1	0.1	
V71A0081A	G07902	TACPOD(2)	TACAN NO 2 POWER STATUS	TACAN 2	0.1	
V71A0091A	G07003	TACPOD(3)	TACAN NO 3 POWER STATUS	TACAN 3	0.1	

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TABLE C-1.— Continued.

OUTPUT FUNCTIONAL PARAMETERS FROM THE TACTICAL AIR NAVIGATION AM MODULE (TACAN MM.4.771)

M/S ID	LEVEL B NO.	NOMENCLATURE		DESTINATION	RANGE	UNITS
V90X3501X	G15901	TACAN_FAIL(1)	TACAN 1 FAIL	GAX	0,1	
V90X3701X	G15902	TACAN_FAIL(2)	TACAN 2 FAIL	GAX	0,1	
V90X3001X	G15903	TACAN_FAIL(3)	TACAN 3 FAIL	GAX	0,1	
V90J3602C		TAC_STREQ	TACAN SELF TEST REQUEST	TACAN SOP	0,3	BITS
V90H3592C		OUT_SEL_RNG	SELECTED RANGE DATA	ENT NAV,PRELAND NAV,RTLS NAV. TLM		FT
V90H3599C		OUT_SEL_BRG	SELECTED BEARING DATA	ENT NAV,PRELAND NAV,RTLS NAV. TLM	0,360	DEG
V90X3591X	G50307	OUT_BRG_DG	BEARING DATA GOOD	ENT NAV,PRELAND NAV,RTLS NAV. TLM	0,1	
V90X3593X	G50306	OUT_RNG_DG	RANGE DATA GOOD	ENT NAV,PRELAND NAV,RTLS NAV. TLM	0,1	
V90X3600X	G50991	BRGFAIL(1)	TACAN BEARING 1 FAIL	5,7,6,21,TLM	0,1	
V90X3709X	G50992	BRGFAIL(2)	TACAN BEARING 2 FAIL	5,7,6,21,TLM	0,1	
V90X3608X	G50993	BRGFAIL(3)	TACAN BEARING 3 FAIL	5,7,6,21,TLM	0,1	
V90X3611X	G50994	RNGFAIL(1)	TACAN RANGE 1 FAIL	5,7,6,21,TLM	0,1	
V90X3711X	G50995	RNGFAIL(2)	TACAN RANGE 2 FAIL	5,7,6,21,TLM	0,1	
V90X3611X	G50996	RNGFAIL(3)	TACAN RANGE 3 FAIL	5,7,6,21,TLM	0,1	
V90X3593X	G50997	BRGDIL	TACAN BEARING DILEMMA FLAG	5,7,6,21,TLM	0,1	
V90X3604X	G50998	RNGDIL	TACAN RANGE DILEMMA FLAG	GAX	0,1	
V90X3605X		TACANDIL	TACAN DILEMMA	ENT AUTO TAC SEL,	0,1	
V90X3599X		ID_CHANGE_REQUEST	ID CHANGE REQUEST	ASC AUTO TAC SEL,TLM		
V90X3598X		IN_CONE_FLAG	INSIDE CONE FLAG	ENT NAV,PRELAND NAV,RTLS NAV	0,1	
V90J5595C	G14426	SEL_LRU_ID	SELECTED LRU ID	ENT NAV,PRELAND NAV,RTLS NAV.	1,3	
V90X3598C		T_TACAN	TACAN TIME TAG	ENT NAV,PRELAND NAV,RTLS NAV. TLM		
V90U0720CD	G50935	ELEV_ANG	TACAN/SHUTTLE ELEV ANG	TLM	0,90	DEG

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INPUT FUNCTIONAL PARAMETERS FOR THE TACAN SOP MODULE (TACAN SOP.4.43)

