628 pt B

STS 83-00058

SPACE SHUTTLE ORBITER OPERATIONAL

LEVEL C
FUNCTIONAL SUBSYSTEM SOFTWARE REQUIREMENTS
GUIDANCE, NAVIGATION, AND CONTROL

PART B
NAVIGATION
ASCENT/RTLS

June 30, 1987

Contract NAS9-14000
IRD SE-694D
WBS 19.9.1

SOC TECH. LIBRARY
FILE COPY
RECEIVED
SEP 13 1988

Approved by

12/9/87

E.L. Freddolino, Director
Software Engineering
Systems Engineering

Rockwell International
Space Transportation
Systems Division

PAGE CHANGE NOTICE

PAGE CHANGE NOTICE NO: 4 OI-8D
CHANGE DATE: July 31, 1989
PAGE 1 OF 1

DOCUMENT NO./REV: STS 83-0005B
TITLE: Functional Subsystem Software Requirements
Guidance, Navigation, and Control
Part B: Navigation Ascent/RTLS

DATE: June 30, 1989

DATA RELEASE—PLEASE ADD THE ENCLOSED REVISED DATA TO YOUR COPY OF SUBJECT DOCUMENT AS APPENDIX "Y."
IT CONTAINS THE DELTA REQUIREMENTS CHANGES BASELINED BY THE SASCB FOR FLIGHT SOFTWARE RELEASE OI-8C. RECOMMEND KEEPING IT SEPARATED FROM THE OI-8B BASE REQUIREMENTS UNTIL SUCH TIME OI-8B IS NO LONGER NEEDED.
INSERT THIS SHEET BEHIND THE TITLE PAGE AT TIME OF INCORPORATION TO IDENTIFY THE CHANGE STATUS OF THIS REQUIREMENTS DOCUMENT.

REMOVE PAGE(S)	REPLACE WITH	ADD NEW PAGE(S)	DELETE OLD PAGE(S)
v	v		
vii	vii		
4-11, 4-12	4-11, 4-12		
4-22 to 4-23	4-21 to 4-24		
4-32	4-31, 4-32		
4-42	4-41, 4-42		
4-78 to 4-81	4-77 to 4-82		
4-174 to 4-179	4-173 to 4-180		
4-226 to 4-228	4-225 to 4-228		
4-257 to 4-271a	4-257 to 4-271a		
4-277	4-277, 4-278		
4-289 to 4-293	4-289 to 4-294		
4-300	4-299, 4-300		
4-333 to 4-339	4-333 to 4-340		
4-382 to 4-385	4-381 to 4-386		
4-398	4-398		

STSOC TECH. LIBRARY
FILE COPY

RECEIVED
SEP 25 1989

PAGE CHANGE NOTICE

PAGE CHANGE NOTICE NO PCN-3 OI-8C
CHANGE DATE. May 30, 1989
PAGE 1 OF 9

DOCUMENT NO./REV. STS 83-0005B
TITLE. Functional Subsystem Software Requirements
Guidance, Navigation, and Control
Part B: Navigation Ascent/RTLS

DATE: June 30, 1988

***** IMPORTANT—PLEASE READ *****

PLEASE ADD THE ENCLOSED REVISED DATA TO YOUR COPY OF SUBJECT DOCUMENT AS APPENDIX "X". IT CONTAINS THE DELTA REQUIREMENTS CHANGES BASELINED BY THE SASCB FOR FLIGHT SOFTWARE RELEASE OI-8C. RECOMMEND KEEPING IT SEPARATED FROM THE OI-8B BASE REQUIREMENTS UNTIL SUCH TIME OI-8B IS NO LONGER NEEDED. INSERT THIS SHEET BEHIND THE TITLE PAGE AT TIME OF INCORPORATION TO IDENTIFY THE CHANGE STATUS OF THIS REQUIREMENTS DOCUMENT.

REMOVE PAGE(S)	REPLACE WITH	ADD NEW PAGE(S)	DELETE OLD PAGE(S)
v	v	4-371, 4-372	4-371, 4-372 (PCN-2 dated 11-30-88)
vii	vii		
xxi, xxii	xxi, xxii		
4-365, 4-366	4-365, 4-366		
5-41, 5-42	5-41, 5-42		
5-129, 5-130	5-129, 5-130		

STSOC TECH. LIBRARY
FILE COPY

RECEIVED
JUN 28 1989

SPACE DIVISION
ROCKWELL INTERNATIONAL

CHANGE NO: PCN-2A

CHANGE DATE: November 30, 1988

PAGE 1 OF 1

REPORT NO: STS 83-0005B

TITLE: Ascent/RTLS Navigation
FSSR

DATA RELEASE—PLEASE INCORPORATE THE ENCLOSED REVISED DATE INTO YOUR COPY OF STS 83-0005B DATE June 30, 1988

DESTROY OBSOLETE PAGES, AS NOTED. INSERT THIS SHEET BEHIND THE TITLE PAGE TO IDENTIFY THE CHANGE STATUS OF THIS BOOK.

REPLACE PAGES	ADD NEW PAGE(S)	DELETE OLD PAGE(S)
vii 4-271, 4-272	4-271A	

RECEIVED
MAY 03 1989

STSOC TECH. LIBRARY
FILE COPY

SPACE DIVISION ROCKWELL INTERNATIONAL	CHANGE NO: PCN-2 CHANGE DATE: November 30, 1988
REPORT NO: STS 83-0005B TITLE: Ascent/RTLS Navigation FSSR	PAGE 1 OF 1

DATA RELEASE—PLEASE INCORPORATE THE ENCLOSED REVISED DATE INTO YOUR COPY OF STS 83-0005B DATE June 30, 1988

DESTROY OBSOLETE PAGES, AS NOTED. INSERT THIS SHEET BEHIND THE TITLE PAGE TO IDENTIFY THE CHANGE STATUS OF THIS BOOK.

REPLACE PAGES	ADD NEW PAGE(S)	DELETE OLD PAGE(S)
v, vii 4-6, 4-7, 4-47, 4-48 4-73, 4-74, 4-85 through 4-93A 4-273, 4-274 4-341, 4-342 4-371, 4-372 4-385, 4-386 4-389, 4-390 5-11 through 5-14 5-41, 5-42 5-97, 5-98 5-157, 5-158	xxvi 4-342 (this page left intentionally blank)	

STSOC TECH. LIBRARY
FILE COPY

RECEIVED
MAY 03 1989

SPACE TRANSPORTATION SYSTEMS DIVISION ROCKWELL INTERNATIONAL	CHANGE NO. 1 CHANGE DATE March 25, 1988 PAGE 1 OF 1

REPORT NO. STS 83-0005B

TITLE FSR 0005B

DATA RELEASE. PLEASE INCORPORATE THE ENCLOSED REVISED DATA INTO YOUR COPY OF STS 83-0005B dated March 25, 1988

DESTROY OBSOLETE PAGES, AS NOTED. INSERT THIS SHEET BEHIND THE TITLE PAGE TO IDENTIFY THE CHANGE STATUS OF THIS BOOK.

REPLACE PAGES

v, vii, 4-1, 4-8, 4-64, 4-86, 4-87, 4-111, 4-186 to 4-191a, 4-217, 4-230 to 4-230a, 4-276, 4-299, 4-295, 4-316, 4-341, 4-370, 5-7, 5-13, 5-89 to 5-94, 5-97 to 5-98, 5-153, 5-162

VED
SEP 1(1 0

INSERT NEW PAGES	DELETE
4-15 to 4-16, 4-26 to 4-27, 4-35, 4-45, 4-92 to 4-93a, 4-25, 4-192, 4-193, 4-194, 4-231 to 4-232, 4-273, 4-297, 4-343, 4-398	

Reviewed by

J.K. Cox 7/5/88

J.K. Cox,
Supervisor
Flight Software Integration

J.D. Almanza,
Supervisor
Second-Stage IGN&C
Powered Flight Guidance

D.E. Gavert,
Supervisor
Orbit/Entry GN&C
and Navigation

E.W. Nelson,
Manager
Software Requirements
and Integration

R.J. Tomooka,
Manager
Integrated IGN&C

CR89596C

Prepared by

D.L. Jeffredo

D.L. Jeffredo
Flight Software Integration
(213) 922-5532

CR89596C

FOREWORD

The primary avionics software system (PASS) requirments for the computer programs that execute in the Shuttle general-purpose computers (GPC's) are specified in the Computer Program Development Specifications (CPDS's) and the Functional Subsystem Software Requirements (FSSR) documents. The requirements are specified at three levels:

Level A CPDS - System-level constraints and capabilities
Level B CPDS - Functional requirements
Level C FSSR - Detailed-level requirements

The Level A CPDS specifies system-level constraints and capabilities that are not oriented toward any particular program end item. The Level B CPDS specifies system-level requirements for guidance, navigation, and control (GN&C) and detailed requirements for systems management (SM) and vehicle utility (VU). The Level C FSSR's specify the detailed requirements for GN&C and display/ controls. The Level C reconfigurable requirements are specified in the systems management and payload documents. The Level A, Level B, and Level C requirements documents are listed in Section 2, Applicable Documents.

CHANGE REQUEST SUMMARY

The following tabulation lists the paragraphs, tables (T), and figures (F) that have been changed as a result of approved change requests commencing with OI-8A. Changes incorporated prior to OI-8A are listed in the Historical Change Request Summary.

Paragraph	CR No.	OI	Title
4.6.1	79646D	8A	Auto-Loft, 1st-Stage Contingency
N/A	89546	8B	STS 83-0005B Errata/Baseline CR
4.6.1.5 (T)	89599C	8B	Cleanup to Level B GN&C
N/A	89596C	8B	STS 83-0005B PCN-1 Errata
4.6.2.3	89621A	8B	Drag Acceleration Limits
N/A	89947A	8B	STS 83-0005B PCN-2 Errata
5.4-9	89864A	8C	Change BEAR_RW Lower Limit Value
4.6.1.5-1 (T)	89903B	8C	Add Fuel Dissipation REF
4.6.2.7-1 (T)			
4.6.1 (T)	89150H	8D	Abort Control Sequence Scrub
4.6.1.5-1 (T)			
4.6.2 (T)			
4.6.2.7-1 (T)			
4.3.2.9-1 (T)	89805	8D	Errata Change - CR 89665B Page 3 and IDD
4.6.2.7-1 (T)			
4.7.1-1 (T)			

DOCUMENT CHANGE RECORD

The following tabulation summarizes the change activity associated with this document since Revision A dated June 30, 1985. A vertical line (change bar) and the appropriate CR number in the outer margin indicate the latest changes to each page.

Issue and Date	Change Summary
OI-8B Release (Revision B) June 30, 1987	This issue updates the baseline to OI-8B and includes the following CR: 79646D and 89546.
PCN-1 March 25, 1988	This change notice updates OI-8B to include the following CR's: 89596C and 89621A.
PCN-2 November 30, 1988	This change notice updates OI-8B and includes CR 89947A.
PCN-2A November 30, 1988	This change notice updates OI-8B and is an addendum to PCN-2.
PCN-3 OI-8C May 30, 1989	This page change notice provides OI-8C for post OI-8B insertion to include CR 89864A.
PCN-4 OI-8D July 31, 1989	This page change notice updates the previous release to include CR's 89150H, 89599C, 89805, and 89903B. Referenced is CR 89461A and IDR 87019 for I-Loads.

HISTORICAL CHANGE REQUEST SUMMARY

The following tabulation is a historical record of approved change requests incorporated since the initial baseline up to OI-8A. Change requests commencing with OI-8A are reformatted and listed in the Change Request Summary.

CR No.	Title
2166	OFT GN&C ENTRY FUNCTIONAL UPDATE
2213	DELETION OF DRAG BIAS INTEGRAL FDBK LOCKOUT IN ENT GUID FOR RUNWAY REDESIGNATION & FOR MANUAL CONTROL MODE
2235A	NAV DATA UPDATE, GAX CHANGE & MSC REVISION
2265B	ADD IMU ALIGN CAPABILITY TO OPS-3
2433C	ADDITION OF GN&C/SM-PL IF (4.111) TO GNC OPS GNC OPS 3/5M OPS-2
2449D	CONTINGENCY ABORT REQUIREMENT
2461	DELETION OF 1 PARAMETER CALCULATION FROM ASCENT UPP P.F.
2471	DISPLAY PRECSN V_AVGG AS PF
2474	DELETE A "DESTINATION" FOR A VARIABLE IN ASC UPP
12019	STANDARDIZATION OF FSSR PRINCIPAL FUNCTION I/O TABLES
12054B	HORIZONTAL SIT DISP CHANGES
12071A	MANEUVER EXECUTE
12148	MSBLS SOP CHANGES
12174A	MOD TO THE AREA NAV
12177B	DEDICATED DISPLAY
12190D	ASC/RTLS GUIDANCE, PFG MOD TEAM
12191	DELETE ROTATIONAL ACCELERATION OF NAV BASE WRT C.G. IN ENTRY UPP
12202A	GAMMA COMPENSATION
12216	ASCENT UPP (4.19)
12225B	GNC LVL C U/L REQUIREMENTS
12260A	NEW METHOD FOR COMPUTING H, $\dot{H}$ AND $\bar{H}$ WITHIN UPP/PLUS CONSOLIDATION OF UPP REQUIREMENTS
12266A	TACAN SOP & RM
12269	MSID CORRECTIONS
12285	M50 XFORMIN CHANGES
12305	MODS TO RTLS
12312	CHANGE CRITERION
12313C	ADDITION OF TLM REQUIREMENTS
12316	GN&C SWITCH RM PROCESSING RATE REDUCTION
12325A	INIT UPP PROPAGATION OPS-3
12328A	EVENT LIGHT MODIFICATION
12336	I-LOAD OFT-1 BASELINE, OF MISSION AND LRV DEPENDENT PARAMETERS
12337	I-LOAD OFT-1 BASELINE OF DESIGN DEPENDENT PARAMETERS
12338	I-LOAD OFT-1 BASELINE OF CONSTANTS
12339	I-LOAD OFT-1 BASELINE OF REMOVALS
12349A	RCS JET SELECT LOGIC
12402	MEASUREMENT DEPENDENT SCALE

HISTORICAL CHANGE REQUEST SUMMARY (Cont)

CR No.	Title
12403A	MSBLS RANGE ELEVATION & AZIMUTH LIMITS
12405A	INCORPORATION OF ASCENT NAV
12411B	OMS ENGINE FDI SIMPLIFICATION
12418B	MODS TO NAV
12423A	CHANGE ASCENT/RTLS ENTRY NAV
12424A	CHANGE TO ASCENT RTLS
12432A	MOD TO THE AREA NAV P.F.
12442A	INTEGRATED ENT NAV
12443	I-LOAD FOR ENTRY FACI
12456A	PAGE CHANGES FOR CR 12338
12474C	REDUCE IMU VELOCITY
12478	UPDATE TO VEHICLE MASS
12492B	CONTINGENCY ABORT DISPLAY (6-49)
12499D	MANUAL LANDING SOP
12507	RAISE THE USE IMU DATA
12517	HORIZONTAL SITUATION DISPLAY CHANGES
12551	CHANGE METHOD OF INITIAL PARAMETERS
12553B	OASCB BASELINE OF PASS/BFS INTERFACE
12561A	GAX & SYSTEM SUMMARY
12589A	DEDICATED DISPLAY REQUIREMENTS
12600C	INTEGRATED MSID
12606A	IMU RM MODE TEAM
12645B	ATT PROC, ADI & HSI
12679	CHANGE IN DRAG CONST
12696	UPP DRAG ACCELERATION PROTECTION
12698A	TACAN SOP/SITE LOCK UP INTERFACE
12790	UPDATE VALUES OF UPP
12826A	VENT DOOR CONTROL UPDATE
12848H	OPTIONAL TAEM TARGETING
12864	MODS TO RTLS
12938A	XXXXXX TRAJECTORY IDD
12983	LAST CHANGE I-LOAD
19022	MODS TO SEPTEMBER 4, 1978 AND DECEMBER 11, 1978 MPAD I-LOAD PAPER BASELINE OF SEPTEMBER 21, 1978
19039C	ASCENT/ENTRY STRUCTURAL PTI'S
19101A	I-LOAD CORRECTIONS FOR ASCENT FCS
19122	AREA NAV HEADING CALCULATIONS
19185A	XXXXXX TRAJECTORY DISPLAY ADDITIONS
19188	I_LOAD_MSID REASSIGNMENT
19246B	CORRECTIONS TO RUNWAY NAME MSID's & ASSOCIATED CRT DISPLAY CHANGES (STS-1)
19361A	REWRITE OF NOVEMBER 1977 NAVIGATION LEVEL C FSSR
19397	INCORRECT REQUIREMENTS IN A_PROVED GC_STEER CR

HISTORICAL CHANGE REQUEST SUMMARY (Cont)

CR No.	Title
19405A	GUIDANCE/UPP USE OF FLIGHT PATH ANGLE
19427B	REMOVAL OF DIRECT CALL TO PRECISE PREDICTOR BY CYCLIC NAV
19455	MEASUREMENT ATTRIBUTE DIRECTIONS
19485A	IMU AND ASC UPP RATE CHANGE
19488A	IMU AND ASC UPP RATE CHANGE
19408B	RTLS PQD GUIDANCE/UPP USE OF FLIGHT PATH ANGLE
19438A	XXXXXX TRAJ DIP CHANGES (STS-2)
19452B	I-LOAD CORRECTION NECESSARY FOR MARCH 19, 1978
19484A	I-LOAD DATA TAPE CORRECTIONS FROM COMMUNITY REVIEW
19556A	I-LOAD CORRECTIONS FOR VERSION 2.3
19557	SCRUB GRTLS GUIDANCE BY DELETING GLIDE SLOPE INDEX
19611A	PROVIDE TIME HOMOGENEOUS DATA TO NAVDAD SOP
19697A	ASCENT, NAV INTERFACE SIGNAL CORRECTION
19810B	STS-2 NAV DOWNLIST DELTA
19831A	OPTIONAL TAEM TARGETING RELATED IL CLEAN-UP FOR STS-2 (IDD ONLY)
19852	CHANGE THE METHOD OF COMPUTING "LOAD-TOTAL" IN ASCENT AND RTLS UPP
19857B	UPP I-LOAD AND REQUIREMENTS CHANGES TO AGREE WITH IMPLEMENTATION
19888	I-LOAD CHANGE TO FIX INCORRECT IMPLEMENTATION OF CR19101A
29002B	ADDITION OF PULL-OUT NZ CMD TO CONTINGENCY ABORT DISPLAY
29041A	DELETION OF_ELEV_ANG TEST I-LOAD
29093E	MPAD I-LOAD UPDATE 1 FOR STS-1, CYCLE 3
29149B	ADD PROGRAM INTERRUP HANDLING
29164	BFS I-LOAD CLEANUP
29259	NAV FILTER TACAN VARIANCE I-LOAD CHANGES
29260	NAV FILTER MSBLS VARIOUS I-LOAD CHANGES
29355	USE OF IMU-SENSED VELOCITY WITHIN
29471B	HFE OVERRUN DEFINITION
29589A	UPDATE SITE-DEPENDENT PARAMS - I/L
29590A	UPDATE DATE-DEPENDENT PARAMS - I/L
29591A	UPDATE DESIGN-DEPENDENT PARAM - I/L
29657C	STS-1 CYCLE 3.1.1 MPAD - I/L
29660A	CURRENT VEHICLE MASS UPDATE
29699A	D&C USAGE OF GUID I-LOAD
29740	CHANGE I/L FOR NAV DRAG MODEL - I/L
29741A	NAV DRAG MODEL FUNCT OF ALT
29762A	ATT PROC IDD CLEAN UP
29800	FSSR UPDATE NO. 8
29841	TACAN BIAS DELETION
29889	UPDATES FOR TACAN STATIONS
29902A	CYCLE 3.2.2 I/L, 3/10/81 LAUNCH
29938	STS-1 CYCLE 3.2.2 - AOA TO EDW
29972B	UPDATE STS-2 D/L LOADING
29999A	OTT REWRITE

HISTORICAL CHANGE REQUEST SUMMARY (Cont)

CR No.	Title
39076A	I LOAD VALUES - TACAN SITE DATA
39084	I L VALUE AOA EDW
39087A	HEAD UP DISPLAY (HUD)
39184B	STS-2 CYCLE/MPAD I-LOADS
39192A	CYCLE 3 3.3 I-LOADS
39204A	RTLS ABORT
39264B	HUD AUTOLAND MONITOR FORMAT (IDD ONLY)
39300B	RTLS GUID RUNWAY REDESIGNATE
39307C	CRT CHANGES - RTLS UPP & HSD
39353B	RTLS FUEL DISSIPATION MOD
39365F	HUD PROC I O CLEANUP
39386B	DRAG PROC AFTER BARO DEPLOY
39398	DELETE RN ALTITUDE USE IN UPP (REF)
39401A	TRANSATLANTIC ABORT LANDING
39405	TACAN BEARING - VARIANCE AND EDIT
39406B	NAV FILTER DELTA_STATE I/L
39409A	RTLS NAV COVARIANCE MATRIX
39436F	TACAN AND RUNWAY TABLE REORGANIZATION AND VALUE UPDATES (REF CR_F)
39530F	STS-2 CYCLE 2 I-LOADS
39 02B	STS 3 CYCLE 2 ORB ENT I-LOAD (REF ONLY)
39604B	STS 3 CYCLE 2 AOA TO NOR (REF)
396 8	LOAD KSC PERMANENT TACAN (REF)
3962?	E NATE EDW MOBILE TACAN
39655	TACAN Y MODE SELECTION (IDD)
39653	STS-4 C CLE 1 MPAD I-LOADS (REF)
39697B	STS-2 CY3 NORM-SEASON UPDATE (REF)
39773A	RESTATE RADIUS_NEP I/L (REF)
39784	CHANGE KSC TACAN I-LOADS (REF)
39803C	LAUNCH DELAY WINDOW
39888A	TACAN 40 DEG BEARING GLITCH (IDD REF ONLY)
39898B	I-LOAD PRECISION CHANGE
39904	RADIUS NEP I-LOAD TO I_COMMON (REF)
39920A	STS-3 CYCLE 3-SEASONAL UPDATE (REF)
39988F	STS-5 CYCLE 3 DESC ENT I/L'S
59012	STS-4 CYCLE 3 CAT I-LOAD
590138	ADD DACAR TO SITE I-LOADS (REF ONLY)
59021	DACAR RW LENGTH FOR HUD (REF ONLY)

HISTORICAL CHANGE REQUEST SUMMARY (Cont)

CR No.	Title
59043C	STS-6 CYCLE 1 NAV/END I-LOADS (REF ONLY)
59162	STS-5 CY4 TAL TO DAKAR NAV
59129	DAKAR TACAN AND RUNWAY-TAL (I-LOADS STS-4 ONLY)
59166A	CONSTANT RHO FOR ALT 200K FT
59253A	CORRECTIONS TO CR 39803C
59270B	STS-7 CY7 NAV/ENT I/L (REF ONLY)
59314C	OTT CORRECTION (BFS DOC ONLY)
59362A	TERMINATE PRECISE PREDICTION
59408D	STS-8 CYC 1 NAV/ENT IL (REF ONLY)
59426F	LANDING SITE TABLE MOD
59436	LOW ALT MSBLS EL STATE UPDATE
59452B	STOP LOW ALT BASE UPDATES
59545	ADD MSID--CR 59436 (IL REF ONLY)
59624A	CORRECT CR 59426F--LANDING SITE (IDD ONLY)
59564B	ADD MSBLS FOR DAKAR (TAL)--IL VALUES ONLY
59649	CHANGE DAKAR RUNWAY (IL REF ONLY)
59652B	STS-9 CYC 1 NAV/LAND SITE IL (REF ONLY)
59228	X NEP I-LOAD FOR OPS 3 (REF ONLY)
59588	CORRECT CR 39803 I/L PRECISION (BFS REF ONLY)
59772A	BYPASSED HIS/OTT COMP
59926D	STS-11 CYC 1 NAV I-LOADS (REF ONLY)
59998	STS-11 SUBS SITE DATA (REF ONLY)
69056	STS-13 CYC 1 NAV I-LOADS ONLY
69154A	STS-14 CYCLE 1 NAV I-LOADS (REF ONLY)
69189	CR 59542B CLEANUP-LOW ALT BASE
69251A	DAKAR SURVEY UPDATE (IL REF ONLY)
69319	DRC CATEGORY CREATION (IL REF ONLY)
69321B	A1N CATEGORY CHANGE (IL REF ONLY)
69418	I/L UNITS/CONFIG CHANGE--IMRB (13)
69449B	ENT & RTLS SEL UPP RV MAG
69550B	CR IMPLEMENTATION--MARCH/APRIL BASELINE--1984
59960	I-LOAD SCRUB: LANDING SITE
59971	I-LOAD SCRUB: NAV UTILITY
59972	I-LOAD SCRUB: ATMOSPHERE
69119C	I-LOAD SCRUB: TACAN SCALE FACTOR (REF ONLY)
69555A	TAL/RTLS WEATHER ALTERNATE
69624	41-D (STS-14) DRAG CONST UPDATE (IL REF ONLY)
69877I	TAL/RTLS WEATHER ALT CLEANUP
69923A	AUTOLAND UPP CORRECTIONS FOR SLOPING RUNWAYS
79217A	ENTRY TACAN SOP INTERFACE DOCUMENTATION CLEANUP (IDD REF ONLY)
79705	ASCENT HSI OSCILLATION CORRECTION (IDD ONLY)
79770	ADD RW BR'NG TO HSI/TAL ABT

CONTENTS

Section		Page
1.0	INTRODUCTION	1-1
2.0	APPLICABLE DOCUMENTS	2-1
3.0	OVERVIEW	3-1
	3.1 Operational Navigation Program	3-1
	3.2 GN&C Software Major Functions	3-1
	3.3 Navigation System Overview	3-1
	3.3.1 Navigation Functions	3-2
	3.3.2 Navigation-Related Functions	3-3
	3.3.3 General Requirements	3-3
	3.3.4 Requirements and Assumptions Overview	3-3
	3.3.4.1 Requirements	3-3
	3.3.4.2 Assumptions	3-4
	3.4 Operation Sequences and Major Modes	3-6
	3.5 Implementation Constraints	3-7
	3.6 Timing	3-7
4.0	DETAILED REQUIREMENTS	4-1
	4.1 Navigation and User Parameter Sequencer Principal Functions	4-2
	4.1.1 Ascent Navigation Sequencer (4.139)	4-2
	4.1.1.1 Ascent Navigation Sequencer Principal Function Tables (4.139)	4-10
	4.1.2 Ascent/RTLS Navigation Sequencer (4.147)	4-18
	4.1.2.1 Ascent/RTLS Navigation Sequencer Principal Function Tables	4-21
	4.1.3 Ascent User Parameter Processing Sequencer (4.197)	4-28
	4.1.3.1 Ascent User Parameter Processing Sequencer Principal Function Tables	4-31
	4.1.4 RTLS User Parameter Processing Sequencer (4.200)	4-37
	4.1.4.1 RTLS User Parameter Processing Sequencer (4.200) Principal Function Tables	4-41
	4.2 Subfunctions Common to Several Navigation Functions	4-47
	4.2.1 State Propagation	4-47
	4.2.1.1 IMU Data Snap	4-47
	4.2.1.2 Acceleration Models	4-47
	4.2.1.2.1 Gravity	4-49

Section

			Page
		4.2.1.2.2 Drag	4-51
		4.2.1.3 Integration of State Equations of Motion	4-55
	4.2.2	State Vector Interpolation	4-56
	4.2.3	Covariance Matrix Initialization	4-57
	4.2.4	User Parameter Propagator Reset	4-59
	4.2.5	Delta State Update	4-59
4.3		Navigation Processing Principal Functions	4-61
	4.3.1	Ascent Navigation (4.15)	4-61
		4.3.1.1 Ascent Control	4-61
		4.3.1.2 State Propagation	4-67
		4.3.1.3 Delta State Update	4-71
		4.3.1.4 Ascent State Vector Prediction Task	4-73
		4.3.1.5 Ascent Navigation (4.15) Principal Function Tables	4-77
	4.3.2	RTLS Navigation (4.205)	4-95
		4.3.2.1 RTLS Control	4-95
		4.3.2.2 External Sensor Data Snap	4-100
		4.3.2.3 Sensor Measurement Selection	4-105
		4.3.2.4 RTLS Navigation Reconfiguration	4-114
		4.3.2.4.1 Measurement Reconfiguration	4-114
		4.3.2.4.2 Delta State Update	4-115
		4.3.2.5 State Propagation	4-119
		4.3.2.6 Covariance Matrix Propagation	4-123
		4.3.2.7 State and Covariance Measurement Incorporation	4-126
		4.3.2.7.1 Drag Altitude	4-132
		4.3.2.7.2 TACAN Range	4-136
		4.3.2.7.3 TACAN Bearing	4-141
		4.3.2.7.4 Barometric Altimeter	4-147
		4.3.2.7.5 MSBLS Range	4-151
		4.3.2.7.6 MSBLS Azimuth	4-155
		4.3.2.7.7 MSBLS Elevation	4-159
		4.3.2.8 Measurement Processing Statistics	4-163
		4.3.2.9 RTLS Navigation Principal Function Tables	4-173
4.4		Subfunctions Common to Several Navigation-Related Principal Functions	4-196
	4.4.1	User Parameter State Propagation	4-196
	4.4.2	Coordinate Transformations	4-198
		4.4.2.1 Transformation From Aries Mean of 1950 to Earth-Fixed	4-198
		4.4.2.2 Earth-Fixed to M50	4-199
		4.4.2.3 Geodetic to Earth-Fixed	4-204
		4.4.2.4 Earth-Fixed to Topodetic	4-204
		4.4.2.5 Earth-Fixed to Runway	4-205
		4.4.2.6 Earth-Fixed to Scanner	4-205

Section

			Page
		4.4.2.7 Body to M50	4-206
		4.4.2.8 Earth-Fixed to Geodetic	4-207
		4.4.2.9 UVW to M50	4-209
	4.4.3	User Parameter Ascent/RTLS Computations	4-210
	4.4.4	Powered HSI Computations	4-214
	4.4.5	Utility Subfunctions	4-215
		4.4.5.1 Altitude Above the Reference Ellipsoid	4-215
		4.4.5.2 Velocity Relative to the Windless, Rotating Atmosphere	4-218
		4.4.5.3 Partial Derivatives of an Angular Measurement With Respect to the State Vector	4-218
		4.4.5.4 Derivative of the Gravitational Acceleration Vector With Respect to the Position Vector	4-219
4.5	General Requirement Principal Functions		4-220
	4.5.1	Ascent Precise Predictor (4.236)	4-220
		4.5.1.1 Ascent Precise Predictor (4.236) Principal Function Tables	4-225
	4.5.2	Ascent Site Lookup (4.238)	4-234
		4.5.2.1 Ascent Site Lookup Initialization	4-235
		4.5.2.2 Ascent Runway/MSBLS Site Lookup	4-243
		4.5.2.3 Ascent TACAN Site Lookup	4-251
		4.5.2.4 Ascent Site Lookup (4.238) Principal Function Tables	4-255
4.6	User Parameter Processing Principal Functions		4-275
	4.6.1	Ascent User Parameter Processing (4.19)	4-276
		4.6.1.1 User Parameter State Propagation	4-276
		4.6.1.2 Ascent/RTLS User Parameter Calculations	4-280
		4.6.1.3 Ascent User Parameter Processing Initialization	4-283
		4.6.1.4 Ascent User Parameter HSI Calculations	4-286
		4.6.1.5 Ascent User Parameter Processing (4.19) Principal Functions Tables	4-288
	4.6.2	RTLS User Parameter Processing (4.20)	4-299
		4.6.2.1 User Parameter State Propagation	4-299
		4.6.2.2 Powered RTLS User Parameter Calculations	4-304
		4.6.2.3 Glide RTLS User Parameter Calculations	4-309
		4.6.2.4 Ascent/RTLS User Parameter Calculations	4-323

Section

		Page
	4.6.2.5 RTLS User Parameter Processing HSI Calculations	4-327
	4.6.2.6 TACAN Display Computations	4-329
	4.6.2.7 RTLS User Parameter Processing (4.20) Principal Function Tables	4-332
4.7	Ascent Area Navigation Principal Function (4.237)	4-345
	4.7.1 Ascent Area Navigation Processing (4.237) Principal Function Tables	4-381
4.8	Specialist Functions Navigation Support Formulations	4-391
	4.8.1 Keyboard Delta State Update	4-392
4.9	Downlist Requirements	4-394
4.10	Uplink Requirements	4-395
	4.10.1 Delta State Vector Update	4-396
	4.10.2 Orbiter State Vector Update	4-397
5.0	SUPPLEMENTAL MATERIAL	5-1
5.1	Navigation Sequencer Principal Functions and Navigation Principal Functions Variable Names and Descriptions	5-2
5.2	Navigation Sequencer Principal Function and Navigation Principal Function Flow Charts	5-28
5.3	General Requirement Principal Functions and Coordinates Transformations Flow Charts, Variable Names, and Descriptions	5-75
5.4	Area Navigation Flow Charts, Variable Names, and Descriptions	5-114
5.5	Specialist Function Navigation Support Flow Charts, Variable Names, and Descriptions	5-145
5.6	User Parameter Flow Charts, Variable Names, and Descriptions	5-149

ILLUSTRATIONS

Figure		Page
4.3.2.6-1	State Noise Formulation	4-124
4.7-1	Left-hand Forward Flight Station	4-377
4.7-2	HSI Display	4-378
4.7-3	Flightpath Geometry - Horizontal Plane	4-379
4.7-4	Flightpath Geometry - Vertical	4-380
5.2-1	ASCENT_NAV_SEQ	5-29
5.2-2	ASCENT_INIT	5-31
5.2-3	V_REL (FUNCTION)	5-32
5.2-4	ACCEL (FUNCTION)	5-33
5.2-5	CENTRAL	5-34
5.2-6	ACCEL_EARTH_GRAV CODE	5-35
5.2-7	DENSITY CODE	5-37
5.2-8	H_ELLIPSOID (FUNCTION)	5-38
5.2-9	ACCEL_DRAG CODE	5-39
5.2-10	UPP_STATE_RESET	5-40
5.2-11	NAV_ASCENT	5-41
5.2-12	STATE_VECTOR_PRED_TASK_ASC	5-42
5.2-13	NAV_STATE_PROP_ASCENT_AND_RTLS	5-43
5.2-14	ASC_DELTA_STATE_UPDATE	5-44
5.2-15	ASCENT_RTLS_NAV_SEQUENCER	5-45
5.2-16	GRTLS_INITIALIZE_CODE	5-46
5.2-17	COVINIT_RTLS	5-47
5.2-18	NAV_GRTLS	5-48
5.2-19	RTLS_SENSOR_SELECT CODE	5-51
5.2-20	COVEXTRAP_PF_RTLS	5-55
5.2-21	GRAVITY_GRADIENT (FUNCTION)	5-56
5.2-22	RTLS_DRAG_NAV CODE	5-57
5.2-23	RTLS_NAV_FILTER	5-59
5.2-24	RTLS_MLS_NAV CODE	5-60
5.2-25	RTLS_MLS_RANGE_NAV CODE	5-61
5.2-26	SV_INTERP_RTLS	5-62
5.2-27	RTLS_MLS_AZ_NAV CODE	5-63
5.2-28	ANGLE_PARTIALS	5-64
5.2-29	RTLS_MLS_EL_NAV CODE	5-65
5.2-30	TACAN_INIT CODE	5-66
5.2-31	RTLS_TACAN_NAV CODE	5-67
5.2-32	RTLS_BARO_NAV CODE	5-71
5.2-33	MEAS_PROCESSING_STATISTICS_RTLS CODE	5-72
5.3-1	Aries Mean of 1950, Cartesian	5-76
5.3-2	Earth Fixed Greenwich True of Data	5-77
5.3-3	Aries True of Data, Cartesian	5-78
5.3-4	Basic Definitions - Geodetic Parameters	5-79

Figure		Page
5.3-5	Detailed Explanation - Geodetic Parameters	5-80
5.3-6	Runway Coordinate System	5-81
5.3-7	Topodetic Coordinate System	5-82
5.3-8	MSBLS Radar Coordinate System	5-83
5.3-9	Body Coordinate System (Structural)	5-84
5.3-10	Stable Member (IMU)	5-85
5.3-11	NWU Geographic Coordinate System	5-86
5.3-12	Body Axis	5-87
5.3-13	UVW Coordinate System	5-88
5.3-14	EARTH_FIXED_TO_M50_COORD (FUNCTION)	5-100
5.3-15	EF_TO_TOPDET (FUNCTION)	5-101
5.3-16	EF_TO_RUNWAY (FUNCTION)	5-102
5.3-17	EF_TO_SCANNER (FUNCTION)	5-103
5.3-18	EF_TO_GEODETIC	5-104
5.3-19	GEODETIC_TO_EF (FUNCTION)	5-105
5.3-20	UVW_TO_M50 (FUNCTION)	5-106
5.3-21	SBODY_TO_M50	5-107
5.3-22	QUAT_TO_MAT (FUNCTION)	5-108
5.3-23	ASC_PRECISE_PREDICTOR	5-109
5.3-24	ASC_SITE_LOOKUP_INIT	5-111
5.3-25	ASC_RUNWAY_SITE_LOOKUP	5-112
5.3-26	ASC_TACAN_SITE_LOOKUP	5-113
5.4-1	HSI_SEQUENCER	5-115
5.4-2	NAV_STATE_TO_RW_CODE	5-121
5.4-3	TAC_BARO_TO_RW CODE	5-122
5.4-4	TAC_BARO_TO_TOPODETIC CODE	5-123
5.4-5	MSBLS_TO_RW CODE	5-124
5.4-6	ENTRY_HSI_COMP CODE	5-125
5.4-7	RANGE_BEAR_TO_HAC_ENTRY	5-127
5.4-8	LAND_HSI_COMP CODE	5-129
5.4-9	TAEM_HSI_COMP CODE	5-130
5.5-1	ASCENT_UPLINK_PROCESSOR	5-147
5.5-2	KEYBOARD PROCESSOR	5-148
5.6-1	ASCENT_UPP_SEQ	5-166
5.6-2	USER_PARAM_PROPAGATOR_ASCENT_AND_RTLS	5-168
5.6-3	ASCENT_UPP_INIT	5-170
5.6-4	ASCENT_RTLS_COMPS	5-171
5.6-5	PW_HSI_COMPS	5-174
5.6-6	RTLS_UPP_SEQ	5-175
5.6-7	RTLS_SECOND_STAGE_COMPS	5-178
5.6-8	GUIDECOMP_RTLS	5-181
5.6-9	TACAN_DISP_COMPS	5-186

TABLES

Table		Page
1.3-1	Symbols Used in Tables	1-1
3.4-1	Operation Sequences and Major Modes	3-7
4.0-1	Software Requirement Traceability	4-1
4.1.1-1	OPS-1 Level B Events	4-6
4.1.1-2	Ascent Navigation Sequencer Input Parameters	4-7
4.1.1-3	Ascent Navigation Sequencer Output Parameters	4-8
4.1.1.1-1	Ascent Navigation Sequencer (4.139) Input/Output Functional Parameters	4-11
4.1.1.1-2	Ascent Navigation Sequencer (4.139) I-Loads	4-13
4.1.1.1-3	Ascent Navigation Sequencer (4.139) K-Loads	4-14
4.1.1.1-4	Ascent Navigation Sequencer (4.139) Constants	4-15
4.1.1.1-5	Ascent Navigation Sequencer (4.139) Cross-References	4-17
4.1.2-1	OPS-6 Level B Events	4-19
4.1.2-2	Ascent/RTLS Navigation Sequencer Input Parameters	4-20
4.1.2-3	Ascent/RTLS Navigation Sequencer Output Parameters	4-20
4.1.2.1-1	Ascent/RTLS Navigation Sequencer (4.147) Input/Output Functional Parameters	4-22
4.1.2.1-2	Ascent/RTLS Navigation Sequencer (4.147) I-Loads	4-24
4.1.2.1-3	Ascent/RTLS Navigation Sequencer (4.147) K-Loads	4-25
4.1.2.1-4	Ascent/RTLS Navigation Sequencer (4.147) Constants	4-26
4.1.2.1-5	Ascent/RTLS Navigation Sequencer (4.147) Cross-References	4-27
4.1.3-1	Event Flag Inputs for Ascent User Parameter Processing Sequencer	4-30
4.1.3.1-1	Ascent/User Parameter Processing Sequencer (4.197) Input/Output Functional Parameters	4-32
4.1.3.1-2	Ascent/User Parameter Processing Sequencer (4.197) I-Loads	4-33
4.1.3.1-3	Ascent/User Parameter Processing Sequencer (4.197) K-Loads	4-34
4.1.3.1-4	Ascent/User Parameter Processing Sequencer (4.197) Constants	4-35
4.1.3.1-5	Ascent/User Parameter Processing Sequencer (4.197) Cross-References	4-36
4.1.4-1	Event Flag Inputs for RTLS UPP Sequencer	4-39
4.1.4.1-1	RTLS User Parameter Processing Sequencer (4.200) Input/ Output Functional Parameters	4-42
4.1.4.1-2	RTLS User Parameter Processing Sequencer (4.200) I-Loads	4-43
4.1.4.1-3	RTLS User Parameter Processing Sequencer (4.200) K-Loads	4-44
4.1.4.1-4	RTLS User Parameter Processing Sequencer (4.200) Constants	4-45

Table		Page
4.1.4.1-5	RTLS User Parameter Processing Sequencer (4.200) Cross-References	4-46
4.3.1.1-1	Ascent Control Input Parameters	4-63
4.3.1.1-2	Ascent Control Output Parameters	4-65
4.3.1.2-1	Ascent State Propagation Input Parameters	4-69
4.3.1.2-2	Ascent State Propagation Output Parameters	4-70
4.3.1.3-1	Ascent Delta State Update Input Parameters	4-72
4.3.1.3-2	Ascent Delta State Update Output Parameters	4-72
4.3.1.4-1	Ascent State Vector Prediction Task Input Parameters	4-75
4.3.1.4-2	Ascent State Vector Update Output Parameters	4-76
4.3.1.5-1	Ascent Navigation (4.15) Input/Output Functional Parameters	4-78
4.3.1.5-2	Ascent Navigation (4.15) I-Loads	4-82
4.3.1.5-3	Ascent Navigation (4.15) K-Loads	4-86
4.3.1.5-4	Ascent Navigation (4.15) Constants	4-92
4.3.1.5-5	Ascent Navigation (4.15) Cross-References	4-94
4.3.2.1-1	RTLS Control Input Parameters	4-98
4.3.2.1-2	RTLS Control Output Parameters	4-99
4.3.2.2-1	RTLS External Sensor Data Snap Input Parameters	4-102
4.3.2.2-2	RTLS External Sensor Data Snap Output Parameters	4-103
4.3.2.3-1	MSBLS Versus TACAN	4-108
4.3.2.3-2	BARO-DRAG Selection Results	4-109
4.3.2.3-3	RTLS Sensor Measurement Selection Input Parameters	4-110
4.3.2.3-4	RTLS Sensor Measurement Selection Output Parameters	4-112
4.3.2.4.1-1	Measurement Reconfiguration Input Parameters	4-116
4.3.2.4.1-2	Measurement Reconfiguration Output Parameters	4-116
4.3.2.4.2-1	Delta State Update Input Parameters	4-117
4.3.2.4.2-2	Delta State Update Output Parameters	4-118
4.3.2.5-1	State Propagation Input Parameters	4-121
4.3.2.5-2	State Propagation Output Parameters	4-122
4.3.2.6-1	RTLS Covariance Matrix Propagation Input Parameters	4-125
4.3.2.6-2	RTLS Covariance Matrix Propagation Output Parameters	4-125
4.3.2.7-1	State and Covariance Measurement Incorporation Inputs	4-130
4.3.2.7-2	State and Covariance Measurement Incorporation Outputs	4-131
4.3.2.7.1-1	Drag Measurement Input Parameters	4-134
4.3.2.7.1-2	Drag Measurement Output Parameters	4-135
4.3.2.7.2-1	TACAN Range Measurement Subfunction Input Parameters	4-138
4.3.2.7.2-2	TACAN Range Measurement Subfunction Output Parameters	4-140
4.3.2.7.3-1	TACAN Bearing Measurement Subfunction Input Parameters	4-144
4.3.2.7.3-2	TACAN Bearing Measurement Subfunction Output Parameters	4-146
4.3.2.7.4-1	Barometric Altimeter Input Parameters	4-149
4.3.2.7.4-2	Barometric Altimeter Output Parameters	4-150
4.3.2.7.5-1	MSBLS Range Measurement Input Parameters	4-153
4.3.2.7.5-2	MSBLS Range Measurement Output Parameters	4-154
4.3.2.7.6-1	MSBLS Azimuth Measurement Input Parameters	4-157
4.3.2.7.6-2	MSBLS Azimuth Measurement Output Parameters	4-158

Table		Page
4.3.2.7.7-1	MSBLS Elevation Measurement Input Parameters	4-161
4.3.2.7.7-2	MSBLS Elevation Measurement Output Parameters	4-162
4.3.2.8-1	RTLS Measurement Processing Statistics Input Parameters	4-168
4.3.2.8-2	RTLS Measurement Processing Statistics Output Parameters	4-171
4.3.2.9-1	RTLS Navigation (4.205) Input/Output Functional Parameters	4-174
4.3.2.9-2	RTLS Navigation (4.205) I-Loads	4-181
4.3.2.9-3	RTLS Navigation (4.205) K-Loads	4-186
4.3.2.9-4	RTLS Navigation (4.205) Constants	4-192
4.3.2.9-5	RTLS Navigation Cross-References	4-195
4.4.2-1	Coordinate Transformations Input Parameters	4-201
4.4.2-2	Coordinate Transformations Output Parameters	4-203
4.4.5-1	Utility Subfunctions Input Parameters	4-217
4.4.5-2	Utility Subfunctions Output Parameters	4-217
4.5.1-1	Ascent Precise Predictor Input Parameters	4-224
4.5.1-2	Ascent Precise Predictor Output Parameters	4-224
4.5.1.1-1	Ascent Precise Predictor (4.236) Input/Output Functional Parameters	4-226
4.5.1.1-2	Ascent Precise Predictor (4.236) I-Loads	4-229
4.5.1.1-3	Ascent Precise Predictor (4.236) K-Loads	4-230
4.5.1.1-4	Ascent Precise Predictor (4.236) Constants	4-231
4.5.1.1-5	Ascent Precise Predictor (4.236) Cross-Reference	4-233
4.5.2.1-1	Ascent Site Lookup Initialization Input Parameters	4-241
4.5.2.1-2	Ascent Site Lookup Initialization Output Parameters	4-241
4.5.2.2-1	Ascent Runway/MSBLS Site Lookup Input Parameters	4-247
4.5.2.2-2	Ascent Runway/MSBLS Site Lookup Output Parameters	4-249
4.5.2.3-1	Ascent TACAN Site Lookup Input Parameters	4-253
4.5.2.3-2	Ascent TACAN Site Lookup Output Parameters	4-254
4.5.2.4-1	Ascent Site Lookup (4.238) Input/Output Functional Parameters	4-256
4.5.2.4-2	Ascent Site Lookup (4.238) I-Loads	4-260
4.5.2.4-3	Ascent Site Lookup (4.238) K-Loads	4-272
4.5.2.4-4	Ascent Site Lookup (4.238) Constants	4-273
4.5.2.4-5	Ascent Site Lookup (4.238) Cross-Reference	4-274
4.6.1	Ascent User Parameter Processing Principal Function Interface Diagram	4-277
4.6.1.1-1	Ascent User Parameter State Propagation Input Parameters	4-278
4.6.1.1-2	Ascent User Parameter State Propagation Output Parameters	4-279
4.6.1.2-1	Inputs for Ascent/RTLS User Parameter Calculations	4-281
4.6.1.2-2	Outputs From Ascent/RTLS User Parameter Calculations	4-282
4.6.1.3-1	Ascent User Parameter Processing Initialization Input Parameters	4-285
4.6.1.3-2	Ascent User Parameter Processing Initialization Output Parameters	4-285
4.6.1.4-1	Inputs for Ascent HSI Calculations	4-287
4.6.1.4-2	Output for Ascent HSI Calculations	4-287