M/S ID	LEVEL B NO.		NOMENCLATURE	SOURCE		RANGE	UNITS
V90J3602C		TAC_STREQ	TACAN SELF TEST REQUEST	TACAN RM		0,3	BITS
V95X2111X	G44891	SOURCE_LEFT	LH HSI SOURCE SELECT	GNSC SW RM		0,1	
V96X2211X	G44892	SOURCE_RIGHT	RH HSI SOURCE SELECT	GNSC SW RM		0,1	
V96J2105C	G44893	RCVR_LEFT	LH HSI RECEIVER SELECT	GNSC SW RM		1,3	
V96J2205C	G44894	RCVR_RIGHT	RH HSI RECEIVER SELECT	GNSC SW RM		1,3	
V96J0124CA	G50319	AUTO_CHANNEL_ID	TACAN CHANNEL SELECTION	ASC AUTO TAC SEL		1,126	
V96J0124CB	G50319	AUTO_CHANNEL_ID	TACAN CHANNEL SELECTION	ERT AUTO TAC SEL			
V91X3500X	G46254	TAC_CF(1)	TACAN 1 COMM FAULT	FCOS		0,1	
V91X3510X	G46255	TAC_CF(2)	TACAN 2 COMM FAULT	FCOS		0,1	
V91X3520X	G46256	TAC_CF(3)	TACAN 3 COMM FAULT	FCOS		0,1	
V91X5000C	G07823	CLOCK	CLOCK-COMPUTER(GMT)	FCOS			S
V74X1530P	G07900	TACBEARA(1)	TACAN 1 BEARING WORD A	WD1 TACAN 1		0,360	DEG
V74X1531F	G07903	TACBEARB(1)	TACAN 1 BEARING WORD B	WD2 TACAN 1		0,360	DEG
V74X1550P	G07906	TACRANGA(1)	TACAN 1 RANGE WORD A	WD1 TACAN 1		0,400	NM
V74X1551P	G07909	TACRANGB(1)	TACAN 1 RANGE WORD B	WD2 TACAN 1		0,400	NM
V74X0070X		TAC_TSM(1)	TACAN NO 1 TEST STATUS MONITOR	WD2 TACAN 1			
V74X1630P	G07901	TACBEARA(2)	TACAN 2 BEARING WORD A	WD1 TACAN 2		0,360	DEG
V74X1631P	G07904	TACBEARB(2)	TACAN 2 BEARING WORD B	WD2 TACAN 2		0,360	DEG
V74X1650CP	G07907	TACRANGA(2)	TACAN 2 RANGE WORD A	WD1 TACAN 2		0,400	NM
V74X1651P	G07910	TACRANGB(2)	TACAN 2 RANGE WORD B	WD2 TACAN 2		0,400	NM
V74X0080X		TAC_TSM(2)	TACAN NO 2 TEST STATUS MONITOR	WD2 TACAN 2			
V74X1730P	G07902	TACBEARA(3)	TACAN 3 BEARING WORD A	WD1 TACAN 3		0,360	DEG
V74X1731P	G07905	TACBEARB(3)	TACAN 3 BEARING WORD B	WD2 TACAN 3		0,360	DEG
V74X1750P	G07908	TACRANGA(3)	TACAN 3 RANGE WORD A	WD1 TACAN 3		0,400	NM
V74X1751P	G07911	TACRANGB(3)	TACAN 3 RANGE WORD B	WD2 TACAN 3		0,400	NM
V74X0090X		TAC_TSM(3)	TACAN NO 3 TEST STATUS MONITOR	WD2 TACAN 3			
V72X1510PA			TACAN NO 1 CONTROL WORD	D3C PNL			
V72X1610PA			TACAN NO 2 CONTROL WORD	D3C PNL			
V72X1710PA			TACAN NO 3 CONTROL WORD	D3C PNL			
V72X3607P			M3M FF01 DSCR IN CD 09 CH 02	MCDR			
V72X3607P			M3M FF03 DSCR IN CD 09 CH 02	MCDR			
V72X3599P			M3M FF01 DSCR IN CD 09 CH 5	MDWR			
V72X6649P			M3M FF02 DSCR IN CD 00 CH 5	MDWR			
V72X6599P			M3M FF03 DSCR IN CD 00 CH 5	MDWR			
V72X6410X		TAC_GPC(1)	TACAN NO 1 AUTO DISCRETE(COMPUTER)	MDWR		0,1	
V72X6430X		TAC_GPC(2)	TACAN NO 2 AUTO DISCRETE(COMPUTER)	MDWR		0,1	
V72X6450X		TAC_GPC(3)	TACAN NO 3 AUTO DISCRETE(COMPUTER)	MCWR		0,1	

TABLE C-2. — Continued.

OUTPUT FUNCTIONAL PARAMETERS FROM THE TACAN SOP MODULE (TACAN SOP.4.13)

M/S ID	LEVEL B NO.	NOMENCLATURE	DESTINATION	RANGE	UNITS
V95H5001C	G07824 TAC_TIM_TAG	TACAN TIME TAG	TACAN RW.TLM		
V95H5102C	G07807 TACRANGEO(1)	TACAN NO 1 RANGE OUT	ENT AREA NAV,ASC AREA NAV, TACAN RW,TLM,ENT UPP,TAEM UPP,	0,2432000	FT
V95X5104X	G07815 TACRANGOG(1)	TACAN NO 1 RANGE LOCKED ON	A/L UPP,RTLS UPP GAK,TACAN RW,TLM	0,1	
V95H5122C	G07811 TACBEARO(1)	TACAN NO 1 BEARING OUT	ENT AREA NAV,ASC AREA NAV, TACAN RW,TLM,ENT UPP,TAEM UPP,	0,6.28	RAD
V95X5124X	G07818 TACBEARDG(1)	TACAN NO 1 BEARING LOCKED ON	A/L UPP,RTLS UPP GAK,TACAN RW,TLM	0,1	
V95J5130C	G07921 TACCHAN(1)	TACAN NO 1 CHANNEL W/MODE	ASC AREA NAV,ENT AREA NAV, TACAN RW,TLM	+/-126	
V95H5202C	G07808 TACRANGEO(2)	TACAN NO 2 RANGE OUT	ENT AREA NAV,ASC AREA NAV, TACAN RW,TLM,ENT UPP,TAEM UPP,	0,2432000	FT
V95X5204X	G07816 TACRANGDG(2)	TACAN NO 2 RANGE LOCKED ON	A/L UPP,RTLS UPP GAK,TACAN RW,TLM	0,1	
V95H5222C	G07812 TACBEARO(2)	TACAN NO 2 BEARING OUT	ENT AREA NAV,ASC AREA NAV, TACAN RW,TLM,ENT UPP,TAEM UPP,	0,6.28	RAD
V95X5224X	G07819 TACBEARDG(2)	TACAN NO 2 BEARING LOCKED ON	A/L UPP,RTLS UPP GAK,TACAN RW,TLM	0,1	
V95J5230C	G07822 TACCHAN(2)	TACAN NO 2 CHANNEL W/MODE	ASC AREA NAV,ENT AREA NAV, TACAN RW,TLM	+/-126	
V95H5302C	G07809 TACRANGEO(3)	TACAN NO 3 RANGE OUT	ENT AREA NAV,ASC AREA NAV, TACAN RW,TLM,ENT UPP,TAEM UPP,	0,2432000	FT
V95X5304X	G07817 TACRANGDG(3)	TACAN NO 3 RANGE LOCKED ON	A/L UPP,RTLS UPP GAK,TACAN RW,TLM	0,1	
V95H5322C	G07813 TACBEARO(3)	TACAN NO 3 BEARING OUT	ENT AREA NAV,ASC AREA NAV, TACAN RW,TLM,ENT UPP,TAEM UPP,	0,6.28	RAD
V95X5324X	G07820 TACBEARDG(3)	TACAN NO 3 BEARING LOCKED ON	A/L UPP,RTLS UPP GAK,TACAN RW,TLM	0,1	
V95J5330C	G07823 TACCHAN(3)	TACAN NO 3 CHANNEL W/MODE	ASC AREA NAV,ENT AREA NAV, TACAN RW,TLM	+/-126	
V95X5140X	G51002 TRNG_CMLK(1)	TACAN 1 RANGE COMFAULT/LOCKON FLAG	ENT AREA NAV,ASC AREA NAV,5.7, TLM	0,1	
V95X5240X	G51003 TRNG_CMLK(2)	TACAN 2 RANGE COMFAULT/LOCKON FLAG	ENT AREA NAV,ASC AREA NAV,5.7, TLM	0,1	
V95X5340X	G51004 TRNG_CMLK(3)	TACAN 3 RANGE COMFAULT/LOCKON FLAG	ENT AREA NAV,ASC AREA NAV,5.7, TLM	0,1	
V95X5141X	G50999 TBRG_CMLK(1)	TACAN 1 BEAR COMFAULT/LOCKON FLAG	ENT AREA NAV,ASC AREA NAV,5.7, TLM	0,1	
V95X5241X	G51000 TBRG_CMLK(2)	TACAN 2 BEAR COMFAULT/LOCKON FLAG	ENT AREA NAV,ASC AREA NAV,5.7, TLM	0,1	
V95X5341X	G51001 TBRG_CMLK(3)	TACAN 3 BEAR COMFAULT/LOCKON FLAG	ENT AREA NAV,ASC AREA NAV,5.7, TLM	0,1	
V95X5146X	TCH_CHNG(1)	TACAN 1 CHANNEL CHANGE INDICATOR	TACAN RW,ENT AREA NAV, ASC AREA NAV	0,1	
V95X5246X	TCH_CHNG(2)	TACAN 2 CHANNEL CHANGE INDICATOR	TACAN RW,ENT AREA NAV, ASC AREA NAV	0,1	
V95X5346X	TCH_CHNG(3)	TACAN 3 CHANNEL CHANGE INDICATOR	TACAN RW,ENT AREA NAV, ASC AREA NAV	0,1	
V95X5143X	TAC_BRGF(1)	TACAN NO 1 BEARING SELF TEST FAIL	TACAN RW	0,1	
V95X5243X	TAC_BRGF(2)	TACAN NO 2 BEARING SELF TEST FAIL	TACAN RW	0,1	