Table		Page
4.6.1.5-1	Ascent User Parameter Processing (4.19) Input/Output Functional Parameters	4-289
4.6.1.5-2	Ascent User Parameter Processing (4.19) I-Loads	4-292
4.6.1.5-3	Ascent User Parameter Processing (4.19) K-Loads	4-295
4.6.1.5-4	Ascent User Parameter Processing (4.19) Constants	4-297
4.6.1.5-5	Ascent User Parameter Processing (4.19) Cross-Reference	4-298
4.6.2	RTLS User Parameter Processing Principal Function Interface Diagram	4-300
4.6.2.1-1	Ascent/RTLS User Parameter State Propagation Input Parameters	4-302
4.6.2.1-2	Ascent/RTLS User Parameter State Propagation Output Parameters	4-303
4.6.2.2-1	Input Parameters for Powered RTLS User Parameter Calculations	4-307
4.6.2.2-2	Outputs From Powered RTLS User Parameter Calculations	4-308
4.6.2.3-1	Input Parameters for Glide RTLS User Parameter Calculations	4-318
4.6.2.3-2	Output Parameters From Glide RTLS User Parameter Calculations	4-320
4.6.2.4-1	Ascent/RTLS Calculations Input Parameters	4-324
4.6.2.4-2	Ascent/RTLS Calculations Output Parameters	4-326
4.6.2.5-1	RTLS User Parameter Processing HSI Calculations Input Parameters	4-328
4.6.2.5-2	RTLS User Parameter Processing HSI Calculations Output Parameters	4-328
4.6.2.6-1	TACAN Display Calculations Input Parameters	4-331
4.6.2.6-2	TACAN Display Calculations Output Parameters	4-331
4.6.2.7-1	RTLS User Parameter Processing (4.20) Input/Output Functional Parameters	4-333
4.6.2.7-2	RTLS User Parameter Processing (4.20) I-Loads	4-338
4.6.2.7-3	RTLS User Parameter Processing (4.20) K-Loads	4-341
4.6.2.7-4	RTLS User Parameter Processing (4.20) Constants	4-343
4.6.2.7-5	RTLS User Parameter Processing (4.20) Cross-Reference	4-344
4.7-1	HSI Display Parameter/Mode Switch Matrix	4-369
4.7-2	Correspondence of Ascent Area Navigation Mission Dependent Parameters and GRTLS TAEM and TAEM and A/L Guidance Parameters	4-370
4.7-3	Area Navigation Input Parameters	4-371
4.7-4	Area Navigation Output Parameters	4-375
4.7.1-1	Ascent Area Navigation Processing (4.237) Input/Output Functional Parameters	4-382
4.7.1-2	Ascent Area Navigation Processing (4.237) I-Loads	4-386
4.7.1-3	Ascent Area Navigation Processing (4.237) K-Loads	4-388
4.7.1-4	Ascent Area Navigation Processing (4.237) Constants	4-389
4.7.1-5	Ascent Area Navigation Processing (4.237) Cross-Reference	4-390
4.8.1-1	Keyboard Delta State Update Input Parameters	4-393
4.8.1-2	Keyboard Delta State Update Output Parameters	4-393
5.1-1	Variable List - Basic Ascent/RTLS Navigation	5-4

Table		Page
5.3-1	Variable List - General Requirements Principal Functions and Coordinate Transformations	5-89
5.4-1	Variable List - Area Navigation	5-133
5.5-1	Variable List - Specialist Functions Navigation Support Functions	5-146
5.6-1	Variable List - User Parameters	5-151

Ascent/RTLS Navigation
FSSR/PRD Correlation

PFS FSSR	PRINCIPAL FUNCTION	FSSR PARA	FSSR TITLE	BFS PRD	PRD PARAGRAPH	BFS TITLE
5	G4.15	4.3.1	ASCENT NAVIGATION	MG038104	3.2.2.3.3.1	ASCENT NAVIGATION
5	G4.19	4.6.1	ASCENT USER PARAMETER PROCESSING	MG038104	3.2.2.3.6.1	ASCENT USER PARAMETER PROCESSING
5	G4.20	4.6.2	RTLS USER PARAMETER PROCESSING	MG038104	3.2.2.3.6.3	RTLS USER PARAMETER PROCESSING
5	G4.139	4.1.1	ASCENT NAVIGATION SEQUENCER	MG038104	3.2.2.3.1.1	ASCENT NAVIGATION SEQUENCING
5	G4.147	4.1.2	ASCENT/RTLS NAVIGATION SEQUENCER	MG038104	3.2.2.3.1.5	RTLS NAVIGATION SEQUENCING
5	G4.197	4.1.3	ASCENT USER PARAMETER PROCESSING SEQUENCER	MG038104	3.2.2.3.1.3	ASCENT USER PARAMETER PROCESSING SEQUENCING
5	G4.200	4.1.4	RTLS USER PARAMETER PROCESSING	MG038104	3.2.2.3.1.6	RTLS USER PARAMETER PROCESSING SEQUENCING
5	G4.205	4.3.2	RTLS NAVIGATION	MG038104	3.2.2.3.12	RTLS NAVIGATION
5	G4.236	4.5.1	ASCENT PRECISE PREDICTOR	MG038104	3.2.2.3.5.1	ASCENT/ENTRY PRECISE PREDICTOR
5	G4.237	4.7	ASCENT AREA NAVIGATION PROCESSING	MG038104	3.2.2.3.3	NAVIGATION PROCESSING
5	G4.238	4.5.2	ASCENT SITE LOOKUP	MG038104	3.2.2.3.13	SITE LOOKUP

1.0 INTRODUCTION

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of the Ascent/Return to Launch Site (RTLS) Navigation Level C document is to present the requirement details and formulations of the Ascent/RTLS navigation Level B functional requirements for the orbiter guidance, navigation, and control (GN&C) flight software.

1.2 SCOPE

This document contains the requirements, details, and formulations for those navigation functions that are operative during the ascent and RTLS portions of the space transportation system (STS). The navigation functions are those specified in the GN&C Level B functional requirements document.

1.3 ORGANIZATION

This document is organized into the following sections:

1.0 Introduction
2.0 Applicable Documents
3.0 Overview
4.0 Detail Requirements
5.0 Supplemental Material

Section 1 defines the purpose, scope, and organization of this document. Applicable documents are listed in Section 2, and an overview of the navigation program is described in Section 3. Section 4 presents the detailed requirements of the document. In general, each subsection of Section 4 is structured as follows:

- Text
- Input parameter table
- Output parameter table
- Principal function tables (input/output, I-load, K-load, constants, and cross-references)

Table 1.3-1. Symbols Used in Tables

Symbol	Description
Char	Character string
D	Discrete
DP	Double precision
F	Scalar, floating point
I	Integer
M	Matrix
S	Single precision
V	Vector

2.0 APPLICABLE DOCUMENTS

2.0 APPLICABLE DOCUMENTS

2.1 LEVEL A DOCUMENTS

SS-P-0002-140 NSTS Downlist/Uplink Software Requirements

SS-P-0002-150 NSTS Launch Data Bus Software Interface Requirements

SS-P-0002-170 NSTS Systems Level Requirements, Software

2.2 LEVEL B DOCUMENTS

SS-P-0002-510 NSTS Functional Level Requirements, GN&C

SS-P-0002-550 NSTS Functional Level Requirements, Vehicle Utility-02

SS-P-0002-580 NSTS Functional Level Requirements, Systems Management

2.3 LEVEL C DOCUMENTS

STS 83-0001 Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part A, Entry Through Landing Guidance

STS 83-0002 Operational Flight Level C, Functional Susbsystem Software Requirements; Guidance, Navigation, and Control, Part A, Guidance Ascent/RTLS

STS 83-0003 Operational Flight Level C, Functional Susbsystem Software Requirements; Guidance, Navigation, and Control, Part A, Guidance On-Orbit/Deorbit

STS 83-0004 Operational Flight Level C, Functional Susbsystem Software Requirements; Guidance, Navigation, and Control, Part B, Entry Through Landing Navigation

STS 83-0005 Operational Flight Level C, Functional Susbsystem Software Requirements; Guidance, Navigation, and Control, Part B, Navigation Ascent/RTLS

STS 83-0006 Operational Flight Level C, Functional Susbsystem Software Requirements; Guidance, Navigation, and Control, Part B, On-Orbit Navigation

STS 83-0007	Operational Flight Level C, Functional Susbsystem Software Requirements; Guidance, Navigation, and Control, Part C, Flight Control Entry--GRTLS
STS 83-0008	Operational Flight Level C, Functional Susbsystem Software Requirements; Guidance, Navigation, and Control, Part C, Flight Control Volume 1, Ascent Flight Phase, Volume 2, Ascent
STS 83-0009	Operational Flight Level C, Functional Susbsystem Software Requirements; Guidance, Navigation, and Control, Part C, flight Control Orbit DAP
STS 83-0010	Operational Flight Level C, Functional Susbsystem Software Requirements; Guidance, Navigation, and Control, Part D, Redundancy Management
STS 83-0013	Operational Flight Level C, Functional Susbsystem Software Requirements; Guidance, Navigation, and Control, Part E, Inertial Measurement Unit Subsystem Operating Program
STS 83-0014	Operational Flight Level C, Functional Susbsystem Software Requirements; Guidance, Navigation, and Control, Part E, Volume 1, Navigation Aids Subsystem Operating Program, Volume 2, Star Tracker Subsystem Operating Program
STS 83-0015	Operational Flight Level C, Functional Susbsystem Software Requirements; Guidance, Navigation, and Control, Part E, Subsystem Operating Programs, FC Sensor/Controller
STS 83-0016	Operational Flight Level C, Functional Susbsystem Software Requirements; Guidance, Navigation, and Control, Part E, Subsystem Operating Programs, FC Effector
STS 87-0017	Operational Flight Level C, Functional Subsystem Software Requirements; Remote Manipulator System
STS 83-0020	Operational Flight Level C, Functional Subsystem Software Requirements; Displays and Controls
STS 83-0026	Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control Sequencing

JSC-19350	NSTS Flight Software Initialization Load • Volume I General Requirements • Volume II Mission I-Load Requirements
JSC-19478	Payload Management, Level C Flight Software Requirements
JSC-19590	Systems Management, Level C Flight Software Requirements

2.4 ICD DOCUMENTS

ICD 3-1011-02	GPC/DEU ICD
ICD 3-0068-03	PASS/BFS ICD

In the event of a conflict between the documents referenced herein and the contents of this specification, the precedence shall be determined as defined in paragraph 1.3 of CPDS SS-P-0002-170, Volume 1, System Level Requirements, Software.

3.0 OVERVIEW

3.0 OVERVIEW

3.1 OPERATIONAL NAVIGATION PROGRAM

For the space transportation system (STS) the operational navigation program has requirements specified at three levels: system level (A), functional level (B), and detailed level (C). In addition, the level B and C requirements are specified in separate documents for guidance, navigation, and control (GN&C) and for system management (SM). This document is the ascent/RTLS navigation part of the GN&C level C STS requirements.

3.2 GN&C SOFTWARE MAJOR FUNCTIONS

The orbiter general-purpose computer (GPC) provides the following GN&C major functions:

- Guidance (GUID)
- Navigation (NAV)
- Flight control (FC)
- Redundancy management/moding, sequencing, and control (RM/MSC)
- Subsystem operation programs (SOP)
- Displays and controls (D&C)
- Other

This document specifies the software functional requirements for the GN&C major function, ascent and RTLS navigation.

3.3 NAVIGATION SYSTEM OVERVIEW

The basic function of the navigation system is to provide an estimate of the Orbiter state, based on either inertial measurement unit (IMU) only or IMU-NAVAID data during all of the flight phases. This document provides detailed navigation software functional requirements for the ascent and RTLS operation sequences (a list of operation sequences is contained in Table 3.4-1).

3.3.1 Navigation Functions

In general, the navigation software requirements can be divided into the following major functions:

Navigation control. Performs the initialization of navigation function parameters and sets up the sequencing of functions to accomplish navigation requirements.

Measurement scheduler. Selects the appropriate sensor measurements in accordance with selection criteria.

Data handler. Prepares data for sensor measurement processing.

Navigation reconfiguration. Initializes state vector (and covariance matrix for sensor measurement processing or navigation state updates) and prepares site location data.

State and covariance propagation. Propagates (i.e., integrates to current time) state and covariance matrix for subsequent sensor measurement processing. Also propagates state at a faster rate for user parameter calculations (see below for definition).

State and covariance update. Determines and performs state and covariance updates, i.e., calculates new values of the state and the covariance matrix based on the measurements.

User parameter calculations. Computes state-related parameters for guidance, display, control, and other users.

In this document, each of these functions is discussed in detail according to navigation phases for which they are applicable.

The navigation software requirements, as presented, make assumptions about how nonnavigation functions will be performed. Completion of the software requirements will require adequate definition of the timing and data timetagging mechanization and the input/output processor (IOP) mechanization. Changes in the navigation software requirements may be necessary, depending on actual implementation of the nonnavigation functions.

The details of each function and their interconnection with each other are shown in Section 5.2 by means of flow charts. These flow charts are not to be construed as requirements but rather as examples of how the requirements stated in the text may be implemented.

In the ascent and RTLS navigation principal functions, the state vector has six components: three each for position and velocity. This state vector is time-propagated with IMU data. In addition, in the RTLS navigation function, the state vector may be measurement-updated with data from barometric

altimeter, TACAN, and MSBLS. Drag pseudomeasurements are also utilized for state vector updating. The Kalman filter scheme is employed.

The RTLS navigation software has provisions to allow the crew to select some sensors manually and to override the automatic measurement residual edit. Provisions have also been made to enable the crew to manually update the state vector by means of a keyboard entry. A ground uplink command may also cause the onboard state vector to be updated based on ground observations.

The navigation software also provides parameters needed by guidance and display. Position and velocity propagation has been designed so that it may occur at a faster rate for users than for the navigation external sensor data (filter) processing (ESDP). Covariance matrix propagation must be performed by the ESDP function. The fast-rate propagation for users is updated with the ESDP updated vector (which is more accurate) each navigation cycle.

3.3.2 Navigation-Related Functions

The above designation refers to a function called "area navigation." This function supports a specialized display device by providing it with information related to the navigation and guidance functions.

3.3.3 General Requirements

General requirements are software requirements in the category of services available to one or more users, that are not uniquely related to the navigation function.

The general requirements include, but are not limited to, the following:

- Ascent precise predictor
- Ascent site lookup

3.3.4 Requirements and Assumptions Overview

The following two sections present an overview of the requirements and assumptions of the STS ascent and RTLS navigation software.

3.3.4.1 Requirements. The following statements are navigation requirements that must not be violated.

1. During the time that a state vector is being read by nonnavigation application software, that state vector or portions thereof will not be updated by the navigation software. The reset equations in the user parameter propagator shall be so protected.

2. Statements that snap data on entry into navigation shall be made so that each sensor's data and the respective time tag are consistent. The time tag is assumed to be measured in mean solar seconds from December 31 0.0 hours prior to the year in which the mission is launched. If a mission extends into a new year, the time will not be reinitialized to zero at the beginning of the new year.

3. Data from all sensors will be collected at the beginning of each filter cycle, so that they are timewise as close to each other as possible. The sensor data snap functions should not be interrupted by other programs until they are completed.

4. During RTLS navigation, processing of a measurement to update the state vector and the covariance matrix must be completed before the processing of the next measurement is started.

5. Processing of all sensor data available at a given filter cycle will be completed before starting the next filter cycle.

6. The IMU redundancy management selection filter must provide navigation with the total accumulated sensed velocity in M50 coordinates. Redundancy management must also provide navigation with ADTA (barometric altitude), TACAN, and MSBLS data with data validity indicators and time tags as appropriate.

7. Filter statistics are in double precision so that the quadratic form of the Kalman filter can be used.

8. There will be a manual override of the filter residual edit for TACAN and barometric altimeter sensors and for drag altitude measurement processing.

9. Both automatic and manual capability will be available for selecting navigation sensors for navigation processing.

10. The six elements of the navigated state vector consist of the position and the velocity of the Shuttle navigation base point in M50 coordinates. The vector is converted to appropriate coordinates (such as runway coordinates) for users.

11. Selected sensed velocity data are used without reference to the quality of the data. IMU data good flags, if any, are not used by navigation, but by the IMU redundancy management.

3.3.4.2 Assumptions. The following statements represent assumptions used for the navigation formulations and are reflected in the flow charts given in Section 5.2.

1. Initialization (event 14) shall be performed after platform release but before engine ignition. Initialization shall occur 8 seconds prior to SRB ignition to prevent long-term integration of accelerometer biases.

2. Completion of initialization shall be the event that initiates cyclic execution of both the ascent navigation principal function and user parameter-state propagation function.

3. If a launch hold of more than 1 minute occurs after navigation initialization has been performed, cyclic execution of the ascent navigation principal function shall be cancelled and initialization shall be performed again. This recycle shall be performed by software external to the navigation flight software and accomplished while the vehicle is still on the ground.

4. No external sensor data processing shall be performed by the ascent navigation principal function.

5. Modeled venting accelerations shall not be employed in the state propagation during OPS-1 and OPS-6 (Table 3.4-1 for OPS definitions). Modeled drag accelerations shall be employed only during periods of nonthrusting flight when IMU sensed accelerations are below a given threshold level (in magnitude).

6. If no RTLS abort occurs, the final action of the ascent navigation sequencer principal function is to save then-current data (in protected locations) for initialization of navigation in the succeeding computer memory load (either OPS-2 or OPS-3). It is the responsibility of the incoming navigation function to take appropriate action to account for the time lapse between memory reconfigurations.

7. OPS-1 and OPS-6 software are core-resident, and selection of an RTLS abort (i.e., hand-over of control authority from one navigation sequencer to another) does not cause a computer memory reconfiguration or stop then-current cyclic processes. No provision is made to initialize OPS-6 navigation from saved OPS-1 data.

8. The ascent navigation principal function will be used throughout Major Mode 601 (Table 3.4-1 for major mode definitions) until completion of the external tank separation maneuver.

9. The ascent navigation principal function shall be cancelled and the RTLS navigation principal function selected on proceeding to Major Mode 602.

10. Once the RTLS navigation principal function is active, drag, TACAN, MSBLS, and barometric data processing capability will be provided.

11. Once OPS-6 is selected, there is no provision to exit to any other OPS except OPS-9. The ascent/RTLS navigation sequencer shall remain in control until the end of rollout.

12. The capability to select only TACAN range or only TACAN bearing is not in the current baseline. The navigation software will assume that RM will satisfy a separate DG for each of TACAN range and bearing and that RM will set the appropriate DG to bad if either range or bearing is not locked up.

13. Drag may be processed with TACAN, and drag may be processed with barometric data. However, both drag and barometric data may not be used together to update the state vectors.

14. Nav assumes that RM sets a data-good for each of the MSBLS measurements.

15. The baro probe is assumed to be at the navigation base.

16. There is no onboard antenna location correction for MSBLS range and azimuth and TACAN range and azimuth measurements.

17. All MSBLS onboard antennas are assumed to be collocated.

18. No manual capability to override sensor data-good flags exists within the navigation software. Such override, if any, will be through the redundancy management or selection filter functions. Data will be presented to the filter for processing only if the data-validity flag is set to GOOD. Even in that case, however, the data will be incorporated only if the residual edit passes or the sensor force switch is set.

19. A whole vector (M50 coordinates) update to the onboard state may be command uplinked from the ground during OPS-1. A delta state vector (in runway coordinates) correction update from ground calculated data may be performed either directly by ground command uplink or manually by the crew during OPS-1 or OPS-6.

20. The air data transducer assembly (ADTA) will supply navigation with a flag indicating the air speed of the vehicle is in the Mach jump region.

3.4 OPERATION SEQUENCES AND MAJOR MODES

Table 3.4-1 identifies the names for the various operation sequences (OPS) and their major modes referenced in Section 4, Detailed requirements, and Section 5.2. Detailed descriptions may be found in Level B CPDS.

Table 3.4-1. Operation Sequences and Major Modes
(Major modes listed are only for ascent and RTLS operations)

Operation Sequence	Major Mode No.	Major Mode Name
OPS-1: Ascent operations	101	Terminal count
	102	First stage
	103	Second stage
	104	OMS 1 insertion
	105	OMS 2 insertion
	106	Insertion coast
OPS-6: RTLS operations	601	RTLS second stage
	602	RTLS entry
	603	RTLS TAEM
OPS-2: Orbital operations		
OPS-3: Entry through landing operations		
OPS-8: On orbit checkout		
OPS-9: Preflight/postflight checkout		

3.5 IMPLEMENTATION CONSTRAINTS

The navigation subsystem design is capable of recovering from the effects of many transient-type errors. Accordingly, the software design shall not preclude this capability by causing a program halt, permanent discontinuance of navigation processing, or loss of protected data as a result of program check or error interrupts.

Check or error interrupts shall be prevented by software safeguards, or standard fixup and error returns shall be provided that are appropriate in the navigation function as described in Level A CPDS, Section 4.6.4.

The footnotes (F1, F2, etc.) specified in Section 4 of this document refer to the specific fixup described in the Level A CPDS.

3.6 TIMING

Timing in this document is related to error free processing conditions. See Level A CPDS SS-P-0002-170, paragraph 4.4.2A, for timing related to error processing conditions.

4.0 DETAILED REQUIREMENTS

4.0 DETAILED REQUIREMENTS

The various subsections of this section specify the detailed requirements for the Shuttle navigation system flight software package operation during OPS-1 and OPS-6. This document contains STS detailed requirements for navigation and user parameter processing principal functions for ascent and RTLS.

When viewed in the larger context of the total Shuttle flight software, the navigation software package documented herein is, itself, a modular system whose function is to supply various parameters required by other major modular systems such as guidance, displays, flight control, and others. The requirements placed upon the navigation system by these various users often play a large role in determining the design structure and cyclic rate structure of the navigation system. The required interfaces between the navigation system and the other major software systems that use navigation system data are presented in the Level B CPDS document which controls all the interfaces between principal functions.

Table 4.0-1 shows the traceability of the software segments in FSSR Level C with respect to the CPDS Level B.

Table 4.0-1. Software Requirement Traceability

CPDS Level B Section No.	Software Segment	FSSR Level C Section No.
4.139	Ascent navigation sequencer	4.1.1
4.147	Ascent/RTLS navigation sequencer	4.1.2
4.15	Ascent navigation	4.3.1
4.205	RTLS navigation	4.3.2
4.238	Ascent site lookup	4.5.2
4.197	Ascent user parameter processing sequencer	4.1.3
4.19	Ascent user parameter processing	4.6.1
4.200	RTLS user parameter processing sequencer	4.1.4
4.20	RTLS user parameter processing	4.6.2
4.236	Ascent precise predictor	4.5.1
4.237	Ascent area navigation	4.7

The automated data base (IDD, I-load, and K-load) tables provided herein define initialization and signal (parameter) interface requirements either between hardware (LRU) and software elements or between software elements and other software elements.[1] In the event of a conflict between the data base tables and other internal tables, the SASCB data base-controlled tables take precedence.

CR89596C

[1]A GN&C software element is either a sequenced principal function, crew-generated specialist/display function, or an OPS display function.

Note that IDD output (source) tables which reflect parameters going to input (destination) "TLM" shall not be interpreted as a signal actually being downlisted. The parameter may only be available for downlist in COMPOOL and may not appear in a downlist format.

If there is a conflict between the data in the flow diagrams and the written requirements, the written requirements shall have precedence.

4.1 NAVIGATION AND USER PARAMETER SEQUENCER PRINCIPAL FUNCTIONS

The sequencer principal functions shall initialize and sequence the proper navigation and user parameter functions to meet navigation and user requirements. For the STS ascent and RTLS computer load, there shall be two navigation sequencer principal functions and two user parameter sequencer principal functions that control navigation and user parameter principal functions.

Sequencers	Operational Sequences (OPS)
Ascent	Ascent - OPS-1
Ascent/RTLS	RTLS - OPS-6

For purposes of discussion in this section, the act of cancelling a cyclic process shall mean that the process is permitted to complete an in-progress cycle (if applicable) before initialization computations and subsequent scheduling activities are performed.

4.1.1 Ascent Navigation Sequencer (4.139)

The ascent navigation sequencer principal function will initialize and initiate cyclic execution of the ascent navigation principal function. Cues for performing the proper navigation initialization and sequencing during OPS-1 are defined in the Level B GN&C CPDS. The particular events and navigation actions pertaining to the ascent navigation sequencer are shown in Table 4.1.1-1.

A. Detailed Requirements. The ascent navigation sequencer principal function will be invoked upon occurrence of Event 14 (approximately 8 seconds prior to SRB ignition and after platform release) and terminated in one of three ways:

- When normal termination occurs on proceeding to OPS-2.
- When an AOA abort occurs on proceeding to OPS-3.
- When an RTLS abort occurs and the ascent/RTLS navigation sequencer principal function is invoked on selection of OPS-6.

1. Navigation initiation (Event 14) - Prior to initiation of cyclic execution of the ascent navigation principal function, initialization of necessary parameters shall be performed.

The selected accumulated IMU velocity (V _CURRENT_FILT) and time tag (T_CURRENT_FILT) shall be read and saved. A special read request may be required for this first-time initialization to acquire IMU data. These data are then stored for future use by the state propagation subfunction:

$$V\_LAST\_FILT = V\_CURRENT\_FILT$$

$$T\_LAST\_FILT = T\_CURRENT\_FILT$$

The pad-loaded navigation base origin in earth-fixed geodetic coordinates (latitude, longitude, and altitude) shall be transformed to an earth-fixed Cartesian position vector (R _LAUNCH_EF) by using the geodetic to earth-fixed function (refer to Section 4.4.2.3) and shall also be transformed to a M50 vector (R _FILT) by using the earth-fixed to M50 transformation matrix obtained from the coordinate systems function (refer to Section 4.4.2) evaluated at the sensed velocity time tag (T_LAST_FILT):

$$R\_LAUNCH\_EF = GEODETIC\_TO\_EF(NAVBASE\_LAT\_ZERO, NAV\ BASE\_LONG\_ZERO, NAVBASE\_ALT\_ZERO)$$

$$R\_FILT = EARTH\_FIXED\_TO\_M50\_COORD(T\_LAST\_FILT)\ R\_LAUNCH\_EF$$

The M50 velocity vector (V _FILT) will be computed with use of the M50 position vector (R _FILT) and the earth's angular velocity vector:

$$V\_FILT = -V\_REL\ (0, R\_FILT)$$

The function V _REL is discussed in Section 4.4.5.2

The model employed for computing the initial acceleration vector will be the basic gravitational model (Section 4.2.1.2) with no drag accelerations modeled. Selection of this model configuration is accomplished by setting

$$GM\_DEG = 2$$

$$GM\_ORD = 0$$

The acceleration due to gravitational forces (G _OLD) shall be computed for use in user parameter processing position and velocity propagation. The equations for this calculation are presented in the acceleration model subfunction (Section 4.2.1.2).

$$G\_OLD = ACCEL(GM\_DEG, GM\_ORD, R\_FILT, V\_FILT, T\_LAST\_FILT)$$

A control flag (indicating usage of IMU data) will be set to the appropriate value:

$$USE\_IMU\_DATA = ON$$

Additional initialization for the user parameter state propagation subfunction (Section 4.6.1.1) will be accomplished as:

$$T\_IMU\_LAST = T\_LAST\_FILT$$

$$\underline{V}\_IMU\_LAST = \underline{V}\_LAST\_FILT$$

$$\underline{A}\_SENSED = -\underline{G}\_OLD$$

Initialization for the user parameter state propagation subfunction will be completed as described in Section 4.2.4.

The IMU-sensed accelerometer threshold level used in the ascent navigation state propagation subfunction will be set to zero, thus forcing usage of IMU data until the main engines are stowed.

$$ACC\_PROP\_MIN = 0$$

The last task of the initiation process is to enable the cyclic execution of the user parameter state propagation and ascent navigation principal functions.

$$ASCENT\_INIT\_COMPLETE = ON$$

After completion of initiation, cyclic repetition of the ascent navigation principal function will be initiated. The repetition rate (DT_ASCENT_NAV) of the ascent navigation principal function will be premission determined and independent of the repetition rate for any other navigation principal function.

2. Stow SSME's for Entry (Event 43A) - When the main engines are stowed, the IMU-sensed acceleration threshold value will be reset to a nonzero I-load value

$$ACC\_PROP\_MIN = ACC\_PROP\_MIN\_REF$$

thus enabling use or nonuse of IMU data based on a test of this value by the ascent navigation state propagation subfunction. No cancellation and rescheduling of the ascent navigation principal function is required.

3. Initiate guidance (Event 45) - 15 seconds prior to OMS-2 ignition, the IMU-sensed acceleration threshold value will be reset to zero

$$ACC\_PROP\_MIN = 0$$

thus forcing use of IMU data by the ascent navigation state propagation subfunction. No cancellation and rescheduling of the ascent navigation principal function is required.

4. OMS engine purge completed (Event 488) or Reconfigure after RCS backup translation burn (Event 478) - After completion of either the OMS-2 burn or the RCS backup translation burn, whichever occurs, the IMU-sensed acceleration threshold value will be reset to a nonzero I-load value

ACC_PROP_MIN = ACC_PROP_MIN_REF

thus enabling use or nonuse of IMU data based on a test of this value by the ascent navigation state propagation subfunction. No cancellation and rescheduling of the ascent navigation principal function is required.

5. Transition from Major Mode 106 to Major Mode 201 or Transition from Major Mode 106 to Major Mode 301 (Event 60 or Event 59) - On a crew command to exit Major Mode 106 to either OPS-2 or OPS-3 (i.e., a computer memory reconfiguration), the final action of the ascent navigation sequencer is to save parameters in protected memory locations to supply initialization data for the OPS-2 or OPS-3 navigation functions. Current data will be saved, and it is the responsibility of the OPS-2 or OPS-3 navigation functions to account for the time lapse occupied by the reconfiguration of computer memory. Prior to the saving of this data, cyclic execution of the ascent navigation principal function must be cancelled. The necessary computations are:

$$\underline{R}\_FILT\_INIT = \underline{R}\_FILT$$

$$\underline{V}\_FILT\_INIT = \underline{V}\_FILT$$

$$T\_FILT\_INIT = T\_CURRENT\_FILT$$

B. Interface Requirements. Input and output parameters are given in Tables 4.1.1-2 and 4.1.1-3, respectively. Principal function input and output parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.1.1.1-1 through 4.1.1.1-5.

C. Processing Requirements. None.

D. Constraints. The IMU's must have been released (placed in an inertial mode) prior to Event 14. In addition, the IMU SOP and IMU RM selection filter must be active and supply data for the navigation initialization before execution of the navigation initialization equations which occur at Event 14.

Calculation of ACC_PROP_MIN upon changing flight phases shall not interrupt operation of the ascent navigation principal function.

E. Supplemental Information. A suggested implementation of these requirements is illustrated in ASCENT_NAV_SEQ of Section 5.2.

Forcing use of IMU data until the main engines are stowed is required to insure incorporation of accelerations due to the MPS dump into the navigated state as these accelerations may be less than the nonzero I-loaded value.

Forcing the usage of IMU data immediately before and during the OMS-2 burn is required to ensure the detection of thrusting by the user parameter state propagation subfunction even if the ascent navigation state propagation subfunction has not detected thrusting yet. This action prevents an abrupt change in the user parameter state the first time it is reset by navigation after OMS-2 ignition.

Table 4.1.1-1. OPS-1 Level B Events

Event No.[a]	Event Name	Navigation Criteria	Navigation Action
14	Navigation initiation	T_L - 8.0 sec navigation	Initialize ascent navigation
43A	Stow SSME's for entry	End of 1st powered flight mode	Reset ACC_PROP_MIN to ACC_PROP_MIN_REF
45	Initiate guidance	Begin second powered flight mode	Reset ACC_PROP_MIN to zero
48B	OMS engine purge completed	End of OMS-2 maneuver	Reset ACC_PROP_MIN to ACC_PROP_MIN_REF
60	Transition from Major Mode 106 to Major Mode 201	OPS transition to OPS-2 from OPS-1	Save data for OPS-2 navigation initialization in protected memory locations
59	Transition from Major Mode 106 to Major Mode 301	OPS transition to OPS-3 from OPS-1	Save data for OPS-3 navigation initialization in protected memory locations
47B	Reconfigure after RCS backup translation burn	End RCS backup translation burn	Reset ACC_PROP_MIN to ACC_PROP_MIN_REF

[a]Current Level B CPDS designation.

Table 4.1.1-2. Ascent Navigation Sequencer Input Parameters

Description	Symbol	Input Sources	Type	Precision	Range	Units	Sample Rate
Latitude of vehicle navigation base at reference point on pad	NAVBASE_LAT_ZERO	(a)	F	DP		rad	Sequencer rate
Longitude of vehicle navigation base at reference point on pad	NAVBASE_LONG_ ZERO	(a)	F	DP		rad	Sequencer rate
Altitude of vehicle navigation base at reference point on pad	NAVBASE_ALT_ZERO	(a)	F	S		ft	Sequencer rate
Accelerometer sensed acceleration threshold value	ACC_PROP_MIN_ REF	(a)	F	S		ft/sec^2	As required
Current Shuttle position vector	R_FILT	(b)	V	DP		ft	Sequencer rate
Current Shuttle velocity vector	V_FILT	(b)	V	S		ft/ sec	Sequencer rate
Accumulated IMU velocities associated with R_FILT and V_FILT	V_CURRENT_ FILT	(b)	V	DP		ft/ sec	Sequencer rate
Time tag of current Shuttle position and velocity vector	T_CURRENT_ FILT	(b)	F	DP		sec	Sequencer rate
MSC event: liftoff minus 8 sec	EVENT_14	(b)	D		ON/OFF		Sequencer rate
MSC event: stow SSME's	EVENT_43A	(b)	D		ON/OFF		Sequencer rate
MSC event: OMS-2 TIG-15 sec	EVENT_45	(b)	D		ON/OFF		Sequencer rate
MSC event: flag indicating RCS backup translation burn	EVENT_47B	(b)	D		ON/OFF		Sequencer rate
MSC event: OMS engine purge completed	EVENT_48B	(b)	D		ON/OFF		Sequencer rate
MSC event: terminate OPS-1 and transition to OPS-2	EVENT_60	(b)	D		ON/OFF		Sequencer rate
MSC event: terminate OPS-1 and transition to OPS-3	EVENT_59	(b)	D		ON/OFF		Sequencer rate

NOTE: Input parameters associated with the acceleration models are identified in Section 4.2.1.2 for the ascent/RTLS operations computer load in the ascent precise predictor K-load table.

[a]See ascent navigation principal function (4.15) I-load and K-load tables.
[b]See ascent navigation sequencer principal function input parameter table (Table 4.1.1.1-1).

CR89546

CR89546

Table 4.1.1-3. Ascent Navigation Sequencer Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Time of the filter state vectors	T_LAST_FILT	(b)	F	DP		sec	Sequencer rate
Current Shuttle position vector	R_FILT	(b)	V	DP		ft	Sequencer rate
Current Shuttle velocity vector	V_FILT	(b)	V	S		ft/sec	Sequencer rate
Flag indicating the use of IMU data in state propagation	USE_IMU_DATA	(b)	D		ON/OFF		Sequencer rate
Vehicle total acceleration vector (M50) used in user parameter state propagation	G_RESET	(b)	V	S		ft/sec^2	Sequencer rate
Vehicle position vector after all navigation updates. Reserved for reset of guidance integrator position vector R_AVGG	R_RESET	(b)	V	DP		ft	Sequencer rate
Vehicle velocity vector after all navigation updates. Reserved for reset of guidance integrator velocity vector V_AVGG	V_RESET	(b)	V	S		ft/sec	Sequencer rate
Time associated with reserved reset state	T_RESET	(b)	F	DP		sec	Sequencer rate
Copy of V_CURRENT_FILT reserved as velocity count at start of extrapolation interval when guidance integrator is reset	V_IMU_RESET	(b)	V	DP		ft/sec	Sequencer rate
Switch indicating (on) that current measurement processing is complete	FILT_UPDATE	(b)	D		OFF ON		Sequencer rate
Shuttle velocity vector saved across memory reconfiguration and used for navigation initialization	V_FILT_INIT	(b)	V	S		ft/sec	Sequencer rate
Signal to ascent UPP sequencer indicating completion of ascent navigation initialization	ASCENT_INIT_COMPLETE	(b)	D		OFF/ON		
Accelerometer threshold test for state propagation	ACC_PROP_MIN	(b)	F	S	$\geq 0.$	ft/sec^2	Sequencer rate
Previously read selected accumulated IMU velocity	V_LAST_FILT	(b)	V	S		ft/sec	Sequencer rate
Shuttle position vector saved across memory reconfiguration and used for navigation initialization	R_FILT_INIT	(b)	V	DP		ft	Sequencer rate
Time tag of navigation initialization data carried across memory reconfiguration	T_FILT_INIT	(b)	F	DP		sec	Sequencer rate

[b] See ascent navigation sequencer principal function output parameter table (Table 4.1.1.1-1).

CR895960 CR895960

Table 4.1.1-3. Ascent Navigation Sequencer Output Parameters (Cont)

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Previous value of T_LAST_FILT	T_IMU_LAST	(b)	F	DP		sec	Sequencer rate
Previous value of V_LAST_FILT	V_IMU_LAST	(b)	V	DP		ft/sec	Sequencer rate
Sensed acceleration	A_SENSED	(b)	V	S		ft/sec^2	Sequencer rate

[b]See ascent navigation sequencer principal function output parameter table (Table 4.1.1.1-1).

4.1.1.1 Ascent Navigation Sequencer (4.139) Principal Function Tables. The ascent navigation sequencer principal function input and output parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.1.1.1-1 through 4.1.1.1-5.

The values for the I-loads are contained in the I-loads requirements document (JSC-19350).

Table 4.1.1.1-1. Ascent Navigation Sequencer (4.139) Input/Output
Functional Parameters

DBFN: D38008-D PN: VP70710037P00L JULY 17, 1989
INPUT FUNCTIONAL PARAMETERS FOR ASCENT NAVIGATION SEQUENCER

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PRE CR
			ASC NAV SEQ	OI8D REV00	G4.139	BOOK: S PAGE 303
ENT_STOW_GIM_POSN	V90X8254XC	ENTRY STOW GIMBAL POS FLAG	MSC		BD	CR89599C
MM_CODE_105/MM_105	V90X8623X	MAJOR MODE 105 FLAG	MSC			
MM_201	V90X8169X	MAJOR MODE 201 FLAG	MSC		BD	
NAV_INIT_FLAG	V90X8414X	NAV INIT FLAG	R/S LCH SEQ			
NAV_PF_INIT	V90X8195X	INITIATE PHD FLT NAV	HSC			
OPS_PRO_FLAG_101	V93X00009X	OPS 101 PRO FLAG	UI		DPL	
PROP_FLAG_OFS	V94J3791CA	PRIME PROP SYS INDICATOR FLAG	ASC MNVR DIP		DPL	
R_FILT(1)	V90H0584CA	X-COMP OF FLTR'S CURR POS VECTOR	ASC NAV	FT	DPL	
R_FILT(2)	V90H0585CA	Y-COMP OF FLTR'S CURR POS VECTOR	ASC NAV	FT		
R_FILT(3)	V90H0586CA	Z-COMP OF FLTR'S CURR POS VECTOR	ASC NAV	FT		
SEL_V_M50(1)	V90L25557C	SEL TOTAL X VEL M50	IHU RH	FT/S		
SEL_V_M50(2)	V90L25558C	SEL TOTAL Y VEL M50	IHU RH	FT/S		
SEL_V_M50(3)	V90L25559C	SEL TOTAL Z VEL M50	IHU RH	FT/S		
TIME_O	V90W25553CA	TIME OF SEL TOTAL M50 VEL VECTOR	ASC NAV	S		
TIME_V/T_CURR_FILT	V90W25553CB	TIME OF SEL TOTAL M50 VEL VECTOR	ASC NAV	FT/S		
V_FILT(1)	V90L06624CA	X-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV	FT/S		
V_FILT(2)	V90L06625CA	Y-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV	FT/S		
V_FILT(3)	V90L06626CA	Z-COMP OF FLTR'S CURR VEL VECTOR	HSC			
	V90X8169X	MM 301 FROM MM 106 FLAG	HSC			
	V90X8632X	OMS ENGINE PURGE COMPLETE				

Table 4.1.1.1-1. Ascent Navigation Sequencer (4.139) Input/Output Functional Parameters (Cont)

DBFN: D3B008-D PN: VP707100037P00L JULY 17, 1989 OI8D REV00 PAGE 223
OUTPUT FUNCTIONAL PARAMETERS FROM ASCENT NAVIGATION SEQUENCER ASC NAV SEQ 04.139 BOOK: S

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
A_SENSED(1)	V90A8946C	X-COMP OF SENSED ACCELERATION	ASC UPP	FT/S2		
A_SENSED(2)	V90A8947C	Y-COMP OF SENSED ACCELERATION	ASC UPP	FT/S2		
A_SENSED(3)	V90A8948C	Z-COMP OF SENSED ACCELERATION	ASC UPP	FT/S2		
ACC_PROP_MIN	V90A8938CA	ACC THRESHOLD TEST FOR STATE PROP	ASC NAV,RTLS NAV	FT/S2		
ASC_INIT_COMPLETE	V90X8924X	ASCENT INIT COMPLETE FLAG	ASC UPP SEQ,LPS			
DRAG_CONST	V90U8937CA	ACC MODEL DRAG CONST FOR ST PROP	ASC NAV,RTLS NAV	FT2/SLUG		
FILT_UPDATE	V90X0224XB	FLAG IND NAV FILTER PROC COMPLETE	ASC UPP			
G_RESET(1)	V90A0243CB	SEL X-COMP OF GRAV ACCEL VCTR RST	ASC UPP,TLM	FT/S2		
G_RESET(2)	V90A0244CB	SEL Y-COMP OF GRAV ACCEL VCTR RST	ASC UPP,TLM	FT/S2		
G_RESET(3)	V90A0245CB	SEL Z-COMP OF GRAV ACCEL VCTR RST	ASC UPP,TLM	FT/S2		
R_FILT(1)	V90H0584CB	X-COMP OF FLTR'S CURR POS VECTOR	ASC NAV	FT		
R_FILT(2)	V90H0585CB	Y-COMP OF FLTR'S CURR POS VECTOR	ASC NAV	FT		
R_FILT(3)	V90H0586CB	Z-COMP OF FLTR'S CURR POS VECTOR	ASC NAV	FT		
R_FILT_INIT(1)	V90H1276CC	X-COMP POS VCTR TO INIT NEXT OPS	ORB/RND NAV SEQ,D/L NAV SEQ	FT		
R_FILT_INIT(2)	V90H1277CC	Y-COMP POS VCTR TO INIT NEXT OPS	ORB/RND NAV SEQ,D/L NAV SEQ	FT		
R_FILT_INIT(3)	V90H1278CC	Z-COMP POS VCTR TO INIT NEXT OPS	ORB/RND NAV SEQ,D/L NAV SEQ	FT		
R_RESET(1)	V90H0235CB	SEL X-COMP OF UPDATED POS VCTR RST	ASC UPP	FT	DPL	
R_RESET(2)	V90H0236CB	SEL Y-COMP OF UPDATED POS VCTR RST	ASC UPP	FT	DPL	
R_RESET(3)	V90H0237CB	SEL Z-COMP OF UPDATED POS VCTR RST	ASC UPP	FT	DPL	
T_FILT_INIT	V90W1287CC	TIME TAG OF VCTR TO INIT NEXT OPS	ORB/RND NAV SEQ,D/L NAV SEQ	S		
T_IMU_LAST	V90W8941C	PREVIOUS VALUE OF T_IMU	ASC UPP	S		
T_LAST_FILT	V90W8522CA	TIME OF FILTER STATE VECTOR	ASC NAV,RTLS NAV	S		
T_RESET	V90W0225CB	TIME OF FILTER STATE VCTR	ASC UPP,TLM	S		
USE_IMU_DATA	V90X0538XE	FLAG TO USE IMU ACCUM VEL OR NOT	TLM			
V_FILT(1)	V90L0624CB	X-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV	FT/S		
V_FILT(2)	V90L0625CB	Y-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV	FT/S		
V_FILT(3)	V90L0626CB	Z-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV	FT/S		
V_FILT_INIT(1)	V90L1279CC	X-COMP VEL VCTR TO INIT NEXT OPS	ORB/RND NAV SEQ,D/L NAV SEQ	FT/S		
V_FILT_INIT(2)	V90L1280CC	Y-COMP VEL VCTR TO INIT NEXT OPS	ORB/RND NAV SEQ,D/L NAV SEQ	FT/S		
V_FILT_INIT(3)	V90L1281CC	Z-COMP VEL VCTR TO INIT NEXT OPS	ORB/RND NAV SEQ,D/L NAV SEQ	FT/S		
V_IMU_LAST(1)	V90L8942C	X-COMP OF PREVIOUS V_IMU_CURRENT	ASC UPP	FT/S		
V_IMU_LAST(2)	V90L8943C	Y-COMP OF PREVIOUS V_IMU_CURRENT	ASC UPP	FT/S		
V_IMU_LAST(3)	V90L8944C	Z-COMP OF PREVIOUS V_IMU_CURRENT	ASC UPP	FT/S		
V_IMU_RESET(1)	V90L0247CB	SEL X-COMP OF ACCUM SENSED VEL RST	ASC UPP	FT/S		
V_IMU_RESET(2)	V90L0248CB	SEL Y-COMP OF ACCUM SENSED VEL RST	ASC UPP	FT/S		
V_IMU_RESET(3)	V90L0249CB	SEL Z-COMP OF ACCUM SENSED VEL RST	ASC UPP	FT/S		
V_LAST_FILT(1)	V90L0621CB	X-COMP VEL W COV MTRX & FLTR UPDTE	ASC NAV	FT/S		
V_LAST_FILT(2)	V90L0622CB	Y-COMP VEL W COV MTRX & FLTR UPDTE	ASC NAV	FT/S		
V_LAST_FILT(3)	V90L0623CB	Z-COMP VEL W COV MTRX & FLTR UPDTE	ASC NAV	FT/S		
V_RESET(1)	V90L0239CB	SEL X-COMP OF UPDATED VEL VCTR RST	ASC UPP	FT/S		
V_RESET(2)	V90L0240CB	SEL Y-COMP OF UPDATED VEL VCTR RST	ASC UPP	FT/S		
V_RESET(3)	V90L0241CB	SEL Z-COMP OF UPDATED VEL VCTR RST	ASC UPP	FT/S		

Table 4.1.1.1-2. Ascent Navigation Sequencer (4.139) I-Loads

FSSR NAME	MSID	ENG UNIT	PFS ILOADS UPDATE B/L DT PR D S PR FCTN CAT
NO REQUIREMENTS			

Table 4.1.1.1-3. Ascent Navigation Sequencer (4.139) K-Loads

PFS KLOADS UPDATE B/L

FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT PR S PR FCTN	LAST CR EQTN MSID
NO REQUIREMENTS					

Space Transportation Systems Division
Rockwell International

Table 4.1.1.1-4. Ascent Navigation Sequencer (4.139) Constants

NROKRMM.FSSR2.DATA(X01)BOOK5
PFS CONSTANTS UPDATE B/L

FSSR NAME / DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
C(01) TESSERAL HARMONIC COEFFICIENT			-.27635957 E-09	ND	F	D				
C(02) TESSERAL HARMONIC COEFFICIENT			+.15711423 E-05	ND	F	D				
C(03) TESSERAL HARMONIC COEFFICIENT			+.21907694 E-05	ND	F	D				
C(04) TESSERAL HARMONIC COEFFICIENT			+.30466825 E-06	ND	F	D				
C(05) TESSERAL HARMONIC COEFFICIENT			+.97966803 E-07	ND	F	D				
C(06) TESSERAL HARMONIC COEFFICIENT			+.50552749 E-06	ND	F	D				
C(07) TESSERAL HARMONIC COEFFICIENT			+.78842815 E-07	ND	F	D				
C(08) TESSERAL HARMONIC COEFFICIENT			+.59073749 E-07	ND	F	D				
C(09) TESSERAL HARMONIC COEFFICIENT			-.41542493 E-08	ND	F	D				
DT ASCENT NAV SEQUENCING TIME INTERVAL FOR ASCENT NAVIGATION			+3.84	SEC	F	S				
EARTH MU EARTH GRAVITATIONAL CONSTANTS	V97U4378C		+.140764487566 E+17	FT**3/ SEC**2	F	D				
EARTH POLE(1) X COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8460C		.28322844 E-02	ND	F	S				
EARTH POLE(2) Y COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8461C		-.50279960 E-04	ND	F	S				
EARTH POLE(3) Z COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8462C		.99999598 E+00	ND	F	S				
EARTH RADIUS EQUATOR EARTH EQUATORIAL RADIUS	V97U5324C		.209257414698 1630 E+08	FT	F	D				
EARTH RADIUS GRAV EARTH RADIUS (GRAV ACCEL)	V97U5325C		+.209256561680 E+08	FT	F	D				
EARTH RATE EARTH'S ROTATIONAL RATE	V97U4379C		.7292115146460 000 E-04	RAD/SEC	F	D				
ELLIPT EARTH'S ELLIPTICITY CONSTANTS	V97U5332C		.335232980000 0000 E-02	ND	F	D				
S(01) TESSERAL HARMONIC COEFFICIENT	V97U5492C		-.52357454 E-08	ND	F	D				
S(02) TESSERAL HARMONIC COEFFICIENT	V97U5493C		-.90231337 E-06	ND	F	D				

CR89596C

CR89596C

Table 4.1.1.1-4. Ascent Navigation Sequencer (4.139) Constants (Cont)

NROKRMM FSSR2.DATA(X01)BOOK5
PFS CONSTANTS UPDATE B/L

FSSR NAME / DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
S(03) TESSERAL HARMONIC COEFFICIENT	V97U5494C		+.27267074 E-06	ND	F	D				
S(04) TESSERAL HARMONIC COEFFICIENT	V97U5495C		-.21259298 E-06	ND	F	D				
S(05) TESSERAL HARMONIC COEFFICIENT	V97U5496C		+.19681077 E-06	ND	F	D				
S(06) TESSERAL HARMONIC COEFFICIENT	V97U5497C		-.44125015 E-06	ND	F	D				
S(07) TESSERAL HARMONIC COEFFICIENT	V97U5498C		+.14718958 E-06	ND	F	D				
S 08) TESSERAL HARMONIC COEFFICIENT	V97U5499C		-.12140873 E-07	ND	F	D				
S 09 TESSERAL HARMONIC COEFFICIENT	V97U5500C		+.63163541 E-08	ND	F	D				
ZONAL 01 ZONAL HARMONIC COEFFICIENT	V97U5582C		.0	ND	F	D				
ZONAL 02 ZONAL HARMONIC COEFFICIENT	V97U5583C		+.10826271 E-02	ND	F	D				
ZONAL 03 ZONAL HARMONIC COEFFICIENT	V97U5584C		-.25358868 E-05	ND	F	D				
ZONAL(04) ZONAL HARMONIC COEFFICIENT	V97U5585C		-.16246180 E-05	ND	F	D				

CR89596C

CR89596C

Table 4.1.1.1-5. Ascent Navigation Sequencer
(4.139) Cross-Reference

FSSR Name	Source Name
V_CURRENT_FILT	SEL_V_M50
T_CURRENT_FILT	TIME_V
ASCENT_INIT_COMPLETE	ASC_INIT_COMPLETE

4.1.2 Ascent/RTLS Navigation Sequencer (4.147)

The ascent/RTLS navigation sequencer principal function shall provide a capability for control of the navigation principal functions should an RTLS abort be required during ascent. Initialization, canceling, and sequencing of navigation processing principal functions for these two navigation phases shall be accomplished.