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TABLE C-2.— Concluded.

OUTPUT FUNCTION... PARAMETERS FROM THE TACAN SOP MODULE (TACAN SOP.4.43)

M/S ID	LEVEL & NO.	NOMENCLATURE	DESTINATION	RANGE	UNITS
V95X5343X	TAC_BTGFL(3)	TACAN NO 3 BEARING SELF TEST FAIL	TACAN RW	0. 1	
V95N5144X	TAC_RNGFL(1)	TACAN NO 1 RANGE SELF TEST FAIL	TACAN RW	0. 1	
V95X5244X	TAC_RNGFL(2)	TACAN NO 2 RANGE SELF TEST FAIL	TACAN 602	0. 1	
V95X5144X	TAC_RNGFL(3)	TACAN NO 3 RANGE SELF TEST FAIL	TACAN RN	0. 1	
V95A5C06X	TAC_STIP	TACAN SELF TEST IN PROGRESS	TACAN RN	0. 1	
V95J5020C	NEW STATION ID G50321	TACAN 1,2,OR 3 NEW STATION CHAN NO	TACAN RW.CAX.6.21	+/-128	
V95J5021C	LRU_ID G46531	TACAN LRU NUMBER	ENT SITE LOOKUP.ASC SITE LOOKUP	1. 3	
V74K1510PB	TAC_CNTRL(1)	TACAN NO 1 CONTROL WORD	TACAN 1.TLM		
V74K1610PB	TAC_CNTRL(2)	TACAN NO 2 CONTROL WORD	TACAN 2.TLM		
V74K1710PB	TAC_CNTRL(3)	TACAN NO 3 CONTROL WORD	TACAN 3.TLM		
V74K0170X	TACANTSEL(1)	TACAN NO 1 UPPER/LOWER ANT LOCK	TACAN 1.TLM	0. 1	
V74K0180X	TACANTSEL(2)	TACAN NO 2 UPPER/LOWER ANT LOCK	TACAN 2.TLM	0. 1	
V74K0190X	TACANTSEL(3)	TACAN NO 3 UPPER/LOWER ANT LOCK	TACAN 3.TLM	0. 1	
V74K0141X	TACANTINH(1)	TACAN NO 1 ANTENNA SELECT INHIBIT	TACAN 1.TLM	0. 1	
V74K0151X	TACANTINH(2)	TACAN NO 2 ANTENNA SELECT INHIBIT	TACAN 2.TLM		
V74K0161X	TACANTINH(3)	TACAN NO 3 ANTENNA SELECT INHIBIT	TACAN 3.TLM	0. 1	
V72K5536P		MDM FF01 DSCR OUT SET CO 00 CH 7	TACAN 1.TLM		
V72K5636P		MDM FF02 DSCR OUT SET CO 00 CH 7	TACAN 2.TLM		
V72K5736P		MDM FF03 DSCR OUT SET CO 00 CH 7	TACAN 3.TLM		
V74K1511B		TACAN NO 1 MODE X/Y	TALAN 3.TLM		
V74K1611B		TACAN NO 2 MODE X/Y	TACAN 1.TLM		
V74K1711B		TACAN NO 3 MODE X/Y	TACAN 2.TLM		
V74K1512B		TACAN NO 1 A/A	TACAN 3.TLM		
V74K1612B		TACAN NO 2 A/A	TACAN 1.TLM		
V74K1712B		TACAN NO 3 A/A	TACAN 2.TLM		
V74K1513B		TACAN NO 1 T/R+RCV ONLY	TACAN 3.TLM		
V74K1613B		TACAN NO 2 T/R+RCV ONLY	TACAN 1.TLM		
V74K1713B		TACAN NO 3 T/R+RCV ONLY	TACAN 2.TLM		
V74K1514B		TACAN NO 1 CHANNEL SELECT	TACAN 3.TLM		
V74K1614B		TACAN NO 2 CHANNEL SELECT	TACAN 1.TLM		
V74K1714B		TACAN NO 3 CHANNEL SELECT	TACAN 3.TLM		

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.

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

[a]The 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

PRINCIPAL FUNCTION MGR REPORT   G4.77   ISYS-1/VER2.3/CHDS BASE
DOC. NUMBER OO1O PARAGRAPH 4.1.9   DBIN - OO1O (O4/18/79)

FORMAT 2	REQUIREMENTS SYMBOLIC NAME / HAL NAME / NOMENCLATURE	MC VALUE	UNITS	D·B·DT·PR MAXIMUM MINIMUM	CR NUM
MSID					
V97U3004C	ALT_CUTOFF ALTITUDE CUTOFF	*01·+1.5000000 *03·+1.5000000	E·O3·FEET E·O3·	M·P·F ·S	·122664
V97U3013C	BRG_COUNT_LIM BEARING COUNTER LIMIT	*01·+10 *03·+10	·ND	M·P·I ·S	·122664
V97U3015C	BRG_JUMP_LIM BEARING JUMP LIMIT	*01·+4.5000000 *03·+4.5000000	E·OO·DEG E·OO·	M·P·F ·S	·122664
V97U3016C	BRG_TOL BEARING TOLERANCE	*01·+6.0000000 *03·+6.0000000	E·OO·DEG E·OO·	M·P·F ·S	·122664
V97U3029C	ELEV_ANG_LIM ELEVATION ANGLE LIMIT	*03·+4.5000000	E·O1·DEG	M·P·F ·S	·12443
V97U3234C	RNG_COUNT_LIM RANGE COUNTER LIMIT	*01·+5 *03·+5	·ND	M·P·I ·S	·122664
V97U3236C	RNG_TOL RANGE TOLERANCE	*01·+3.0000000 *03·+3.0000000	E·O3·FT E·O3·	M·P·F ·S	·122664
V97U3290C	TWO_LOCK_CTR_LIM TWO LOCK COUNTER LIMIT	*01·+20 *03·+20	·ND	M·C·I ·S	·19397
V97U3291C	RNG_K RANGE CONSTANT	*01·+1.0000000 *03·+1.0000000	E·O4·FT E·O4·	M·P·F ·S	·122664
V97U3292C	RNG_R RANGE RATE	*01·+0.0 *03·+0.0	E·OO·SEC E·OO·	M·P·F ·S	·122664
V98U9722C	RNG_JUMP_CTR_LIM RANGE JUMP COUNTER LIMIT	*01·+5.0000000 *03·+5.0000000	E·OO·ND E·OO·	M·P·F ·S	·19065
V98U9723C	V_RNG_LIM VELOCITY RANGE LIMIT	*01·+4.5000000 *03·+4.5000000	E·O3·KNOTS E·O3·	M·P·F ·S	·19065
V98U9724C	R_ACQ_LIM_H RANGE ACQ LIMIT HIGH	*01·+10 *03·+10	·ND	M·P·I ·S	·19065
V98U9725C	R_ACQ_LIM_L RANGE ACQ LIMIT LOW	*01·+5 *03·+5	·ND	M·P·I ·S	·19065

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TABLE D-2.— Concluded.

MSID	REQUIREMENTS SYMBOLIC NAME / HAL NAME / NOMENCLATURE	M	VALUE	UNITS	U·M·DI·PH	S	MAXIMUM MINIMUM	CB NAME
V98U9726C	BRG_JUMP_CTR_LIM / BEARING JUMP COUNTER LIMIT		01·11.0000000 / 03·11.0000000	E·01·ND / E·01·		M·P·F	S		19065
V98U9727C	V_BRG_LIM / VELOCITY BEARING LIMIT		01·14.5000000 / 03·14.5000000	E·02·KNOTS / E·03·		M·P·F	S		19065
V98U9728C	B_ACQ_LIM_H / BEARING ACQ LIMIT HIGH		01·+12 / 03·+12	ND		M·P·I	S		19387
V98U9729C	B_ACQ_LIM_L / BEARING ACQ LIMIT LOW		01·+12 / 03·+12	ND		M·P·I	S		19387

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PRINCIPAL FUNCTION SIGN ALPHA1 / CA.77 · DOC. NUMBER 0010 PARAGRAPH 4.3

GSO..1/VLN2.3/CPU5 BASE / DBEN - 0010 (04/10/79)

FORMAT 2

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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