Cues for performing the proper navigation initialization and sequencing during OPS-6 are defined in the Level B GN&C CPDS. The particular events and navigation actions pertaining to the ascent/RTLS navigation sequencer are shown in Table 4.1.2-1.

A. Detailed Requirements. The ascent/RTLS navigation sequencer principal function shall accept control from the ascent navigation sequencer principal function on a crew selection of OPS-6. Once initiated, the ascent/RTLS navigation sequencer principal function shall maintain control of the navigation principal functions until the end of the rollout major mode (crew proceed to OPS-9).

1. Crew selection of Major Mode 601 - Crew selection of Major Mode 601 is accomplished via a hardware switch selection or keyboard entry. Cyclic repetition of the ascent navigation principal function will be discontinued and then reinitiated at the repetition rate DT_RTLS_SECOND_STAGE; the rate shall be premission-determined and independent of the repetition rate(s) of any other navigation principal functions. No further control activity is required of the ascent/RTLS navigation sequencer principal function during Major Mode 601.

2. Crew proceed to Major Mode 602 - On a proceed to Major Mode 602, cyclic repetition of the ascent navigation principal function shall be discontinued and the required parameters shall be initialized for subsequent execution of the RTLS navigation principal function. The computations necessary are the following.

Pad-loaded values of the expected values of the magnitude of the errors in each of the components of the position and velocity vectors, together with the associated cross-correlations, expressed in the UVW coordinate system, are used to construct the initial M50 6 x 6 covariance matrix by invoking the covariance initialization subfunction (Section 4.2.3). Then the drag constant and the minimum acceleration threshold for employment of IMU data in state propagation are computed by the equations

$$DRAG\_CONST = DRAG\_CONST\_RTLS$$

$$ACC\_PROP\_MIN = ACC\_PROP\_MIN\_REF$$

where DRAG_CONST_RTLS is an I-load parameter.

After initialization is complete, cyclic repetition of the RTLS navigation principal function shall be initiated. This cyclic repetition shall be continued at the same rate until selected MSBLS range and azimuth data are valid, at which time cyclic repetition of the RTLS navigation principal function at a higher rate shall be initiated and continued until the end of rollout.

The repetition rates for the RTLS navigation principal function shall be premission determined and independent of the repetition rate of any other navigation principal function.

B. Interface Requirements. Input and output parameters are given in Tables 4.1.2-2 and 4.1.2-3, respectively. Principal function input and output parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.1.2.1-1 through 4.1.2.1-5.

C. Processing Requirements. None.

D. Constraints. It is assumed that transition to Major Mode 601 occurs before the ascent navigation sequencer discontinues use of IMU data for state propagation and that transition to Major Mode 602 will occur only after final termination of thrusting for the duration of the mission. Without this assumption, it would be necessary to reconfigure the gravity model and the employment of IMU data at either or both of the above-mentioned transitions.

E. Supplemental Information. A suggested implementation of these requirements is represented in Section 5.2, ASCENT_RTLS_NAV_SEQUENCER.

Table 4.1.2-1. OPS-6 Level B Events

Event No.[a]	Event Name	Navigation Criteria	Navigation Action
A30	Mode transition from 102 to 601	Transition from OPS-1 to mode 601	Cancel ascent navigation; reschedule at RTLS rate
A31	Mode transition 103 to 601	Transition from OPS-1 to mode 601	Cancel ascent navigation; reschedule at RTLS rate
A39	Mode transition from 601 to 602	Mode transition from 601 to 602	Cancel ascent navigation; initiate RTLS navigation
A39B	Mode transition from 104 to 602	Transition from OPS-1 to mode 602	Cancel ascent navigation; initiate RTLS navigation
N/A	N/A	RTLS navigation with MSBLS range and azimuth valid	Cancel RTLS navigation; reinitiate at higher rate

[a]Current Level B designation.

Table 4.1.2-2. Ascent/RTLS Navigation Sequencer Input Parameters

Description	Symbol	Input Sources	Type	Precision	Range	Units	Sample Rate
Flag indicating availability of MLS data	MLS_AVAIL	(a)	D		ON/OFF		As needed
Flag indicating MSBLS range data are good	MSBLS_RANGE_ DATA_GOOD	(a)	D		ON/OFF		As needed
Flag indicating MSBLS azimuth data are good	MSBLS_AZIMUTH_ DATA_GOOD	(a)	D		ON/OFF		As needed
Square root of diagonal elements for OPS 6 covariance matrix initialization	SIG_DIAG_UVW_ RTLS	(b)	V	DP		vary	As needed
Correlation coefficients to initialize covariance matrix for RTLS	CORR_COEFF_RTLS	(b)	V	DP			As needed
Shuttle position vector in M50 coordinates	R_FILT	(a)	V	DP		ft	As needed
Shuttle velocity vector in M50 coordinates	V_FILT	(a)	V	S		ft/ sec	As needed
Shuttle drag constant	DRAG_CONST_RTLS	(b)	F	S		ft^2/ slug	As needed
Minimum magnitude of nongravitational acceleration required for employment of IMU data in state propagation	ACC_PROP_MIN_REF	(b)	F	S		ft/sec^2	As needed
Sequencing time interval for ascent navigation during RTLS second stage	DT_RTLS_SECOND_ STAGE	(c)	F	S		sec	As needed
High rate sequencing time interval for RTLS navigation	DT_GRTLS_NAV_ HIGH	(c)	F	S		sec	As needed
Low rate sequencing time interval for RTLS navigation	DT_GRTLS_NAV_ LOW	(c)	F	S		sec	As needed

[a]See ascent/RTLS navigation sequencer input parameter table (Table 4.1.2.1-1).
[b]See ascent/RTLS navigation (4.205) I-load and K-load tables.
[c]See ascent/RTLS navigation sequencer constant table (Table 4.1.2.1-4).

Table 4.1.2-3. Ascent/RTLS Naviatgion Sequencer Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Covariance matrix	E	(a)	M	DP		vary	As needed
Minimum magnitude of nongravitational acceleration required for employment of IMU data in state propagation	ACC_PROP_MIN	(a)	F	S		ft/sec^2	As needed
Shuttle drag constant	DRAG_CONST	(a)	F	DP		ft^2/ slug	As needed

[d]See ascent/RTLS navigation sequencer output parameter table (Table 4.1.2.1-1).

4.1.2.1 Ascent/RTLS Navigation Sequencer (4.197) Principal Function Tables. The ascent/RTLS navigation sequencer principal function input and output parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.1.2.1-1 through 4.1.2.1-5.

The values for the I-loads are contained in the I-loads requirements document (JSC-19350).

CR89599C CR89599C

Table 4.1.2.1-1. Ascent/RTLS Navigation Sequencer (4.147) Input/Output Functional Parameters

DBFN- D3B008-D PN: VP707100037P00L
INPUT FUNCTIONAL PARAMETERS FOR ASCENT/RTLS NAVIGATION SEQUENCER JULY 17, 1989

A/RTLS NAV SEQ OI8D REV00 G4.147 PAGE 304 BOOK: 5

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
MLS_AVAIL	V90X3720XB	MLS AVAILABILITY	ASC SITE LOOKUP			
MLSAZ_DATA_GOOD	V90X3003X	MSBLS AZIMUTH DATA GOOD	SF			
MLSRANGE_DATA_GOOD	V90X3063X	MSBLS RANGE DATA GOOD	SF		BD	
MM_CODE_601/MM_601	V90X8194X	MAJOR MODE 601 FLAG	MSC		BD	
MM_602	V90X8174X	MAJOR MODE 602 FLAG	MSC			
R_FILT 1)	V90H0584CA	X-COMP OF FLTR'S CURR POS VECTOR	ASC NAV	FT		
R_FILT 2)	V90H0585CA	Y-COMP OF FLTR'S CURR POS VECTOR	ASC NAV	FT		
R_FILT 3)	V90H0586CA	Z-COMP OF FLTR'S CURR POS VECTOR	ASC NAV	FT		
V_FILT(1)	V90L0624CA	X-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV	FT/S		
V_FILT(2)	V90L0625CA	Y-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV	FT/S		
V_FILT(3)	V90L0626CA	Z-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV	FT/S		
	V90X8159X	MM 601 FROM MM 102	MSC			

Table 4.1.2.1-1. Ascent/RTLS Navigation Sequencer (4.147)
Input/Output Functional Parameters (Cont)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
ACC_PROP_MIN	V90A8938CB	ACC THRESHOLD TEST FOR STATE PROP	RTLS NAV	FT/S2		
DRAG_CONST	V90U8937CB	ACC MODEL DRAG CONST FOR ST PROP	RTLS NAV	FT2/SLUG		
E(1-1)	V90U0650CB	COVARIANCE MATRIX ELEMENT 1-1	RTLS NAV,TLM			
E(1-2)	V90U0651CB	COVARIANCE MATRIX ELEMENT 1-2	RTLS NAV			
E(1-3)	V90U0652CB	COVARIANCE MATRIX ELEMENT 1-3	RTLS NAV			
E(1-4)	V90U0653CB	COVARIANCE MATRIX ELEMENT 1-4	RTLS NAV			
E(1-5)	V90U0654CB	COVARIANCE MATRIX ELEMENT 1-5	RTLS NAV			
E(1-6)	V90U0655CB	COVARIANCE MATRIX ELEMENT 1-6	RTLS NAV			
E(2-1)	V90U0656CB	COVARIANCE MATRIX ELEMENT 2-1	RTLS NAV			
E(2-2)	V90U0657CB	COVARIANCE MATRIX ELEMENT 2-2	RTLS NAV,TLM			
E(2-3)	V90U0658CB	COVARIANCE MATRIX ELEMENT 2-3	RTLS NAV			
E(2-4)	V90U0659CB	COVARIANCE MATRIX ELEMENT 2-4	RTLS NAV			
E(2-5)	V90U0660CB	COVARIANCE MATRIX ELEMENT 2-5	RTLS NAV			
E(2-6)	V90U0661CB	COVARIANCE MATRIX ELEMENT 2-6	RTLS NAV			
E(3-1)	V90U0662CB	COVARIANCE MATRIX ELEMENT 3-1	RTLS NAV			
E(3-2)	V90U0663CB	COVARIANCE MATRIX ELEMENT 3-2	RTLS NAV			
E(3-3)	V90U0664CB	COVARIANCE MATRIX ELEMENT 3-3	RTLS NAV,TLM			
E(3-4)	V90U0665CB	COVARIANCE MATRIX ELEMENT 3-4	RTLS NAV			
E(3-5)	V90U0666CB	COVARIANCE MATRIX ELEMENT 3-5	RTLS NAV			
E(3-6)	V90U0667CB	COVARIANCE MATRIX ELEMENT 3-6	RTLS NAV			
E(4-1)	V90U0668CB	COVARIANCE MATRIX ELEMENT 4-1	RTLS NAV			
E(4-2)	V90U0669CB	COVARIANCE MATRIX ELEMENT 4-2	RTLS NAV			
E(4-3)	V90U0670CB	COVARIANCE MATRIX ELEMENT 4-3	RTLS NAV			
E(4-4)	V90U0671CB	COVARIANCE MATRIX ELEMENT 4-4	RTLS NAV,TLM			
E(4-5)	V90U0672CB	COVARIANCE MATRIX ELEMENT 4-5	RTLS NAV			
E(4-6)	V90U0673CB	COVARIANCE MATRIX ELEMENT 4-6	RTLS NAV			
E(5-1)	V90U0674CB	COVARIANCE MATRIX ELEMENT 5-1	RTLS NAV			
E(5-2)	V90U0675CB	COVARIANCE MATRIX ELEMENT 5-2	RTLS NAV			
E(5-3)	V90U0676CB	COVARIANCE MATRIX ELEMENT 5-3	RTLS NAV			
E(5-4)	V90U0677CB	COVARIANCE MATRIX ELEMENT 5-4	RTLS NAV			
E(5-5)	V90U0678CB	COVARIANCE MATRIX ELEMENT 5-5	RTLS NAV,TLM			
E(5-6)	V90U0679CB	COVARIANCE MATRIX ELEMENT 5-6	RTLS NAV			
E(6-1)	V90U0680CB	COVARIANCE MATRIX ELEMENT 6-1	RTLS NAV			
E(6-2)	V90U0681CB	COVARIANCE MATRIX ELEMENT 6-2	RTLS NAV			
E(6-3)	V90U0682CB	COVARIANCE MATRIX ELEMENT 6-3	RTLS NAV			
E(6-4)	V90U0683CB	COVARIANCE MATRIX ELEMENT 6-4	RTLS NAV			
E(6-5)	V90U0684CB	COVARIANCE MATRIX ELEMENT 6-5	RTLS NAV			
E(6-6)	V90U0685CB	COVARIANCE MATRIX ELEMENT 6-6	RTLS NAV,TLM			
MM_CODE	V90Q0555CB	SNAP-MAJOR MODE CODE	TLM			

Space Transportation Systems Division
Rockwell International

Table 4.1.2.1-2. Ascent/RTLS Navigation Sequencer (4.147) I-Loads

FSSR NAME	MSID	ENG UNIT	DT	PR	O	S	PR	FCTN	CAT
NO REQUIREMENTS									

Table 4.1.2.1-3. A/RTLS Navigation Sequencer (G4.147) K-Loads Ascent/RTLS Navigation Sequencer

OI88 MISSIONS

FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT	PR	S	PR FCTN	LAST CR EQTN MSID
CORR_COEFF_RTLS(1)	V97U5784C	+0.0	E+00 ND	F	D	C	G4.147	89661A
CORR_COEFF_RTLS(2)	V97U5785C	+9.0	E-01 ND	F	D	C	G4.147	89661A
CORR_COEFF_RTLS(3)	V97U5786C	+0.0	E+00 ND	F	D	C	G4.147	89661A
CORR_COEFF_RTLS(4)	V97U5787C	+0.0	E+00 ND	F	D	C	G4.147	89661A
CORR_COEFF_RTLS(5)	V97U5788C	+9.0	E-01 ND	F	D	C	G4.147	89661A
CORR_COEFF_RTLS(6)	V97U5789C	+9.0	E-01 ND	F	D	C	G4.147	89661A
CORR_COEFF_RTLS(7)	V97U5790C	+0.0	E+00 ND	F	D	C	G4.147	89661A
SIG_DIAG_UVW_RTLS(1)	V97U5791C	+1.0000000	E+03 FT	F	D	C	G4.147	89661A
SIG_DIAG_UVW_RTLS(2)	V97U5792C	+2.0	E+03 FT	F	D	C	G4.147	89661A
SIG_DIAG_UVW_RTLS(3)	V97U5793C	+3.0	E+03 FT	F	D	C	G4.147	89661A
SIG_DIAG_UVW_RTLS(4)	V97U5794C	+4.0000000	E+00 FT/SEC	F	D	C	G4.147	89661A
SIG_DIAG_UVW_RTLS(5)	V97U5795C	+4.0000000	E+00 FT/SEC	F	D	C	G4.147	89661A
SIG_DIAG_UVW_RTLS(6)	V97U5796C	+6.0	E+00 FT/SEC	F	D	C	G4.147	89661A

DBFN:0534 DATE:07/14/88

Table 4.1.2.1-4. Ascent/RTLS Navigation Sequencer (4.147) Constants

NROKRMM.FSSR2.DATA(X02)BOOK5
PFS CONSTANTS UPDATE B/L

FSSR NAME DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
DT_RTLS_SECOND_STAGE SEQUENCING TIME INTERVAL FOR ASCENT NAVIGATION DURING RTLS SECOND STAGE			1.92	SEC	F	S				
DT_GRTLS_NAV_HIGH HIGH-RATE SEQUENCING TIME INTERVAL FOR GLIDE RTLS NAVIGATION			1.92	SEC	F	S				
DT_GRTLS_NAV_LOW LOW-RATE SEQUENCING TIME INTERVAL FOR GLIDE RTLS NAVIGATION			3.84	SEC	F	S				

Space Transportation Systems Division
Rockwell International

STS 83-0005B
March 25, 1988

Table 4.1.2.1-5. Ascent/RTLS Navigation Sequence (4.147) Cross-References

FSSR Name	Source Name
MSBLS_RANGE_DATA_GOOD	MLSRANGE_DATA_GOOD
MSBLS_AZIMUTH_DATA_GOOD	MLSAZ_DATA_GOOD

4.1.3 Ascent User Parameter Processing Sequencer (4.197)

This principal function will provide a capability for initialization and control of principal functions and subfunctions associated with the computation of user parameters during the nominal ascent operational sequence. This sequencer will provide initialization and control of the ascent user parameter processing principal function and its subfunctions.

Events that are to be used as cues for performing the required initialization and sequencing are defined in the Level B GN&C CPDS. The particular events and a summary of the associated user parameter actions pertaining to the ascent user parameter processing sequencer are given in Table 4.1.3-1. Principal function input parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.1.3.1-1 through 4.1.3.1-5.

A. Detailed Requirements. The ascent user parameter processing sequencer shall be invoked at navigation initiation and will be terminated in one of four ways:

1. When termination occurs upon a proceed to OPS-2.

2. When termination occurs upon a proceed to OPS-3.

3. When an ascent abort occurs and the RTLS user parameter processing sequencer is invoked upon transition to OPS-6 (abort selection of RTLS during mode 103 or following SRB separation command for abort selection of RTLS during mode 102).

4. On any exit to GN&C OPS-9 from mode 101.

The following paragraphs state the detailed requirements for the sequencer itself, on an event-by-event basis.

ASCENT INIT COMPLETE-Navigation initialized. Prior to cyclic execution of the user parameter state propagator (Section 4.6.1.1), initialization of necessary parameters shall be performed. This initialization will be accomplished within the ascent navigation sequencer described in Section 4.1.1. Thus, it is required that cyclic execution of the user parameter state propagation function not begin until the flag

ASCENT_INIT_COMPLETE

is received from the ascent navigation sequencer indicating that ascent initialization is complete. Cyclic execution of the user parameter state propagator then will commence at a repetition rate of 6.25 Hertz.

EVENT 19-Solid rocket booster ignition command. Based upon this cue, the ascent user parameter processing initialization subfunction (Section 4.6.1.3) will be performed:

CALL: ASCENT_UPP_INIT.

Following this initialization, cyclic repetition of the ascent/RTLS user parameter calculations (Section 4.6.1.2) and the ascent user parameter HSI calculations (Section 4.6.1.4) will commence at a repetition rate of 1.04 Hertz.

EVENT 28-Solid rocket booster separation command. Cyclic repetition of the user parameter state propagation function shall be changed to a repetition rate of 2.08 Hertz.

EVENT 31-Guidance fine countdown initiate event. Based upon this cue, the cyclic repetition rate of the user parameter state propagation function shall be changed to a repetition rate of 6.25 Hertz.

EVENT 32-MECO command. Based upon this cue, the cyclic repetition rate of the user parameter state propagator shall be changed to a repetition rate of 1.04 Hertz.

EVENT 36-Transition to mode 104 (OMS-1 insertion). Based upon this cue, the current schedulings of HSI calculations, and the ascent/RTLS user parameter calculations are to be cancelled.

EVENT 45-Initiate guidance (OMS-2). Based upon this cue, the current scheduling of user parameter state propagation is to be cancelled. Cyclic processing of user parameter state propagation is to be rescheduled at a repetition rate of 1.04 Hertz beginning with this event.

B. Interface Requirements. Input parameters for the sequencer are given in the principal function interface, Table 4.1.3.1-1. The sequencer has no output parameters.

C. Processing Requirements. None.

D. Constraints. None.

E. Supplemental Information. It is required that the state vector be updated by the user parameter state propagator just prior to initiating cyclic processing of the orbit insertion guidance principal function and, further, that the state vector also be updated immediately following OMS ignition. The scheduling of the ascent user parameter state propagator is to be shifted to meet these requirements whenever orbit insertion guidance is to be initiated. The intent here is to get the executions of the user parameter state propagator in synchronization with those of the guidance program, with the propagation occurring just prior to each guidance pass. These processes will be begun at such a time before ignition that OMS ignition occurs only shortly before a propagation cycle so that little sensed velocity change will be missed over the next propagation step. A suggested implementation for these requirements is illustrated in Section 5.6, flow chart ASCENT_UPP_SEQ.

Table 4.1.3-1. Event Flag Inputs for Ascent User Parameter Processing Sequencer

Event Flag	Event Flag Description	Action Taken by Sequencer in Response to Event Flag
ASCENT_INIT_COMPLETE	Navigation initialization complete flag	Initiate performance of the user parameter state propagation function at a repetition rate of 6.25 Hertz.
EVENT_19	Solid rocket booster ignition command	Perform the ascent user parameter processing initialization. Initiate ascent/RTLS user parameter calculations and ascent user parameter HSI calculations at a repetition rate of 1.04 Hertz.
EVENT_28	Solid rocket booster separation command	Change the repetition rate of the user parameter state propagation function to 2.08 Hertz.
EVENT_31	Guidance fine countdown initiate	Change the repetition rate of the user parameter state propagation function to 6.25 Hertz.
EVENT_32	MECO command	Change the repetition rate of the user parameter state propagation function to 1.04 Hertz.
EVENT_36	Transition to mode 104 (OMS-1 insertion)	Cancel ascent/RTLS user parameter calculations and ascent user parameter HSI calculations.
EVENT_45	Initiate guidance for OMS-2	Cancel and reschedule cyclic processing of user parameter state propagation at a rate of 1.04 Hertz.

4.1.3.1 Ascent User Parameter Processing Sequencer (4.197) Principal Function Tables. The ascent user parameter processing principal function input and output parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.1.3.1-1 through 4.1.3.1-5.

The values for the I-loads are contained in the I-loads requirements document (JSC-19350).

Table 4.1.3.1-1. Ascent/User Parameter Processing Sequencer (4.197)
Input/Output Functional Parameters

DBFN: D3B008-D PN: VP707100037P00L JULY 17, 1989 OI8D REV00 PAGE 308
INPUT FUNCTIONAL PARAMETERS FOR ASCENT USER PARAMETER PROCESSING SEQUENCER ASC UPP SEQ G4.197 BOOK: 5

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
ASC_INIT_COMPLETE	V90X8924X	ASCENT INIT COMPLETE FLAG	ASC NAV SEQ			
MECO_CMD	V90X8569XA	MECO COMMAND FLAG	SSME OPS			
MM_CODE_104/MM_104	V90X8152X	MAJOR MODE 104 FLAG	MSC			
MM_CODE_601/MM_601	V90X8194X	MAJOR MODE 601 FLAG	MSC			
NAV_INIT_FLAG	V90X8414X	NAV INIT FLAG	R/S LCH SEQ		BD	
NAV_PF_INIT	V90X8195X	INITIATE PWD FLT NAV	MSC			
S_MECO	V90X1963XB	FINE COUNTDOWN DISCRETE	ASC 2STG GUID			
SRB_IGNITION_CMD	V90X8377X	SRB IGNITION CMD FLAG	R/S LCH SEQ		BD	
SRB_SEP_CMD_FLAG	V90X8331XA	SRB SEPARATION COMMAND FLAG	SRB SEP SEQ			
SRB_SEP_CMD_FLAG	V90X8331XB	SRB SEPARATION COMMAND FLAG	ET SEP SEQ			
	V90X8333X	SRB SEPARATION INITIATION FLAG	SRB SEP SEQ		BD	

CR89599C

Table 4.1.3.1-2. Ascent/User Parameter Processing Sequencer (4.197) I-Loads

FSSR NAME	MSID	ENG UNIT	DT PR D S PR FCTN	CAT
NO REQUIREMENTS				

Table 4.1.3.1-3. Ascent/User Parameter Processing Sequencer (4.197) K-Loads

FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT PR S PR FCTN	LAST CR EQTN MSID
NO REQUIREMENTS					

Table 4.1.3.1-4. Ascent/User Parameter Processing
Sequencer (4.197) Constants

NROKRMM.FSSR2.DATA(X10)BOOK5
PFS CONSTANTS UPDATE B/L

FSSR NAME DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID

NO REQUIREMENTS.

Table 4.1.3.1-5. Ascent User Parameter
Processing Sequencer (4.197)
Cross-References

FSSR Name	Source Name
ASCENT_INIT_COMPLETE	ASC_INIT_COMPLETE
SRB_IGNITION_COMMAND	SRB_IGNITION_CMD

4.1.4 RTLS User Parameter Processing Sequencer (4.200)

This principal function shall provide a capability for initialization and control of those principal functions and subfunctions associated with the computations of user parameters during the return-to-launch-site (RTLS) operational sequence. The RTLS user parameter processing principal function and its subfunctions, as well as the ascent area navigation principal function, shall be initiated and controlled by this sequencer.

Events, which are to be used as cues by the sequencer for performing the required initialization and sequencing, are defined in the Level B GN&C CPDS. The particular events and a summary of the associated user parameter actions pertaining to the ascent/RTLS user parameter processing sequencer are given in Table 4.1.4-1.

A. Detailed Requirements. The ascent/RTLS user parameter processing sequencer shall be initiated upon the occurrence of any of the following events:

1. Abort selection of RTLS during mode 102

2. Abort selection of RTLS during mode 103

3. Abort selection of RTLS during mode 104

This sequencer shall be terminated upon the transition from OPS-6 to vehicle utility OPS-9.

The following paragraphs specify the detailed requirements that were summarized in Table 4.1.4-1. These requirements specify, for each of the event cues to be utilized by the sequencer, the actions that the sequencer is to initiate.

EVENT A30 - Solid rocket booster separation command. On the basis of this cue, cyclic processing of the user parameter state propagation subfunction (Section 4.6.2.1) shall continue at a repetition rate of 6.25 Hertz. Cyclic processing of the user parameter HSI calculations (Section 4.6.2.5) shall continue at a repetition rate of 1.04 Hertz. Cyclic processing of the powered RTLS user parameter calculations subfunction (Section 4.6.2.2) shall commence at a repetition rate of 1.04 Hertz.

EVENT A31 - Abort selection is RTLS during Major Mode 103. On the basis of this cue, cyclic processing of the user parameter state propagation subfunction (Section 4.6.2.1) shall be increased to a repetition rate of 6.25 Hertz. Cyclic processing of the user parameter HSI calculations (Section 4.6.2.5) shall continue at a repetition rate of 1.04 Hertz. Cyclic processing of the powered RTLS user parameter calculations subfunction (Section 4.6.2.2) shall commence at a repetition rate of 1.04 Hertz. Cyclic processing of the ascent/RTLS calculations (Section 4.6.2.4) shall continue at a repetition rate of 1.04 Hertz.

EVENT A34A - MPS guidance cutoff task discrete. On the basis of this cue, the cyclic processing rate of the powered RTLS user parameter calculations subfunction (Section 4.6.2.2) and the ascent/RTLS calculations (Section 4.6.2.4) shall be increased to a repetition rate of 2.08 Hertz. The cyclic processing rate of the user parameter state propagation function (Section 4.6.2.1) shall continue at 6.25 Hertz.

EVENT A39 - Transition from Major Mode 601 to Major Mode 602. On the basis of this cue, cyclic processing of the powered RTLS user parameter calculations subfunction (Section 4.6.2.2) and the RTLS HSI calculations (Section 4.6.2.5) shall be cancelled. Cyclic processing of the ascent/RTLS calculations (Section 4.6.2.4) shall be decreased to a repetition rate of 1.04 Hertz. The cyclic processing of the TACAN display computations for RTLS (Section 4.6.2.6) shall commence at a repetition rate of 0.52 Hertz. Cyclic processing of the user parameter state propagation subfunction (Section 4.6.2.1) shall continue at a repetition rate of 6.25 Hertz. Cyclic processing of the area navigation principal function (Section 4.7) shall commence at a repetition rate of 1.04 Hertz.

EVENT A39B - Transition from Major Mode 104 to Major Mode 602. On the basis of this cue, cyclic processing of the ascent/RTLS calculations, the glide RTLS user parameter calculations subfunction (Section 4.6.2.3), and the area navigation principal function (Section 4.7) shall commence at a repetition rate of 1.04 Hertz. Cyclic processing of the user parameter state propagation subfunction (Section 4.6.2.1) shall be increased to a repetition rate of 6.25 Hertz. The cyclic processing of the TACAN display computations for RTLS (Section 4.6.2.6) shall commence at a repetition rate of 0.52 Hertz.

EVENT A41 - Transition from Major Mode 602 to Major Mode 603. On the basis of this cue, cyclic processing of the glide RTLS user parameter calculations subfunction GUIDECOMP_RTLS shall be increased to a repetition rate of 6.25 Hz.

TG END - Transition to Approach/Land. On the basis of this cue, the ascent/RTLS calculations (Section 4.6.2.4) shall be cancelled. Cyclic processing of the user parameter state propagation subfunction (Section 4.6.2.1) shall continue at a repetition rate of 6.25 Hertz. The cyclic processing of the TACAN display computations for RTLS (Section 4.6.2.6) shall continue at a repetition rate of 0.52 Hertz. Cyclic processing of the area navigation principal function (Section 4.7) shall continue at a repetition rate of 1.04 Hertz.

B. Interface Requirements. Principal function input and output parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.1.4.1-1 through 4.1.4.1-5

C. Processing Requirements. None.

D. Constraints. None.

E. Supplemental Information. A suggested implementation for these requirements is illustrated in Section 5.6, flow chart RTLS_UPP_SEQ.

Table 4.1.4-1. Event Flag Inputs for RTLS UPP Sequencer

Event Flag	Event Flag Description	Action Taken by Sequencer in Response to Event Flag
EVENT_A30	SRB separation command	Continue ASCENT_RTLS_COMPS and PW_HSI_COMPS at a repetition rate of 1.04 Hertz. Initiate powered RTLS user parameter calculations at a repetition rate of 1.04 Hertz. Continue repetition of user parameter state propagation at a rate of 6.25 Hertz.
EVENT_A31	Transition from Major Mode 103 to 601	Increase repetition rate of user parameter state propagation to 6.25 Hertz. Initiate powered RTLS user parameter calculations at a repetition rate of 1.04 Hertz. Continue ASCENT_RTLS_COMPS and PW_HSI_COMPS at a repetition rate of 1.04 Hertz.
EVENT_A34A	MPS guidance cutoff task discrete	Change repetition rate of powered RTLS user parameter calculations and ASCENT_RTLS_COMPS to 2.08 Hertz. Continue repetition of user parameter state propagation at a rate of 6.25 Hertz.
EVENT_A39	Transition from Major Mode 601 to 602	Initiate glide RTLS user parameter calculations at a repetition rate of 1.04 Hertz. Initiate the area navigation principal function at a repetition rate of 1.04 Hertz. Cancel the powered RTLS user parameter calculations and the PW_HSI_COMPS. Change repetition rate of ASCENT_RTLS_COMPS to 1.04 Hertz. Initiate TACAN_DISP_COMPS at a repetition rate of 0.52 Hertz.

Table 4.1.4-1. Event Flag Inputs for RTLS UPP Sequencer (Cont)

Event Flag	Event Flag Description	Action Taken by Sequencer in Response to Event Flag
EVENT_A39B	Transition from Major Mode 104 to 602	Increase repetition of user parameter state propagation to a rate of 6.25 Hertz. Initiate ASCENT_RTLS_COMPS at a repetition rate of 1.04 Hertz. Initiate glide RTLS user parameter calculations at a repetition rate of 1.04 Hertz. Initiate the area navigation principal function at a repetition rate of 1.04 Hertz. Initiate TACAN_DISP_COMPS at a repetition rate of 0.52 Hertz.
TG_END	Transition to autoland	Cancel ASCENT_RTLS_COMPS
EVENT_A41	Transition from Major Mode 602 to Major Mode 603	Increase glide RTLS UPP subfunction GUIDECOMP_RTLS to a repetition rate of 6.25 Hertz

4.1.4.1 RTLS User Parameter Processing Sequencer (4.200) Principal Function Tables. The RTLS user parameter processing sequencer principal function input and output parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.1.4.1-1 through 4.1.4.1-5.

The values for the I-loads are contained in the I-loads requirements document (JSC-19350).

Table 4.1.4.1-1. RTLS User Parameter Processing Sequencer (4.200)
Input/Output Functional Parameters

DBFN: D3B008-D PN: VP707100037P00L
INPUT FUNCTIONAL PARAMETERS FOR RETURN TO LAUNCH SITE(RTLS) UPP SEQUENCER JULY 17, 1989

RTLS UPP SEQ OI8D REV00 G4.200 PAGE 312 BOOK: 5

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
MM_CODE_601/MM_601	V90X8194X	MAJOR MODE 601 FLAG	MSC			
MM_602	V90X8174X	MAJOR MODE 602 FLAG	MSC			
S_RECO	V90X1963XA	FINE COUNTDOWN DISCRETE	PW RTLS GUID			
SRB_SEP_CMD_FLAG	V90X8331XA	SRB SEPARATION COMMAND FLAG	SRB SEP SEQ			
SRB_SEP_CMD_FLAG	V90X8331XB	SRB SEPARATION COMMAND FLAG	ET SEP SEQ			
TG_END	V90X1108XB	TAEM GUIDANCE TERMINATION FLAG	GRTLS TAEM GUID			

CR89599C

Space Transportation Systems Division
Rockwell International

STS 83-0005B
PCN-4 OI-8D
July 31, 1989

Table 4.1.4.1-2. RTLS User Parameter Processing Sequencer (4.200) I-Loads

FSSR NAME	MSID	ENG UNIT	DT PR D S PR FCTN CAT
NO REQUIREMENTS			

Table 4.1.4.1-3. RTLS User Parameter Processing Sequencer (4.200) K-Loads

OI88 MISSIONS DBFN:0509
- 0005 - ASCENT/RTLS NAVIGATION
ACTIVE MEMORY CONFIGURATIONS:

FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT PR S PR FCTN	LAST CR EQTN MSID

NO REQUIREMENTS

Table 4.1.4.1-4. RTLS User Parameter Processing Sequencer (4.200) Constants

NROKRMM.FSSR2.DATA(X10)BOOK5
PFS CONSTANTS UPDATE B/L

FSSR NAME DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID

NO REQUIREMENTS.

Table 4.1.4.1-5. RTLS User Parameter Processing Sequencer (4.200) Cross-References

FSSR Name	Source Name
No requirements	

4.2 SUBFUNCTIONS COMMON TO SEVERAL NAVIGATION FUNCTIONS

This section documents detailed requirements for subfunctions that have been identified as being common to two or more navigation principal functions or their major subfunctions. The detailed requirements specified here will be referenced from the sections to which they are common and may be regarded as inserts to paragraph A (Detailed Requirements).

4.2.1 State Propagation

This subfunction will perform a number of tasks related to propagation of the Shuttle state vector. The task of reading (snapping) the IMU is performed when the total accumulated sensed velocity is required to account for nongravitational accelerations during integration of the equations of motion. Modeled drag acceleration is computed in those circumstances in which IMU accumulated sensed velocity is not used. The equations of motion are integrated with the use of a super-g algorithm designed primarily for powered-flight phases (i.e., those phases in which appreciable nongravitational acceleration is experienced) but used also during coasting flight phases.

CR89941A

4.2.1.1 IMU Data Snap. The IMU data snap task will provide the capability to obtain the selected IMU-sensed accumulated velocity, expressed in M50 coordinates, along with the associated time tag. These data will be stored for use in the state propagation subfunction. Data from one good IMU are required as indicated in the following example:

SNAP IMU ($\underline{V}$ _CURRENT_FILT, T_CURRENT_FILT)

These data are obtained from the IMU RM.

The SNAP statement above implies the assignment of current values to the variable names shown in parentheses.

4.2.1.2 Acceleration Models. The tasks that perform integration of the Shuttle equations of motion require models to compute either gravitational and/or nongravitational (drag) accelerations. If IMU accelerometer-sensed velocity data are used in the integration process, then only gravitational accelerations need be modeled. If accelerometer data are not used, then drag acceleration needs to be modeled in addition to the gravitational acceleration.

The acceleration function shall be called by its users with values for GMD, GMO, $\underline{R}$, $\underline{V}$, and T. The input flags GMD and GMO control the degree and order of the gravitational potential model to be used. $\underline{R}$ and $\underline{V}$ are the position and velocity vectors of the vehicle in the M50 coordinate system and T is the time tag associated with both of these vectors.

First, the central force term of the earth's gravitational acceleration shall be computed. This is to be accomplished by calling a special routine (CENTRAL), which is available for execution by functions other than the navigation function.

CALL: CENTRAL

INLIST: $\underline{R}$

OUTLIST: $\underline{A}$CCEL,R_INV

The calculations performed within the routine CENTRAL are the following:

$$R\_INV = 1./|\underline{R}|$$

$$\underline{A}CCEL = -EARTH\_MU\ R\_INV^3\ \underline{R}$$

The parameter R_INV must be output because it will be used later in computing the other (noncentral force) terms of the gravitational acceleration if so requested by the user function.

Next, one of the input flags (GMD) is tested to see if only the central force term is requested or if additional acceleration calculations are desired. If the central force alone is required (GMD = 0), then no other calculations are to be performed. If, however, perturbing accelerations are wanted (GMD > 0), the following gravity and drag perturbing acceleration vectors shall be initialized:

$$\underline{G} = \underline{0}$$

$$\underline{D} = \underline{0}$$

Next, the transformation matrix from earth-fixed to M50 coordinates shall be obtained, in order to find the earth-fixed position vector and the corresponding unit vector:

$$FIFTY = EARTH\_FIXED\_TO\_M50\_COORD(T)$$

$$\underline{R}\_EF = FIFTY^T\ \underline{R}$$

$$\underline{U}R = R\_INV\ \underline{R}\_EF$$

The gravitational perturbation to $\underline{A}$CCEL shall be calculated (Section 4.2.1.2.1) and stored in the vector $\underline{G}$. If GMD = 4, then the acceleration vector due to drag shall be calculated (Section 4.2.1.2.2) and stored in the vector $\underline{D}$. The total acceleration is now calculated

$$\underline{A}CCEL = \underline{A}CCEL + \underline{G} + \underline{D}$$

A suggested implementation of this task in the form of detailed flow charts may be found in Section 5.2.

4.2.1.2.1 Gravity. The earth's gravitational attraction will be modeled by using S. Pines' uniform formulation of the spherical harmonics development. The following variables are to be set up to serve as starting values for the recursion relations used in the Pines formulation:

$$\text{AUXILIARY} = 0$$

$$\text{RO\_ZERO} = \text{EARTH\_RADIUS\_GRAV R\_INV}$$

$$\text{RO\_N} = \text{RO\_ZERO EARTH\_MU R\_INV}^2$$

$$A_{1,2} = 3.\ UR_3$$

$$A_{2,2} = 3.$$

$$L = 1$$

$$\text{ZETA\_REAL}_1 = 1.$$

$$\text{ZETA\_IMAG}_1 = 0.$$

A is a two-column array used for temporary storage of the Legendre polynomials and the derived Legendre functions (which are latitude-dependent terms), RO_N is the distance-related term, and AUXILIARY is an intermediate scalar variable.

The recursive calculations then will proceed, using as many components of the one-column arrays ZETA_REAL and ZETA_IMAG as required to account for the effects of the tesseral harmonics.

Do for I = 1 to GMO:

$$\text{ZETA\_REAL}_{I+1} = UR_1\ \text{ZETA\_REAL}_I - UR_2\ \text{ZETA\_IMAG}_I$$

$$\text{ZETA\_IMAG}_{I+1} = UR_1\ \text{ZETA\_IMAG}_I + UR_2\ \text{ZETA\_REAL}_I$$

The derived Legendre functions will then be obtained by means of recursion formulas, multiplied by the appropriate combinations of tesseral harmonics (the Legendre polynomials will be multiplied by the zonal harmonics coefficients), and stored as certain auxiliary variables - F1, F2, F3, and F4.

Do for N = 2 to GMD the following steps (1 through 5):

1. $A_{N+1,1} = 0.$

   $A_{N+1,2} = (2.\ N + 1.)\ A_{N,2}$

   $A_{N,1} = A_{N,2}$

   $A_{N,2} = UR_3\ A_{N+1,2}$

   $K = 2$

2. Do for J = 2 to N:

$A_{N-J+1,1} = A_{N-J+1,2}$

$A_{N-J+1,2} = (UR_3\ A_{N-J+2,2} - A_{N-J+2,1})/K$

$K = K + 1$

3. $F1 = 0.$

$F2 = 0.$

$F3 = -A_{1,1}\ ZONAL_N$

$F4 = -A_{1,2}\ ZONAL_N$

(These account for the zonal harmonics contributions.)

4. If the maximum order of tesserals wanted has not been attained (i.e., if $N \leq GMO$), do for N1 = 1 to N:

$F1 = F1 + N1\ A_{N1,1}\ (C_L\ ZETA\_REAL_{N1} + S_L\ ZETA\_IMAG_{N1})$

$F2 = F2 + N1\ A_{N1,1}\ (S_L\ ZETA\_REAL_{N1} - C_L\ ZETA\_IMAG_{N1})$

$DNM = C_L\ ZETA\_REAL_{N1+1} + S_L\ ZETA\_IMAG_{N1+1}$

$F3 = F3 + DNM\ A_{N1+1,1}$

$F4 = F4 + DNM\ A_{N1+1,2}$

$L = L + 1$

(These take into account the contributions of the tesseral and sectorial harmonics.)

5. $RO\_N = RO\_N\ RO\_ZERO$

$G_1 = G_1 + RO\_N\ F1$

$G_2 = G_2 + RO\_N\ F2$

$G_3 = G_3 + RO\_N\ F3$

$AUXILIARY = AUXILIARY + RO\_N\ F4$

(These equations multiply the sum of the zonal and tesseral effects by the appropriate distance-related factors, store the results as the components of the acceleration vector $\underline{G}$, and prepare for final computation by obtaining the intermediate scalar variable AUXILIARY, which accounts for an additional effect proportional to the unit radius vector UR.)

Once these calculations have been completed (N = GMD) and stored, the earth-fixed force vector will be obtained and rotated to the M50 coordinate system.

$\underline{G}$= $\underline{G}$ - AUXILIARY $\underline{UR}$

$\underline{G}$= FIFTY $\underline{G}$

This is the perturbing gravitational acceleration vector needed for the equations of motion of the Shuttle. The values of GMD and of GMO may be set by the user independently. However, it is necessary that GMO $\leq$ GMD. A maximum value of 4 for GMD will be used, which will make the array ZONAL have 4 components, the arrays $\underline{C}$ and $\underline{S}$ have 9 components each, ZETA_REAL and ZETA_IMAG have 5 components each, and A have a maximum dimension of 5 by 2.

The terms shown in the earth's gravity calculations as C_L and S_L are usually represented by $C_{n,m}$ and $S_{n,m}$, respectively, but were renumbered for single subscript utilization; the terms called $ZONAL_N$ correspond to J_N.

A suggested implementation of this task is shown in the detailed flow chart, ACCEL_EARTH_GRAV CODE, in Section 5.2.

The S. Pines formulation of the gravitational potential may be found, in condensed form, in the paper "Uniform Representation of the Gravitational Potential and its Derivatives," AIAA Journal, Vol. 11, No. 11, November 1973. In expanded form and with an earlier draft of the computer program herein presented, it may be found in JSC Internal Note No. 75-FM-29, May 27, 1975, "Use of a Nonsingular Potential."

4.2.1.2.2 Drag. The computation of drag accelerations will vary according to the values of an input indicator, designated here as GMD. The value $\underline{D}$ of this acceleration will be set to zero when the acceleration function is called.

IF GMD $\neq$ 4, the value of D shall not be changed.

IF GMD = 4, $\underline{D}$ shall be computed as

$$\underline{D} = - CD\ RHO\ DRAG\_CONST\ |\underline{V}\_R|\ \underline{V}\_R$$

where the CD is the vehicle's drag coefficient; $\underline{V}\_R = \underline{V}\_REL\ (\underline{V},\underline{R})$, where $\underline{V}$ and $\underline{R}$ are, respectively, the velocity and position vectors in M50 coordinates; $\underline{V}\_REL$ is the function that computes the relative velocity of the vehicle with respect to the atmosphere (assuming no wind), described in Section 4.4.5.2.

RHO is the density of the earth's atmosphere; and DRAG_CONST which is an I-load for ascent and RTLS navigation, is one-half the cross-sectional area of the vehicle divided by the vehicle's mass.

The calculations will be performed in the following order: First, the altitude (needed for the computation of the atmospheric density, RHO) will be obtained from the expression

$$ALT = H\_ELLIPSOID\ (\underline{R})$$

H_ELLIPSOID is the function that computes altitude above the reference ellipsoid, described in Section 4.4.5.1.

The density then will be found, from one of three different equations; the equation used will depend on the altitude range.

For ALT < 200,000 ft,
RHO = 5.27039 E-7
(1962 standard atmosphere atmospheric density for altitude of 200,000 ft).

For 200,000 ≤ ALT ≤ ALT_ZONE_CHANGE,
$RHO = SEA\_LEVEL\_DENSITY\ EXP\ (DENSE_1 + DENSE_2\ ALT + DENSE_3/ALT)$ (F1, F2, F3)

For ALT > ALT_ZONE_CHANGE
$RHO = SEA\_LEVEL\_DENSITY\ EXP\ (DENSE_4 + DENSE_5\ ALT + DENSE_6/ALT)$ (F1, F2, F3)

Once the atmospheric density has been obtained, the velocity relative to the atmosphere expressed in M50 coordinates, $\underline{V}\_R$, will be found.

After the vector $\underline{V}\_R$ has been calculated, the drag coefficient will be obtained from the square of the sine of the angle of attack (SA) and the absolute value of the sine of the sideslip angle (SB)

$$SA = (SIN(ALPHA))^2 \quad \text{(F9)}$$

$$SB = |SIN(BETA)| \quad \text{(F9)}$$

where the angle of attack (ALPHA) and the angle of sideslip (BETA) are available from the attitude applications calculation subfunction. The sine of double the sideslip angle is also needed.

$$S2B = 2.\ SB\ SQRT(1. - SB^2) \quad \text{(F4)}$$

F1 This equation shall be protected against floating point overflow (Section 3.5).
F2 This equation shall be protected against floating point underflow (Section 3.5).
F3 This equation shall be protected against divisions by zero (Section 3.5).
F4 This reference shall be protected against square roots of a negative number (Section 3.5).
F9 This equation shall be protected against return value of sine or cosine with magnitude greater than unity (Section 3.5).

and the drag coefficient is given by

$$CD = (CDF + CDN\ SA^{EXP\_SHAPE\_FACTOR})\ (1. - SB) + CDS\ SB + CDA\ S2B\ SA$$

where CDF, CDN, CDA, CDS and EXP_SHAPE_FACTOR are K-loads for the ascent precise predictor principal function.

The altitude will be obtained from the expression

$$ALT = H\_ELLIPSOID\ (\underline{R})$$

H_ELLIPSOID is the function that computes altitude above the reference ellipsoid, described in Section 4.4.5.1.

Next, a test on the altitude will be performed. If the current altitude is less than 600,000 feet, a second test will be performed to see if the altitude is less than 300,000 feet. If the second test is true, then altitude will be assigned the value of 300,000 feet. Regardless of the outcome of the second test, the angle of attack effects on the drag coefficient will be modeled according to

$$DIFF\_CD = DIFCD1\ SIN\ (DIFCD2\ ABS\ (ALPHA) - DIFCD3) + DIFCD4$$

where DIFCD1 through DIFCD4 are K-loads for the ascent precise predictor principal function. The altitude effects on the drag coefficient will then be calculated. If the altitude is less than 400,000 feet, a parameter reflecting this altitude dependence will be computed as

$$LOG\_10\_KN = KN1 + KN2\ ALT + KN3\ ALT^2$$

Otherwise, this parameter will take the form,

$$LOG\_10\_KN = 0.054287\ LOG\ (KN4 + KN5\ ALT + KN6\ ALT^2)$$

The parameters, KN1 through KN6, are constants for the ascent navigation, RTLS navigation, and ascent precise predictor principal functions.

The effects of angle of attack and altitude variables on the drag coefficient will then be combined according to

$$DELCD = DIFF\_CD\ (COS(PI(0.375 + LOG\_10\_KN)))^2$$

The drag coefficient will then be adjusted to reflect the effects of variations in angle of attack and altitude.

$$CD = CD - DELCD$$

If the altitude is greater than 600,000 feet, no variational effects are included in the computation of the drag coefficient.

Finally, the drag acceleration shall be obtained from the expression presented earlier

$$\underline{D} = -CD\ RHO\ DRAG\_CONST\ |\underline{V}\_R|\ \underline{V}\_R$$

A suggested implementation of this task is shown in the detailed flow charts, ACCEL, DENSITY, and ACCEL_DRAG CODE, in Section 5.2.

The parameters used in the computation of accelerations are: ALT_ZONE_CHANGE, CDF, CDN, CDA, CDS, EXP_SHAPE_FACTOR, DENSE, C, S, ZONAL, SEA_LEVEL_DENSITY, EARTH_MU, and EARTH_RADIUS_GRAV (see I-load, K-load, and constant tables for the ascent precise predictor principal function).

4.2.1.3 Integration of State Equations of Motion. The algorithm for integration of the Shuttle position and velocity state equations of motion can either use accumulated IMU-sensed velocity to represent the nongravitational acceleration, or model drag to compute this acceleration. Section 4.2.1.2 presents detailed requirements for the ACCEL function, which computes the Shuttle acceleration vector (gravitational only or with modeled drag). The super-g computational scheme will be performed as follows:

1. Compute the change in accumulated IMU-sensed velocity:

$$\underline{DV}\_FILT = \underline{V}\_CURRENT\_FILT - \underline{V}\_LAST\_FILT$$

2. Compute the sensed acceleration magnitude

$$ACC\_SENSED = |\underline{DV}\_FILT|/DT\_FILT \qquad (F3)$$

where DT_FILT equals the integration time interval.

3. Test this sensed acceleration level versus a threshold value (ACC_PROP_MIN)

   a. If ACC_SENSED > ACC_PROP_MIN, then set flags indicating that IMU data and a 2 x 0 gravity model are to be used

$$USE\_IMU\_DATA = ON$$
$$GM\_DEG = 2$$
$$GM\_ORD = 0$$

   b. If ACC_SENSED ≤ ACC_PROP_MIN, then set the same flags to indicate usage of a 4 x 4 gravity model, modeled drag, and no IMU data

$$USE\_IMU\_DATA = OFF$$
$$GM\_DEG = 4$$
$$GM\_ORD = 4$$

   also reset the change in IMU-sensed velocity to zero

$$\underline{DV}\_FILT = 0$$

4. Evaluate the acceleration vector with the use of the previous value of position, velocity, time, and the indicators GM_DEG and GM_ORD as arguments of the ACCEL function:

$$\underline{G} = \underline{ACCEL}(GM\_DEG, GM\_ORD, \underline{R}\_FILT, \underline{V}\_FILT, T\_LAST\_FILT)$$

[F3] This equation shall be protected against divisions by zero. Should this occur the quotient should be set equal to zero (Section 3.5)

5. Advance the position vector with use of the previous position, velocity, and acceleration vector and the time interval DT_FILT:

$$\underline{R}\_FILT = \underline{R}\_FILT + DT\_FILT\ (\underline{V}\_FILT + 0.5\ (\underline{DV}\_FILT + DT\_FILT\ \underline{G}))$$

6. Reevaluate the acceleration vector with use of the new value of the position vector, the old value of velocity, and the final time:

$$\underline{G}\_OLD = \underline{ACCEL}(GM\_DEG, GM\_ORD, \underline{R}\_FILT, \underline{V}\_FILT, T\_CURRENT\_FILT)$$

7. Advance the velocity vector with the use of an average acceleration vector and IMU-sensed velocity change:

$$\underline{V}\_FILT = \underline{V}\_FILT + \underline{DV}\_FILT + 0.5\ DT\_FILT\ (\underline{G}\_OLD + \underline{G})$$

8. Adjust the position vector with use of the new acceleration vector:

$$\underline{R}\_FILT = \underline{R}\_FILT + \frac{1}{6}\ (\underline{G}\_OLD - \underline{G})\ DT\_FILT^2$$

4.2.2 State Vector Interpolation

The state vector interpolation subfunction will provide the capability to propagate the Shuttle's position vector over a small time increment. Propagation will be accomplished by using a simple, low-order integrator. This subfunction will be used to update the position vector from its current time to the time of a sensor measurement (either TACAN, MSBLS, or barometric altimeter), as required by the navigational filter to correctly compute an estimated measurement and residual. The effect of using the low-order integrator in calculating the position vector is not cumulative, and, in fact, a position propagation is required only when the difference between the sensor measurement time and the current time exceeds a predetermined value (EPS_TAG). This value is a function of sensor accuracy and is premission-loaded.

It will first be determined, within this subfunction, whether propagation is required according to the inequality

$$|T\_SENSORS - T\_LAST\_FILT| \leq EPS\_TAG$$

If this inequality is satisfied, the output parameter, $\underline{R}$ _RESID, will be equated to the filter's previously determined position:

$$\underline{R}\_RESID = \underline{R}\_FILT$$

If this inequality is not satisfied, the filter's state vector will be propagated to the time of the external sensor measurement, T_SENSORS. This will be accomplished by the following equations, where the IMU-sensed acceleration is being approximated by the term $\underline{DV}$_FILT/DT_FILT:

$$DT\_INTERP = T\_SENSORS - T\_LAST\_FILT$$

$$\underline{R}\_RESID = \underline{R}\_FILT + DT\_INTERP\ (\underline{V}\_FILT + 0.5\ DT\_INTERP\ (\underline{DV}\_FILT/DT\_FILT + G\_OLD)) \quad \text{(F3)}$$

[F3] This equation will be protected against division by zero (Section 3.5)

A suggested implementation of this task is shown in the detailed flow chart, SV_INTERP_RTLS, of Section 5.2.

4.2.3 Covariance Matrix Initialization

In circumstances in which the orbiter position and velocity elements of the onboard filter covariance matrix are to be initialized to UVW values, the following steps must be performed (in the order indicated):

1. Data will be input to this subfunction as described by the in list below:

   IN LIST: SIG, COR, R, V

   where SIG is a six-element vector of standard deviations in the UVW coordinate system

   SIG_1, U-position (U)

   SIG_2, V-position (V)

   SIG_3, W-position (W)

   SIG_4, U-velocity (DU)

   SIG_5, V-velocity (DV)

   SIG_6, W-velocity (DW)

   and where COR is a seven-element vector of correlation coefficients, also in the UVW coordinate system

   COR_1, correlation between U-V

   COR_2, correlation between U-DU

   COR_3, correlation between U-DV

   COR_4, correlation between V-DU

   COR_5, correlation between V-DV

   COR_6, correlation between W-DW

   COR_7, correlation between DU-DV

   and where R and V are the current orbiter position and velocity vectors, respectively, in M50 coordinates.

2. The current 6 by 6 covariance matrix will be zeroed

   E_TEMP = 0.

3. The diagonal elements of E_TEMP will be computed

$$E\_TEMP_{I,I} = SIG_I \; SIG_I, \text{ for } I = 1,6$$

4. Next, position and velocity submatrix elements, as well as the upper right position-velocity covariance elements, will be computed

$$E\_TEMP_{1,2} = COR_1 \; SIG_1 \; SIG_2$$

$$E\_TEMP_{1,4} = COR_2 \; SIG_1 \; SIG_4$$

$$E\_TEMP_{1,5} = COR_3 \; SIG_1 \; SIG_5$$

$$E\_TEMP_{2,4} = COR_4 \; SIG_2 \; SIG_4$$

$$E\_TEMP_{2,5} = COR_5 \; SIG_2 \; SIG_5$$

$$E\_TEMP_{3,6} = COR_6 \; SIG_3 \; SIG_6$$

$$E\_TEMP_{4,5} = COR_7 \; SIG_4 \; SIG_5$$

$$E\_TEMP_{2,1} = E\_TEMP_{1,2}$$

$$E\_TEMP_{5,4} = E\_TEMP_{4,5}$$

5. And, finally, a transformation matrix from UVW to M50 coordinate system is acquired at current time, and used to rotate portions of the E_TEMP matrix into the M50 system. The lower left position-velocity covariance is also defined

$$M = UVW\_TO\_M50 \; (\underline{R},\underline{V})$$

$$E\_TEMP_{1 \text{ TO } 3,\ 1 \text{ TO } 3} = M \; (E\_TEMP_{1 \text{ TO } 3,\ 1 \text{ TO } 3}) \; M^T$$

$$E\_TEMP_{4 \text{ TO } 6,\ 4 \text{ TO } 6} = M \; (E\_TEMP_{4 \text{ TO } 6,\ 4 \text{ TO } 6}) \; M^T$$

$$E\_TEMP_{1 \text{ TO } 3,\ 4 \text{ TO } 6} = M \; (E\_TEMP_{1 \text{ TO } 3,\ 4 \text{ TO } 6}) \; M^T$$

$$E\_TEMP_{4 \text{ TO } 6,\ 1 \text{ TO } 3} = (E\_TEMP_{1 \text{ TO } 3,\ 4 \text{ TO } 6})^T$$

6. The 6 by 6 covariance matrix E_TEMP will be output from this subfunction.

A suggested implementation of this task is shown in the detailed flow chart, COVINIT_RTLS, in Section 5.2.

4.2.4 User Parameter Propagator Reset

The user parameter propagator reset subfunction will store the vehicle position, the velocity, the associated time tag, the accumulated velocity count, and the gravity acceleration vector after all navigation updates for use by the user parameter state propagator.

$$\underline{R}\_RESET = \underline{R}\_FILT$$

$$\underline{V}\_RESET = \underline{V}\_FILT$$

$$T\_RESET = T\_LAST\_FILT$$

$$\underline{V}\_IMU\_RESET = \underline{V}\_LAST\_FILT$$

$$\underline{G}\_RESET = \underline{G}\_OLD$$

Also, the current value of the filter state vector will be saved for subsequent covariance matrix propagation.

$$\underline{R}\_COV\_LAST = \underline{R}\_FILT$$

Finally, the filter update flag will be set to ON to indicate to users that the current navigation filter update is complete.

$$FILT\_UPDATE = ON$$

A suggested implementation of this task is shown in the detailed flow chart, UPP_STATE_RESET, in Section 5.2.

4.2.5 Delta State Update

A capability will be provided for updating the position and velocity of the Shuttle in flight by using information conveyed via ground-originated command uplink or by voice from the ground to the crew for entry via the HSD. This capability will be provided by a task that corrects the Shuttle's position and velocity vectors by using state deviations in the current selected runway coordinate system.

The performance of a delta state update will require two difference vectors (DR_RW and DV_RW) to be supplied. These vectors must be set to the desired values before the delta state update task is invoked. The appropriate navigation control subfunction (ascent or RTLS) will invoke the delta state update task only when a flag (DO_DELTA_UPDATE) has been set to ON (the control subfunctions are described in Sections 4.3.1.1 (ascent) and 4.3.2.1 (RTLS)).

DR_RW is the difference between the ground estimated position of the Shuttle and the onboard navigation system's estimate of the Shuttle's position in runway coordinates. DV_RW is the difference between the ground estimated velocity of the Shuttle and the onboard navigation system's estimate of the Shuttle's velocity in runway coordinates.

The sense of these differences is: ground estimated minus onboard estimated. The onboard estimated vectors are downlinked to the ground at regular intervals (see Section 4.9 for downlist rates) and used by the ground to calculate these differences, which are then used to correct the onboard vectors. The correction update will be performed as follows:

1. Using the earth-fixed to M50 transformation matrix and the runway to Earth-fixed transformation matrix for the current selected runway (see Sections 4.4.2.2 and 4.4.2.5 for these transformations) the delta state update task will convert the difference vectors from the runway system to M50 coordinates.

2. A new filter state will then be formed by adding the M50 difference vectors to the filter state with the same time tag as that used for the Earth-fixed to M50 transformation matrix. For the velocity part, it will be necessary to take into account the rotation of the earth.

The equations required to generate the new vectors $\underline{R}\_FILT$ and $\underline{V}\_FILT$ and to perform the required reinitialization of the navigation subsystem are detailed in the following description:

$$M\_TEMP = EARTH\_FIXED\_TO\_M50\_COORD(T\_CURRENT\_FILT)M\_EFTORW^T$$

$$\underline{DR} = M\_TEMP\ \underline{DR\_RW}$$

$$\underline{R}\_FILT = \underline{R}\_FILT + \underline{DR}$$

$$\underline{V}\_FILT = \underline{V}\_FILT + M\_TEMP\ \underline{DV\_RW} + EARTH\_RATE(\underline{EARTH\_POLE} \times \underline{DR})$$

After computation of the updated state vector the difference vectors shall be set to zero and the DO_DELTA_UPDATE flag set to the OFF position to inhibit repeated state updates. The necessary equations are:

$$\underline{DR\_RW} = \underline{0}$$

$$\underline{DV\_RW} = \underline{0}$$

$$DO\_DELTA\_UPDATE = OFF$$

A suggested implementation of this task is shown in the detailed flow chart DELTA_STATE_UPDATE of Section 5.2.

4.3 NAVIGATION PROCESSING PRINCIPAL FUNCTIONS

The two navigation processing principal functions contained in the ascent/RTLS computer load are ascent navigation and RTLS navigation. Each of these functions shall be initialized and cyclically executed under the control of the appropriate navigation sequencer principal function(s) (Section 4.1). Detailed requirements for each of the navigation processing principal functions are discussed in one of the following subsections.

4.3.1 Ascent Navigation (4.15)

The ascent navigation principal function shall be repetitively executed as specified by and under the control of either the ascent navigation sequencer principal function or the ascent/RTLS navigation sequencer principal function.

The ascent navigation principal function shall use selected IMU data and a model of the earth's gravitational acceleration and drag acceleration to maintain a current estimate of the Shuttle state vector. No external sensor data shall be processed, and no covariance matrix shall be propagated. A capability for manual or automatic (via command uplink) delta state vector update shall be available by this principal function. The capability for a whole vector state update (via command uplink) shall also be available by this principal function.

The ascent navigation principal function is composed of four primary subtasks:

1. A control task described in Section 4.3.1.1.
2. A state propagation task described in Section 4.3.1.2.
3. A delta state update task described in Section 4.3.1.3.
4. A state vector prediction task described in Section 4.3.1.4.

Principal function input and output parameters are presented in Section 4.3.1.5, along with I-load, K-load, constant, and cross-reference tables.

4.3.1.1 Ascent Control. The ascent navigation principal function shall provide the capability to control the state propagation subfunction by using either IMU-sensed data or modeled drag to represent the nongravitational accelerations.

A. Detailed Requirements. Ascent control shall perform the following tasks in the order indicated. (For definitions of variables, refer to input and output Tables 4.3.1.1-1 and 4.3.1.1-2.)

1. Selected accumulated sensed IMU velocity and the associated time tag shall be obtained as described in Section 4.3.1.2. (This task is part of the state propagation subfunction.)

2. Attitude data (angle of attack and sideslip angle) shall then be snapped and converted from degrees to radians:

```
SNAP ATTITUDE (ALPHAIN, BETAIN)

ALPHA = ALPHAIN RAD_PER_DEG

BETA = BETAIN RAD_PER_DEG
```

3. If the flag DO_DELTA_UPDATE_UP is ON, the delta state vectors used by the ascent delta state update task shall be set equal to those output by the uplink processing software. The flag DO_DELTA_UPDATE shall be set to the ON position, and the flag DO_DELTA_UPDATE_UP shall be returned to the OFF position to prevent repetitive incorporation of the same uplinked data. The necessary equations are:

```
If DO_DELTA_UPDATE_UP = ON

   DR_RW = DR_RW_UP

   DV_RW = DV_RW_UP

   DO_DELTA_UPDATE = ON

   DO_DELTA_UPDATE_UP = OFF
```

If the flag DO_DELTA_UPDATE_UP is OFF, these computations shall not be performed.

4. If the flag STATE_VECTOR_UPDATE is ON, the filter state vectors and time tag shall be set equal to the uplinked-predicted state vectors and time tag. The flag STATE_VECTOR_UPDATE shall then be set to the OFF position to prevent repetitive incorporation of the same uplinked data. The necessary equations are:

```
If STATE_VECTOR_UPDATE = ON

   R_FILT = R_TO_NAV

   V_FILT = V_TO_NAV

   T_LAST_FILT = T_TO_NAV

   STATE_VECTOR_UPDATE = OFF
```

If the flag STATE_VECTOR_UPDATE is OFF, these computations shall not be performed.

5. The state vector shall be propagated as described in Section 4.3.1.2.

6. The delta state update task shall be invoked if a flag (DO_DELTA_UPDATE) is ON. If this flag is OFF, then no delta state update is to be performed. See Section 4.3.1.3 for detailed requirements for this task.

Table 4.3.1.1-1. Ascent Control Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Current Shuttle position vector	R_FILT	(a) Ascent state propagation	V	DP		ft	Filter rate
Current Shuttle velocity vector	V_FILT	(a) Ascent state propagation	V	S		ft/sec	Filter rate
Time of the filter state vectors	T_LAST_FILT	(a) Ascent state propagation	F	DP		sec	Filter rate
Previously read accumulated velocity	V_LAST_FILT	(a) Ascent state propagation	V	DP		ft/sec	Filter rate
Total vehicle acceleration vector %50	G_OLD	Ascent state propagation	V	S		ft/sec^2	Filter rate
Angle of attack	ALPHAIN	(a)	F	S		deg	Filter rate
Sideslip angle	BETAIN	(a)	F	S		deg	Filter rate
Delta runway position vector received via command uplink	DR_RW_UP	(a)	V	S	--	ft	
Delta runway velocity vector received via command uplink	DV_RW_UP	(a)	V	S	--	ft/sec	
Uplinked, predicted position vector	R_TO_NAV	Ascent state vector prediction task	V	DP	--	ft	
Uplinked, predicted velocity vector	V_TO_NAV	Ascent state vector prediction task	V	S	--	ft/sec	
Time to which R_TO_NAV and V_TO_NAV have been predicted	T_TO_NAV	Ascent state vector prediction task	F	DP	--	sec	

[a]Refer to the ascent navigation principal function input parameter table.

CR89596C

Table 4.3.1.1-1. Ascent Control Input Parameters (Cont)

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Flag indicating (ON) that a delta state vector update shall be performed	DO_DELTA_UPDATE	(a) Delta state ascent control update	D	—	ON/OFF	—	Filter rate
Conversion factor from degrees to radians	RAD_PER_DEG	(b)	F	8	—	rad/deg	Filter rate
Flag indicating (ON) that a delta state update has been received via command uplink	DO_DELTA_ UPDATE_UP	(a) Ascent control	D	—	ON/OFF	—	Filter rate
Flag indicating (ON) that a whole vector state update is ready for replacement of the navigated state vector	STATE_VECTOR_ UPDATE	Ascent state vector prediction task, ascent control	D	—	ON/OFF	—	Filter rate

CR89596C

[a]Refer to the ascent navigation principal function input parameter table.
[b]Refer to the ascent navigation principal function constant table.

Table 4.3.1.1-2. Ascent Control Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Vehicle position vector after all navigation updates reserved for reset of guidance integrator position vector R_AVGG	R_RESET	(a)	V	DP		ft	Filter rate
Vehicle velocity vector after all navigation updates reserved for reset of guidance integrator velocity vector V_AVGG	V_RESET	(a)	V	S		ft/sec	Filter rate
Time associated with reserved reset state	T_RESET	(a)	F	DP		sec	Filter rate
Copy of V_IMU_CURRENT raw velocity counts reserved for measurement processing	V_IMU_RESET	(a)	V	DP		ft/sec	Filter rate
Switch indicating (ON) that current measurement processing is complete	FILT_UPDATE	(a)	D		OFF/ON		Filter rate
Vehicle current M50 position vector (saved for potential use by RTLS nav cov prop)	R_COV_LAST	(a)	V	DP		ft	Filter rate
Current vehicle acceleration vector (M50) for use by user parameter state prop	G_RESET	(a)	V	S		ft/sec^2	Filter rate
Angle of attack	ALPHA	ASC STATE PROP, (a)	F	S		rad	Filter rate
Ground computed position deviations to update onboard state vector	DR_RW	Ascent delta state update task	V	S	—	ft	
Ground computed velocity deviations to update onboard state vector	DV_RW	Ascent delta state update task	V	S	—	ft/sec	
Current Shuttle position vector	R_FILT	(a) Ascent state prop, ascent delta state update	V	D	—	ft	
Current Shuttle velocity vector	V_FILT	(a) Ascent state prop, ascent delta state update	V	S	—	ft/sec	
Time tag at Shuttle state vector	T_LAST_FILT	(a) Ascent state prop, ascent delta state update	F	D	—	sec	
Angle of sideslip	BETA	ASC STATE PROP, (a)	F	S		rad	Filter rate
Flag indicating (ON) that a delta state update has been received via command uplink	DO_DELTA_UPDATE_UP	Ascent control	D	—	OFF/ON	—	Filter rate

[a]Refer to the ascent navigation principal function output parameter table.

Table 4.3.1.1-2. Ascent Control Output Parameters (Cont)

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Flag indicating (ON) that a whole vector state update is ready for replacement of the navigated state	STATE_ VECTOR_ UPDATE	Ascent control	B	—	OFF/ON	—	Filter rate
Flag indicating (ON) that a delta state update is to be performed	DO_DELTA_ UPDATE	Ascent control	B	—	OFF/ON	—	Filter rate

[a]Refer to the ascent navigation principal function output parameter table.

7. The user parameter propagator reset values shall then be stored as described in Section 4.2.4.

B. Interface Requirements. The input and output parameters are listed in Tables 4.3.1.1-1 and 4.3.1.1-2.

C. Processing Requirements. Ascent control shall be executed at a premission-determined rate when the ascent navigation principal function is active.

If simultaneous uplink and keyboard entry of a delta state update occur, the uplinked information will overwrite and take priority over the keyboard entries.

If both a delta state update is requested and a replacement M50 vector is received from the state vector prediction task, the replacement (M50) vector will be incorporated and propagated, followed immediately by the incorporation of the delta state update (i.e., the propagated M50 vector will have the delta state update applied to it).

D. Constraints. The attitude data snap statement implies the assignment of current values to the variable names shown in parentheses. The variables ALPHAIN and BETAIN are assumed to be in units of degrees from the ATT PROC principal function. This data SNAP and the IMU data SNAP (Section 4.2.1.1) are assumed to yield a time-consistent set of values for the ascent navigation principal function (i.e., staleness not to exceed 0.0005 second). Since the ACCEL module is used by both the ascent navigation principal function and the ascent precise predictor principal function, execution of ACCEL in conjunction with one of these principal functions shall not interfere with its use by the other.

E. Supplementary Information. NAV_ASCENT and UPP_STATE_RESET in Section 5.2 illustrate a suggested implementation of ascent control.

4.3.1.2 State Propagation. During the ascent navigation phase, the state propagation subfunction of the ascent navigation principal function shall perform super-g integration of the equations of motion in the M50 coordinate system. Both the derived gravitational accelerations (and drag acceleration, when IMU data are not in use) and the changes in sensed velocities measured by the IMU's are to be used for this purpose. The state vector shall contain six elements, three M50 position and three M50 velocity, and shall be maintained in a single string (state) configuration.

A. Detailed Requirements. Propagation of Shuttle position and velocity vector shall be performed as follows:

1. Acquire selected IMU-sensed total accumulated velocity and the associated time tag by snapping data from the IMU RM.

   $\underline{V}$ _CURRENT_FILT

   T_CURRENT_FILT

Detailed requirements for this IMU data snap task are given in Section 4.2.1.1 (Attitude data are snapped in the ascent control subfunction, Section 4.3.1.1.)

2. Compute the difference between the current and the previous time tag associated with the IMU data snap. This will be the interval over which state propagation is desired.

   DT_FILT = T_CURRENT_FILT - T_LAST_FILT

3. Perform integration of the position/velocity equations of motion, using the super-g task (refer to Section 4.2.1.3 for detailed requirements). Position and velocity vectors shall be propagated to the current time of IMU data collection (T_CURRENT_FILT).

   $\underline{R}$ _FILT

   $\underline{V}$ _FILT

4. Save the current total accumulated IMU-sensed velocity and time tag for this next cycle.

   $\underline{V}$ _LAST_FILT = $\underline{V}$ _CURRENT_FILT

   T_LAST_FILT = T_CURRENT_FILT

B. Interface Requirements. The input and output parameters are listed in Tables 4.3.1.2-1 and 4.3.1.2-2, respectively.

C. Processing Requirements. The state propagation subfunction shall be the first subfunction performed upon initiation of each cycle of the ascent navigation principal function. This subfunction shall be performed at the ascent navigation rate.

D. Constraints. None.

E. Supplementary Information. A suggested implementation in the form of detailed flow diagrams may be found in Section 5.2. The particular flow diagrams associated with this subfunction are as follows:

NAV_STATE_PROP_ASCENT_AND_RTLS
NAV_ASCENT, ACCEL

Table 4.3.1.2-1. Ascent State Propagation Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Current accumulated IMU velocity counts	V_CURRENT_FILT	(a)	V	DP		ft/sec	Filter rate
MTU or clock time when IMU was read	T_CURRENT_FILT	(a)	F	DP		sec	Filter rate
Time of the filter state vectors	T_LAST_FILT	Ascent state propagation,(a)	F	DP		sec	Filter rate
Current Shuttle position vector	R_FILT	Ascent state propagation,(a)	V	DP		ft	Filter rate
Current Shuttle velocity vector	V_FILT	Ascent state propagation,(a)	V	S		ft/sec	Filter rate
Previously read accumulated IMU velocity	V_LAST_FILT	Ascent state propagation,(a)	V	DP		ft/sec	Filter rate
Parameter used in the accel drag model	DRAG_CONST	(b)	F	DP		ft^2/slug	Filter rate
Threshold value of sensed acceleration above which IMU data is to be used	ACC_PROP_MIN	(a)	F	S	0.	ft/sec^2	Filter rate
Angle of attack	ALPHA	ASC control	F	S		rad	Filter rate
Sideslip angle	BETA	ASC control	F	S		rad	Filter rate

NOTE: Input constants associated with the acceleration models are identified in Section 4.2.1.2 for the ascent/RTLS operations computer load.

[a]Refer to the ascent navigation principal function input parameter table.
[b]Refer to the ascent navigation principal function I-load table.

Table 4.3.1.2-2. Ascent State Propagation Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Current Shuttle position vector	R_FILT	Ascent state propagation, (a)	V	DP		ft	Filter rate
Shuttle velocity vector	V_FILT	Ascent state propagation, (a)	V	S		ft/sec	Filter rate
Gravity acceleration vector at beginning of integration interval	G_OLD	(a)	V	S		ft/sec^2	Filter rate
Time of the filter state vectors	T_LAST_FILT	Ascent state propagation, (a) ascent control	F	DP		sec	Filter rate
Previously read accumulated IMU velocity	V_LAST_FILT	Ascent state propagation, (a) ascent control	V	DP		ft/sec	Filter rate
Flag indicating (ON) that IMU data is to be used by the UPP state propagator	USE_IMU_DATA	(a)	D		ON/OFF		Filter rate

[a]Refer to the ascent navigation principal function output parameter table.

4.3.1.3 Delta State Update. During the operation of the ascent navigation principal function, a capability for a delta state update of the orbiter's on-board navigated state shall be provided.

A. Detailed Requirements. Detailed requirements for the delta state update task are described in Section 4.2.5.

B. Interface Requirements. Input and output requirements for the delta state update task are shown in Tables 4.3.1.3-1 and 4.3.1.3-2.

C. Processing Requirements. The delta state update task shall be initiated by the HSD specialist function or by uplink processing software by setting the flag DO_DELTA_UPDATE to the on state. The delta state update task (during operation of the ascent navigation principal function) shall be performed after state propagation has been accomplished, and only when a flag (DO_DELTA_UPDATE) is ON. The flag will be checked at a rate specified by either the ascent navigation sequencer principal function or the ascent/RTLS navigation sequencer principal function, whichever is active.

D. Constraints. None.

E. Supplemental Information. Correction terms rather than the total vector are used because the correction terms are less sensitive to errors between the time of their computation on the ground and the time that they are actually applied to correct the on-board state vector during powered flight.

A suggested implementation in the form of a detailed flow chart (ASC_DELTA_STATE_UPDATE) may be found in Section 5.2.

Table 4.3.1.3-1. Ascent Delta State Update Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Time of the filter state vectors	T_CURRENT_FILT	ASC state propagation	F	DP		sec	As needed
Ground computed position deviations to update on-board state vector	DR_RW	(a), Ascent control	V	S		ft	As needed
Ground computed velocity deviations to update on-board state vector	DV_RW	(a), Ascent control	V	S		ft/sec	As needed
Earth fixed to prime RW transformation matrix	M_EFTORW	(a)	M	S			As needed
Earth rotation rate	EARTH_RATE	(b)	F	DP		rad/sec	As needed
Unit vector in direction of earth's axis of rotation	EARTH_POLE	(b)	V	S			As needed
Shuttle position vector	R_FILT	ASC state prop	V	DP		ft	As needed
Shuttle velocity vector	V_FILT	ASC state prop	V	S		ft/sec	As needed

[a]See ascent navigation principal function input parameter table.
[b]See ascent navigation principal function constant table.

Table 4.3.1.3-2. Ascent Delta State Update Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Current Shuttle position vector	R_FILT	ASC state prop	V	DP		ft	As needed
Current Shuttle velocity vector	V_FILT	ASC state prop	V	S		ft/sec	As needed
Flag indicating (ON) that a delta state vector update is to be performed	DO_DELTA_UPDATE	Ascent control	D		ON/OFF		As needed
Delta position correction	DR_RW	(a)	V	S		ft	As needed
Delta velocity correction	DV_RW	(a)	V	S		ft/sec	As needed

[a]See ascent navigation principal function output parameter table

4.3.1.4 Ascent State Vector Prediction Task. During operation of the ascent navigation principal function, a capability shall be provided to predict a M50 position and velocity vector to current (cyclic) filter time. This capability is provided to time synchronize an uplinked M50 state vector with current filter time.

A. Detailed Requirements. A capability shall be provided for updating the position and velocity of the Orbiter in flight by ground-originated command uplink.

The performance of a state vector update will require the vectors R_GND and V_GND and the associated time tag T_GND to be supplied. These variables must be set to the desired values before the state vector prediction task is invoked. The definition of input data and initiation of the state vector prediction task is accomplished by flight software external to the cyclic navigation function as described in Section 4.11.

R_GND is the uplinked ground estimated position of the orbiter in M50 coordinates.

V_GND is the uplinked ground estimated velocity of the orbiter in M50 coordinates.

T_GND is the uplinked time tag of the ground-estimated state vector.

The prediction shall be performed as follows:

1. Initialize input parameters required by the Ascent Precise Predictor

GMD_PRED = 4	V_INIT = V_GND
GMO_PRED = 4	T_INIT = T_GND
DT_MAX = DEL_TIME_STEP	T_FINAL = T_RESET
R_INIT = R_GND	

2. Compare the length of the total prediction interval, T_INIT-T_RESET, to a premission determined parameter, MAX_TIME_TOL. If the prediction interval is greater than or equal to MAX_TIME_TOL, skip step 3 and do nothing else.

3. Iteratively call the ascent precise predictor until the result of the prediction agrees with current (cyclic) filter time to less than a premission determined value SV_TIME_TAG_DIFF, or an OPS transition request occurs (OPS_TRANS_REQUEST=ON). When the data returned from the predictor agrees with current filter state vector time to within the tolerance, define the output position and velocity vectors and time tag and set STATE_VECTOR_UPDATE = ON indicating the availability of a replacement vector to the ascent navigation principal function.

CR89947A

The necessary equations are:

DO UNTIL |T_INIT-T_RESET| < SV_TIME_TAG_DIFF or OPS_TRANS_REQUEST = ON

CALL: Ascent Precise Predictor

R _INIT = R _FINAL

V _INIT = V _FINAL

T_INIT = T_FINAL

T_FINAL = T_RESET

If OPS_TRANS_REQUEST = OFF, then proceed:

R _TO_NAV = R _FINAL

V _TO_NAV = V _FINAL

T_TO_NAV = T_INIT

STATE_VECTOR_UPDATE = ON

B. Interface Requirement. Input and output requirements for the ascent state vectors prediction task are shown in Tables 4.3.1.4-1 and 4.3.1.4-2, respectively.

C. Processing Requirements. The ascent state vector prediction task is designed as a noncyclic, on-demand function where execution is initiated by software external to the cyclic navigation function (see Section 4.10). This task must execute in a manner that does not preclude or interfere with execution of the cyclic navigation functions. The value of T_RESET used in Step 3 must be permitted to be updated by the cyclic navigation function execution during the course of a particular prediction.

D. Constraints. Initialization of this task is limited to uplink processing software. It is also the responsibility of the initiating function to establish input data needed by this task before initiating execution.

E. Supplemental Information. The ascent state vector prediction task should be performed only during periods of unperturbed coasting flight as any venting or thrusting will result in degraded performance. A suggested implementation in the form of a detailed flow chart (STATE_VECTOR_PRED_TASK_ASC) may be found in Section 5.2.

Table 4.3.1.4-1. Ascent State Vector Prediction Task Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Step size for ASC precise predictor	DEL_TIME_STEP	(a)	F	S		sec	As needed
Uplinked position vector (M50)	R_GND	(b)	V	DP		ft	As needed
Uplinked velocity vector (M50)	V_GND	(b)	V	S		ft/sec	As needed
Time tag of uplinked vectors	T_GND	(b)	F	DP		sec	As needed
Time tag of filter state vectors	T_RESET	ASC CONTROL	F	DP		sec	As needed
Shuttle position at end of prediction	R_FINAL	(b)	V	DP		ft	As needed
Shuttle velocity at end of prediction	V_FINAL	(b)	V	S		ft/sec	As needed
Flag indicating that an OPS transition has been requested	OPS_TRANS_REQUEST	(b)	D		ON/OFF	N/A	As needed
Max allowable total prediction interval	MAX_TIME_TOL	(a)	F	S	-	sec	As needed
Accuracy within which the output vectors' time tag must match the current filter vectors' time tag	SV_TIME_TAG_DIFF	(a)	F	S	-	sec	As needed

[a]See ascent navigation principal function I-load, K-load, and constant tables.
[b]See ascent navigation principal function input parameter table.

NOTE: Input constants associated with the acceleration models are identified in Section 4.2.1.2 for the ascent/RTLS operations computer load.

Table 4.3.1.4-2. Ascent State Vector Update Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Maximum allowable step size for ASC precise predictor	DT_MAX	(a)	F	S		sec	As needed
Flag indicating the degree of the gravity model	GMD_PRED	(a)	I	S	0-4	—	As needed
Flag indicating the order of the gravity model	GMO_PRED	(a)	I	S	0-4	—	As needed
Time at beginning of prediction	T_INIT	(a)	F	DP		sec	As needed
Time at which state is desired	T_FINAL	(a)	F	DP		sec	As needed
Shuttle position vector at T_INIT	R_INIT	(a)	V	DP		ft	As needed
Shuttle velocity vector at T_INIT	V_INIT	(a)	V	S		ft/sec	As needed
Replacement position vector for Nav filter	R_TO_NAV	ASC control	V	DP	—	ft	As needed
Replacement velocity vector for Nav filter	V_TO_NAV	ASC control	V	S	—	ft/sec	As needed
Time tag for replacement vector	T_TO_NAV	ASC control	F	DP	—	sec	As needed
Flag indicating availability of replacement vectors	STATE_VECTOR_UPDATE	ASC control	D	—	ON/OFF	—	As needed

[a]See ascent navigation principal function output parameter table.

4.3.1.5 Ascent Navigation (4.15) Principal Function Tables. The ascent navigation principal function inputs and outputs, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.3.1.5-1 through 4.3.1.5-5.

The values for the I-loads are contained in the I-loads requirements document (JSC-19350).

Table 4.3.1.5-1. Ascent Navigation (4.15) Input/Output Functional Parameters

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
ACC_PROP_MIN	V90A8938CA	ACC THRESHOLD TEST FOR STATE PROP	ASC NAV SEQ	FT/S2		
ALPHA_N	V90H2246C	NAV DERIVED ANGLE OF ATTACK	A/E ATT PROC	DEG	SPL	
BETA_N	V90H2249C	INERTIAL SIDESLIP ANGLE	A/E ATT PROC	DEG	SPL	
DO_DELTA_UPDATE	V93X5030X	UPDATE DELTAS CMD	6.21		BD	
DO_DELTA_UPDATE_UP	V91X8894X	DO DELTA STATE UPDATE UPLINK CMD	SYS S/W			
DR_RW(1)	V93H5010CA	NAV UPDATE DELTA X POSITION	6.21	FT		
DR_RW(2)	V93H5011CA	NAV UPDATE DELTA Y POSITION	6.21	FT		
DR_RW(3)	V93H5012CA	NAV UPDATE DELTA Z POSITION	6.21	FT		
DR_RW_UP	V96U8554CB	NAV UPDATE DELTA X POS UPLINK CMD	SYS S/W	FT		
DRAG_CONST	V90U8937CA	ACC MODEL DRAG CONST FOR ST PROP	ASC NAV SEQ	FT2/SLUG		
DV_RW(1)	V93L5020CA	NAV UPDATE DELTA X VELOCITY	6.21	FT/S		
DV_RW(2)	V93L5021CA	NAV UPDATE DELTA Y VELOCITY	6.21	FT/S		
DV_RW(3)	V93L5022CA	NAV UPDATE DELTA Z VELOCITY	6.21	FT/S		
DV_RW_UP	V96U8557CB	NAV UPDATE DELTA X VEL UPLINK CMD	SYS S/W	FT/S		
M_EFTORW(1-1)	V90U1805CB	EF TO PRIME RW XFORM MTRX ELE 1-1	ASC SITE LOOKUP			
M_EFTORW(1-2)	V90U1806CB	EF TO PRIME RW XFORM MTRX ELE 1-2	ASC SITE LOOKUP			
M_EFTORW(1-3)	V90U1807CB	EF TO PRIME RW XFORM MTRX ELE 1-3	ASC SITE LOOKUP			
M_EFTORW(2-1)	V90U1808CB	EF TO PRIME RW XFORM MTRX ELE 2-1	ASC SITE LOOKUP			
M_EFTORW(2-2)	V90U1809CB	EF TO PRIME RW XFORM MTRX ELE 2-2	ASC SITE LOOKUP			
M_EFTORW(2-3)	V90U1810CB	EF TO PRIME RW XFORM MTRX ELE 2-3	ASC SITE LOOKUP			
M_EFTORW(3-1)	V90U1811CB	EF TO PRIME RW XFORM MTRX ELE 3-1	ASC SITE LOOKUP			
M_EFTORW(3-2)	V90U1812CB	EF TO PRIME RW XFORM MTRX ELE 3-2	ASC SITE LOOKUP			
M_EFTORW(3-3)	V90U1813CB	EF TO PRIME RW XFORM MTRX ELE 3-3	ASC SITE LOOKUP			
OPS_TRANS_REQUEST	V90X0892XB	OPS TRANSITION REQUEST FLAG	ASC PREC PRED			
R_FILT(1)	V90H0584CB	X-COMP OF FLTR'S CURR POS VECTOR	ASC NAV SEQ	FT		
R_FILT(2)	V90H0585CB	Y-COMP OF FLTR'S CURR POS VECTOR	ASC NAV SEQ	FT		
R_FILT(3)	V90H0586CB	Z-COMP OF FLTR'S CURR POS VECTOR	ASC NAV SEQ	FT		
R_FINAL(1)	V90H0881CB	X-COMP PREDICTED SHUTTLE POS VECTR	ASC PREC PRED	FT		
R_FINAL(2)	V90H0882CB	Y-COMP PREDICTED SHUTTLE POS VECTR	ASC PREC PRED	FT		
R_FINAL(3)	V90H0883CB	Z-COMP PREDICTED SHUTTLE POS VECTR	ASC PREC PRED	FT		
R_GND(1)	V96H3500CB	UPLINKED ORBITER POS VECTOR X	SYS S/W	FT		
R_GND(2)	V96H3501CB	UPLINKED ORBITER POS VECTOR Y	SYS S/W	FT		
R_GND(3)	V96H3502CB	UPLINKED ORBITER POS VECTOR Z	SYS S/W	FT		
SEL_V_M50(1)	V90L2557C	SEL TOTAL X VEL M50	IMU RM	FT/S	DPL	
SEL_V_M50(2)	V90L2558C	SEL TOTAL Y VEL M50	IMU RM	FT/S	DPL	
SEL_V_M50(3)	V90L2559C	SEL TOTAL Z VEL M50	IMU RM	FT/S	DPL	
T_GND	V96W3520CB	UPLINKED ORB STATE VEC TIME TAG	SYS S/W	S		
T_LAST_FILT	V90W8522CA	TIME OF FILTER STATE VECTOR	ASC NAV SEQ	S		
TIME_V	V90W2553CA	TIME OF SEL TOTAL M50 VEL	IMU RM	S		
V_FILT(1)	V90L0624CB	X-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV SEQ	FT/S		
V_FILT(2)	V90L0625CB	Y-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV SEQ	FT/S		
V_FILT(3)	V90L0626CB	Z-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV SEQ	FT/S		
V_FINAL(1)	V90L0885CB	X-COMP PREDICTED SHUTTLE VEL VECTR	ASC PREC PRED	FT/S		
V_FINAL(2)	V90L0886CB	Y-COMP PREDICTED SHUTTLE VEL VECTR	ASC PREC PRED	FT/S		
V_FINAL(3)	V90L0887CB	Z-COMP PREDICTED SHUTTLE VEL VECTR	ASC PREC PRED	FT/S		
V_GND(1)	V96H3510CB	UPLINKED ORBITER VEL VECTOR X	SYS S/W	FT/S		
V_GND(2)	V96H3511CB	UPLINKED ORBITER VEL VECTOR Y	SYS S/W	FT/S		
V_GND(3)	V96L3512CB	UPLINKED ORBITER VEL VECTOR Z	SYS S/W	FT/S		
V_LAST_FILT(1)	V90L0621CB	X-COMP VEL W COV MTRX & FLTR UPDTE	ASC NAV SEQ	FT/S		
V_LAST_FILT(2)	V90L0622CB	Y-COMP VEL W COV MTRX & FLTR UPDTE	ASC NAV SEQ	FT/S		
V_LAST_FILT(3)	V90L0623CB	Z-COMP VEL W COV MTRX & FLTR UPDTE	ASC NAV SEQ	FT/S		
	V96U8555CB	NAV UPDATE DELTA Y POS UPLINK CMD	SYS S/W	FT		

Table 4.3.1.5-1. Ascent Navigation (4.15) Input/Output Functinal Parameters (Cont)

DBFN: D3B008-D PN: VP707100037P00L JULY 17, 1989 ASC NAV OI8D REV00 04.15 PAGE 306
INPUT FUNCTIONAL PARAMETERS FOR ASCENT NAVIGATION BOOK: 5

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
	V96U8556CB	NAV UPDATE DELTA Z POS UPLINK CMD	SYS S/W	FT		
	V96U8558CB	NAV UPDATE DELTA Y VEL UPLINK CMD	SYS S/W	FT/S		
	V96U8559CB	NAV UPDATE DELTA Z VEL UPLINK CMD	SYS S/W	FT/S		

Space Transportation Systems Division
Rockwell International

STS 83-0005B
PCN-4 OI-8D
July 31, 1989

Table 4.3.1.5-1. Ascent Navigation (4.15) Input/Output Functional Parameters (Cont)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
ALPHA_SNAP	V90U8932CA	SNAPPED CONVERTED ALPHA IN	TLM			
BETA	V90U8933CA	SNAPPED CONVERTED BETA IN	TLM			
DR_RW(1)	V93H5010CE	NAV UPDATE DELTA X POSITION	6.21	FT		
DR_RW(2)	V93H5011CE	NAV UPDATE DELTA Y POSITION	6.21	FT		
DR_RW(3)	V93H5012CE	NAV UPDATE DELTA Z POSITION	6.21	FT		
DT_MAX	V90U8500CK	MAX ALLOW TIME STEP SIZE	ASC PREC PRED	S		
DV_RW(1)	V93L5020CE	NAV UPDATE DELTA X VELOCITY	6.21	FT/S		
DV_RW(2)	V93L5021CE	NAV UPDATE DELTA Y VELOCITY	6.21	FT/S		
DV_RW(3)	V93L5022CE	NAV UPDATE DELTA Z VELOCITY	6.21	FT/S		
FILT_UPDATE	V90X0224XA	FLAG IND NAV FILTER PROC COMPLETE	ASC UPP,RTLS UPP			
G_RESET(1)	V90A0243CA	SEL X-COMP OF GRAV ACCEL VCTR RST	ASC UPP,RTLS UPP,TLM	FT/S2		
G_RESET(2)	V90A0244CA	SEL Y-COMP OF GRAV ACCEL VCTR RST	ASC UPP,RTLS UPP,TLM	FT/S2		
G_RESET(3)	V90A0245CA	SEL Z-COMP OF GRAV ACCEL VCTR RST	ASC UPP,RTLS UPP,TLM	FT/S2		
GMD_PRED	V90U8501CK	GRAVITY MODEL DEGREE	ASC PREC PRED			
GMO_PRED	V90U8502CK	GRAVITY MODEL ORDER	ASC PREC PRED			
R_COV_LAST(1)	V90H0581CB	X-COMP OF POS VCT W CURR COV MTRX	RTLS NAV	FT		
R_COV_LAST(2)	V90H0582CB	Y-COMP OF POS VCT W CURR COV MTRX	RTLS NAV	FT		
R_COV_LAST(3)	V90H0583CB	Z-COMP OF POS VCT W CURR COV MTRX	RTLS NAV	FT		
R_FILT(1)	V90H0584CA	X-COMP OF FLTR'S CURR POS VECTOR	ASC NAV SEQ,A/RTLS NAV SEQ, RTLS NAV	FT		
R_FILT(2)	V90H0585CA	Y-COMP OF FLTR'S CURR POS VECTOR	ASC NAV SEQ,A/RTLS NAV SEQ, RTLS NAV	FT		
R_FILT(3)	V90H0586CA	Z-COMP OF FLTR'S CURR POS VECTOR	ASC NAV SEQ,A/RTLS NAV SEQ, RTLS NAV	FT		
R_INIT(X)	V90H8508CK	X-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT		
R_INIT(Y)	V90H8509CK	Y-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT		
R_INIT(Z)	V90H8510CK	Z-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT		
R_RESET(1)	V90H0235CA	SEL X-COMP OF UPDATED POS VCTR RST	ASC UPP,RTLS UPP,TLM	FT		
R_RESET(2)	V90H0236CA	SEL Y-COMP OF UPDATED POS VCTR RST	ASC UPP,RTLS UPP,TLM	FT		
R_RESET(3)	V90H0237CA	SEL Z-COMP OF UPDATED POS VCTR RST	ASC UPP,RTLS UPP,TLM	FT		
T_FINAL	V90W8506CK	TIME AT WHICH STATE IS DESIRED	ASC PREC PRED	S		
T_INIT	V90W8512CK	TIME AT BEGINNING OF PRED	ASC PREC PRED	S		
T_LAST_FILT	V90W8522CB	TIME OF FILTER STATE VECTOR	RTLS NAV	S		
T_RESET	V90W0225CA	TIME OF FILTER STATE VCTR	ASC UPP,RTLS UPP,TLM	S		
TIME_V/T_CURR_FILT	V90W2553CB	TIME OF SEL TOTAL M50 VEL	ASC NAV SEQ	S		
USE_IMU_DATA	V90X0538XA	FLAG TO USE IMU ACCUM VEL OR NOT	TLM			
V_CURRENT_FILT(1)	V90L8927CA	SNAPPED SEL TOTAL X VEL M50	TLM	FT/S		
V_CURRENT_FILT(2)	V90L8928CA	SNAPPED SEL TOTAL Y VEL M50	TLM	FT/S		
V_CURRENT_FILT(3)	V90L8929CA	SNAPPED SEL TOTAL Z VEL M50	TLM	FT/S		
V_FILT(1)	V90L0624CA	X-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV SEQ,A/RTLS NAV SEQ, RTLS NAV	FT/S		
V_FILT(2)	V90L0625CA	Y-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV SEQ,A/RTLS NAV SEQ, RTLS NAV	FT/S		
V_FILT(3)	V90L0626CA	Z-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV SEQ,A/RTLS NAV SEQ, RTLS NAV	FT/S		
V_IMU_RESET(1)	V90L0247CA	SEL X-COMP OF ACCUM SENSED VEL RST	ASC UPP,RTLS UPP	FT/S		
V_IMU_RESET(2)	V90L0248CA	SEL Y-COMP OF ACCUM SENSED VEL RST	ASC UPP,RTLS UPP	FT/S		
V_IMU_RESET(3)	V90L0249CA	SEL Z-COMP OF ACCUM SENSED VEL RST	ASC UPP,RTLS UPP	FT/S		
V_INIT(X)	V90L8513CK	X-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED	FT/S		
V_INIT(Y)	V90L8514CK	Y-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED	FT/S		
V_INIT(Z)	V90L8515CK	Z-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED	FT/S		
V_LAST_FILT(1)	V90L0621CA	X-COMP VEL W COV MTRX & FLTR UPDTE	RTLS NAV,TLM	FT		

Space Transportation Systems Division
Rockwell International

Table 4.3.1.5-1. Ascent Navigation (4.15) Input/Output Functional Parameters (Cont)

DBFN: D3B008-D PN: VP707100037P00L
OUTPUT FUNCTIONAL PARAMETERS FROM ASCENT NAVIGATION JULY 17, 1989 ASC NAV OI8D REV00 G4.15 PAGE BOOK F 5 226

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
V_LAST_FILT(2)	V90L0622CA	Y-COMP VEL W COV MTRX & FLTR UPDTE	RTLS NAV,TLM	FT/S		
V_LAST_FILT(3)	V90L0623CA	Z-COMP VEL W COV MTRX & FLTR UPDTE	RTLS NAV,TLM	FT/S		
V_RESET(1)	V90L0239CA	SEL X-COMP OF UPDATED VEL VCTR RST	ASC UPP,RTLS UPP,TLM	FT/S		
V_RESET(2)	V90L0240CA	SEL Y-COMP OF UPDATED VEL VCTR RST	ASC UPP,RTLS UPP,TLM	FT/S		
V_RESET(3)	V90L0241CA	SEL Z-COMP OF UPDATED VEL VCTR RST	ASC UPP,RTLS UPP,TLM	FT/S		

Space Transportation Systems Division
Rockwell International

STS 83-0005B
PCN-4 OI-8D
July 31, 1989

BOOK 0005

[illegible] NAME	MSID	ENG UNITS	ASCENT NAV CAT ON	G4	CAT
BASE_BEN	[illegible]	[illegible]	F D H C	G4 [illegible]	PR40 [illegible]
BASE BEN	V [illegible]	[illegible]	D H	G4 [illegible]	PR40 PE41
BASE BEN (1)	V [illegible]	[illegible]	D H	G4 [illegible]	PR40
BASE BEN(4)	V97U52 AC	$LUDS/ [illegible]	F D H C	G4 27 G4 4 G4 G4 2 5	PR40 PE
BIAS DRAG LAYER(1)	V97U5243C	FT	F S H C	G4 27 G4 4 G4 5 G4 2 5	PR40 PE4
BIAS DRAG LAYER(2)	V97U5244C	FT	F S H C	G4 127 G4 144 G4 15 G4 205	PR40 PE41
BIAS DRAG LAYER(3)	V97U5245C	FT	F S H C	G4 127 G4 144 G4 15 G4.205	PR40 PE41
BIAS DRAG LAYER(4)	V97U5246C	FT	F S H C	G4 127 G4 144 G4 15 G4 205	PR40 PE41
C DRAG ONE	V97U5277C	RAD** 1	F S H C	G4 127 G4 144 G4 5 G4 205	DRN0
C DRAG TWO	V97U5278C	RAD** 2	F S H C	G4 2 G4 144 G4 5 G4 205	DRN0

DBFN 0477 DATE 06 0 89

Space Transportation Systems Division

Table 4.3.1.5-2. Ascent Navigation (4.15) I-Loads (Cont)

OI08B MISSIONS DBFN:0431
G4.15 - 0005 - ASCENT NAVIGATION
ACTIVE MEMORY CONFIGURATIONS: 01

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
C_DRAG_ZERO	V97U5279C	ND	F	SP	M	C	G4.127	DRN0
							G4.144	
							G4.15	
							G4.205	
DEL_TIME_STEP	V97U6548C	SEC	F	S	D	C	G4.127	ZFT2
							G4.144	ZFT2
							G4.198	
							G4.15	
							G4.205	
DENSITY_LIMIT(1)	V97U5310C	FT	V	S	M	C	G4.127	PR40
							G4.144	PE41
							G4.15	
							G4.205	
DENSITY_LIMIT(2)	V97U5311C	FT	V	S	M	C	G4.127	PR40
							G4.144	PE41
							G4.15	
							G4.205	
DENSITY_LIMIT(3)	V97U5312C	FT	V	S	M	C	G4.127	PR40
							G4.144	PE41
							G4.15	
							G4.205	
DENSITY_LIMIT(4)	V97U5313C	FT	V	S	M	C	G4.127	PR40
							G4.144	PE41
							G4.15	
							G4.205	
DRAG_CONST	V97U5317C	FT**2/SLUG	F	D	M	C	G4.127	DRC0
							G4.144	DRC0
							G4.223	
							G4.236	
							G4.15	
							G4.205	
DRAG_CONST_RTLS	V97U9010C	FT**2/SLUG	F	DP	M	C	G4.15	XS71
							G4.205	
K_MAX	V97U5348C	ND	I	S	D	C	G4.15	ZFT2
							G4.205	
							G4.127	
							G4.144	
K_UND_MGT	V97U5350C	ND	F	S	M	X	G4.126	ZFT2
							G4.15	ZPA0
							G4.205	ZFT2
							G4.127	
							G4.144	

Table 4.3.1.5-2. Ascent Navigation (4.15) I-Loads (Cont)

OI08B MISSIONS DBFN:0431
G4.15 - 0005 - ASCENT NAVIGATION
ACTIVE MEMORY CONFIGURATIONS: 01

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
M_M50TOEF_AT_EPOCH(1,1)	V97U5738C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(1,2)	V97U5739C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(1,3)	V97U5740C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(2,1)	V97U5741C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(2,2)	V97U5742C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(2,3)	V97U5743C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(3,1)	V97U5744C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(3,2)	V97U5745C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(3,3)	V97U5746C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
MS_POS_UND_WGT	V97U5411C	FT**2	F	S	D	X	G4.126 G4.127 G4.144 G4.15 G4.205	ZFT2 ZPA0 ZFT2

Table 4.3.1.5-2. Ascent Navigation (4.15) I-Loads (Cont)

OI08B MISSIONS DBFN:0431
G4.15 - 0005 - ASCENT NAVIGATION
ACTIVE MEMORY CONFIGURATIONS: 01

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
NAVBASE_ALT_ZERO	V97U5749C	FT	F	D	D	C	G4.15 G4.205	NVBO
NAVBASE_LAT_ZERO	V97U5750C	RAD	F	DP	D	C	G4.15 G4.19 G4.20 G4.205	NVBO
NAVBASE_LONG_ZERO	V97U5751C	RAD	F	DP	D	C	G4.15 G4.19 G4.20 G4.205	NVBO
RV_MAX	V99U7596C	FT/SEC	F	S	D	C	G4.15 G4.205	ZFT2
SCALE_HT(1)	V97U5501C	FT	V	S	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
SCALE_HT(2)	V97U5502C	FT	V	SP	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
SCALE_HT(3)	V97U5503C	FT	V	SP	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
SCALE_HT(4)	V97U5504C	FT	V	SP	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
T_EPOCH	V97U5528C	SEC	F	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
VAR_H1	V99U7594C	FT**2	F	S	D	C	G4.15 G4.205	ZFT2
VAR_H2	V99U7595C	ND	F	S	D	C	G4.15 G4.205	ZFT2

Table 4.3.1.5-3. Ascent Navigation (G4.15) K-Loads Ascent Navigation

OI8B MISSIONS

FSSR NAME / DESCRIPTION	MSID	MC KLOAD VALUE		ENG UNIT	DT	PR	S	PR FCTN	LAST CR EQTN MSID
ACC_DRAG_MIN	V97U5200C	+1.1000000	E+01	FT/SEC**2	F	S	C	G4.127 G4.144 G4.15 G4.205	59971
ACC_DRAG_MIN_REF									
ACC_PROP_MIN_REF	V97U5700C	+3.20	E-02	FT/SEC**2	F	S	C	G4.15 G4.205	59971
ACCEL MAG ABVE VENT & DRAG									
ALT_ZONE_CHANGE	V97U5718C	+5.0000000	E+05	FT	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
ALT MODEL ATMOS DEN CHANGED									
DENSE(1)	V97U5304C	-3.9570	E+01	ND	F	S	G	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
DENSITY MODEL CONST									
DENSE(2)	V97U5305C	+1.0440	E-05	FT**-1	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
DENSITY MODEL CONST									
DENSE(3)	V97U5306C	+6.9560000	E+06	FT	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
DENSITY MODEL CONST									
DENSE(4)	V97U5307C	-2.420	E+01	ND	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
DENSITY MODEL CONST									

DBFM:0541 DATE:03/01/89

Table 4.3.1.5-3. Ascent Navigation (G4.15) K-Loads Ascent Navigation (Cont)

OI8B MISSIONS

FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE		ENG UNIT	DT	PR	S	PR FCTN	LAST CR EQTN MSID
DENSE(5)	V97U5308C	-2.8890	E-06	FT**-1	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
DENSITY MODEL CONST									
DENSE(6)	V97U5309C	+2.6050000	E+06	FT	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
DENSITY MODEL CONST									
DIFCD1	V96U9743C	+3.9589	E-01	ND	F	S	C	G4.236 G4.223 G4.15 G4.127 G4.144 G4.205	89661A
DIFCD2	V96U9744C	+3.3962	E+00	ND	F	S	C	G4.236 G4.223 G4.15 G4.127 G4.144 G4.205	89661A
DIFCD3	V96U9745C	+6.5414	E-01	RAD	F	S	C	G4.236 G4.223 G4.15 G4.127 G4.144 G4.205	89661A
DIFCD4	V96U9746C	+8.3589	E-01	ND	F	S	C	G4.236 G4.223 G4.15 G4.127 G4.144 G4.205	89661A
MAX_TIME_TOL	V96U8685C	+5.4	E+04	SEC	F	S	P	G4.15 G4.126 G4.127 G4.148	89945A
MAX ALLOWABLE TOTAL PREDICTION INTERVAL									

DBFN:0541 DATE:03/01/89

Table 4.3.1.5-3. Ascent Navigation (4.15) K-Loads (Cont)

OI8B MISSIONS

FSSR NAME / DESCRIPTION	MSID	MC KLOAD VALUE		ENG UNIT	DT	PR	S	C	PR FCTN	LAST CR EQTN MSID
SEA_LEVEL_DENSITY	V97U5505C	+2.3768840	E-03	SLUGS/FT**3	F	S	C		G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
SEA LEVEL ATOMOSPHERIC DENSITY										

Space Transportation Systems Division
Rockwell International

STS 83-0005B
PCN-2 OI-8B
November 30, 1988

THIS PAGE INTENTIONALLY LEFT BLANK

THIS PAGE INTENTIONALLY LEFT BLANK

THIS PAGE INTENTIONALLY LEFT BLANK

Table 4.3.1.5-4. Ascent Navigation (4.15) Constants

NROKRMM FSSR2.DATA(X03MBOOKS
PFS CONSTANTS UPDATE B/L

FSSR NAME / DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
C 01) TESSERAL HARMONIC COEFFICIENT			-.27635957 E-09	ND	F	D				
C 02) TESSERAL HARMONIC COEFFICIENT			+.15711423 E-05	ND	F	D				
C 03 TESSERAL HARMONIC COEFFICIENT			+.21907694 E-05	ND	F	D				
C(04) TESSERAL HARMONIC COEFFICIENT			+.30466825 E-06	ND	F	D				
C(05) TESSERAL HARMONIC COEFFICIENT			+.97966803 E-07	ND	F	D				
C(06) TESSERAL HARMONIC COEFFICIENT			+.50552749 E-06	ND	F	D				
C(07) TESSERAL HARMONIC COEFFICIENT			+.78842815 E-07	ND	F	D				
C(08) TESSERAL HARMONIC COEFFICIENT			+.59073749 E-07	ND	F	D				
C(09) TESSERAL HARMONIC COEFFICIENT			-.41542493 E-08	ND	F	D				
EARTH MU EARTH GRAVITATIONAL CONSTANTS	V97U4378C		+140764487566 E+17	FT**3/ SEC**2	F	B				
EARTH POLE(1) X COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8460C		.28322844 E-02	ND	F	S				
EARTH POLE(2) Y COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8461C		-.50279960 E-04	ND	F	S				
EARTH POLE(3) Z COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8462C		.99999598 E+00	ND	F	S				
EARTH RADIUS EQUATOR EARTH EQUATORIAL RADIUS	V97U5324C		.209257414698 1630 E+08	FT	F	D				
EARTH RADIUS GRAV EARTH RADIUS (GRAV ACCEL)	V97U5325C		+.209256561680 E+08	FT	F	D				
EARTH RATE EARTH'S ROTATIONAL RATE	V97U4379C		.7292115146460 000 E-04	RAD/SEC	F	D				
ELLIPT EARTH'S ELLIPTICITY CONSTANTS	V97U5332C		.335232980000 0000 E-02	ND	F	D				
KN1 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT LESS THAN 400K FEET			-.17980000 E+01	ND	F	S				
KN2 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT LESS THAN 400K FEET			.66670000 E-05	FT**-1	F	S				

CR89596C

Table 4.3.1.5-4. Ascent Navigation (4.15) Constants (Cont)

FSSR NAME / DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
KN3 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT LESS THAN 400K FEET			-.57890000 E-11	FT**-2	F	S				
KN4 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT BETWEEN 400K AND 600K FEET			.27518150 E-02	ND	F	S				
KN5 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT BETWEEN 400K AND 600K FEET			-.14990900 E-03	FT**-1	F	S				
KN6 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT BETWEEN 400K AND 600K FEET			.20490000 E-09	FT**-2	F	S				
ID_MATRIX_3X3(01) (1,1) COMPONENT OF 3X3 IDENTITY MATRIX			1.0	ND	F	S				
ID_MATRIX_3X3(02) (1,2) COMPONENT OF 3X3 IDENTITY MATRIX			.0	ND	F	S				
ID_MATRIX_3X3(03) (1,3) COMPONENT OF 3X3 IDENTITY MATRIX			.0	ND	F	S				
ID_MATRIX_3X3(04) (2,1) COMPONENT OF 3X3 IDENTITY MATRIX			.0	ND	F	S				
ID_MATRIX_3X3(05) (2,2) COMPONENT OF 3X3 IDENTITY MATRIX			1.0	ND	F	S				
ID_MATRIX_3X3(06) (2,3) COMPONENT OF 3X3 IDENTITY MATRIX			.0	ND	F	S				
ID_MATRIX_3X3(07) (3,1) COMPONENT OF 3X3 IDENTITY MATRIX			.0	ND	F	S				
ID_MATRIX_3X3(08) (3,2) COMPONENT OF 3X3 IDENTITY MATRIX			.0	ND	F	S				
ID_MATRIX_3X3(09) (3,3) COMPONENT OF 3X3 IDENTITY MATRIX			1.0	ND						
PI RATIO CIRCUMFERENCE TO DIAMETER	V98U8725C		3.1415926535897	ND	F	D				
RAD_PER_DEG DEGREES TO RADIANS CONVERSION FACTOR	V97U0383C		.17453293 E-01	RAD/DEG	F	S				
S(01) TESSERAL HARMONIC COEFFICIENT	V97U5492C		-.52357454 E-08	ND	F	D				

CR89596C

CR89596C

Table 4.3.1.5-4. Ascent Navigation (4.15) Constants (Cont)

NROKRMM FSSR2.DATA(X3)BOOK5
PFS CONSTANTS UPDATE B/L

FSSR NAME DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
S(02) TESSERAL HARMONIC COEFFICIENT	V97U5493C		-.90231337 E-06	ND	F	D				
S(03) TESSERAL HARMONIC COEFFICIENT	V97U5494C		+.27267074 E-06	ND	F	D				
S(04) TESSERAL HARMONIC COEFFICIENT	V97U5495C		-.21259298 E-06	ND	F	D				
S(05) TESSERAL HARMONIC COEFFICIENT	V97U5496C		+.19681077 E-06	ND	F	D				
S(06) TESSERAL HARMONIC COEFFICIENT	V97U5497C		-.44125015 E-06	ND	F	D				
S(07) TESSERAL HARMONIC COEFFICIENT	V97U5498C		+.14718958 E-06	ND	F	D				
S(08) TESSERAL HARMONIC COEFFICIENT	V97U5499C		-.12140873 E-07	ND	F	D				
S(09) TESSERAL HARMONIC COEFFICIENT	V97U5500C		+.63163541 E-08	ND	F	D				
ZONAL(01) ZONAL HARMONIC COEFFICIENT	V97U5582C		.0	ND	F	D				
ZONAL(02) ZONAL HARMONIC COEFFICIENT	V97U5583C		+.10826271 E-02	ND	F	D				
ZONAL(03) ZONAL HARMONIC COEFFICIENT	V97U5584C		-.25358868 E-05	ND	F	D				
ZONAL(04) ZONAL HARMONIC COEFFICIENT	V97U5585C		-.16246180 E-05	ND	F	D				
SV TIME TAG DIFF TIME TOLERANCE FOR PREDICTION			1.0	SEC	F	S				

CR89596C

CR89596C

CR89947A

Space Transportation Systems Division

Rockwell International

Table 4.3.1.5-5. Ascent
Navigation (4.15)
Cross-References

FSSR Name	Source Name
V_CURRENT_FILT	SEL_V_M50
T_CURRENT_FILT	TIME_V
ALPHA	ALPHA_SNAP
ALPHAIN	ALPHA_SNAP
BETAIN	BETA_N

4.3.2 RTLS Navigation (4.205)

The RTLS navigation principal function shall provide an up-to-date estimate of the Shuttle's position, velocity, and other parameters for software users such as guidance and displays. The principal function shall be scheduled by the ascent/RTLS navigation sequencer. The interface between RTLS navigation and other principal functions is defined in the Level B GN&C CPDS. Principal function input and output parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.3.2.9-1 through 4.3.2.9-5.

RTLS navigation shall use selected data from up to three IMU's to maintain a current estimate of a single six-component state vector. Navigation state propagation shall employ accelerometer data in propagating the state to the current time. The measured acceleration due to drag will be used to generate pseudoaltitude measurements.

A Kalman filtering technique shall be used when updating the inertial state vector with TACAN, MSBLS, barometric altimeter, or drag pseudoaltitude measurements. The state vector shall be propagated. If a delta state update has been indicated, the position and velocity vectors shall be updated and the covariance matrix reinitialized. Otherwise, the state transition matrix shall be calculated and the covariance matrix shall be propagated. The measurement partials and the Kalman filter gain matrix shall be computed. After a reasonability test and data editing, the Kalman gain and the measurement residuals will be used to update the state vector. The state vector will be available for computing user parameters and display parameters.

4.3.2.1 RTLS Control. The RTLS navigation principal function shall provide the capability to control state and covariance matrix propagation and filter updates; one state vector shall be maintained.

A. Detailed Requirements. RTLS control shall perform the following task in the order indicated. (For definitions of variables, see input and output Tables 4.3.2.1-1 and 4.3.2.1-2.)

1. The accumulated sensed velocity from selected IMU data and the corresponding time tag shall be obtained (Section 4.2.1.1), and the current angle of attack, sideslip angle, and pitch angle shall be obtained and converted to radians.

2. An external sensor data snap shall be performed as described in Section 4.3.2.2.

3. If the flag DO_DELTA_UPDATE_UP is ON, the delta state vectors used by the ascent delta state update task shall be set equal to the output by the uplink processing software, the flag DO_DELTA_UPDATE

shall be set to the ON position, and the flag DO_DELTA_UPDATE_UP shall be returned to the OFF position to prevent repetitive incorporation of the same uplinked data:

DR_RW = DR_RW_UP

DV_RW = DV_RW_UP

DO_DELTA_UPDATE = ON

DO_DELTA_UPDATE_UP = OFF

If the flag DO_DELTA_UPDATE_UP is OFF, these computations shall not be performed.

4. The RTLS sensor selection subfunction shall determine which measurements (drag altitude, barometric altimeter altitude, Tacan range and bearing, MSBLS range, azimuth, and elevation) are to be presented to the filter for processing as described in Section 4.3.2.3.

5. The state vector shall be propagated as described in Section 4.3.2.5.

6. If a delta state update is indicated, it shall be performed by the delta state update function, as described in Section 4.3.2.4.2.

7. The covariance matrix will be either reinitialized as described in Section 4.2.3 (if a delta state update was performed) or propagated in the manner shown in Section 4.3.2.6 (if a delta state update was not required).

8. The navigation measurement reconfiguration subfunction shall reconfigure the necessary parameters for use by state and covariance measurement incorporation subfunction, as described in Section 4.3.2.4.1.

9. The state and covariance matrix incorporation subfunction shall update the state vector and covariance matrix, as described in Section 4.3.2.7. A counter shall be incremented for each measurement type processed to indicate the mark number for postmission analysis purposes.

10. The user parameter state propagator reset task shall be performed as described in Section 4.2.4.

11. Finally, the RTLS measurement processing statistics subfunction (Section 4.3.2.8) shall be performed.

B. Interface Requirements. The input and output parameters are listed in Tables 4.3.2.1-1 and 4.3.2.1-2.

C. Processing Requirements. RTLS control shall be executed at a premission-determined rate when the RTLS navigation principal function is scheduled.

D. Constraints. None.

E. Supplemental Information. A suggested implementation of RTLS control is illustrated by NAV_GRTLS in Section 5.2.

Table 4.3.2.1-1. RTLS Control Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Time of the filter state vector	T_LAST_FILT	RTLS state propagation	F	DP		sec	Filter rate
Previously read selected accumulated IMU velocity	V_LAST_FILT	RTLS state propagation	V	DP		ft/sec	Filter rate
Flag indicating (ON) that baro altimeter data are to be processed	DO_BARO_NAV	RTLS sensor selector	D		OFF/ON		Filter rate
Filter current Shuttle position vector in M50 coordinates	R_FILT	RTLS state and covariance measurement incorporation	V	DP		ft	Filter rate
Shuttle velocity vector	V_FILT	RTLS state and covariance measurement incorporation	V	S		ft/sec	Filter rate
Uplinked delta position vector	DR_RW_UP	(b)	V	S	—	ft	As needed
Uplinked delta velocity vector	DV_RW_UP	(b)	V	S	—	ft/sec	As needed
Flag indicating (ON) that a delta state vector update has been received via command uplink	DO_DELTA_UPDATE_UP	(b), RTLS control	D	—	OFF/ON	—	As needed
Flag indicating (ON) that drag altitude data are to be processed	DO_DRAG_NAV	RTLS sensor selector	D		OFF/ON		Filter rate
Flag indicating (ON) that TACAN range and bearing data are to be processed	DO_TACAN_NAV	RTLS sensor selector	D		OFF/ON		Filter
Flag indicating (ON) that MSBLS range, azimuth, and elevation data are to be processed	DO_MLS_NAV	RTLS sensor selector	D		OFF/ON		Filter rate
Radians per degree	RAD_PER_DEG	(a)	F	S		rad/deg	Filter rate
Current vehicle pitch angle	THETAIN	(b)	F	S		deg	Filter rate
Current vehicle angle of attack	ALPHAIN	(b)	F	S		deg	Filter rate
Current vehicle sideslip angle	BETAIN	(b)	F	S		deg	Filter rate
Flag indicating (ON) that a delta state update is to be performed	DO_DELTA_UPDATE	Delta state update, (b)	D		OFF/ON		Filter rate
Acceleration vector in M50 coordinates	G_OLD	RTLS state propagation	V	S		ft/sec^2	Filter rate

[a] See RTLS navigation principal function constant table.
[b] See RTLS navigation principal function input parameter table.

Table 4.3.2.1-2. RTLS Control Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Vehicle position vector after all navigation updates received for reset of user parameter propagator position vector R_AVGG	R_RESET	(a)	V	DP		ft	Filter rate
Vehicle velocity vector after all navigation updates, reserved for reset of guidance integrator velocity vector V_AVGG	V_RESET	(a)	V	S		ft/sec	Filter rate
Time associated with reserved reset state	T_RESET	(a)	F	DP		sec	Filter rate
Switch indicating (ON) that current measurement processing is complete	FILT_UPDATE	(a)	D		OFF/ON		Filter rate
Updated vehicle position vector associated with current covariance matrix	R_COV_LAST	RTLS covariance propagation	V	DP		ft	Filter rate
Copy of V_LAST_FILT reserved as velocity count at start of extrapolation interval when guidance integrator is reset	V_IMU_RESET	(a)	V	DP		ft/sec	Filter rate
Counter indicating the particular MSBLS measurement processed by the filter	MLS_MARK_NUM	(a)	I	S			Filter rate
Counter indicating the particular TACAN measurement processed by the filter	TACAN_MARK_NUM	(a)	I	S			Filter rate
Counter indicating the particular baro measurement processed by the filter	BARO_MARK_NUM	(a)	I	S			Filter rate
Counter indicating the particular drag measurement processed by the filter	DRAG_MARK_NUM	(a)	I	S			Filter rate
Acceleration vector at beginning of navigation integration interval	G_RESET	(a)	V	S		ft/sec^2	Filter rate
Vehicle angle of attack	ALPHA	State propagation, drag processing	F	S		rad	Filter rate
Vehicle sideslip angle	BETA	State propagation	F	S		rad	Filter rate
Flag indicating (OFF) that an uplinked delta state update has been accepted	DO_DELTA_UPDATE_UP	RTLS control	D	—	OFF/ON	—	Filter rate
Position vector for delta state update	DR_RW	Delta state update	V	S		ft	Filter rate
Velocity vector for delta state update	DV_RW	Delta state update	V	S		ft/sec	Filter rate

[a]See RTLS navigation principal function output parameter table.

4.3.2.2 External Sensor Data Snap. The purpose of this subfunction during RTLS navigation is to collect sensor data and store the data for subsequent use in the state and covariance measurement incorporation subfunction. Included in the sensor data are the measurements, their data-good flags (which indicate the validity of the measurements) and the measurements' time tags. Time tags of the data collected from sensors are adjusted according to premission biases. This subfunction is required to ensure that the data sets used in the navigation processing are properly saved for use in the state and covariance measurement incorporation subfunction, whereas the actual data may continue to be refreshed by hardware sensor reading, sensor SOP processing, and selection filter unification.

A. Detailed Requirements. During RTLS navigation, external sensor data will be collected in three groups: (1) barometric altimeter data (air data system), (2) TACAN data, and (3) MSBLS data. Barometric altimeter and TACAN data collection is required at the navigation filter rate. Since the hardware refreshment rate for the MSBLS sensors is rather infrequent, it is desirable to sample the data frequently to determine whether the data have changed so that, if they have, the time of change may be assumed to be the time tag of a new measurement. (Mechanization of this process is in the MSBLS SOP.) The pertinent navigation sensors and their measurement sets are defined below:

1. Barometric altimeter - the Shuttle's barometric altitude, its data-good flag, and the associated time tag, adjusted by a premission-loaded time bias, will be collected and stored:

   SNAP BARO ALTIMETER (Q_BARO, BARO_DATA_GOOD, T_BARO)

   T_BARO = T_BARO - TIME_BIAS_BARO

2. TACAN - The magnetic bearing of the TACAN station from the Shuttle and the slant range distance from the TACAN ground beacon, together with the range and bearing data-good flags, shall be collected and stored. The associated time tag will be collected, adjusted by a premission-loaded time bias, and stored. The current TACAN line replacement unit (LRU) number also will be collected and stored. The following equations define the parameters necessary to accomplish the above requirements:

   SNAP TACAN (Q_TAC_BRG, Q_TAC_R, T_TACAN,

   TAC_RNG_DATA_GOOD, TAC_BRG_DATA_GOOD,

   SEL_LRU_ID)

   T_TACAN = T_TACAN - TIME_BIAS_TACAN

3. MSBLS - The Shuttle's azimuth, slant-range distance from the DME antenna, and elevation (given as a wedge angle) will be collected

and stored, together with the data-good flags. The associated time tags will be collected, adjusted by a premission-loaded time bias, and stored. The following equations define the parameters necessary to accomplish the above requirements:

SNAP MSBLS (Q_RANGE, Q_AZMLS, Q_ELMLS, MLSRANGE_DATA_GOOD,

MLSAZ_DATA_GOOD, MLSEL_DATA_GOOD, T_EF_RMLS, T_EF_AZMLS,

T_EF_ELMLS)

T_EF_RMLS = T_EF_RMLS - TIME_BIAS_MLS

T_EF_AZMLS = T_EF_AZMLS - TIME_BIAS_MLS

T_EF_ELMLS = T_EF_ELMLS - TIME_BIAS_MLS

B. Interface Requirements. The input and output parameters are listed in Tables 4.3.2.2-1 and 4.3.2.2-2. All output time tags are assumed to have been associated with the sensors' measurements (the time FCOS commands the read, adjusted by applying time bias corrections).

C. Processing Requirements. It is required that the navigation sensor data measurements, validity flags, and time tags be made available for the collection and storing processes. The collection rates (not necessarily sensor interrogations) are indicated by the navigation sequencers. However, these rates assume the available data are fresh. This implies that SOP's processing and selection filtering must be at a rate equal to or greater than the collection rate.

D. Constraints. The data collections should occur after a complete current set is available and just prior to use in navigation in order to supply current data.

E. Supplementary Information. A suggested implementation of the RTLS external sensor data snap subfunction, in the form of a detailed flow chart, can be found in Section 5.2 (NAV_GRTLS). The SNAP statements above imply the assignment of current values to the variable names shown in parentheses.

Table 4.3.2.2-1. RTLS External Sensor Data Snap Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Barometric altimeter sensor measurement	Q_BARO	(a)	F	S		ft	Filter rate
Copy of current data good discrete reserved for measurement processing (navigation)	BARO_DATA_GOOD	(a)	D		OFF/ON		Filter rate
Time tag associated with barometric measurement	T_BARO	(a)	F	DP		sec	Filter rate
Bias used to correct barometric time tag	TIME_BIAS_BARO	(b)	F	S		sec	
TACAN bearing sensor measurement	Q_TAC_BRG	(a)	F	S		rad	Filter rate
TACAN range sensor measurement	Q_TAC_R	(a)	F	S		ft	Filter rate
Time as which TACAN was read	T_TACAN	(a)	F	DP		sec	Filter rate
Bias used to correct TACAN time tag	TIME_BIAS_TACAN	(b)	F	DP		sec	
MSBLS range sensor measurement	Q_RANGE	(a)	F	S		ft	Filter rate
MSBLS azimuth sensor measurement	Q_AZMLS	(a)	F	S		rad	Filter rate
MSBLS elevation sensor measurement	Q_ELMLS	(a)	F	S		rad	Filter rate
Copy of current data good discrete reserved for measurement processing	MLSRANGE_DATA_GOOD	(a)	D		OFF/ON		Filter rate
Copy of current data good discrete reserved for measurement processing	MLSAZ_DATA_GOOD	(a)	D		OFF/ON		Filter rate
Copy of current data good discrete reserved for measurement processing	MLSEL_DATA_GOOD	(a)	D		OFF/ON		Filter rate
Time at which MSBLS range measurement was read	T_EF_RMLS	(a)	F	DP		sec	Filter rate
Time at which MSBLS azimuth was read (adjusted)	T_EF_AZMLS	(a)	F	DP		sec	Filter rate
Time tage of current MSBLS elevation measurement	T_EF_EMLS	(a)	F	DP		sec	Filter rate
Current TACAN range data good	TAC_RNG_DATA_GOOD	(a)	D		OFF/ON		Filter rate
Current TACAN bearing data good	TAC_BRG_DATA_GOOD	(a)	D		OFF/ON		Filter rate
Bias used to correct MSBLS time tag	TIME_BIAS_MLS	(b)	F	S		sec	Filter rate
LRU number that the selection filter picked, and that identifies the site parameter list (no. 1, 2, 3)	SEL_LRU_ID	(a)	I	S	1, 2, or 3		Filter rate

[a]See the RTLS navigation principal function input parameter table.
[b]See RTLS navigation principal function K-load table.

Table 4.3.2.2-2. RTLS External Sensor Data Snap Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Barometric altimeter sensor measurement	Q_BARO	RTLS barometric altimeter data process	F	S		ft	Filter rate
Copy of current data good discrete reserved for measurement processing (navigation)	BARO_DATA_GOOD	RTLS barometric altimeter data process	D		OFF/ON		Filter rate
Time tag associated with barometric measurement (adjusted)	T_BARO	RTLS barometric altimeter data process	F	DP		sec	Filter rate
TACAN bearing sensor measurement	Q_TAC_BRG	RTLS TACAN bearing data process	F	S		rad	Filter rate
TACAN range sensor measurement	Q_TAC_R	RTLS TACAN range data process	F	S		ft	Filter rate
Current data good discretes for TACAN measurement processing	TAC_RNG_DATA_GOOD TAC_BRG_DATA_GOOD	RTLS TACAN range data process, TACAN bearing data process	D		OFF/ON		Filter rate
Time at which TACAN was read (adjusted)	T_TACAN	RTLS TACAN range data process, RTLS TACAN bearing data process	F	DP		sec	Filter rate
MSBLS range sensor measurement	Q_RANGE	RTLS MSBLS range meas incorp	F	S		ft	Filter rate
MSBLS azimuth sensor measurement	Q_AZMLS	RTLS MSBLS azimuth meas incorp	F	S		rad	Filter rate
MSBLS elevation sensor measurement	Q_ELMLS	RTLS MSBLS elevation meas incorp	F	S		rad	Filter rate
Copy of current data good discrete reserved for measurement processing	MLSRANGE_DATA_GOOD	RTLS MSBLS range meas incorp	D		OFF/ON		Filter rate
Copy of current data good discrete reserved for measurement processing	MLSAZ_DATA_GOOD	RTLS MSBLS azimuth meas incorp	D		OFF/ON		Filter rate

Table 4.3.2.2-2. RTLS External Sensor Data Snap Output Parameters (Cont)

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Copy of current data good discrete reserved for measurement processing	MLSEL_DATA_GOOD	RTLS MSBLS elevation meas incorp	D		OFF/ON		Filter rate
Time at which MSBLS range measurement was read (adjusted)	T_EF_RMLS	RTLS_MSBLS range meas incorp	F	DP		sec	Filter rate
Time at which MSBLS azimuth was read (adjusted)	T_EF_AZMLS	RTLS_MSBLS azimuth meas incorp	F	DP		sec	Filter rate
Time tag of current MSBLS elevation measurement (adjusted)	T_EF_ELMLS	RTLS_MSBLS elevation meas incorp	F	DP		sec	Filter rate
TACAN LRU number which the selection filter picked, and which identifies the site parameter list (no. 1, 2, 3)	SEL_LRU_ID	RTLS measurement reconfiguration	I	S	1, 2, or 3		Filter rate

4.3.2.3 Sensor Measurement Selection. A capability, designated as the RTLS sensor measurement selection subfunction, is required for the selection of external sensor measurement data to be presented to the state and covariance measurement incorporation subfunction (Section 4.3.2.7) when the RTLS navigation principal function is active. Selection of a sensor data type will also mean that knowledge of this measurement data selection will be presented to the measurement reconfiguration subfunction (Section 4.3.2.4.1) to cause proper initialization of TACAN site data.

A. Detailed Requirements. The requirements for this subfunction are given as a set of necessary sensor measurement selection capabilities. Only the following measurement types will be employed while the RTLS navigation principal function is active: barometric altimeter, MSBLS, drag altitude, and TACAN. The following capabilities will be provided:

1. There will be both manual (crew) and automatic control of TACAN, drag, and barometric altimeter measurement selection.

2. The crew will be able to manually force or inhibit TACAN, drag, and barometric altimeter sensor data or select the automatic mode.

3. For each measurement type, manual control (force or inhibit) will override automatic sensor selection; that is, if a crewman desires to force a particular type of sensor data, then these data will be sent to the state and covariance measurement incorporation subfunction (data may not be incorporated if indicated to be invalid), with two exceptions (see items 5 and 9 below). The force or inhibit will stay in effect across major modes and will be removed by reverting to automatic sensor measurement selection.

4. The forcing of sensor data will override the residual edit for that particular sensor type.

5. Neither the crew nor the automatic selection criteria will be able to simultaneously select any of the following combinations:

    a. TACAN and MSBLS data

    b. MSBLS and barometric altimeter data

    c. MSBLS and drag altitude data

    d. Barometric altimeter and drag altitude data

6. If TACAN is in the automatic selection mode, MSBLS data are indicated to be available, and MSBLS range and azimuth data are indicated as valid, then MSBLS data will be selected. TACAN data will be selected if no valid MSBLS range and azimuth data have been snapped for the

last k (premission constant) executions of the RTLS navigation principal function and MSBLS range or azimuth data are indicated as invalid during the current execution and TACAN range or bearing data are indicated to be valid.

7. When MSBLS data are first selected, or are reselected after having been deselected, portions of the covariance matrix shall be reinitialized by setting all the cross-correlation terms between position and velocity to zero.

8. If MSBLS data are not selected and barometric altimeter data are indicated to be not valid, then barometric altimeter data will not be considered for selection and the following selection criteria will be employed for drag data, if barometric altimeter data are processed for display purposes only and the vehicle is not in the Mach jump region. If the automatic selection mode is employed for drag data, then these data will be selected for processing if the magnitude of the sensed acceleration of the Shuttle exceeds a premission-determined minimum and the current altitude of the Shuttle is above a premission determined minimum. If drag data are forced, then these data will be selected for processing, and the drag residual edit test will be overridden. If drag data are inhibited, then these data will be selected for processing for statistical display purposes only.

9. If MSBLS data are not selected and barometric altimeter data are indicated as valid, then drag data will not be considered for selection. If barometric altimeter data are not chosen for display purposes only (DO_BARO_NAV = BARO_STAT) or the vehicle is in the Mach jump region (ADS_MJ ≠ OFF), then the following selection criteria will be employed for barometric altimeter data. If the automatic selection mode is employed for barometric altimeter data, then these data will be selected for processing if the relative velocity magnitude of the Orbiter does not exceed a premission-determined maximum and does not lie in the premission-determined barometric altimeter discontinuity region and the orbiter is above a minimum altitude for bias processing. If barometric altimeter data are forced, the baro data will be selected for processing provided that the magnitude of the relative velocity of the Orbiter does not lie in the barometric altimeter discontinuity region. If baro altimeter data are inhibited, then these data shall be selected for processing for statistical display purposes only. If barometric altimeter data are not to be inhibited and the vehicle is in the Mach jump region, then H_INHIB is set to ON and barometric (DO_BARO_NAV = ON and BARO_STAT = ON) data are processed for display purposes only.

The minimum altitude above the runway for processing barometric altimeter data shall be ALT_BARO_CUTOFF. If MSBLS data are processed at a vehicle altitude less than ALT_BARO_CUTOFF_HIGH, then the baro

cutoff altitude, ALT_BARO_CUTOFF, shall be set to ALT_BARO_CUTOFF_HIGH to preclude state updates with baro data if MSBLS data is lost at low vehicle altitudes, otherwise, state updates with baro data will continue to a vehicle altitude specified by the initial value of ALT_BARO_CUTOFF.

This subfunction will provide a positive-feedback record of the manual inputs affecting the selection of drag, TACAN, and barometric altimeter data. These records are used by horizontal situation display processing. If drag or barometric altimeter data are not selected for processing as a result of failure to meet an altitude, relative velocity magnitude, or acceleration magnitude constraint, then knowledge of this deselection will be made available to measurement processing statistics to be employed in event lamp processing by setting H_INHIB to ON.

This subfunction will also perform sensor measurement selection when the data are employed only to compute TACAN, drag, and barometric altimeter statistics for display purposes. The following capabilities will be provided:

1. A maximum of three pieces of sensor measurement data (i.e., MSBLS range, azimuth, and elevation or TACAN range and azimuth and drag or barometric altimeter) will be processed on any one execution of the RTLS navigation principal function.

2. Selection of a TACAN and barometric altimeter or drag measurements for computation of measurement statistics will be subordinate to selection of MSBLS for possible state and covariance incorporation.

The result of selection of sensor measurements for processing of data or for computation of measurement statistics will be provided as indicated in Tables 4.3.2.3-1 and 4.3.2.3-2. The terminology "process" means that the state and covariance measurement incorporation subfunction may incorporate the measurement data into the state estimation. The terminology "display" means that the state and covariance measurement incorporation subfunction may perform the processing of data for display of measurement statistics but is prohibited from incorporating the data into the state estimation.

Finally, this subfunction will initialize the measurement edit indicators to zero for subsequent use by the state and covariance measurement incorporation subfunction.

B. Interface Requirements. The input and output for this function are given in Tables 4.3.2.3-3 and 4.3.2.3-4.

C. Processing Requirements. This function will be performed after complete set of the external sensor measurement data to be used (while the RTLS navigation principal function is active) has been saved and before the measurement reconfiguration subfunction is executed.

Table 4.3.2.3-1. MSBLS Versus TACAN

TACAN	MSBLS Not Available	MSBLS available	
		Data-Good (AZ and Range)	Data-Bad (k Cycles)
Auto			
Data-good (range or bearing)	Process TACAN	Process MSBLS	Process TACAN
Data-bad (range and bearing)	Process neither MSBLS nor TACAN	Process MSBLS	Process neither MSBLS nor TACAN
Force	Process TACAN[a]	Process TACAN[a]	Process TACAN[a]
Inhibit	Display TACAN	Process MSBLS	Display TACAN

[a]Will not result in update if TACAN range or bearing data are bad

A candidate implementation of this subfunction is shown in RTLS_SENSOR_SELECT code in Section 5.2. This code is executed by NAV_GRTLS, the candidate implementation of the RTLS navigation control subfunction.

D. Constraints. None.

E. Supplemental Information. The foregoing requirements indicate the existence of a three-position software switch for TACAN, drag, and barometric altimeter data - that is, three AUTO/INHIBIT/FORCE switches.

Table 4.3.2.3-2. BARO-DRAG Selection Results

SYMBOLOGY NS = No select P = Process (state uplink) P+ = P+ edit override D = Display stats (no state update) ◣ = Nav Edit Flag Activity If Auto Process Criteria Are Satisfied			BARO DATA GOOD								BARO DATA NOT VALID AND MACH JUMP = OFF
			MACH Jump = ON			MACH Jump = OFF					
						Auto		Inhibit	Force		
			Auto	Inhibit	Force	RV_MAG ≤ RV_MAX	RV_MAG > RV_MAX OR ALTITUDE < ALT_BARO_CUTOFF				
DRAG	Auto	Alt, Acc Criteria OK	No Selector	Display BARO	No Select	P / NS	D / P	D / P	P+ / NS		Process DRAG *
		Alt, Acc Criteria Not OK				P / NS	D / NS	P+ / NS	P+ / NS		No Select
	Inhibit					P / NS	D / D	D / D	P+ / NS		Display DRAG
	Force					P / NS	D / P+	D / P+	P+ / NS		Process+ Drag

Table 4.3.2.3-3. RTLS Sensor Measurement Selection Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Copy of current data good discrete reserved for measurement processing	MLSRANGE_DATA_GOOD	RTLS sensor data snap	D		OFF/ON		Filter rate
Copy of current data good discrete reserved for measurement processing	MLSAZ_DATA_GOOD	RTLS sensor data snap	D		OFF/ON		Filter rate
	MLSEL_DATA_GOOD	RTLS sensor data snap	D		OFF/ON		Filter rate
Prescribed number of consecutive MLS azimuth measurement data good "fails" to force inhibit of MLS processing and allow TACAN processing	R_AZ_COUNT_MAX	(a)	I	S			Filter rate
Auto-inhibit-force switch for TACAN sensor selection	TACAN_AIF	(b)	CHAR				Filter rate
Auto-inhibit-force switch for barometric altimeter sensor selection	BARO_AIF	(b)	CHAR				Filter rate
Altitude above the Fischer ellipsoid	ALT	(b)	F	S		ft	Filter rate
Altitude below which drag data are not processed	H_DRAG_LOW	(a)	F	S		ft	Filter rate
Magnitude of the orbiter's current drag acceleration	ACC_DRAG	(b)	F	S		ft/sec^2	Filter rate
Minimum allowable magnitude of drag acceleration of orbiter for drag processing	ACC_DRAG_MIN	(a)	F	S		ft/sec^2	Filter rate
Copy of current data-good discrete reserved for measurement processing	BARO_DATA_GOOD	RTLS sensor data snap	D		OFF/ON		Filter rate
Auto-inhibit-force switch for drag data selection	DRAG_AIF	(b)	CHAR				Filter rate
Copy of current TACAN range data-good discrete	TAC_RNG_DATA_GOOD	RTLS sensor data snap	D		OFF/ON		Filter rate
Copy of current TACAN bearing data-good discrete	TAC_BRG_DATA_GOOD	RTLS sensor data snap	D		OFF/ON		Filter rate
MSBLS availability discrete	MLS_AVAIL	(b)	D		OFF/ON		Filter rate
Flag indicating speed of orbiter is in baro altimeter discontinuity region	ADS_MJ	(b)	D		OFF/ON		As needed
Maximum relative velocity magnitude for processing barometric altimeter data	RV_MAX	I-load	F	S		ft/sec	As needed

[a] See RTLS navigation principal function K-load table.
[b] See RTLS navigation input parameter table.

Table 4.3.2.3-3. RTLS Sensor Measurement Selection Input Parameters (Cont)

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Magnitude of vehicle relative velocity	RV_MAG	(b)	F	S		ft/sec	As needed
Baro processing cutoff altitude	ALT_BARO_CUTOFF	(c)	F	S		ft	As needed
Baro processing cutoff altitude if MSBLS data processing terminated below ALT_BARO_CUTOFF_HIGH	ALT_BARO_CUTOFF_HIGH	I-load	F	S		ft	As needed

[a]See RTLS navigation principal function K-load table.
[b]See RTLS navigation input parameter table.
[c]ALT_BARO_CUTOFF is initialized to I-load name ALT_BARO_CUTOFF_LOW

CR89596C

CR89596C

Table 4.3.2.3-4. RTLS Sensor Measurement Selection Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Flag indicating (ON) that barometric altimeter data are to be processed	DO_BARO_NAV	RTLS baro measurement incorporation	D		OFF/ON		Filter rate
Flag indicating (ON) that TACAN data are to be processed	DO_TACAN_NAV	RTLS TACAN measurement incorporation and reconfiguration	D		OFF/ON		Filter rate
General edit indicator for I-th sensor measurement, I = 1, 7	$SENSOR\_EDIT_I$	RTLS state and covariance measurement incorporation, RTLS measurement processing statistics	V	S			Filter rate
Switch used to force incorporation of barometric data regardless of residual edit test	BARO_EDIT_ OVERRIDE	RTLS barometric altimeter data processing	D		OFF/ON		Filter rate
Switch used to override TACAN residual edit test	TACAN_EDIT_ OVERRIDE	RTLS TACAN range data processing, RTLS TACAN bearing data processing	D		OFF/ON		Filter rate
Flag indicating stat-flag setting for barometric measurements	BARO_STAT	RTLS barometric altimeter data processing	D		OFF/ON		Filter rate
Flag indicating TACAN data processed only for statistical display	TACAN_STAT	RTLS TACAN range data processing, RTLS TACAN bearing data processing	D				Filter rate
Covariance matrix	E	Covariance matrix propagation, state and covariance measurement incorporation	M	DP			Filter rate
Flag indicating which TACAN_AIF command is in effect	TAC_AIF_RCVD	(a)	CHAR				Filter rate

[a]See RTLS navigation output parameter table.

Table 4.3.2.3-4. RTLS Sensor Measurement Selection Output Parameters (Cont)

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Flag indicating (ON) that MSBLS data are to be processed	DO_MLS_NAV	RTLS control, RTLS measurement processing statistics	D		OFF/ON		Filter rate
Flag indicating (ON) that drag data are to be processed	DO_DRAG_NAV	RTLS control	D		OFF/ON		Filter rate
Flag indicating which BARO_AIF command is in effect	BARO_AIF_RCVD	(a)	CHAR				Filter rate
Flag indicating which DRAG_AIF command is in effect	DRAG_AIF_RCVD	(a)	CHAR				Filter rate
Switch used to override drag residual edit test	DRAG_EDIT_ OVERRIDE	RTLS drag data processing	D		OFF/ON		Filter rate
Flag indicating stat-flag setting for drag data	DRAG_STAT	RTLS drag data processing	D		OFF/ON		Filter rate
Flag indicating if altitude data have been deselected for not meeting altitude or acceleration constraints	H_INHIB	MEAS processing statistics	D		OFF/ON		Filter rate

[a]See RTLS navigation output parameter table.

4.3.2.4 RTLS Navigation Reconfiguration. A capability shall be provided for initialization or reinitialization of certain navigation variables when events occur that require reconfiguration of the navigation software. These events include the initialization of TACAN station information when the TACAN ID changes, and delta state updates to the onboard navigated state vector and the associated covariance matrix reinitialization.

4.3.2.4.1 Measurement Reconfiguration. A capability will be provided for initialization of the TACAN station information when TACAN processing begins or when the TACAN station ID has changed.

A. Detailed Requirements. The RTLS sensor measurement selection subfunction will provide a capability for determining when TACAN measurements are to be processed. The measurement reconfiguration subfunction will be executed when TACAN measurements are first available and when the TACAN station ID has changed. This subfunction will obtain the following information from the site lookup principal function (Section 4.5.2) only if the selected TACAN channel is indicated valid.

TACAN station information:

$$TAC\_CHAN\_VALID = TACAN\_CHAN\_VALID\_SL_{SEL\_LRU\_ID}$$

$$R\_TACAN\_EF = R\_TACAN\_EF\_SL_{SEL\_LRU\_ID}$$

$$M\_EFTOTD\_TACAN = M\_EFTOTD\_TACAN\_SL_{SEL\_LRU\_ID}$$

$$ANGLE\_CORR\_TNTOMAG = ANGLE\_CORR\_TNTOMAG\_SL_{SEL\_LRU\_ID}$$

$$TACAN\_ID\_LAST = TACAN\_ID_{SEL\_LRU\_ID}$$

B. Interface Requirements. The input and output variables for this subfunction are described in Tables 4.3.2.4.1-1 and 4.3.2.4.1-2.

C. Processing Requirements. The measurement reconfiguration subfunction shall be performed prior to processing of TACAN measurements.

D. Constraints. It is required that the TACAN redundancy management selection filtering and the RTLS navigation principal function execute at the same rate in the following sequence.

1. TACAN RM selection filtering.

2. RTLS navigation.

It is important that the identifier SEL_LRU_ID, and all the variables that have SEL_LRU_ID as a subscript in the above equations remain unchanged in the site lookup principal function while the above equations are being executed.

E. Supplementary Information. A suggested implementation of the measurement reconfiguration subfunction is illustrated by the flow chart TACAN_INIT CODE in Section 5.2.

4.3.2.4.2 Delta State Update. During operation of the RTLS navigation principal function a capability for a delta state update of the orbiter's on-board navigated state and reconfiguration of the covariance matrix shall be provided.

A. Detailed Requirements. Detailed requirements for the performance of the delta state update task are described in Section 4.2.5. After execution of the delta state update task, the covariance initialization task described in Section 4.2.3 shall be invoked to reconfigure the on-board covariance matrix. Input values of sigmas and correlation coefficients are peculiar to and associated with the state update reconfiguration.

B. Interface Requirements. Input and output requirements for the delta state update task are shown in Tables 4.3.2.4.2-1 and 4.3.2.4.2-2 respectively.

C. Processing Requirements. The delta state update task and covariance matrix reconfiguration will be initiated from inputs supplied by either the HSD specialist function processing software or by the ground uplink processing software. The delta state update subfunction and the covariance matrix reconfiguration shall be performed after the state propagation and measurement selection subfunctions have been completed, and only upon detection of an ON value in the DO_DELTA_UPDATE flag. This flag is checked by the RTLS control subfunction in every cycle of the RTLS navigation principal function.

D. Constraints. None.

E. Supplementary Information. Procedures will be established to inhibit redesignation of the runway and the incorporation of measurement data into the onboard state vector during the time interval between (1) the time of the difference vectors computation and (2) the time of their application to the on-board state vector. Correction terms, rather than the total vector, are used because the correction terms are less sensitive to errors between the time of their computation and the time that they are actually applied to correct the onboard state vector.

A suggested implementation in the form of the detailed flow charts ASC DELTA_STATE_UPDATE and COVINIT_RTLS may be found in Section 5.2.

Table 4.3.2.4.1-1. Measurement Reconfiguration Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Integer indicating which TACAN LRU (1, 2, or 3) is selected by RM for use by nav filter for TACAN data processing	SEL_LRU_ID	External sensor data snap	I	S			As needed
Switch indicating ("ON") a valid TACAN channel has been selected (site lookup output) I = 1, 3	TAC_CHAN_VALID_ SL_I	(a)	D		OFF/ON		As needed
Earth-fixed position vector of TACAN station (each LRU) output from site lookup, I = 1, 3	R_TACAN_EF_ SL_I	(a)	V	S		ft	As needed
Transformation matrix from earth-fixed to topodetic coordinates at TACAN site (each LRU) output from site lookup, I = 1, 3	M_EFTOTD_TACAN_ SL_I	(a)	M	S			As needed
Variation of magnetic north from true north at TACAN site (each LRU) output from site lookup, I = 1, 3	ANGLE_CORR_ TNTOMAG_SL_I	(a)	F	S		rad	As needed
Current TACAN channel/mode identified (each LRU) output from site lookup, I = 1, 3	$TACAN\_ID_I$	(a)	I	S	±126		As needed

[a]See RTLS navigation principal function input parameter table.

Table 4.3.2.4.1-2. Measurement Reconfiguration Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Copy of R_TACAN_EF_SL for TACAN station used by nav filter	R_TACAN_EF	RTLS nav state and covariance measurement incorporation	V	S		ft	As needed
Copy of M_EFTOTD_TACAN_SL from site lookup	M_EFTOTD_TACAN	RTLS nav state and covariance measurement incorporation	M	S			As needed
Copy of ANGLE_CORR_TNTOMAG_SL for navigation processing	ANGLE_CORR_ TNTOMAG	RTLS nav state and covariance measurement incorporation	F	S		rad	As needed
Copy of TACAN CHAN VALID_SL for TACAN station used by nav filter	TACAN_CHAN_ VALID	RTLS nav state and covariance measurement incorporation	D		OFF ON		As needed

Table 4.3.2.4.2-1. Delta State Update Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Time of the filter state vector	T_CURRENT_FILT	RTLS navigation state propagation	F	DP		sec	As needed
Ground computed position deviations to update on-board state vector	DR_RW	(a), RTLS control	V	S		ft	As needed
Ground computed velocity deviations to update on-board state vectors	DV_RW	(a), RTLS control	V	S		ft/sec	As needed
Earth-fixed to prime RW transformation matrix	M_EFTORW	(a)	M	S			As needed
Earth rotation rate	EARTH_RATE	(b)	F	DP		rad/sec	
Unit vector in direction of earth's axis of rotation	EARTH_POLE	(b)	V	S			
Vehicle state vector variance loaded when manual update is invoked	SIG_DIAG_UPDATE	(b)	V	DP		ft^2	
Shuttle position vector	R_FILT	RTLS navigation state propagation	V	DP		ft	As needed
Shuttle velocity vector	V_FILT	RTLS navigation state propagation	V	S		ft/sec	As needed
Covariance correlation coefficients	CORR_COEFF_UPDATE	(b)	V	S			As needed

[a]See RTLS navigation principal function input parameter table.
[b]RTLS navigation principal function K-load and constant tables.

Table 4.3.2.4.2-2. Delta State Update Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Current Shuttle position vector	R_FILT	RTLS navigation state propagation, entry state and covariance measurement incorporation	V	DP		ft	As needed
Shuttle velocity vector	V_FILT	RTLS navigation state propagation, entry state and covariance measurement incorporation	V	S		ft/sec	As needed
Filter covariance matrix	E	RTLS covariance propagation	M	DP			As needed
Position deviations to update on-board state vector (zeroed out for display)	DR_RW	(a)	V	S		ft	As needed
Velocity deviations to update on-board state vector (zeroed out for display)	DV_RW	(a)	V	S		ft/sec	As needed
Flag indicating (OFF) that a delta state update is not to be performed	DO_DELTA_UPDATE	(a), RTLS control	D		OFF/ON		As needed

[a]See RTLS navigation principal function output parameter table.

4.3.2.5 State Propagation. The state propagation subfunction that is active during operation of the RTLS navigation principal function will be invoked for the purpose of propagating orbiter position and velocity vectors. This subfunction will also snap IMU-sensed accelerations to be used together with modeled gravitational accelerations by the super-g integration task.

A. Detailed Requirements. Propagation of position and velocity vectors will be performed as follows:

1. Acquire current IMU-sensed total accumulated velocity and associated time tag.

V_CURRENT_FILT

T_CURRENT_FILT

Detailed requirements for this IMU data snap task are given in Section 4.2.1.1.

2. Compute the difference between the current and the previous time tag associated with the IMU data snap. This will be the interval over which state propagation is desired.

DT_FILT = T_CURRENT_FILT-T_LAST_FILT

3. Perform integration of the position and velocity equations of motion with use of the super-g task (see Section 4.2.1.3 for detailed requirements). Position and velocity vectors will be propagated to the current time of the IMU data snap (T_CURRENT_FILT),

R_FILT

V_FILT

4. Save the current time tag and accumulated IMU velocity for the next cycle.

T_LAST_FILT = T_CURRENT_FILT

V_LAST_FILT = V_CURRENT_FILT

B. Interface Requirements. The input and output parameters are listed in Tables 4.3.2.5-1 and 4.3.2.5-2.

C. Processing Requirements. The state propagation subfunction will be performed after the sensor measurement selection subfunction and before the covariance propagation subfunction. This subfunction will be performed each cycle at the RTLS navigation rate.

D. Constraints. None.

E. Supplementary Information. A suggested implementation in the form of detailed flow charts may be found in Section 5.2.

NAV_GRTLS

NAV_STATE_PROP_ASCENT_AND_RTLS

ACCEL

Table 4.3.2.5-1. State Propagation Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Copy of V_IMU_CURRENT raw velocity counts reserved for measurement processing	V_CURRENT_FILT	(a)	V	DP		ft/sec	Filter rate
MTU or clock time when IMU was read	T_CURRENT_FILT	(a)	F	DP		sec	Filter rate
Time of the filter state vector	T_LAST_FILT	RTLS state propagation,[a]	F	DP		sec	Filter rate
Filter current Shuttle position vector in M50 coordinates	R_FILT	RTLS state propagation, delta state update, RTLS state and covariance measurement incorporation	V	DP		ft	Filter rate
Shuttle velocity vector	V_FILT	RTLS state propagation, delta state update, RTLS state and covariance measurement incorporation	V	S		ft/sec	Filter rate
Previously read selected accumulated IMU velocity	V_LAST_FILT	RTLS state propagation,[a]	V	DP		ft/sec	Filter rate
Acceleration function related constants	(b)	(c)					
Vehicle angle of attack	ALPHA	RTLS control	F	S		rad	Filter rate
Vehicle sideslip angle	BETA	RTLS control	F	S		rad	Filter rate
Min acc to use IMU data	ACC_PROP_MIN	(a)	F	S		ft/sec^2	Filter rate

[a]See RTLS navigation principal function input parameter table.
[b]See Section 4.2.1.2.
[c]See RTLS navigation principal function K-load and constant tables.

Table 4.3.2.5-2. State Propagation Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Filter current Shuttle position vector in M50 coordinates	R_FILT	RTLS state propagation RTLS delta state update RTLS state, and covariance measurement incorporation	V	DP		ft	Filter rate
Filter current Shuttle velocity vector in M50 coordinates	V_FILT	RTLS state propagation delta state update, RTLS state and covariance measurement incorporation	V	S		ft/sec	Filter rate
Modeled acceleration vector	G_OLD	RTLS control	V	S		ft/sec^2	Filter rate
Time of the filter state vector	T_LAST_FILT	RTLS control	F	DP		sec	Filter rate
Previously read selected accumulated IMU velocity	V_LAST_FILT	RTLS state propagation	V	DP		ft/sec	Filter rate
Difference between present and previous accumulated sensed velocities	DV_FILT	State and covariance measurement incorporation (drag altitude)	V	S		ft/sec	Filter rate
Flag indicating that IMU data are to be used for state propagation	USE_IMU_DATA	(a)	D		ON/OFF		Filter rate
Interval over which to propagate the covariance matrix	DT_FILT	State and covariance measurement incorporation	F	DP		sec	Filter rate

[a]See RTLS navigation principal function output parameter table.

4.3.2.6 Covariance Matrix Propagation. The covariance matrix propagation subfunction propagates the covariance matrix forward in time. The covariance matrix is propagated by utilizing the state transition matrix. Additive process noise is incorporated to account for unmodeled state and dynamic errors.

A. Detailed Requirements. A 6-by-6 covariance matrix will be propagated with the RTLS navigation principal function. This covariance matrix defines the uncertainty in the state vector, which consists of position and velocity of the vehicle. The method of propagation is described as follows:

The components of the state transition matrix, PHI of dimension 6-by-6, are mathematically defined as the partials of the current state with respect to the previous state (old). An approximate formulation which makes use of a gravity gradient matrix (3-by-3) is to be used in construction of this matrix.

$PHI_{1 \text{ to } 6,\ 1 \text{ to } 6}$ is equal to the following submatrices.

$$PHI_{1 \text{ to } 3,\ 1 \text{ to } 3} = ID\_MATRIX\_3X3 + (DT\_FILT^2/2)\ GRAV\_GRAD\_OLD$$

$$PHI_{1 \text{ to } 3,\ 4 \text{ to } 6} = (DT\_FILT)\ ID\_MATRIX\_3X3$$

$$PHI_{4 \text{ to } 6,\ 1 \text{ to } 3} = (DT\_FILT/2)\ (GRAV\_GRAD\_OLD + GRAV\_GRAD\_NEW)$$

$$PHI_{4 \text{ to } 6,\ 4 \text{ to } 6} = ID\_MATRIX\_3X3 + (DT\_FILT^2/2)\ (GRAV\_GRAD\_NEW)$$

where

$$GRAV\_GRAD\_OLD = GRAVITY\_GRADIENT\ (R\_COV\_LAST)$$

$$GRAV\_GRAD\_NEW = GRAVITY\_GRADIENT\ (R\_FILT)$$

The quantity ID_MATRIX_3X3 is the 3-by-3 identity matrix, and the gravity gradient matrix function is defined in Section 4.4.5.4.

The covariance matrix, E, will be propagated using the following equation:

$$E = PHI\ E\ PHI^T + STATE\_NOISE$$

where the state noise covariance matrix, STATE_NOISE, is used to account for unmodeled state errors and uncertainty in the propagation of the state. It shall be formulated as shown in Figure 4.3.2.6-1.

where

$$NOISE = VAR\_ACC\_QUANT + (VAR\_UNMOD\_ACC\_DT)\ DT\_FILT$$

$$NOISE\_R = NOISE\ (DT\_FILT^2)\ 0.25$$

NOISE_RV = NOISE (DT_FILT) 0.5

and VAR_ACC_QUANT and VAR_UNMOD_ACC_DT are K-load parameters.

Finally, since the covariance matrix, E, must be symmetric, state noise terms need only be added to the upper triangular portion of the matrix triple product PHI E PHI^T and symmetry shall be maintained by

$$E_{J,I} = E_{I,J} \text{ for } \begin{Bmatrix} I = 1,6 \\ J = 1,6 \end{Bmatrix}$$

B. Interface Requirements. The input and output data are shown in Tables 4.3.2.6-1 and 4.3.2.6-2.

C. Processing Requirements. This subfunction will be called after the IMU sensor data have been read and after the state propagation subfunction has been executed.

D. Constraints. Prestored data are to be used for initialization. The propagated covariance matrix must remain symmetric.

E. Supplementary Information. A possible implementation of this subfunction is shown in the flow charts COVEXTRAP_PF_RTLS in Section 5.2.

$$\text{STATE\_NOISE} = \left\{ \begin{array}{ccc|ccc} \text{NOISE\_R} & 0 & 0 & \text{NOISE\_RV} & 0 & 0 \\ 0 & \text{NOISE\_R} & 0 & 0 & \text{NOISE\_RV} & 0 \\ 0 & 0 & \text{NOISE\_R} & 0 & 0 & \text{NOISE\_RV} \\ \hline \text{NOISE\_RV} & 0 & 0 & \text{NOISE} & 0 & 0 \\ 0 & \text{NOISE\_RV} & 0 & 0 & \text{NOISE} & 0 \\ 0 & 0 & \text{NOISE\_RV} & 0 & 0 & \text{NOISE} \end{array} \right\}$$

Figure 4.3.2.6-1. State Noise Formulation

Table 4.3.2.6-1. RTLS Covariance Matrix Propagation Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Interval over which to propagate the covariance matrix	DT_FILT	RTLS state propagation	F	S		sec	Filter rate
Filter covariance matrix	E	RTLS state and covariance measurement incorporation, RTLS covariance propagation	M	DP		vary	Filter rate
Derivative of the gravitational acceleration vector with respect to the position vector	GRAVITY_GRADIENT	Utility subfunction	M	DP		sec^{-2}	Filter rate
Identity matrix (3x3)	ID_MATRIX_3X3		M	S	0,1		Filter rate
Updated vehicle position vector associated with current covariance matrix	R_COV_LAST	RTLS control	V	DP		ft	Filter rate
Filter current Shuttle position vector in M50 coordinates	R_FILT	RTLS state propagation	V	DP		ft	Filter rate
Accelerometer quantization error variance	VAR_ACC_QUANT	(a)	F	S		ft^2/sec^4	Filter rate
Variance of unmodeled acceleration times scale time	VAR_UNMOD_ACC_DT	(a)	F	S		ft^2/sec^3	Filter rate

[a]See RTLS navigation principal function K-load table.

Table 4.3.2.6-2. RTLS Covariance Matrix Propagation Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Filter covariance matrix	E	RTLS state and covariance measurement incorporation, RTLS covariance propagation	M	DP		vary	Filter rate

4.3.2.7 State and Covariance Measurement Incorporation. The state and covariance measurement incorporation subfunction updates the state vector and covariance matrix with navigation data with the use of a six state process noise Kalman filter. The six elements of the state vector are navigation base Shuttle position and velocity in M50 coordinates.

A. Detailed Requirements. The state and covariance measurement incorporation subfunction is exercised only if data are available for processing as determined by the sensor measurement selection subfunction (Section 4.3.2.3) and the respective measurement subfunctions (Section 4.3.2.7.1 through 4.3.2.7.7). The sensor measurement selection subfunction determines which measurement types are to be considered for processing. The measurement subfunctions process sensor data that are labeled as valid.

The measurement subfunctions will compute the measurement residual and partials of the estimated measurement with respect to the state vector. The proper a priori measurement variance describing the error will also be selected. The following measurement types will be available with the RTLS navigation principal function: TACAN range and bearing; barometric altimeter; MSBLS range, azimuth, and elevation; and drag altitude.

Once a particular measurement subfunction has completed processing valid data, the filter control flags will be set as follows.

TACAN

MANUAL_EDIT_OVERRIDE = TACAN_EDIT_OVERRIDE

STAT_FLAG = TACAN_STAT

Barometric altimeter

MANUAL_EDIT_OVERRIDE = BARO_EDIT_OVERRIDE

STAT_FLAG = BARO_STAT

MSBLS

MANUAL_EDIT_OVERRIDE = OFF

STAT_FLAG = OFF

Drag

MANUAL EDIT_OVERRIDE = DRAG_EDIT_OVERRIDE

STAT_FLAG = DRAG_STAT

The state and covariance measurement incorporation subfunction shall then update the state vector and covariance matrix in the following manner.

This subfunction will use a Kalman filter to incorporate the measurement data to update the covariance matrix and the state vectors. To perform these tasks, the Kalman filter uses the covariance matrix, measurement partials, measurement residuals, and the a priori measurement variance. Nonlinear compensation will be included if required.

If the measurement data have been judged valid and the proper measurement subfunction has been executed, the following update equations will be computed. (Note: The measurement subfunction generates the partial vector, the residuals, and the a priori variance.)

First, the scalar quantity BT_E_B will be calculated from the covariance matrix E and vector measurement partials $\underline{B}$:

$$\underline{EB\_COPY} = E\ \underline{B}$$

$$BT\_E\_B = B \quad \underline{EB\_COPY}$$

where the second equation requires a dot product. The three diagonal elements of the covariance matrix pertaining to the Shuttle position uncertainty will then be summed: $E_{1,1} + E_{2,2} + E_{3,3}$. If the sum is greater than the constant MS_POS_UND_WGT, the a priori variance will be compensated for nonlinear effects by

$$VAR = VAR + K\_UND\_WGT\ BT\_E\_B$$

This compensation underweights the measurement to prevent the state error covariance matrix from shrinking more rapidly than the actual errors. The quantity MS_DELQ, which represents the expected variance in the measurement, will then be computed by

$$MS\_DELQ = BT\_E\_B + VAR$$

A residual edit will be performed. A flag corresponding to the appropriate measurement subfunction will be set to inform the crew if the edit fails: that is, if the square of the residual is greater than the quantity RESID_TEST, where RESID_TEST = K_RES_EDIT MS_DELQ and K_RES_EDIT is set by the individual measurement subfunctions. It should be noted that nonlinear compensation, when performed, also adjusts this edit. The larger the compensation, the larger will be the residual that passes the edit. The residual edit will be overridden or inhibited, however, if the manual edit override for the particular sensor being processed is active.

If there is no edit, the subfunction will compute the Kalman filter gains,

$$\underline{OMEGA} = \underline{EB\_COPY}/MS\_DELQ \qquad \text{(F3)}$$

[F3]This equation shall be protected against division by zero (Section 3.5).

and update the covariance matrix,

$$E = E - \underline{OMEGA}\ (\underline{EB\_COPY}^T)$$

and the state vector,

$$\underline{R\_FILT} = \underline{R\_FILT} + \underline{OMEGA}_{1\ to\ 3}\ DELQ$$

$$\underline{V\_FILT} = \underline{V\_FILT} + \underline{OMEGA}_{4\ to\ 6}\ DELQ$$

where DELQ corresponds to the appropriate measurement residual. The edit flag corresponding to the appropriate measurement subfunction will be set to indicate that the measurement data have been processed rather than edited.

This subfunction will also be used to compute the residual test quantity for manually selected sensor types whenever the filter is not incorporating data. This quantity, together with residuals calculated by the measurement subfunctions, will be required for display purposes. A flag corresponding to the appropriate measurement type will be set by the navigation sensor selection task to prevent Kalman filter gain computations and state and covariance matrix updates under this condition. The filter edit flag will be set, in this case, to indicate to measurement processing statistics (Section 4.3.2.8) that the data have been computed for display purposes only.

It is required that the residual (DELQ), the residual test quantity (RESID_TEST) and the residual edit flag corresponding to each measurement subfunction be available for display purposes. The following data shall therefore be stored after the particular measurement type has been processed for subsequent computation of measurement processing statistics as described in Section 4.3.2.8.

TACAN

$$SENSOR\_EDIT_{1and2} = EDIT\_FLAG$$

$$SENSOR\_RESID\_TEST_{1and2} = RESID\_TEST$$

$$SENSOR\_DELQ_{1and2} = DELQ$$

where the subscript 1 corresponds to bearing and 2 to range and the quantities for each measurement type are set equal to their respective flag and parameter.

Barometric altimeter

$$SENSOR\_EDIT_3 = EDIT\_FLAG$$

$$SENSOR\_RESID\_TEST_3 = RESID\_TEST$$

$$SENSOR\_DELQ_3 = DELQ$$

Drag

$SENSOR\_EDIT_4$ = EDIT FLAG

$SENSOR\_RESID\ TEST_4$ = RESID TEST

$SENSOR\_DELQ_4$ = DELQ

MSBLS

$SENSOR\_EDIT_{5,\ 6\ and\ 7}$ = EDIT_FLAG

$SENSOR\_RESID\_TEST_{5,\ 6\ and\ 7}$ = RESID_TEST SENSOR

$SENSOR\_DELQ_{5,\ 6\ and\ 7}$ = DELQ

where the subscripts 5, 6 and 7 correspond to azimuth, range, and elevation, respectively. The quantities for each measurement type are set equal to their respective flag or parameter.

B. Interface Requirements. The inputs and outputs for this subfunction are given in Tables 4.3.2.7-1 and 4.3.2.7-2.

C. Processing Requirements. This subfunction is not exercised until the external sensor data snap, sensor measurement selection, RTLS navigation reconfiguration, and state and covariance propagation subfunctions have been performed; and the measurement processing statistics subfunction cannot be initiated until this subfunction is completed.

D. Constraints. There is no requirement in the state and covariance measurement incorporation subfunction to perform updating if the data-validity flag indicates bad data. No manual override of this flag exists in this subfunction. If it is desired to process a particular measurement, the data-validity flag must be made to indicate that the data are valid.

E. Supplementary Information. A possible implementation of the state and covariance measurement incorporation subfunction is presented in various flow charts of Section 5.2. The Kalman filter equations, from the calculation of the weighting factor to the update of the state, are shown in the flow chart RTLS_NAV_FILTER. The setting of the filter control flags MANUAL_EDIT_OVERRIDE and STAT_FLAG and the setting of the appropriate components of the display arrays SENSOR_EDIT, SENSOR_RESID_TEST and SENSOR_DELQ to the desired values are shown in the individual measurement function flow charts RTLS_DRAG_NAV, RTLS_BARO_NAV, RTLS_MLS_RANGE_NAV, RTLS_MLS_AZ_NAV, RTLS_MLS_EL_NAV, and RTLS_TACAN_NAV codes.

Table 4.3.2.7-1. State and Covariance Measurement Incorporation Inputs

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Filter covariance matrix	E	RTLS covariance propagation	M	DP		vary	Filter rate
Measurement first partials with respect to filter state	B	Measurement subfunctions	V	DP		vary	Filter rate
Value of filter mean squared position error below which no measurement underweighting is used	MS_ROS_UND_WGT	(a)		F	S	ft^2	Filter rate
General sensor variance	VAR	Measurement subfunctions	F	S			Filter rate
Scale factor used in measurement underweighting equation	K_UND_WGT	(a)	F	S			Filter rate
Scale factor on filter mean square residual used in residual edit test	K_RES_EDIT	Measurement subfunctions	F	S			Filter rate
Switch used to force incorporation of barometric data regardless of residual edit test	BARO_EDIT_OVERRIDE	RTLS sensor measurement selection	D		OFF/ON		Filter rate
Switch used to force TACAN residual edit test	TACAN_EDIT_OVERRIDE	RTLS sensor measurement selection	D		OFF/ON		Filter rate
General measurement residual	DELQ	Measurement subfunctions	F	S		ft	Filter rate
Filter current Shuttle position vector in M50 coordinates	R_FILT	RTLS state propagations, RTLS state and covariance measurement incorporation	V	DP		ft	Filter rate
Shuttle velocity vector	V_FILT	RTLS state propagation, RTLS state and covariance measurement incorporation	V	S		ft/sec	Filter rate
Flag indicating stat-flag setting for barometric measurements	BARO_STAT	RTLS sensor measurement selection	D		OFF/ON		Filter rate
Flag indicating TACAN data processed only for statistical display	TACAN_STAT	RTLS sensor measurement	D		OFF/ON		Filter rate

[a]See RTLS navigation principal function I-load table.

Table 4.3.2.7-1. State and Covariance Measurement Incorporation Inputs (Cont)

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Flag indicating drag data processed only for statistical display	DRAG_STAT	RTLS sensor measurement selection	D		OFF/ON		Filter rate
Switch used to override drag residual edit test	DRAG_EDIT_ OVERRIDE	RTLS sensor measurement selection	D		OFF/ON		Filter rate

Table 4.3.2.7-2. State and Covariance Measurement Incorporation Outputs

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Filter covariance matrix	P	RTLS covariance propagation[a]	M	DP		Vary	Filter rate
Filter current Shuttle position vector in M50 coordinates	R_FILT	RTLS state propagation[a]	V	DP		ft	Filter rate
Shuttle velocity vector	V_FILT	RTLS state propagation[a]	V	S		ft/sec	Filter rate
Edit indicators for measurements	SENSOR_EDIT	RTLS nav measurement processing statistics	V	S			Filter rate
Measurement residuals	SENSOR_DELQ	RTLS nav measurement processing statistics	V	S		Vary	Filter rate
Value of criterion used in nav filter for residual edit tests for the sensor measurements	SENSOR_ RESID_TEST	RTLS nav measurement processing statistics	V	S		Vary	Filter rate
Residual edit test quantity	RESID_TEST	TACAN range and bearing measurement subfunctions	F	S		Vary	Filter rate

[a]RTLS state and covariance measurement incorporation

4.3.2.7.1 Drag Altitude. The drag altitude measurement subfunction constructs a pseudoaltitude measurement, an estimated altitude measurement, and a measurement residual for the Orbiter state vector. The pseudoaltitude measurement is calculated from accelerometer outputs, a model of air density as a function of altitude, and a model of drag as a function of the angle of attack. The subfunction also calculates the first partial derivatives of the estimated measurement with respect to the state vector, as well as the appropriate variance to model the instrument error.

A. Detailed Requirements. A description of the symbols used in the following equations may be found in Tables 4.3.2.7.1-1 and 4.3.2.7.1-2.

Drag residual. The subfunction shall compute the drag altitude estimate by using the equation

$$Q = H\_ELLIPSOID\ (\underline{R}\_FILT)$$

where the function H_ELLIPSOID generates the height above the reference ellipsoid (requirements for this function are described in Section 4.4.5.1).

A four-layer atmospheric model shall be used to compute the pseudoaltitude measurement. The scale height, H_S, and the density at the base, RHO_ZERO, used in the equations of pseudoaltitude measurement shall be selected as a function of the estimated altitude, Q. Also, the deterministic drag bias shall be selected as a function of the altitude.

Do for I = 1,4;

If $Q > DENSITY\_LIMIT_I$ then LAYER = I. Then set

$$H\_S = SCALE\_HT_{LAYER}$$

$$RHO\_ZERO = BASE\_DEN_{LAYER}, \text{ and}$$

$$BIAS\_DRAG = BIAS\_DRAG\_LAYER_{LAYER}$$

where DENSITY_LIMIT, SCALE_HT, BASE_DEN and BIAS_DRAG_LAYER are premission-determined 4 component arrays.

This subfunction shall then compute the pseudoaltitude measurement with the equations

$$\underline{V}\_RHO = \underline{V}\_REL\ (\underline{V}\_FILT, \underline{R}\_FILT)$$

$$DRAG\_PARAM = \frac{DRAG\_CONST\ DT\_FILT\ \underline{V}\_RHO \cdot \underline{V}\_RHO \cdot}{|UNIT\ (\underline{V}\_RHO) \cdot \underline{DV}\_FILT|} \qquad \text{(F3)}$$

[F3] This equation shall be protected against the division by zero (Section 3.5).

ALP = |ALPHA|

C_DRAG = C_DRAG_ZERO + ALP (C_DRAG_ONE + ALP C_DRAG_TWO)

Q_DRAG = H_S LOG_e (C_DRAG RHO_ZERO DRAG_PARAM)

where $\underline{V}$ _REL is the function that computes the relative velocity of the vehicle with respect to the rotating atmosphere, described in Section 4.4.5.2.

The residual shall then be computed by

DELQ = Q_DRAG - Q - BIAS_DRAG

B. Drag Partials. The partial derivatives of the altitude measurement with respect to the state are to be computed as follows:

$\underline{B}_{1 \text{ to } 3} = \text{UNIT } (\underline{R}\_\text{FILT})$

$\underline{B}_{4 \text{ TO } 6} = \underline{0}$

The variance of the drag altitude measurement error shall be defined by

VAR = VAR_DRAG

The scale factor on the filter mean square residual used in the residual edit test, K_RES_EDIT, shall be set equal to K_EDIT_DRAG, which is a premission load.

The state and covariance matrix will then be updated provided that the residual edit criterion is met as described in Section 4.3.2.7.

C. Interface Requirements. The input and output variables for the drag measurement subfunction are given in Tables 4.3.2.7.1-1 and 4.3.2.7.1-2.

D. Processing Requirements. This subfunction shall be performed, after the state and covariance propagation (Sections 4.3.2.5 and 4.3.2.6), at the basic filter rate. This subfunction is performed as long as drag altitude measurements are being processed.

E. Constraints. None.

F. Supplementary Information. A suggested implementation of this subfunction is shown in the flow chart RTLS_DRAG_NAV in Section 5.2 The flow chart contains a combination of the requirements described in this section with some that are described in Section 4.3.2.7, namely the setting of the filter control flags MANUAL_EDIT_OVERRIDE and STAT_FLAG to DRAG_EDIT_OVERRIDE and to DRAG_STAT respectively, the call to RTLS_NAV_FILTER and the setting of the display parameters $SENSOR\_EDIT_4$, $SENSOR\_RESID\_TEST_4$, and $SENSOR\_DELQ_4$, to EDIT_FLAG, RESID_TEST, and DELQ, respectively.

Table 4.3.2.7.1-1. Drag Measurement Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Interval over which to propagate the covariance matrix	DT_FILT	RTLS state propagation	F	S		sec	Filter rate
Polynomial term for computing drag coefficient as function of angle of attack	C_DRAG_ZERO	(a)	F	S			Filter rate
Polynomial term for computing drag coefficient as function of angle of attack	C_DRAG_ONE	(a)	F	S		1/rad	Filter rate
Polynomial term for computing drag coefficient as function of angle of attack	C_DRAG_TWO	(a)	F	S		$1/rad^2$	Filter rate
Earth rotation rate	EARTH_RATE	(a)	F	DP		rad/sec	Filter rate
Vehicle reference area divided by twice the vehicle mass	DRAG_CONST	(b)	F	DP		ft^2/slug	Filter rate
Current Shuttle position vector in M50 coordinates	R_FILT	RTLS nav state propagation, RTLS nav state and covariance measurement incorporation	V	DP		ft	Filter rate
Shuttle velocity vector	V_FILT	RTLS nav state propagation, RTLS nav state and covariance measurement incorporation	V	S		ft/sec	Filter rate
Current angle of attack	ALPHA	RTLS control	F	S		rad	Filter rate
Scale factor on filter mean square residual used in residual edit test for drag measurement	K_EDIT_DRAG	(a)	F	S			Filter rate
Difference between accumulated sensed IMU readings on present cycle and previous cycle	DV_FILT	RTLS state propagation	V	S		ft/sec	Filter rate
Vector of deterministic drag biases for each layer	BIAS_DRAG_LAYER	(a)	V	S		ft	Filter rate
Vector of scale heights for each layer	SCALE_HT	(a)	V	S		ft	Filter rate
Vector of base densities for each layer	BASE_DEN	(a)	V	DP		$slug/ft^3$	Filter rate

[a]See RTLS navigation principal function I-load, K-load, and constant tables.
[b]See RTLS navigation principal function input parameter table.

Table 4.3.2.7.1-1. Drag Measurement Input Parameters (Cont)

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Altitudes defining atmosphere model layers	DENSITY_ LIMIT	(a)	V	S		ft	Filter rate
Unit vector in direction of earth's axis of rotation	EARTH_POLE	(a)	V	S			Filter rate
Earth ellipticity constant	ELLIPT	(a)	F	DP		ft	Filter rate
Earth equatorial radius	EARTH_RADIUS_ EQUATOR	(a)	F	DP		ft	Filter rate
Drag altitude measurement error variance	VAR_DRAG	(a)	F	S		ft^2	Filter rate

[a]See RTLS navigation principal function I-load, K-load, and constant tables.

Table 4.3.2.7.1-2. Drag Measurement Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp. Rate
Drag altitude measurement residual	DELQ	RTLS nav state and covariance measurement incorporation	F	S		ft	Filter rate
General sensor variance	VAR	RTLS nav state and covariance measurement incorporation	F	S		ft^2	Filter rate
Measurement first partials with respect to filter state	B	RTLS nav state and covariance measurement incorporation	V	DP		Vary	Filter rate
Scale factor on filter mean square residual used in residual edit test	K_RES_EDIT	RTLS nav state and covariance measurement incorporation	F	S			Filter rate

4.3.2.7.2 TACAN Range. The TACAN range measurement subfunction computes the estimated range from the Shuttle to the TACAN station, the range residual, and the range measurement partials, and selects the proper variance to model the uncorrelated instrument error. It is assumed that TACAN range data will be provided by the TACAN RM by way of the sensor data snap.

A. Detailed Requirements. First, the position vector will be interpolated to the time of the TACAN sensor measurement, if required, as described in Section 4.2.2, and saved as the variable $\underline{R}$ _RESID for subsequent use in the partials computation. The range residual will then be calculated as follows:

The subfunction will compute the estimated Shuttle relative range by using the equation

$$Q = |\underline{R}\_RESID - \underline{R}\_SCANNER|$$

where

M_EFTOM50 = EARTH_FIXED_TO_M50_COORD (T_TACAN)

$\underline{R}$ _SCANNER = M_EFTOM50 $\underline{R}$ _TACAN_EF

The earth-fixed TACAN station position vector, $\underline{R}$ _TACAN_EF, is obtained from the measurement reconfiguration subfunction (Section 4.3.2.4.1).

The residual shall then be calculated by

DELQ = Q_TAC_R - Q

where Q_TAC_R is the measured TACAN range.

Then the partial derivatives of the range measurement with respect to the state are to be computed as follows:

$$\underline{B}_{1 \text{ to } 3} = \text{UNIT } (\underline{R}\_RESID - \underline{R}\_SCANNER)$$

$$\underline{B}_{4 \text{ to } 6} = \underline{0}$$

where the function UNIT is to compute the unit vector.

The variance of the TACAN range measurement error is selected from premission determined constants as a function of the relative range from the station to the vehicle, RNG,

$$RNG = |\underline{R}\_FILT - \underline{R}\_SCANNER|$$

If the range, RNG, is greater than a premission constant, RNG_VAR_RNG_STEP, then

VAR = VAR_TAC_R_HIGH

otherwise

VAR = VAR_TAC_R_LOW

The scale factor on the filter mean square residual, used in the residual edit test, K_RESID_EDIT, shall be set equal to K_EDIT_TACR, which is a premission load.

The state vector and covariance matrix will then be updated as described in Section 4.3.2.7.

The quantity RESID_TEST, computed by the filter, shall be compared to the design dependent parameter TACAN_RNG_CONVERG_TEST. Depending on the outcome of this comparison, the flag ONE_RANGE_LOCK shall be set to ON or OFF: ON if RESID_TEST < TACAN_RNG_CONVERG_TEST, OFF otherwise. The flag ONE_RANGE_LOCK shall then be output for use by the TACAN redundancy management.

B. Interface Requirements. The inputs and outputs for the TACAN range measurement subfunction are given in Tables 4.3.2.7.2-1 and 4.3.2.7.2-2.

C. Processing Requirements. This subfunction will be performed after the RTLS navigation reconfiguration subfunction (Section 4.3.2.4) at the basic filter rate. This subfunction will be performed as long as TACAN range measurements are being processed.

D. Constraints. This subfunction will only be executed if the data are indicated valid (i.e., the TAC_RNG_DATA_GOOD flag is ON) and the TACAN channel data as provided by TACAN site lookup (Section 4.5.2.2) are indicated valid (i.e., the TAC_CHAN_VALID flag is ON).

E. Supplementary Information. The location of the TACAN antenna has been neglected in calculating the range measurement estimate, because this error is less than the error associated with the measurement. A possible implementation of this subfunction is shown in a portion of the flow chart RTLS_TACAN_NAV_CODE in Section 5.2. Note that total computation for both TACAN range and bearing are minimized in this flow chart although the sequence shown is different than the text sequence. Besides containing both TACAN range and bearing computations, the flow chart shows some of the requirements described in Section 4.3.2.7, namely the setting of the filter control flags MANUAL_EDIT_OVERRIDE and STAT_ FLAG to TACAN_EDIT_OVERRIDE and TACAN_STAT respectively, the call to RTLS_NAV_FILTER, and the setting of the display parameters SENSOR_EDIT$_{1 \text{ or } 2}$, SENSOR_RESID_TEST$_{1 \text{ or } 2}$, and SENSOR_DELQ$_{1 \text{ or } 2}$ to EDIT_FLAG, RESID_TEST and DELQ, respectively.

Table 4.3.2.7.2-1. TACAN Range Measurement Subfunction Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Current data good flag reserved for range measurement processing	TAC_RNG_DATA_GOOD	External sensor data snap	D		OFF/ON		Filter rate
Copy of TACAN_CHAN_VALID_SL for Tacan station used by navigation filter	TAC_CHAN_VALID	Measurement reconfigure	D		OFF/ON		Filter rate
Time at which TACAN was read	T_TACAN	External sensor data snap	F	DP		sec	Filter rate
Copy of R_TACAN_EF_SL for TACAN station used by navigation filter	R_TACAN_EF	Measurement reconfigure	V	DP		ft	Filter rate
Vehicle position vector used in measurement residual calculation after interpolation to time of measurement	R_RESID	State vector interpolate	V	DP		ft	Filter rate
TACAN range sensor measurement	Q_TAC_R	External sensor data snap	F	S		ft	Filter rate
Current Shuttle position vector in M50 coordinates	R_FILT	RTLS state and covariance measurement incorporation, RTLS nav state propagation	V	DP		ft	Filter rate
Current Shuttle velocity vector in M50 coordinates	V_FILT	RTLS state and covariance measurement incorporation, RTLS nav state propagation	V	S		ft/sec	Filter rate
Difference between accumulated sensed IMU readings on present cycle and previous cycle	DV_FILT	RTLS nav state prop	V	S		ft/sec	Filter rate
Gravity acceleration at end of previous Shuttle state integration interval	G_OLD	RTLS nav state prop	V	S		ft/sec^2	Filter rate
Range criterion to select TACAN instrument variance	RNG_VAR_RNG_STEP	(a)	F	S		ft	Filter rate
Variance of TACAN range instrument error at range > RNG_VAR_RNG_STEP	VAR_TAC_R_HIGH	(a)	F	S		ft^2	Filter rate
Variance of TACAN range instrument error at range ≤ RNG_VAR_RNG_STEP	VAC_TAC_R_LOW	(a)	F	S		ft^2	Filter rate
Scale factor on filter mean square residual edit test used for TACAN range measurement	K_EDIT_TACR	(a)	F	S			Filter rate

[a]See RTLS navigation principal function K-load table.

Table 4.3.2.7.2-1. TACAN Range Measurement Subfunction Input Parameters (Cont)

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Time of the filter state vector	T_LAST_FILT	RTLS nav state prop	F	DP		sec	Filter rate
Interval over which the state is propagated	DT_FILT	RTLS nav state prop	F	S		sec	Filter rate
Criterion for difference between measurement time and state time, above which the filter state will be interpolated	EPS_TAG		F	S		sec	Filter rate
Threshold for residual test quantity, below which data from one LRU alone are acceptable	TACAN_RNG_CONVERG_TEST	(a)	F	S			Filter rate
General residual test variable	RESID_TEST	RTLS state and covariance measurement incorporation	F	S			Filter rate

[a]See RTLS navigation principal function K-load table.

Table 4.3.2.7.2-2. TACAN Range Measurement Subfunction Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
General range measurement residual	DELQ	RTLS state and covariance measurement incorporation, RTLS measurement processing statistics	F	S		ft	Filter rate
General sensor variance	VAR	RTLS state and covariance measurement incorporation	F	S		ft^2	Filter rate
Measurement first partials with respect to filter state	B	RTLS state and covariance measurement incorporation	V	DP		Vary	Filter rate
Scale factor on filter mean square residual edit test	K_RES_EDIT	RTLS state and covariance measurement incorporation	F	S			Filter rate
Flag indicating the filter can accept data from one TACAN LRU	ONE_RANGE_LOCK	RTLS nav principal function output parameter table	D		ON/OFF		Filter rate

4.3.2.7.3 TACAN Bearing. The TACAN bearing measurement subfunction computes the estimated bearing measurement with respect to the TACAN station, the measurement residual, and the bearing measurement partials, and it selects the proper variance to model the instrument error. It is assumed that the TACAN bearing data referenced to magnetic north are available from the TACAN RM by way of the sensor data snap.

A. Detailed Requirements. A description of the symbols used in the following equations may be found in Tables 4.3.2.7.3-1 and 4.3.2.7.3-2.

The position vector of the TACAN station in M50 coordinates, $\underline{R}_{SCANNER}$, is computed by

M_EFTOM50 = EARTH_FIXED_TO_M50_COORD(T_TACAN)

$\underline{R}_{SCANNER} = M_{EFTOM50}\ \underline{R}_{TAC\_EF}$

The transformation from M50 to topodetic coordinates is obtained by

$$M_{M50TOTD} = M_{EFTOTD\_TACAN}\ M_{EFTOM50}^{T}$$

where M_EFTOTD_TACAN and R_TACAN_EF were obtained from the measurement reconfiguration subfunction (Section 4.3.2.4.1).

The flags IN_CONE_FLAG (which, when set to ON, indicates the vehicle is inside the TACAN station's code of confusion) and TAC BRG DATA GOOD (which indicates the validity of beaming data) shall be checked.

The following calculations shall be performed only if the bearing data are indicated valid (TAC_BRG_DATA_GOOD = ON) and the IN_CONE_FLAG is OFF.

First, the position vector shall be interpolated to the time of the TACAN measurement, if required, as described in Section 4.2.2 and saved as the variable $\underline{R}_{RESID}$ for subsequent use in the partial computation. The bearing residual shall then be calculated as follows:

The estimated bearing measurement shall be computed as

$$Q = \text{ARCTAN2}\ (REL\_R_2,\ REL\_R_1) - ANGLE\_CORR\_TNTOMAG + PI^{F7}$$

where ANGLE_CORR_TNTOMAG is the correction from true north to magnetic north, and REL_R, the relative position of the Shuttle in topodetic coordinates, is calculated by

$\underline{REL\_R} = M_{M50TOTD}\ (\underline{R}_{RESID} - \underline{R}_{SCANNER})$

[F7] This equation shall be protected against arc tangents with both arguments equal to zero (Section 3.5).

The residual is then calculated as

DELQ = Q_TAC_BRG - Q

This residual should be checked to ensure that its magnitude is less than 180 degrees. If not, the smaller of the two possible central angles is required:

IF |DELQ| > π then,

IF DELQ > 0, DELQ = DELQ - 2 PI

IF DELQ < 0, DELQ = DELQ + 2 PI

The bearing partials shall be computed by invoking the utility subfunction ANGLE_PARTIALS (Section 4.4.5.3) with inputs R_SCANNER and the third row of the transformation matrix from M50 to topodetic coordinates:

CALL: ANGLE_PARTIALS

IN LIST: R_SCANNER, $M\_M50TOTD_{3,\ 1\ to\ 3}$

The variance of the TACAN bearing measurement error is obtained as a function of the relative range from the station to the vehicle, RNG,

RNG = |R_FILT - R_SCANNER|

If the range, RNG, is greater than a premission constant, RNG_VAR_BEARING_STEP,

then

VAR = VAR_TAC_BRG_HIGH

otherwise

VAR = VAR_TAC_BRG_LOW.

The values VAR_TAC_BRG_HIGH and VAR_TAC_BRG_LOW are design dependent parameters (Section 4.9.3).

The scale factor on the filter mean square residual for use in the residual edit test, K_RES_EDIT, shall be set equal to K_EDIT_TACBR, which is a premission load.

The state vector and covariance matrix will then be updated as described in Section 4.3.2.7.

The quantity RESID_TEST, computed by the filter, shall be compared to the design dependent parameter TACAN_BRG_CONVERG_TEST. The flag ONE_BRG_LOCK shall be set to ON or OFF depending on the outcome of this comparison: ON if RESID_TEST < TACAN_BRG_CONVERG_TEST, OFF otherwise. The flag ONE_BRG_LOCK shall then be output for use by the TACAN RM.

B. Interface Requirements. The inputs and outputs for the TACAN bearing measurement subfunction are given in Tables 4.3.2.7.3-1 and 4.3.2.7.3-2.

C. Processing Requirements. The subfunction will be performed after the RTLS navigation reconfiguration subfunction (Section 4.3.2.4) at the basic filter rate. This subfunction will be performed as long as TACAN measurements are being processed.

D. Constraints. This subfunction will only be executed if the data are indicated valid (i.e., the TAC_BRG_DATA_GOOD flag is ON) and the TACAN channel data as provided by TACAN site lookup (Section 4.5.2.2) are indicated valid (i.e., the TACAN_CHAN_VALID flag is ON).

E. Supplementary Information. The location of the TACAN antenna has been neglected in calculating the bearing measurement estimate, because this error is less than that associated with the error in the measurement itself. A possible implementation of this subfunction is shown in a portion of the flow chart RTLS_TACAN_NAV, which may be found in Section 5.2. In the flow chart, computations have been combined with TACAN range data processing and with requirements shown in Section 4.3.2.7, namely the setting of the filter control flags MANUAL_EDIT_OVERRIDE and STAT_FLAG to TACAN_EDIT_OVERRIDE and TACAN_STAT, respectively, the call to RTLS_NAV FILTER, and the setting of the display parameters $SENSOR\_EDIT_{1 \text{ or } 2}$, $SENSOR\_RESID\_TEST_{1 \text{ or } 2}$, and $SENSOR\_DELQ_{1 \text{ or } 2}$ to EDIT_FLAG, RESID_TEST, and DELQ, respectively.

Table 4.3.2.7.3-1. TACAN Bearing Measurment Subfunction Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Current data good flag reserved for bearing measurement processing	TAC_BRG_DATA_GOOD	RTLS external sensor data snap	D		OFF/ON		Filter rate
Copy of TACAN_CHAN_VALID_SL for TACAN station used by navigation filter	TAC_CHAN_VALID	RTLS measurement reconfiguration	D		OFF/ON		Filter rate
Time at which TACAN was read	T_TACAN	External sensor data snap	F	DP		sec	Filter rate
Copy of R_TACAN_EF_SL for TACAN station used by navigation filter	R_TACAN_EF	RTLS measurement reconfiguration	V	DP		ft	Filter rate
Vehicle position vector used in measurement residual calculation after interpolation to time of measurement	R_RESID	State vector interpolation	V	DP		ft	Filter rate
Copy of M_EFTOTD_TACAN_SL from site lookup	M_EFTOTD_TACAN	RTLS measurement reconfiguration	M	S			Filter rate
Copy of ANGLE_CORR_TNTOMAG_SL for navigation processing	ANGLE_CORR_TNTOMAG	RTLS measurement reconfiguration	F	S	0 to PI	rad	Filter rate
The constant PI	PI	(a)	F	DP			Filter rate
TACAN bearing sensor measurement	Q_TAC_BRG	External sensor data snap	F	S		rad	Filter rate
Range criterion to select TACAN bearing instrument variance	RNG_VAR_BEARING_STEP	(a)	F	S		ft	Filter rate
Flag indicating (ON) vehicle is inside TACAN station's cone of confusion	IN_CONE_FLAG	RTLS nav principal function input parameter table	D		OFF/ON		As needed
Variance of TACAN bearing instrument error at range RNG_VAR_BEARING_STEP	VAR_TAC_BRG_HIGH	(a)	F	S		rad^2	Filter rate
Variance of TACAN bearing instrument error at range RNG_VAR_BEARING_STEP	VAR_TAC_BRG_LOW	(a)	F	S		rad^2	Filter rate
Current Shuttle position vector in M50 coordinates	R_FILT	RTLS state and covariance measurement incorporation, RTLS nav state propagation	V	DP		ft	Filter rate

[a]See RTLS navigation principal function K-load and constant tables.

Table 4.3.2.7.3-1. TACAN Bearing Measurement Subfunction Input Parameters (Cont)

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Current Shuttle velocity vector in M50 coordinates	V_FILT	RTLS state and covariance measurement incorporation, RTLS nav state propagation	V	S		ft/sec	Filter rate
Difference between accumulated sensed IMU readings on present cycle and previous cycle	DV_FILT	RTLS navigation state propagation	V	S		ft/sec	Filter rate
Gravity acceleration at end of previous Shuttle state integration interval	G_OLD	RTLS navigation state propagation	V	S		ft/sec^2	Filter rate
Scale factor on filter mean square residual edit test for TACAN bearing measurement	K_EDIT_TACBR	(a)	F	S			Filter rate
Threshold for residual test quantity, below which one LRU data are acceptable	TACAN_BRG_CONVERG_TEST	(a)	F	S			Filter rate
General residual test variable	RESID_TEST	RTLS state and covariance measurement incorporation	F	S			Filter rate
Time of the filter state vector	T_LAST_FILT	RTLS navigation state propagation		DP		sec	Filter rate
Interval over which the state is propagated	DT_FILT	RTLS navigation state propagation	F	S		sec	Filter rate
Criterion for difference between measurement time and state time above which the filter state will be interpolated	EPS_TAG	(a)	F	S		sec	Filter rate

[a]See RTLS navigation principal function K-load and constant tables.

Table 4.3.2.7.3-2. TACAN Bearing Measurement Subfunction Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
General measurement residual	DELQ	RTLS state and covariance measurement incorporation, RTLS measurement processing statistics	F	S		rad	Filter rate
General sensor variance	VAR	RTLS state and covariance measurement incorporation	F	S		rad^2	Filter rate
Measurement first partials with respect to filter state	$\underline{B}$	RTLS state and covariance measurement incorporation	V	DP		Vary	Filter rate
Flag indicating (ON) that the vehicle is in the ground station cone of confusion	IN_CONE_FLAG	Measurement processing statistics	D		ON/OFF		Filter rate
Scale factor on filter mean square residual used in residual edit test	K_RES_EDIT	RTLS state and covariance measurement incorporation	F	S			Filter rate
Flag indicating the filter can accept data from one TACAN LRU	ONE_BRG_LOCK	RTLS navigation principal function output parameter table	D		ON/OFF		Filter rate

4.3.2.7.4 Barometric Altimeter. The barometric altimeter measurement subfunction calculates the estimated altitude measurement, the measurement residual, the measurement partials, and the variance that models the instrument error. It is assumed that the barometric altitude data will be provided by the ADTA SOP via the sensor data snap.

A. Detailed Requirements. A description of the symbols used in the following equations may be found in Tables 4.3.2.7.4-1, 4.3.2.7.4-2.

The barometric measurement subfunction will compute the barometric altimeter estimate by using the state vector with the following equation:

$$Q = H\_ELLIPSOID\ (\underline{R}\_RESID) + BIAS\_BARO - DELH\_MSL\_ELLIPSOID\ RW$$

The state vector used, $\underline{R}\_RESID$, may have been interpolated to the sensor measurement time, if required, as described in Section 4.2.2. Requirements for H_ELLIPSOID, which is the function used to generate the height above the reference ellipsoid, are contained in Section 4.4.5.1.

The residual will then be calculated by

$$DELQ = Q\_BARO - Q$$

The variance of the barometric measurement error will be calculated as

$$VAR = VAR\_H1 + VAR\_H2\ (Q-ALT\_RW)^2$$

where ALT_RW is the altitude of the runway threshold above the reference ellipsoid.

The partial derivative of the barometric measurement with respect to the state is computed as follows:

$$\underline{B}_{1 \text{ to } 3} = UNIT\ (\underline{R}\_FILT)$$

$$\underline{B}_{4 \text{ to } 6} = \underline{0}$$

where the function UNIT computes the unit vector.

The scale factor on the filter mean square residual used in the residual edit test, K_RES_EDIT, shall be set equal to K_EDIT_BARO, which is a premission load.

The state vector and covariance matrix will then be updated as described in Section 4.3.2.7.

B. Interface Requirements. The input and output variables for the barometric measurement subfunction are given in Tables 4.3.2.7.4-1 and 4.3.2.7.4-2.

C. Processing Requirements. This subfunction will be performed after the RTLS navigation reconfiguration subfunction (Section 4.3.2.4) at the basic filter rate. This subfunction is performed as long as barometric altitude measurements are being processed.

D. Constraints. This subfunction will only be executed if the data are indicated valid (i.e., the BARO_DATA_GOOD flag is ON).

E. Supplementary Information. The assumption is made, for simplification, that the barometric probe is located at the navigation base. This is a valid assumption since the error involved in mislocating the probe is less than the errors associated with the barometric measurement.

A possible implementation of this subfunction is shown in the flow chart RTLS_BARO_NAV_CODE. Note that the flow chart also contains some requirements described in Section 4.3.2.7, namely the setting of this filter control flags MANUAL_EDIT_OVERRIDE and TACAN_STAT to BARO_EDIT_OVERRIDE and BARO_STAT, respectively, the call to RTLS_NAV_FILTER, and the setting of the display parameters $SENSOR\_EDIT_3$, $SENSOR\_RESID\_TEST_3$ and $SENSOR\_DELQ_3$ to EDIT_FLAG, RESID_TEST, and DELQ, respectively.

Table 4.3.2.7.4-1. Barometric Altimeter Input Parameters

Description	Symbol	Input Sources	Type	Precision	Range	Units	Sample Rate
Copy of current data good discrete reserved for measurement processing (navigation)	BARO_DATA_GOOD	External sensor data snap	D		OFF/ON		Filter rate
Time tag associated with barometric measurement	T_BARO	External sensor data snap	F	DP		sec	Filter rate
Vehicle position vector used in measurement residual calculation after interpolation to time of measurement	R_RESID	State vector interpolation	V	DP		ft	Filter rate
Barometric deterministic bias	BIAS_BARO	(a)	F	S		ft	Filter rate
Altitude of mean sea level above reference ellipsoid at the runway	DELH_MSL_ELLSIPSOID_RW	(b)	F	S		ft	Filter rate
Barometric altimeter sensor measurement	Q_BARO	External sensor data snap	F	S		ft	Filter rate
Filter current Shuttle position vector in M50 coordinates	R_FILT	RTLS state and covariance measurement incorporation, RTLS nav state propagation	V	DP		ft	Filter rate
Altitude of the runway above the reference ellipsoid	ALT_RW	Ascent runway/ MSBLS site lookup	F	S		ft	Filter rate
Barometric altimeter instrument variance constant	VAR_H1	I-load	F	S		ft^2	Filter rate
Barometric altimeter instrument variance constant	VAR_H2	I-load	F	S		ft^2	Filter rate
Current Shuttle velocity vector in M50 coordinates	V_FILT	RTLS state and covariance measurement incorporation, RTLS nav state propagation	V	S		ft/ sec	Filter rate
Difference between accumulated sensed IMU readings on present previous cycle	DV_FILT	RTLS nav state propagation	V	S		ft/ sec	Filter rate
Gravity acceleration associated with current position vector	G_OLD	RTLS nav state propagation	V	S		ft/sec^2	Filter rate

[a]See RTLS navigation principal function K-load table.
[b]See RTLS navigation principal function input parameter table.

Table 4.3.2.7.4-1. Barometric Altimeter Input Parameters (Cont)

Description	Symbol	Input Sources	Type	Precision	Range	Units	Sample Rate
Scale factor on filter mean square residual used in residual edit test for BARO measurement	K_EDIT_BARO	(a)	F	S			Filter rate
Time of the filter state vector	T_LAST_FILT	RTLS nav state propagation	F	DP		sec	Filter rate
Interval over which the state is propagated	DT_FILT	RTLS navigation state propagation	F	S		sec	Filter rate
Criterion for difference between measurement time and state time, above which the filter state will be interpolated	EPS_TAG	(a)	F	S		sec	Filter rate

[a]See RTLS navigation principal function K-load and constant tables.

Table 4.3.2.7.4-2. Barometric Altimeter Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Barometric measurement residual	DELQ	RTLS state and covariance measurement incorporation	F	S		ft	Filter rate
Measurement first partials with respect to filter state	$\underline{B}$	RTLS state and covariance measurement incorporation	V	DP		Vary	Filter rate
General sensor variance	VAR	RTLS state and covariance measurement incorporation	F	S		Vary	Filter rate
Scale factor on filter mean square residual used in residual edit test	K_RES_EDIT	RTLS state and covariance measurement incorporation	F	S			Filter rate

4.3.2.7.5 MSBLS Range. The MSBLS range measurement subfunction calculates the estimated range from the Shuttle to the MSBLS station, the range residual, and the measurement partials; and it selects the proper variance that models the instrument error. It is assumed that the MSBLS range measurement data will be provided by the MSBLS RM to this subfunction by way of the sensor data snap.

A. Detailed Requirements. Descriptions of symbols used in the following equations may be found in Tables 4.3.2.7.5-1 and 4.3.2.7.5-2.

First, the estimated range will be calculated with the use of the following equation:

$$Q = |\underline{R}\_RESID - \underline{R}\_SCANNER| + BIAS\_MLSRANGE$$

where

$$\underline{R}\_SCANNER = EARTH\_FIXED\_TO\_M50\_COORD\ (T\_EF\_RMLS)\ \underline{R}\_RMLS\_EF$$

and $\underline{R}\_RMLS\_EF$ is obtained from the runway/MSBLS site lookup subfunction (Section 4.5.2.1). The state vector, $\underline{R}\_RESID$, may be interpolated to the sensor measurement time, if required, as described in Section 4.2.2. The residual will then be computed by

$$DELQ = Q\_RANGE - Q$$

The variance of the MSLBS measurement error is set equal to the design dependent parameter VAR_RMLS (Section 4.9.3):

$$VAR = VAR\_RMLS$$

The MSBLS range measurement partials are to be computed as follows:

$$\underline{B}_{1 \text{ to } 3} = UNIT\ (\underline{R}\_RESID - \underline{R}\_SCANNER)$$

$$\underline{B}_{4 \text{ to } 6} = \underline{0}.$$

The scale factor on the filter mean square residual used in the residual edit test, K_RESID_EDIT, shall be set equal to K_EDIT_MLSR, which is a premission load.

Finally, the state vector and the covariance matrix will be updated as described in Section 4.3.2.7.

B. Interface Requirements. The inputs and outputs for the MSBLS range measurement subfunction are given in Tables 4.3.2.7.5-1 and 4.3.2.7.5-2.

C. Processing Requirements. This subfunction will be performed after the state and covariance matrix have been propagated, at the basic filter rate.

D. Constraints. This subfunction will be executed only if the MSBLS range data are labeled valid (i.e., the MLSRANGE DATA_GOOD flag is ON).

E. Supplementary Information. The location of the onboard MSBLS antenna may be neglected in calculating the range measurement estimate, because this error is much less than the error associated with the measurement. A possible implementation of these requirements is illustrated in flow charts RTLS_MLS_NAV CODE and RTLS_MLS_RANGE_NAV CODE in Section 5.2. Note that the flow chart RTLS_MLS_NAV CODE also contains equations shown in Section 4.3.2.7, namely the setting of the filter control flags MANUAL_EDIT_OVERRIDE and STAT_FLAG to OFF, and that the flow chart RTLS_MLS_RANGE_NAV CODE contains also some requirements from Section 4.3.2.7: the call to RTLS_NAV_FILTER and the setting of the display parameters $SENSOR\_EDIT_6$, $SENSOR\_RESID\_TEST_6$, and $SENSOR\_DELQ_6$ to EDIT_FLAG, RESID_TEST and DELQ, respectively.

Table 4.3.2.7.5-1. MSBLS Range Measurement Input Parameters

Description	Symbol	Input Sources	Type	Precision	Range	Units	Sample Rate
MSBLS deterministic bias	BIAS_MLSRANGE	RTLS navigation principal function input parameter table	F	S		ft	Filter rate
Copy of current data good discrete reserved for measurement processing	MLSRANGE_DATA_GOOD	External sensor data snap	D		OFF/ON		Filter rate
MSBLS range sensor measurement	Q_RANGE	External sensor data snap	F	S		ft	Filter rate
Vehicle position vector used in measurement residual calculation after interpolation to time of measurement	R_RESID	State vector interpolate	V	DP		ft	Filter rate
Earth-fixed position vector of MLS range scanner	R_RMLS_EF	RTLS navigation principal function input parameter table	V	DP		ft	Filter rate
Time at which MSBLS range measurement was read	T_EF_RMLS	External sensor data snap	F	DP		sec	Filter rate
MSBLS range measurement instrument variance	VAR_RMLS	(a)	F	S		ft^2	Filter rate
Filter current Shuttle position vector in M50 coordinates	R_FILT	RTLS nav state propagation	V	DP		ft	Filter rate
Current Shuttle velocity vector in M50 coordinates	V_FILT	RTLS nav state propagation	V	S		ft/sec	Filter rate
Difference between accumulated sensed IMU readings on present and previous cycle	DV_FILT	RTLS nav state propagation	V	S		ft/sec	Filter rate
Gravity acceleration associated with current position vector	G_OLD	RTLS nav state propagation	V	S		ft/sec^2	Filter rate
Scale factor on filter mean square residual used in residual edit test for MSBLS range measurement	K_EDIT_MLSR	(a)	F	S			Filter rate
Time of the filter state vector	T_LAST_FILT	RTLS nav state propagation	F	DP		sec	Filter rate
Interval over which the state is propagated	DT_FILT	RTLS nav state propagation	F	S		sec	Filter rate
Criterion for difference between measurement time and state time, above which the filter state will be interpolated	EPS_TAG	(a)	F	S		sec	Filter rate

[a]See RTLS navigation principal function K-load and constant tables.

Table 4.3.2.7.5-2. MSBLS Range Measurement Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Measurement first partial derivative with respect to filter state	$\underline{B}$	RTLS state and covariance measurement incorporation	V	DP		Vary	Filter rate
MLS range measurement residual	DELQ	RTLS state and covariance measurement incorporation	F	S		ft	Filter rate
General sensor variance	VAR	RTLS state and covariance measurement incorporation	F	S		ft^2	Filter rate
Scale factor on filter mean square residual used in residual edit test	K_RES_EDIT	RTLS state and covariance measurement incorporation	F	S			Filter rate

4.3.2.7.6 MSBLS Azimuth. The MSBLS azimuth measurement subfunction calculates the estimated MSBLS azimuth measurement, the residual, and the measurement partials; and it selects the proper variance that models the instrument error. It is assumed that the MSBLS azimuth measurement data will be provided to this subfunction by the MSBLS RM by way of the sensor data snap.

A. Detailed Requirements. Descriptions of symbols used in the following equations may be found in Tables 4.3.2.7.6-1 and 4.3.2.7.6-2.

First, a transformation matrix from the M50 coordinates to the MSBLS azimuth radar coordinates will be computed at the time tag of the MSBLS azimuth measurement, T_EF_AZMLS.

M_EFTOM50 = EARTH_FIXED_TO_M50_COORD (T_EF_AZMLS)

M_M50_TO_SCANNER = M_EFTORAD_R_AZ $M\_EFTOM50^T$

where M_EFTORAD_R_AZ will be provided by the runway/MSBLS site lookup subfunction (Section 4.5.2.1). The relative position of the Shuttle with respect to the MSBLS azimuth station will then be computed by

$\underline{R}$ = M_M50_TO_SCANNER ($\underline{R}$ _RESID - $\underline{R}$ _AZMLS)

where $\underline{R}$ _AZMLS is computed by using the equation

$\underline{R}$ _AZMLS = M_EFTOM50 $\underline{R}$ _AZMLS_EF

and $\underline{R}$ _AZMLS_EF will be obtained from the runway/MSBLS site lookup subfunction. The state vector used, $\underline{R}$ _RESID, may be interpolated to the sensor measurement time, if required, as described in Section 4.2.2.

The estimated MSBLS azimuth measurement will then be computed by

$$Q = \arctan(R_2/R_1) + BIAS\_AZMLS \qquad (F7,F3)$$

and the residual will be computed by

DELQ = Q_AZMLS - Q

The variance of the MSBLS azimuth measurement error is then set equal to the design dependent parameter VAR_AZMLS (Second 4.9.3):

VAR = VAR_AZMLS

[F7] If both arguments are zero, a value of zero should be returned (Section 3.5).
[F3] This equation shall be protected against division by zero (Section 3.5).

The MSBLS azimuth partials are to be computed next by using the function ANGLE_PARTIALS (Section 4.4.5.3), with R_AZMLS and the third row of the transformation matrix from M50 to MSBLS azimuth radar coordinates as inputs:

CALL: ANGLE_PARTIALS

IN LIST: R_AZMLS, M_M50_TO_SCANNER3, 1 to 3

The scale factor on the filter mean square residual used in the residual edit test, K_RES_EDIT, shall be set equal to K_EDIT_MLSAZ, which is a premission load.

Finally, the state vector and the covariance matrix will be updated as described in Section 4.3.2.7.

B. Interface Requirements. The inputs and outputs for the MSBLS azimuth measurement subfunction are given in Tables 4.3.2.7.6-1 and 4.3.2.7.6-2.

C. Processing Requirements. This subfunction will be performed after the state and covariance matrix have been propagated, at the basic filter rate.

D. Constraints. This subfunction will be executed only if the MSBLS azimuth data are labeled valid (i.e., the MLSAZ_DATA_GOOD flag is ON).

E. Supplementary Information. The location of the on board MSBLS antenna may be neglected in calculating the azimuth measurement estimate, since this error is much less than that error associated with the measurement.

A possible implementation of these requirements is illustrated in flow charts RTLS_MLS_NAV CODE and RTLS_MLS_AZ_NAV CODE in Section 5.2. Note that both of these flow charts contain equations that are described in Section 4.3.2.7. RTLS_MLS_NAV CODE shows the setting of the filter control flags MANUAL_EDIT_OVERRIDE and STAT_FLAG to OFF; RTLS MLS_AZ_NAV CODE contains the call to RTLS_NAV_FILTER and the setting of the display parameters SENSOR $EDIT_5$, SENSOR_RESID_TEST$_5$, and SENSOR_DELQ$_5$ to EDIT FLAG, RESID_TEST, and DELQ, respectively.

Table 4.3.2.7.6-1. MSBLS Azimuth Measurement Input Parameters

Description	Symbol	Input Sources	Type	Precision	Range	Units	Sample Rate
MSBLS deterministic elevation bias	BIAS_AZMLS	(b)	F	S		rad	Filter rate
Transformation matrix from earth-fixed to AZ/range MSBLS radar coordinate frame	M_EFTORAD_R_AZ	(b)	M	S			Filter rate
Copy of current data-good discrete reserved for measurement processing	MLSAZ_DATA_GOOD	RTLS sensor data snap	D		OFF/ON		Filter rate
MSBLS azimuth sensor measurement	Q_AZMLS	RTLS sensor data snap	F	S		rad	Filter rate
Earth-fixed MLS azimuth scanner position vector	R_AZMLS_EF	(b)	V	DP		ft	Filter rate
Vehicle position vector used in measurement residual calculation after interpolation to time of measurement	R_RESID	State vector interpolate	V	DP		ft	Filter rate
Time at which MSBLS azimuth was read (adjusted)	T_EF_AZMLS	RTLS sensor data snap	F	DP		sec	Filter rate
MSBLS azimuth measurement instrument variance	VAR_AZMLS	(a)	F	S		rad^2	Filter rate
Filter current Shuttle position vector in M50 coordinates	R_FILT	RTLS state and covariance measurement incorporation	V	DP		ft	Filter rate
Current Shuttle velocity vector in M50 coordinates	V_FILT	RTLS state and covariance measurement incorporation	V	S		ft/sec	Filter rate
Difference between accumulated several IMU readings on present and previous cycle	DV_FILT	RTLS state propagation	V	S		ft/sec	Filter rate
Gravity acceleration associated with current position vector	G_OLD	RTLS nav state propagation	V	S		ft/sec^2	Filter rate
Scale factor on filter mean square residual used in residual edit test for MSBLS azimuth measurement	K_EDIT_MLSAZ	(a)	F	S			Filter rate
Time of the filter state vector	T_LAST_FILT	RTLS nav state propagation	F	DP		sec	Filter rate

[a]See RTLS navigation principal function K-load table.
[b]See RTLS navigation principal function input parameter table.

Table 4.3.2.7.6-1. MSBLS Azimuth Measurement Input Parameters (Cont)

Description	Symbol	Input Sources	Type	Precision	Range	Units	Sample Rate
Interval over which the state is propagated	DT_FILT	RTLS nav state propagation	F	S		sec	Filter rate
Criterion for difference between measurement time and state time, above which the filter state will be interpolated	EPS_TAG	(a)	F	S		sec	Filter rate

[a]See RTLS navigation principal function constant table.

Table 4.3.2.7.6-2. MSBLS Azimuth Measurement Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Measurement first partial derivative with respect to filter rate	B	RTLS state and covariance measurement incorporation	V	DP		Vary	Filter rate
MLS azimuth measurement residual	DELQ	RTLS state and covariance measurement incorporation	F	S		rad	Filter rate
General sensor variance	VAR	RTLS state and covariance measurement incorporation	F	S		rad^2	Fi ter rate
Scale factor on filter mean square residual used in residual edit test	K_RES_EDIT	RTLS state and covariance measurement incorporation	F	S			Fi ter rate

4.3.2.7.7 MSBLS Elevation. The MSBLS elevation measurement subfunction calculates the estimated MSBLS elevation measurement, the residual, and the measurement partials, and it selects the proper variance that models the instrument error. It is assumed that the MSBLS elevation measurement data will be provided to this subfunction by the MSBLS RM by way of the sensor data snap.

A. Detailed Requirements. Descriptions of the symbols used in the following equations may be found in Tables 4.3.2.7.7-1 and 4.3.2.7.7-2.

First, a transformation matrix from M50 to MSBLS elevation radar coordinates will be computed at the time tag of the MSBLS elevation measurement, T_EF_ELMLS.

M_EFTOM50 = EARTH_FIXED_TO_M50_COORD (T_EF_ELMLS)

$$M\_M50\_TO\_SCANNER = M\_EFTORAD\_EL\ M\_EFTOM50^{T}$$

where M_EFTORAD_EL will be provided by the runway/MSBLS site lookup subfunction (Section 4.5.2.1). The relative position of the Shuttle with respect to the MSBLS elevation radar will then be calculated as

$$\underline{R} = M\_M50\_TO\_SCANNER\ (\underline{R}\_RESID - \underline{R}\_ELMLS)$$

where $\underline{R}$_ELMLS is computed by using the equation

$$\underline{R}\_ELMLS = M\_EFTOM50\ \underline{R}\_ELMLS\_EF$$

and $\underline{R}$_ELMLS_EF will be obtained from the runway/MSBLS site lookup subfunction. The state vector, $\underline{R}$_RESID, may be interpolated to the sensor measurement time, if required, as described in Section 4.2.2.

The subfunction will then compute the estimated elevation measurement by

$$Q = \text{ARCTAN}\ (R_3/R_1) + \text{BIAS ELMLS} \qquad \text{(F7)}$$

and will compensate for antenna displacement by

$$Q = Q + MLSANT\_NB\_DIST\ \text{SIN}(Q + PITCH\_M - MLSANT\_ANG)/R\_RHO$$

where R_RHO is equal to the magnitude of $\underline{R}$, MLSANT_NB_DIST is the distance from the navigation base to the MSBLS antenna location on the vehicle, MLSANT_ ANG is the angle between the navigation base to the MSBLS antenna vector and the vehicle's X body-axis, and PITCH_M is the pitch angle.

[F7] If both arguments are zero, a value of zero should be returned (Section 3.5).

Finally, the residual will be computed by

DELQ = Q_ELMLS - Q

If the estimated measurement, Q, is below a minimum angle cutoff, MSBLS_EL_ANGLE_CUTOFF, then MSBLS elevation data will no longer be used to update the state vector. This termination of state updating will be communicated to the RTLS measurement processing statistics subfunction by setting the flag MSBLS_EL_INHIBIT to ON.

The variance of the MSBLS elevation measurement is to be set equal to the design dependent parameter VAR_ELMLS (Section 4.9.3):

VAR = VAR_ELMLS

The elevation measurement partials are to be computed by using the function ANGLE_PARTIALS (Section 4.4.5.3) with $\underline{R}_{ELMLS}$ and the negative of the second row of the transformation matrix from $\overline{M50}$ to them MSBLS elevation radar coordinates as inputs:

CALL: ANGLE_PARTIALS

IN LIST: $\underline{R}_{ELMLS}$, $-M\_M50\_TO\_SCANNER_{2,\ 1\ to\ 3}$

The scale factor on the filter mean square residual used in the residual edit test, K_RES_EDIT, shall be set equal to K_EDIT_MLSEL, which is a premission load. STAT_FLAG shall be set equal to MSBLS_EL_INHIBIT.

Finally, the state vector and the covariance matrix will be updated as described in Section 4.3.2.7. After display data are saved for use by measurement processing statistics, STAT_FLAG shall be set to OFF.

B. Interface Requirements. The inputs and outputs for the MSBLS elevation measurement subfunction are given in Tables 4.3.2.7.7-1 and 4.3.2.7.7-2.

C. Processing Requirements. This subfunction will be performed at the basic filter rate after the state and covariance matrix have been propagated.

D. Constraints. This subfunction will be executed only if MSBLS elevation data are labeled valid (i.e., the MLSEL_DATA_GOOD flag is ON).

E. Supplementary Information. It is assumed that all vehicle-mounted MSBLS antennas are collocated.

A possible implementation of this subfunction is shown in flow charts RTLS_MLS_NAV CODE and RTLS_MLS_EL_NAV CODE in Section 5.2. Note that these two flow charts contain equations that are described in Section 4.3.2.7. RTLS MLS_NAV contains the setting of the filter control flags MANUAL_EDIT_OVERRIDE and STAT_FLAG to OFF; RTLS_MLS_EL_NAV contains the call to RTLS_NAV_FILTER and the setting of the display parameters $SENSOR\_EDIT_7$, $SENSOR\_RESID\_TEST_7$ and $SENSOR\_DELQ_7$ to EDIT_FLAG, RESID_TEST and DELQ, respectively.

Finally, the residual will be computed by

DELQ = Q_ELMLS - Q

If the estimated measurement, Q, is below a minimum angle cutoff, MSBLS_EL_ANGLE_CUTOFF, then MSBLS elevation data will no longer be used to update the state vector. This termination of state updating will be communicated to the RTLS measurement processing statistics subfunction by setting the flag MSBLS_EL_INHIBIT to ON.

The variance of the MSBLS elevation measurement is to be set equal to the design dependent parameter VAR_ELMLS (Section 4.9.3):

VAR = VAR_ELMLS

The elevation measurement partials are to be computed by using the function ANGLE_PARTIALS (Section 4.4.5.3) with $\underline{R}$_ELMLS and the negative of the second row of the transformation matrix from $\bar{M}50$ to them MSBLS elevation radar coordinates as inputs:

CALL: ANGLE_PARTIALS

IN LIST: $\underline{R}$_ELMLS, $-M\_M50\_TO\_SCANNER_{2,\ 1\ to\ 3}$

The scale factor on the filter mean square residual used in the residual edit test, K_RES_EDIT, shall be set equal to K_EDIT_MLSEL, which is a premission load. STAT_FLAG shall be set equal to MSBLS_EL_INHIBIT.

Finally, the state vector and the covariance matrix will be updated as described in Section 4.3.2.7. After display data are saved for use by measurement processing statistics, STAT_FLAG shall be set to OFF.

B. Interface Requirements. The inputs and outputs for the MSBLS elevation measurement subfunction are given in Tables 4.3.2.7.7-1 and 4.3.2.7.7-2.

C. Processing Requirements. This subfunction will be performed at the basic filter rate after the state and covariance matrix have been propagated.

D. Constraints. This subfunction will be executed only if MSBLS elevation data are labeled valid (i.e., the MLSEL_DATA_GOOD flag is ON).

E. Supplementary Information. It is assumed that all vehicle-mounted MSBLS antennas are collocated.

A possible implementation of this subfunction is shown in flow charts RTLS_MLS_NAV CODE and RTLS_MLS_EL_NAV CODE in Section 5.2. Note that these two flow charts contain equations that are described in Section 4.3.2.7. RTLS_MLS_NAV contains the setting of the filter control flags MANUAL_EDIT_OVERRIDE and STAT_FLAG to OFF; RTLS_MLS_EL_NAV contains the call to RTLS_NAV_FILTER and the setting of the display parameters $SENSOR\_EDIT_7$, $SENSOR\_RESID\_TEST_7$ and $SENSOR\_DELQ_7$ to EDIT_FLAG, RESID_TEST and DELQ, respectively.

Table 4.3.2.7.7-1. MSBLS Elevation Measurement Input Parameters

Description	Symbol	Input Sources	Type	Precision	Range	Units	Sample Rate
MSBLS deterministic bias elevation	BIAS_ELMLS	(b)	F	S		rad	Filter rate
Transformation matrix from earth-fixed to MSBLS elevation radar coordinates	M_EFTORAD_EL	(b)	M	S			Filter rate
Distance from navigation base to MLS antenna	MLSANT_NB_DIST	(a)	F	S		ft	Filter rate
Angle between navigation base-to-MLS antenna vector and positive vehicle X-body axis	MLSANT_ANG	(a)	F	S		rad	Filter rate
Copy of current data good discrete reserved for measurement processing	MLSEL_DATA_GOOD	RTLS control	D		OFF/ON		Filter rate
Copy of pitch-store reserved for MLS elevation processing	PITCH_M	RTLS sensor data snap	F	S		rad	Filter rate
MSBLS elevation sensor measurement	Q_ELMLS	RTLS sensor data snap	F	S		rad	Filter rate
Vehicle position vector used in measurement residual calculation after interpolation to time of measurement	R_RESID	State vector interpolation	V	DP		ft	Filter rate
Earth-fixed MLS elevation scanner position vector	R_ELMLS_EF	(b)	V	DP		ft	Filter rate
Time of tag of current MSBLS elevation measurement	T_EF_ELMLS	RTLS sensor data snap	F	DP		sec	Filter rate
MSBLS elevation instrument variance	VAR_ELMLS	(a)	F	S		rad^2	Filter rate
Filter current Shuttle position vector in M50 coordinates	R_FILT	RTLS state and covariance measurement incorporation	V	DP		ft	Filter rate
Minimum angle below which MSBLS data are not used to update state vector	MSBLS_EL_ANGLE_CUTOFF	I-load	F	S		rad	Filter rate
Current Shuttle velocity vector in M50 coordinates	V_FILT	RTLS state and covariance measurement incorporation	V	S		ft/sec	Filter rate

[a]See RTLS navigation principal function K-load table.
[b]See RTLS navigation principal function input parameter table.

Table 4.3.2.7.7-1. MSBLS Elevation Measurement Input Parameters (Cont)

Description	Symbol	Input Sources	Type	Precision	Range	Units	Sample Rate
Difference between accumulated sensed IMU readings on present and previous cycle	DV_FILT	RTLS nav state propagation	V	S		ft/sec	Filter rate
Gravity acceleration associated with current position vector	G_OLD	RTLS nav state propagation	V	S		ft/sec^2	Filter rate
Scale factor on filter mean square residual used in residual edit test for MSBLS elevation measurement	K_EDIT_MLSEL	(a)	F	S			Filter rate
Time of the filter state vector	T_LAST_FILT	RTLS nav state propagation	F	DP		sec	Filter rate
Interval over which the state is propagated	DT_FILT	RTLS nav state propagation	F	S		sec	Filter rate
Criterion for difference between measurement time and state time, above which the filter state will be interpolated	EPS_TAG	(a)	F	S		sec	Filter rate

[a]See RTLS navigation principal function K-load and constant tables.

Table 4.3.2.7.7-2. MSBLS Elevation Measurement Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Measurement first partial derivative with respect to filter state	B	RTLS state and covariance measurement incorporation	V	DP		vary	Filter rate
MLS elevation measurement residual	DELQ	RTLS state and covariance measurement incorporation	F	S		rad	Filter rate
General sensor variance	VAR	RTLS state and covariance measurement incorporation	F	S		rad^2	Filter rate
Scale factor on filter mean square residual used in residual edit test	K_RES_EDIT	RTLS state and covariance measurement incorporation	F	S			Filter rate
Flag indicating MSBLS elevation data processing is cutoff	MSBLS_EL_INHIBIT	RTLS measurement processing statistics	D	-	ON/OFF	-	Filter rate

Table 4.3.2.7.7-1. MSBLS Elevation Measurement Input Parameters (Cont)

Description	Symbol	Input Sources	Type	Precision	Range	Units	Sample Rate
Difference between accumulated sensed IMU readings on present and previous cycle	DV_FILT	RTLS nav state propagation	V	S		ft/sec	Filter rate
Gravity acceleration associated with current position vector	G_OLD	RTLS nav state propagation	V	S		ft/sec^2	Filter rate
Scale factor on filter mean square residual used in residual edit test for MSBLS elevation measurement	K_EDIT_MLSEL	(a)	F	S			Filter rate
Time of the filter state vector	T_LAST_FILT	RTLS nav state propagation	F	DP		sec	Filter rate
Interval over which the state is propagated	DT_FILT	RTLS nav state propagation	F	S		sec	Filter rate
Criterion for difference between measurement time and state time, above which the filter state will be interpolated	EPS_TAG	(a)	F	S		sec	Filter rate

[a]See RTLS navigation principal function K-load and constant tables.

Table 4.3.2.7.7-2. MSBLS Elevation Measurement Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Measurement first partial derivative with respect to filter state	H	RTLS state and covariance measurement incorporation	V	DP		very	Filter rate
MLS elevation measurement residual	DELQ	RTLS state and covariance measurement incorporation	F	S		rad	Filter rate
General sensor variance	VAR	RTLS state and covariance measurement incorporation	F	S		rad^2	Filter rate
Scale factor on filter mean square residual used in residual edit test	K_RES_EDIT	RTLS state and covariance measurement incorporation	F	S			Filter rate
Flag indicating MSBLS elevation data processing is cutoff	MSBLS_EL_INHIBIT	RTLS measurement processing statistics	B		ON OFF		Filter rate

4.3.2.8 Measurement Processing Statistics. During navigation phases that utilize external sensor measurements, the measurement processing statistics subfunction will compute for display certain parameters that are indicative of the condition of the navigation filter and the external sensor measurements that it utilizes. The measurement processing statistics subfunction will be performed as a subfunction of the RTLS navigation processing principal function. It will be performed after the corresponding state and covariance measurement incorporation subfunction has been performed. Filter edit indicators, which will have been initialized to a default value during the corresponding sensor measurement selection subfunction, will be redefined during the performance of the state and covariance measurement incorporation subfunction. This will indicate to the measurement processing statistics subfunction, for each measurement type being utilized, which of the following four cases has occurred: (1) edit indicator = OFF - the filter was not configured for the measurement type, or the data were bad and the filter did not attempt to process data of that type; (2) edit indicator = ON - the filter did attempt to process the measurement type but automatically edited the data; (3) edit indicator = PROCESSED - the filter did process the measurement type; or (4) edit indicator = STAT - the filter was used solely for producing the residual and ratio parameters for display.

Moreover, the state and covariance measurement incorporation subfunction will provide the measurement processing statistics subfunction with the value of each measurement residual and the square of the denominator of the display residual edit ratio, which is described in the following paragraphs. The data supplied to the measurement processing statistics subfunction can be used for two different purposes: (1) to calculate the status of the processing of the external sensor data and (2) to compute statistics for the sensor measurement type selected by the sensor measurement selection subfunction.

A. Detailed Requirements. The indexed variables have the following definitions:

$SENSOR\_EDIT_1$ is the edit indicator for the TACAN bearing measurement.
$SENSOR\_EDIT_2$ is the edit indicator for the TACAN range measurement.
$SENSOR\_EDIT_3$ is the edit indicator for the barometric altitude measurement.
$SENSOR\_EDIT_4$ is the edit indicator for the drag altitude measurement.
$SENSOR\_EDIT_5$ is the edit indicator for the MSBLS azimuth measurement.
$SENSOR\_EDIT_6$ is the edit indicator for the MSBLS range measurement.
$SENSOR\_EDIT_7$ is the edit indicator for the MSBLS elevation measurement.

For each TACAN, drag altitude, barometric altimeter, and MSBLS measurement type, three parameters are to be computed to show how well the navigation filter is processing external measurements of that particular type. The three parameters to be computed for each measurement are as follows:

1. The display measurement residual is to be the actual measurement residual computed by the navigation filter for the particular type, provided the navigation filter has done the computation (i.e., provided that the filter was configured to attempt processing of that

particular measurement type during the filter cycle just completed). If the filter was not configured for the measurement type, so that no residual was computed, then the display measurement residual for the particular measurement type shall be displayed as a BLANK in accordance with display requirements.

2. The display residual edit ratio is, for a particular measurement type, the absolute value of the actual measurement residual divided by the maximum magnitude that the residual for this measurement type may attain before automatic data editing in the filter occurs. Again, if the filter was not configured for the particular measurement, this display parameter shall be presented as BLANK.

3. The display edit history indicator, if displayed as the symbol "↓" on the cathode ray tube, shall indicate that for more than K_MAX times out of the last 4 times that the filter attempted to process the particular measurement type, automatic data editing occurred. Otherwise, this indicator shall be displayed as a BLANK. K_MAX is a pad-loaded integer such that $1 \leq K\_MAX < 4$.

The actual calculation of the three parameters above shall be accomplished as follows. To compute the display edit history indicators, it is necessary to retain edit information about the last 4 cycles for each measurement type. This will be accomplished by use of an MX4 matrix EDIT_ARRAY, where M represents the maximum number of measurement types to be managed by this subfunction during the various navigation phases. In the equations below, the following definitions are used.

$DISP\_DELQ_I$ = parameter (1) above for the I-th measurement type.

$DISP\_SIG_I$ = parameter (2) above for the I-th measurement type.

$DISP\_EDIT_I$ = parameter (3) above for the I-th measurement type.

$SENSOR\_EDIT_I$ = the filter edit indicator for the I-th measurement type.

$SENSOR\_DELQ_I$ = the filter measurement residual for the I-th measurement type.

$SENSOR\_RESID\_TEST_I$ = the square of the denominator of the display residual edit ratio for the I-th measurement type.

The correspondencee between the subscript, I, and measurement type shall be as follows:

I = 1 - TACAN bearing

I = 2 - TACAN range

I = 3 - barometric altitude

I = 4 - drag altitude

I = 5 - MSBLS azimuth

I = 6 - MSBLS range

I = 7 - MSBLS elevation

For each value of the integer I in the interval (1, 7), the following procedure will be performed.

The indicator $SENSOR\_EDIT_I$ shall be tested; and if found to have the value "OFF," both $DISP\_DELQ_I$ and $DISP\_SIG_I$ shall be given the value "BLANK" and the calculations shall cease at this point. If the value tested is not "OFF," then $DISP\_DELQ_I$ shall be given the value $SENSOR\_DELQ_I$ and $DISP\_SIG_I$ shall be calculated according to

$$DISP\_SIG_I = \frac{ABS(SENSOR\_DELQ_I)}{(SENSOR\_RESID\_TEST_I)^{1/2}} \qquad (F3,F4)$$

provided that $SENSOR\_RESID\_TEST_I$ is positive.

The $SENSOR\_EDIT_I$ indicator shall again be tested; and if found to have the value "STAT", $DISP\_EDIT_I$ shall be given the value "BLANK" and the calculations shall cease at this point. If the value tested is not "STAT," the column index, J_I, shall be incremented by 1 and reset to 1 if its value then should be 5. Next, the parameter SUM_I shall be determined as $SUM_I = SUM_I$ - EDIT_ARRAY (I, COLUMN), where COLUMN = J_I, and $SENSOR\_EDIT_I$ shall again be tested. If its value is "ON", then EDIT_ARRAY (I, COLUMN) shall be given the value one and SUM_I shall be incremented by one. If its value is not "ON", then EDIT_ARRAY (I, COLUMN) shall be set to zero. Finally, SUM_I shall be tested; and if its value exceeds the value K_MAX, $DISP\_EDIT_I$ shall be given the value "+"; otherwise, $DISP\_EDIT_I$ = BLANK.

The range residual, $DISP\_DELQ_2$, will be tested and if found to be not equal to BLANK, it shall be expressed in nautical miles by multiplying it by the conversion factor from feet to nautical miles. Thus,

IF $DISP\_DELQ_2 \neq$ BLANK

THEN $DISP\_DELQ_2 = DISP\_DELQ_2$ NAUTMI_PER_FT

F3 This should be treated in the same manner as floating point overflow (Section 3.5).

F4 The square root of a negative number should be treated in the same manner as floating point overflow (Section 3.5)

The three discretes, NAV_ALT_FLAG, NAV_TAC_FLAG, and NAV_MLS_FLAG, will be used to establish the value of the navigation event lamp indicator, NAV_EDIT_IND, and also to establish crew alerts on the Heads Up Display (HUD). These discretes indicate the status of the processing of the particular external sensor data indicated.

The Shuttle altitude, ALT, shall be tested, and if ALT < $ALT\_NAV\_EVLT_1$, then the discrete, DO_MLS_NAV, shall be tested. If this flag has the value of OFF, then TACAN and baro/drag altitude data processing will be tested. Otherwise, if DO_MLS_NAV has the value of ON, then the discretes, NAV_ALT_FLAG and NAV_TAC_FLAG, will be given the values of OFF.

The baro/drag altitude and TACAN data processing tests are as follows: First, if either $SENSOR\_EDIT_3$, or $SENSOR\_EDIT_4$ have the value 'PROCESSED', or H_INHIBIT has the value 'ON', then the discrete, NAV_ALT_FLAG, will be set to OFF and the sequential counter, N_SEQ_ALT, will be reset to the value N_SEQ_MAX-2. Otherwise, the sequential counter, N_SEQ_ALT, will be incremented by one. Then, if the value of this sequential counter exceeds the maximum allowable value, N_SEQ_MAX, or if either of the display edit history indicators, $DISP\_EDIT_3$, or $DISP\_EDIT_4$ indicate the symbol, "↓", then the discrete, NAV_ALT_FLAG, shall have the value of ON. Second, if $SENSOR\_EDIT_2$ = 'PROCESSED' and if either IN_CONE_FLAG = ON or $SENSOR\_EDIT_1$ = 'PROCESSED', then the discrete, NAV_TAC_FLAG, shall be given the value, 'OFF' and the sequential counter, N_SEQ_TAC, shall be initialized to one. Otherwise, the sequential counter, N_SEQ_TAC, shall be incremented by one and its value tested to see if it exceeds the maximum allowable value, N_SEQ_MAX. If this is true, or if either of the indicators, $DISP\_EDIT_1$ or $DISP\_EDIT_2$ indicate the symbol "↓" , then the discrete, NAV_TAC_FLAG shall be set to ON.

If ALT < $ALT\_NAV\_EVLT_1$, but independent of the value of DO_MLS_NAV, the processing of MSBLS data will be tested.

If each of $SENSOR\_EDIT_5$ and $SENSOR\_EDIT_6$ have the value PROCESSED and either SENSOR $EDIT_7$ has the value PROCESSED or MSBLS_EL_INHIBIT = ON, or if ALT WHEELS > $ALT\_NAV\_EVLT_2$ or MLS_AVAIL = OFF, then the discrete, NAV_MLS_FLAG, shall be given the value of OFF and the sequential counter, N_SEQ_MLS, shall be initialized to a value of N_SEQ_MAX 2. Otherwise, the sequential counter, N_SEQ_MLS, will be incremented by one and its value tested to see if it exceeds the maximum allowable value, N SEQ_MAX. If the value of N_SEQ_MLS does exceed the maximum, then the discrete, NAV MLS FLAG, will be set to ON.

Independent of altitude, the values of the three discretes, NAV_ALT_FLAG, NAV TAC FLAG, and NAV_MLS_FLAG, will be tested and if any have the value ON, the value of the discrete, NAV_EDIT_IND, shall be set to ON, otherwise it shall be set to OFF.

B Interface Requirements. Inputs and outputs are listed in Tables 4.3.2.8-1 and 4 3.2.8 2

C. Processing Requirements. None.

D. Constraints. The discretes, NAV_MLS_FLAG, NAV_ALT_FLAG, and NAV_TAC_FLAG, are required to be premission loaded to values of OFF and the integer N_SEQ shall be initialized to values of one.

E. Supplementary Information. A suggested implementation for this subfunction may be found in the detailed flow chart MEAS_PROCESSING_STATISTICS_RTLS of Section 5.2.

Table 4.3.2.8-1. RTLS Measurement Processing Statistics Input Parameters

Description	Symbol	Input Sources	Type	Precision	Range	Units	Sample Rate
Value of criterion used to set the edit history indicators	K_MAX	(a)	I	S			0.25
Measurement residual for TACAN bearing data	SENSOR_DELQ(1)	RTLS navigation state and covariance measurement incorporation	F	S		rad	0.25
Measurement residual for TACAN range data	SENSOR_DELQ(2)	RTLS navigation state and covariance measurement incorporation	F	S		ft	0.25
Measurement residual for baro altimeter	SENSOR_DELQ(3)	RTLS navigation state and covariance measurement incorporation	F	S		ft	0.25
Four-valued flag defining use of TACAN bearing data by the navigation filter. OFF - no processing attempted. ON - rejected by residual edit test. PROCESSED - used to update state vector. STAT - used for stat display purpose	SENSOR_EDIT(1)	RTLS navigation state and covariance measurement incorporation	Char				0.25
Four-valued flag defining use of TACAN range data by the navigation filter OFF - no processing attempted ON - rejected by residual edit test. PROCESSED - used to update state vector. STAT - used for stat display purpose	SENSOR_EDIT(2)	RTLS navigation state and covariance measurement incorporation	Char				0.25
Four-valued flag defining use of baro altimeter data by the navigation filter, OFF - no processing attempted, ON - rejected by residual edit test, PROCESSED - used to update state vector, STAT - used only for stat display purpose	SENSOR_EDIT(3)	RTLS navigation state and covariance measurement incorporation	Char				0.25
Four-valued flag defining use of drag altitude data by the navigation filter OFF - no processing attempted, ON - rejected by residual edit test, PROCESSED - used to update state vector. STAT - used only for stat display purpose	SENSOR_EDIT(4)	RTLS navigation state and covariance measurement incorporation	Char				0.25
Altitude to rear whee s	ALT WHEELS	(b)	F	S		ft	0.25
F ag indicating ON the availa bi i y f MSBLS transmitter at the current se ected runway	MLS_AVAIL	(b)	F		ON/OFF		0.25

[a]See RTLS nav gat on principal function I load table
[b]See RTLS nav gation principal function input parameter table

Table 4.3.2.8-1. RTLS Measurement Processing Statistics Input Parameters (Cont)

Description	Symbols	Input Sources	Type	Precision	Range	Units	Sample Rate
Flag indicating (ON) that MSBLS data are to be processed	DO_MLS_NAV	RTLS sensor select	D			OFF/ON	0.25
Four-valued flag defining use of MSBLS azimuth data by the navigation filter; OFF - no processing attempted; ON - rejected by residual edit test; PROCESSED - used to update state vector; STAT - used only for stat display purpose	SENSOR_EDIT(5)	RTLS navigation state and covariance measurement incorporation	Char				0.25
Four-valued flag defining use of MSBLS range data by the navigation filter; OFF - no processing attempted; ON - rejected by residual edit test; PROCESSED - used to update state vector. STAT - used only for stat display purpose	SENSOR_EDIT(6)	RTLS navigation state and covariance measurement incorporation	Char				0.25
Four-valued flag defining use of MSBLS elevation data by the navigation filter; OFF - no processing attempted; ON - rejected by residual edit test; PROCESSED - used to update state vector. STAT - used only for stat display purpose	SENSOR_EDIT(7)	RTLS navigation state and covariance measurement incorporation	Char				0.25
Value of criterion used in navigation filter for residual edit test for TACAN bearing measurement	SENSOR_RESID_TEST(1)	RTLS navigation state and covariance measurement incorporation	F	S		rad^2	0.25
Value of criterion used in navigation filter for residual edit test for TACAN range measurement	SENSOR_RESID_TEST(2)	RTLS navigation state and covariance measurement incorporation	F	S		ft^2	0.25
Value of criterion used in navigation filter for residual edit test for baro altimeter measurement	SENSOR_RESID_TEST(3)	RTLS navigation state and covariance measurement incorporation	F	S		ft^2	0.25
Flag indicating (ON) that the vehicle is in the cone of confusion for the current TACAN station	IN_CONE_FLAG	TACAN bearing measurement	D				0.25
Number of sequential failures of the test criteria allowed before activating the nav event lamp	N_SEQ_MAX	(b)	I	S			0.25
Altitude regions for nav event lamp processing	ALT_NAV_EVLT		V	S		ft	0.25
Feet to nautical miles conversion	NAUTMI_PER_FT	(a)	F	S		nmi/ft	0.25

[a]See RTLS navigation principal function K-load and constant tables.
[b]See RTLS navigation principal function input parameter table.

Table 4.3.2.8-1. RTLS Measurement Processing Statistics Input Parameters (Cont)

Description	Symbol	Input Sources	Type	Precision	Range	Units	Sample Rate
Current orbiter altitude above reference ellipsoid	ALT	(b)	F	S		ft	0.25
Measurement residual for drag altitude data	SENSOR_DELQ(4)	RTLS navigation state and covariance measurement incorporation	F	S		ft	0.25
Measurement residual for MSBLS azimuth data	SENSOR_DELQ(5)	RTLS navigation state and covariance measurement incorporation	F	S		rad	0.25
Measurement residual for MSBLS range data	SENSOR_DELQ(6)	RTLS navigation state and covariance measurement incorporation	F	S		ft	0.25
Measurement residual for MSBLS elevation data	SENSOR_DELQ(7)	RTLS navigation state and covariance measurement incorporation	F	S		rad	0.25
Value of criterion used in navigation filter for residual edit test for drag altitude measurement	SENSOR_RESID_TEST(4)	RTLS navigation state and covariance measurement incorporation	F	S		ft^2	0.25
Value of criterion used in navigation filter for residual edit test for MSBLS azimuth measurement	SENSOR_RESID_TEST(5)	RTLS navigation state and covariance measurement incorporation	F	S		rad^2	0.25
Value of criterion used in navigation filters for residual edit test for MSBLS range measurement	SENSOR_RESID_TEST(6)	RTLS navigation state and covariance measurement incorporation	F	S		ft^2	0.25
Value of criterion used in navigation filters for residual edit test for MSBLS elevation measurement	SENSOR_RESID_TEST(7)	RTLS navigation state and covariance measurement incorporation	F	S		rad^2	0.25
Flag indicating (ON) that altitude data have been inhibited because of an altitude constraint	H_INHIB	Sensor selection	D		ON/OFF		0.25

[b]See RTLS navigation principal function input parameter table.

Table 4.3.2.8-1. RTLS Measurement Processing Statistics Input Parameters (Cont)

Description	Symbol	Input Sources	Type	Precision	Range	Units	Sample Rate
Flag indicating (ON) that MSBLS_KL data state updates are inhibited	MSBLS_KL_INHIBIT	RTLS navigation state and covariance measurement incorporation	D		ON/OFF	-	Filter rate

Table 4.3.2.8-2. RTLS Measurement Processing Statistics Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Display measurement residual for TACAN bearing	DISP_DELQ(1)	(a)	F	S		rad	0.25
Display measurement residual for TACAN range	DISP_DELQ(2)	(a)	F	S		nmi	0.25
Display measurement residual for baro altimeter	DISP_DELQ(3)	(a)	F	S		ft	0.25
Display edit history indicator for TACAN bearing measurement	DISP_EDIT(1)	(a)	Char				0.25
Display edit history indicator for TACAN range measurement	DISP_EDIT(2)	(a)	Char				0.25
Display edit history indicator for baro altimeter measurement	DISP_EDIT(3)	(a)	Char				0.25
Display residual edit ratio for TACAN bearing	DISP_SIG(1)	(a)	F	S			0.25
Display residual edit ratio for TACAN range	DISP_SIG(2)	(a)	F	S			0.25
Display residual edit ratio for baro altimeter	DISP_SIG(3)	(a)	F	S			0.25
Display measurement residual for drag altitude	DISP_DELQ(4)	(a)	F	S		ft	0.25
Display measurement residual for MSBLS azimuth	DISP_DELQ(5)	(a)	F	S		rad	0.25
Display measurement residual for MSBLS range	DISP_DELQ(6)	(a)	F	S		ft	0.25
Display measurement residual for MSBLS elevation	DISP_DELQ(7)	(a)	F	S		rad	0.25
Display residual edit ratio for drag altitude	DISP_SIG(4)	(a)	F	S			0.25
Display residual edit ratio for MSBLS azimuth	DISP_SIG(5)	(a)	F	S			0.25
Display residual edit ratio for MSBLS range	DISP_SIG(6)	(a)	F	S			0.25
Display residual edit ratio for MSBLS elevation	DISP_SIG(7)	(a)	F	S			0.25

[a]See RTLS navigation principal function output parameter table.

Table 4.3.2.8-2. RTLS Measurement Processing Statistics Output Parameters (Cont)

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Display edit history indicator for drag altitude measurement	DISP_EDIT(4)	(a)	Char				0.25
Display edit history indicator for MSBLS azimuth measurement	DISP_EDIT(5)	(a)	Char				0.25
Display edit history indicator for MSBLS range measurement	DISP_EDIT(6)	(a)	Char				0.25
Display edit history indicator for MSBLS elevation	DISP_EDIT(7)	(a)	Char				0.25
Nav edit flag	NAV_EDIT_IND	(a)	D		OFF/ON		0.25
Nav edit altitude crew alert	NAV_ALT_FLAG	(a)	D		OFF/ON		0.25
Nav edit TACAN crew alert	NAV_TAC_FLAG	(a)	D		OFF/ON		0.25
Nav edit MSBLS crew alert	NAV_MLS_FLAG	(a)	D		OFF/ON		0.25

[a]See RTLS navigation principal function output parameter table.

4.3.2.9 RTLS Navigation (4.205) Principal Function Tables. The RTLS navigation principal function input and output parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.3.2.9-1 through 4.3.2.9-5.

The values for the I-loads are contained in the I-loads requirements document (JSC-19350).

Table 4.3.2.9-1. RTLS Navigation (4.205) Input/Output Functional Parameters

DBFM: D3B008-D PN: VP707100037P00L JULY 17, 1989
INPUT FUNCTIONAL PARAMETERS FOR RETURN TO LAUNCH SITE(RTLS) NAVIGATION

FSSR NAME	M/S ID	NOMENCLATURE	RTLS NAV SOURCE	UNITS	DATA TYPE	PREC
ACC_DRAG	V95A0160CA	DRAG DECEL				
ACC_PROP_MIM	V90A8938CA	ACC THRESHOLD TEST FOR STATE PROP	RTLS UPP			
ACC_PROP_MIN	V90A8938CB	ACC THRESHOLD TEST FOR STATE PROP	ASC NAV SEQ	FT/S2		
ADS_MJ	V95X3112X	ADS MACH JUMP FLAG	A/RTLS NAV SEQ	FT/S2		
ALPHA_M	V90H2246C	NAV DERIVED ANGLE OF ATTACK	ADTA SOP		BD	
ALT	V95H0175CA	CURR ORB ALT ABOVE REF ELLIPSOID	A/E ATT PROC	DEG	SPL	
ALT_DG	V95X3111X	PRESSURE ALTITUDE DATA GOOD FLAG	RTLS UPP	KFT		
ALT_WHEELS	V95H0165CA	ALT TO REAR WHEELS/NAV BASE(ENTRY)	ADTA SOP		BD	
ANGLE_CORR_TNTOMAG_S1	V90H1843CB	MAGNETIC VARIATION AT TACAN 1 SITE	RTLS UPP	FT		
ANGLE_CORR_TNTOMAG_S2	V90H1844CB	MAGNETIC VARIATION AT TACAN 2 SITE	ASC SITE LOOKUP	RAD		
ANGLE_CORR_TNTOMAG_S3	V90H1845CB	MAGNETIC VARIATION AT TACAN 3 SITE	ASC SITE LOOKUP	RAD		
BARO_AIF	V93J4473C	ADTA A/I/F EDIT CMD	ASC SITE LOOKUP	RAD		
BETA_N	V90H2249C	INERTIAL SIDESLIP ANGLE	6.21		HXS	
BIAS_AZMLS	V90H1886CB	MSBLS AZIMUTH MEASUREMENT BIAS	A/E ATT PROC	DEG	SPL	
BIAS_ELMLS	V90H1887CB	MSBLS ELEVATION MEASUREMENT BIAS	ASC SITE LOOKUP	RAD		
BIAS_RMLS	V90H1885CB	MSBLS RANGE MEASUREMENT BIAS	ASC SITE LOOKUP	RAD		
DELH_MSL_ELLIPSOID_RW	V90H1819CB	ALT OF MSL ABOVE REF ELLIP AT RW	ASC SITE LOOKUP	FT		
DO_DELTA_UPDATE	V93X5030X	UPDATE DELTAS CMD	ASC SITE LOOKUP	FT		
DO_DELTA_UPDATE_UP	V91X8894X	DO DELTA STATE UPDATE UPLINK CMD	6.21		BD	
DR_RW(1)	V93H5010CA	NAV UPDATE DELTA X POSITION	SYS S/W			
DR_RW(2)	V93H5011CA	NAV UPDATE DELTA Y POSITION	6.21	FT		
DR_RW(3)	V93H5012CA	NAV UPDATE DELTA Z POSITION	6.21	FT		
DR_RW_UP	V96U8554CB	NAV UPDATE DELTA X POS UPLINK CMD	6.21	FT		
DRAG_CONST	V90U8937CA	ACC MODEL DRAG CONST FOR ST PROP	SYS S/W	FT		
DRAG_CONST	V90U8937CB	ACC MODEL DRAG CONST FOR ST PROP	ASC NAV SEQ	FT2/SLUG		
DV_RW(1)	V93L5020CA	NAV UPDATE DELTA X VELOCITY	A/RTLS NAV SEQ	FT2/SLUG		
DV_RW(2)	V93L5021CA	NAV UPDATE DELTA Y VELOCITY	6.21	FT/S		
DV_RW(3)	V93L5022CA	NAV UPDATE DELTA Z VELOCITY	6.21	FT/S		
DV_RW_UP	V96U8557CB	NAV UPDATE DELTA X VEL UPLINK CMD	6.21	FT/S		
E(1-1)	V90U0650CB	COVARIANCE MATRIX ELEMENT 1-1	SYS S/W	FT/S		
E(1-2)	V90U0651CB	COVARIANCE MATRIX ELEMENT 1-2	A/RTLS NAV SEQ			
E(1-3)	V90U0652CB	COVARIANCE MATRIX ELEMENT 1-3	A/RTLS NAV SEQ			
E(1-4)	V90U0653CB	COVARIANCE MATRIX ELEMENT 1-4	A/RTLS NAV SEQ			
E(1-5)	V90U0654CB	COVARIANCE MATRIX ELEMENT 1-5	A/RTLS NAV SEQ			
E(1-6)	V90U0655CB	COVARIANCE MATRIX ELEMENT 1-6	A/RTLS NAV SEQ			
E(2-1)	V90U0656CB	COVARIANCE MATRIX ELEMENT 2-1	A/RTLS NAV SEQ			
E(2-2)	V90U0657CB	COVARIANCE MATRIX ELEMENT 2-2	A/RTLS NAV SEQ			
E(2-3)	V90U0658CB	COVARIANCE MATRIX ELEMENT 2-3	A/RTLS NAV SEQ			
E(2-4)	V90U0659CB	COVARIANCE MATRIX ELEMENT 2-4	A/RTLS NAV SEQ			
E(2-5)	V90U0660CB	COVARIANCE MATRIX ELEMENT 2-5	A/RTLS NAV SEQ			
E(2-6)	V90U0661CB	COVARIANCE MATRIX ELEMENT 2-6	A/RTLS NAV SEQ			
E(3-1)	V90U0662CB	COVARIANCE MATRIX ELEMENT 3-1	A/RTLS NAV SEQ			
E(3-2)	V90U0663CB	COVARIANCE MATRIX ELEMENT 3-2	A/RTLS NAV SEQ			
E(3-3)	V90U0664CB	COVARIANCE MATRIX ELEMENT 3-3	A/RTLS NAV SEQ			
E(3-4)	V90U0665CB	COVARIANCE MATRIX ELEMENT 3-4	A/RTLS NAV SEQ			
E(3-5)	V90U0666CB	COVARIANCE MATRIX ELEMENT 3-5	A/RTLS NAV SEQ			
E(3-6)	V90U0667CB	COVARIANCE MATRIX ELEMENT 3-6	A/RTLS NAV SEQ			
E(4-1)	V90U0668CB	COVARIANCE MATRIX ELEMENT 4-1	A/RTLS NAV SEQ			
E(4-2)	V90U0669CB	COVARIANCE MATRIX ELEMENT 4-2	A/RTLS NAV SEQ			
E(4-3)	V90U0670CB	COVARIANCE MATRIX ELEMENT 4-3	A/RTLS NAV SEQ			
E(4-4)	V90U0671CB	COVARIANCE MATRIX ELEMENT 4-4	A/RTLS NAV SEQ			
E(4-5)	V90U0672CB	COVARIANCE MATRIX ELEMENT 4-5	A/RTLS NAV SEQ			

CR89805

Space Transportation Systems Division
Rockwell International

Table 4.3.2.9-1. RTLS Navigation (4.205) Input/Output Functional Parameters (Cont)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
E(4-6)	V90U0673CB	COVARIANCE MATRIX ELEMENT 4-6	A/RTLS NAV SEQ			
E(5-1)	V90U0674CB	COVARIANCE MATRIX ELEMENT 5-1	A/RTLS NAV SEQ			
E(5-2)	V90U0675CB	COVARIANCE MATRIX ELEMENT 5-2	A/RTLS NAV SEQ			
E(5-3)	V90U0676CB	COVARIANCE MATRIX ELEMENT 5-3	A/RTLS NAV SEQ			
E(5-4)	V90U0677CB	COVARIANCE MATRIX ELEMENT 5-4	A/RTLS NAV SEQ			
E(5-5)	V90U0678CB	COVARIANCE MATRIX ELEMENT 5-5	A/RTLS NAV SEQ			
E(5-6)	V90U0679CB	COVARIANCE MATRIX ELEMENT 5-6	A/RTLS NAV SEQ			
E(6-1)	V90U0680CB	COVARIANCE MATRIX ELEMENT 6-1	A/RTLS NAV SEQ			
E(6-2)	V90U0681CB	COVARIANCE MATRIX ELEMENT 6-2	A/RTLS NAV SEQ			
E(6-3)	V90U0682CB	COVARIANCE MATRIX ELEMENT 6-3	A/RTLS NAV SEQ			
E(6-4)	V90U0683CB	COVARIANCE MATRIX ELEMENT 6-4	A/RTLS NAV SEQ			
E(6-5)	V90U0684CB	COVARIANCE MATRIX ELEMENT 6-5	A/RTLS NAV SEQ			
E(6-6)	V90U0685CB	COVARIANCE MATRIX ELEMENT 6-6	A/RTLS NAV SEQ			
HPC	V95H3001C	ADS CORRECTED PRESSURE ALTITUDE	ADTA SOP	FT	SPL	
IN_CONE_FLAG	V90X3598X	INSIDE CONE FLAG	TACAN RM			
M_EFTORAD_EL(1-1)	V90U1875CB	EF TO MSBLS EL COORD, ELE 1-1	ASC SITE LOOKUP			
M_EFTORAD_EL(1-2)	V90U1876CB	EF TO MSBLS EL COORD, ELE 1-2	ASC SITE LOOKUP			
M_EFTORAD_EL(1-3)	V90U1877CB	EF TO MSBLS EL COORD, ELE 1-3	ASC SITE LOOKUP			
M_EFTORAD_EL(2-1)	V90U1878CB	EF TO MSBLS EL COORD, ELE 2-1	ASC SITE LOOKUP			
M_EFTORAD_EL(2-2)	V90U1879CB	EF TO MSBLS EL COORD, ELE 2-2	ASC SITE LOOKUP			
M_EFTORAD_EL(2-3)	V90U1880CB	EF TO MSBLS EL COORD, ELE 2-3	ASC SITE LOOKUP			
M_EFTORAD_EL(3-1)	V90U1881CB	EF TO MSBLS EL COORD, ELE 3-1	ASC SITE LOOKUP			
M_EFTORAD_EL(3-2)	V90U1882CB	EF TO MSBLS EL COORD, ELE 3-2	ASC SITE LOOKUP			
M_EFTORAD_EL(3-3)	V90U1883CB	EF TO MSBLS EL COORD, ELE 3-3	ASC SITE LOOKUP			
M_EFTORAD_R_AZ(1-1)	V90U1865CB	EF TO RNG/AZ MSBLS RDR COORD/1-1	ASC SITE LOOKUP			
M_EFTORAD_R_AZ(1-2)	V90U1866CB	EF TO RNG/AZ MSBLS RDR COORD/1-2	ASC SITE LOOKUP			
M_EFTORAD_R_AZ(1-3)	V90U1867CB	EF TO RNG/AZ MSBLS RDR COORD/1-3	ASC SITE LOOKUP			
M_EFTORAD_R_AZ(2-1)	V90U1868CB	EF TO RNG/AZ MSBLS RDR COORD/2-1	ASC SITE LOOKUP			
M_EFTORAD_R_AZ(2-2)	V90U1869CB	EF TO RNG/AZ MSBLS RDR COORD/2-2	ASC SITE LOOKUP			
M_EFTORAD_R_AZ(2-3)	V90U1870CB	EF TO RNG/AZ MSBLS RDR COORD/2-3	ASC SITE LOOKUP			
M_EFTORAD_R_AZ(3-1)	V90U1871CB	EF TO RNG/AZ MSBLS RDR COORD/3-1	ASC SITE LOOKUP			
M_EFTORAD_R_AZ(3-2)	V90U1872CB	EF TO RNG/AZ MSBLS RDR COORD/3-2	ASC SITE LOOKUP			
M_EFTORAD_R_AZ(3-3)	V90U1873CB	EF TO RNG/AZ MSBLS RDR COORD/3-3	ASC SITE LOOKUP			
M_EFTORW(1-1)	V90U1805CB	EF TO PRIME RW XFORM MTRX ELE 1-1	ASC SITE LOOKUP			
M_EFTORW(1-2)	V90U1806CB	EF TO PRIME RW XFORM MTRX ELE 1-2	ASC SITE LOOKUP			
M_EFTORW(1-3)	V90U1807CB	EF TO PRIME RW XFORM MTRX ELE 1-3	ASC SITE LOOKUP			
M_EFTORW(2-1)	V90U1808CB	EF TO PRIME RW XFORM MTRX ELE 2-1	ASC SITE LOOKUP			
M_EFTORW(2-2)	V90U1809CB	EF TO PRIME RW XFORM MTRX ELE 2-2	ASC SITE LOOKUP			
M_EFTORW(2-3)	V90U1810CB	EF TO PRIME RW XFORM MTRX ELE 2-3	ASC SITE LOOKUP			
M_EFTORW(3-1)	V90U1811CB	EF TO PRIME RW XFORM MTRX ELE 3-1	ASC SITE LOOKUP			
M_EFTORW(3-2)	V90U1812CB	EF TO PRIME RW XFORM MTRX ELE 3-2	ASC SITE LOOKUP			
M_EFTORW(3-3)	V90U1813CB	EF TO PRIME RW XFORM MTRX ELE 3-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(1-1)	V90U1775CB	EF TO TOPO COORD AT TA SITE 1/1-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(1-2)	V90U1776CB	EF TO TOPO COORD AT TA SITE 1/1-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(1-3)	V90U1777CB	EF TO TOPO COORD AT TA SITE 1/1-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(2-1)	V90U1778CB	EF TO TOPO COORD AT TA SITE 1/2-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(2-2)	V90U1779CB	EF TO TOPO COORD AT TA SITE 1/2-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(2-3)	V90U1780CB	EF TO TOPO COORD AT TA SITE 1/2-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(3-1)	V90U1781CB	EF TO TOPO COORD AT TA SITE 1/3-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(3-2)	V90U1782CB	EF TO TOPO COORD AT TA SITE 1/3-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(3-3)	V90U1783CB	EF TO TOPO COORD AT TA SITE 1/3-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(1-1)	V90U1784CB	EF TO TOPO COORD AT TA SITE 2/1-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(1-2)	V90U1785CB	EF TO TOPO COORD AT TA SITE 2/1-2	ASC SITE LOOKUP			

Space Transportation Systems Division
Rockwell International

Table 4.3.2.9-1. RTLS Navigation (4.205) Input/Output Functional Parameters (Cont)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
M_EFTOTD_TACAN_SL2(1-3)	V90U1786CB	EF TO TOPO COORD AT TA SITE 2/1-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(2-1)	V90U1787CB	EF TO TOPO COORD AT TA SITE 2/2-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(2-2)	V90U1788CB	EF TO TOPO COORD AT TA SITE 2/2-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(2-3)	V90U1789CB	EF TO TOPO COORD AT TA SITE 2/2-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(3-1)	V90U1790CB	EF TO TOPO COORD AT TA SITE 2/3-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(3-2)	V90U1791CB	EF TO TOPO COORD AT TA SITE 2/3-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(3-3)	V90U1792CB	EF TO TOPO COORD AT TA SITE 2/3-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(1-1)	V90U1793CB	EF TO TOPO COORD AT TA SITE 3/1-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(1-2)	V90U1794CB	EF TO TOPO COORD AT TA SITE 3/1-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(1-3)	V90U1795CB	EF TO TOPO COORD AT TA SITE 3/1-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(2-1)	V90U1796CB	EF TO TOPO COORD AT TA SITE 3/2-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(2-2)	V90U1797CB	EF TO TOPO COORD AT TA SITE 3/2-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(2-3)	V90U1798CB	EF TO TOPO COORD AT TA SITE 3/2-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(3-1)	V90U1799CB	EF TO TOPO COORD AT TA SITE 3/3-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(3-2)	V90U1800CB	EF TO TOPO COORD AT TA SITE 3/3-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(3-3)	V90U1801CB	EF TO TOPO COORD AT TA SITE 3/3-3	ASC SITE LOOKUP			
MLS_AVAIL	V90X3720XB	MLS AVAILABILITY	ASC SITE LOOKUP			
MLSAZ_DATA_GOOD	V90X3003X	MSBLS AZIMUTH DATA GOOD	SF		BD	
MLSEL_DATA_GOOD	V90X3033X	MSBLS ELEVATION DATA GOOD	SF		BD	
MLSRANGE_DATA_GOOD	V90X3063X	MSBLS RANGE DATA GOOD	SF		BD	
MSBAZIMTIM	V95W6010C	MSBLS AZIMUTH MEASUREMENT TIME	MSBLS SOP	S	DPL	
MSBELEVTIM	V95W6020C	MSBLS ELEVATION MEASUREMENT TIME	MSBLS SOP	S	DPL	
MSBRANGTIM	V95W6000C	MSBLS RANGE MEASUREMENT TIME	MSBLS SOP	S	DPL	
OUT_BRG_DG	V90X3591X	BEARING DATA GOOD	TACAN RM		BD	
OUT_RNG_DG	V90X3593X	RANGE DATA GOOD	TACAN RM		BD	
OUT_SEL_BRG	V90H3590C	SELECTED BEARING DATA	TACAN RM	DEG	DPL	
OUT_SEL_RNG	V90H3592C	SELECTED RANGE DATA	TACAN RM	FT	DPL	
R_AZMLS_EF(1)	V90H1828CB	X-COMP EF POS VCT OF MLS AZ ANT	ASC SITE LOOKUP			
R_AZMLS_EF(2)	V90H1829CB	Y-COMP EF POS VCT OF MLS AZ ANT	ASC SITE LOOKUP			
R_AZMLS_EF(3)	V90H1830CB	Z-COMP EF POS VCT OF MLS AZ ANT	ASC SITE LOOKUP			
R_COV_LAST(1)	V90H0581CB	X-COMP OF POS VCT W CURR COV MTRX	ASC NAV	FT		
R_COV_LAST(2)	V90H0582CB	Y-COMP OF POS VCT W CURR COV MTRX	ASC NAV	FT		
R_COV_LAST(3)	V90H0583CB	Z-COMP OF POS VCT W CURR COV MTRX	ASC NAV	FT		
R_ELMLS_EF(1)	V90H1825CB	X-COMP EF POS VCT MLS ELEV ANT	ASC SITE LOOKUP	FT		
R_ELMLS_EF(2)	V90H1826CB	Y-COMP EF POS VCT MLS ELEV ANT	ASC SITE LOOKUP	FT		
R_ELMLS_EF(3)	V90H1827CB	Z-COMP EF POS VCT MLS ELEV ANT	ASC SITE LOOKUP	FT		
R_FILT(1)	V90H0584CA	X-COMP OF FLTR'S CURR POS VECTOR	ASC NAV	FT		
R_FILT(2)	V90H0585CA	Y-COMP OF FLTR'S CURR POS VECTOR	ASC NAV	FT		
R_FILT(3)	V90H0586CA	Z-COMP OF FLTR'S CURR POS VECTOR	ASC NAV	FT		
R_RMLS_EF(1)	V90H1831CB	X-COMP EF POS VCT OF MLS RNG ANT	ASC SITE LOOKUP			
R_RMLS_EF(2)	V90H1832CB	Y-COMP EF POS VCT OF MLS RNG ANT	ASC SITE LOOKUP			
R_RMLS_EF(3)	V90H1833CB	Z-COMP EF POS VCT OF MLS RNG ANT	ASC SITE LOOKUP			
R_TACAN_EFSL1(1)	V90H1834CB	X-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP	FT		
R_TACAN_EFSL1(2)	V90H1835CB	Y-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP	FT		
R_TACAN_EFSL1(3)	V90H1836CB	Z-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP	FT		
R_TACAN_EFSL2(1)	V90H1837CB	X-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP	FT		
R_TACAN_EFSL2(2)	V90H1838CB	Y-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP	FT		
R_TACAN_EFSL2(3)	V90H1839CB	Z-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP	FT		
R_TACAN_EFSL3(1)	V90H1840CB	X-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP	FT		
R_TACAN_EFSL3(2)	V90H1841CB	Y-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP	FT		
R_TACAN_EFSL3(3)	V90H1842CB	Z-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP	FT		
REL_VEL_MAG/V	V95L0151CA	GND REL VEL MAGNITUDE IN M50 SYS	RTLS UPP	FT/S		
SEL_LRU_ID	V90J3595C	SELECTED LRU ID	TACAN RM			

Space Transportation Systems Division
Rockwell International

Table 4.3.2.9-1. RTLS Navigation (4.205) Input/Output Functional Parameters
(Cont)

DBFN: D3B008-D PN: VP707100037P00L JULY 17, 1989
INPUT FUNCTIONAL PARAMETERS FOR RETURN TO LAUNCH SITE(RTLS) NAVIGATION RTLS NAV OI8D REV00 G4.205

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	PRE DATA TYPE C
SEL_V_M50(1)	V90L2557C	SEL TOTAL X VEL M50	IMU RM	FT/S	DPL
SEL_V_M50(2)	V90L2558C	SEL TOTAL Y VEL M50	IMU RM	FT/S	DPL
SEL_V_M50(3)	V90L2559C	SEL TOTAL Z VEL M50	IMU RM	FT/S	DPL
SQ_AZRLS	V95H6021C	SELECTED MSBLS AZIMUTH-SCLD	MSBLS SOP	RAD	
SQ_ELMLS	V95H6022C	SELECTED MSBLS ELEVATION-SCLD	MSBLS SOP	RAD	
SQ_RANGE	V95H6023C	SELECTED MSBLS RANGE-SCLD	MSBLS SOP	FT	
T_APC	V95W3400C	ADS CORRECTED PRESS ALT TIME TAG	ADTA SOP	S	DPL
T_IMUS	V95W0002C	IMU INPUT TRANS TIME TAG	IMU INT PROC	S	DPL
T_LAST_FILT	V90W8522CA	TIME OF FILTER STATE VECTOR	ASC NAV SEQ	S	
T_LAST_FILT	V90W8522CB	TIME OF FILTER STATE VECTOR	ASC NAV	S	
T_TACAN	V90W3596CB	TACAN TIME TAG	TACAN SOP	S	
TACAN_AIF	V93J4470C	TAC A/I/F EDIT CMD	6.21		HXS
TACAN_CHAN_VALID_SL1	V90X1858XB	TACAN CHANNEL VALIDITY FLAG(TAC 1)	ASC SITE LOOKUP		
TACAN_CHAN_VALID_SL2	V90X1859XB	TACAN CHANNEL VALIDITY FLAG(TAC 2)	ASC SITE LOOKUP		
TACAN_CHAN_VALID_SL3	V90X1860XB	TACAN CHANNEL VALIDITY FLAG(TAC 3)	ASC SITE LOOKUP		
TACAN_ID(1)	V90U1802CB	TACAN 1 GND STA CHAN	ASC SITE LOOKUP		
TACAN_ID(2)	V90U1803CB	TACAN 2 GND STA CHAN	ASC SITE LOOKUP		
TACAN_ID(3)	V90U1804CB	TACAN 3 GND STA CHAN	ASC SITE LOOKUP		
THETA	V90H2217C	BODY PITCH ATTITUDE EULER ANGLE	A/E ATT PROC	DEG	SPL
V_FILT(1)	V90L0624CA	X-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV	FT/S	
V_FILT(2)	V90L0625CA	Y-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV	FT/S	
V_FILT(3)	V90L0626CA	Z-COMP OF FLTR'S CURR VEL VECTOR	ASC NAV	FT/S	
V_LAST_FILT(1)	V90L0621CA	X-COMP VEL W COV MTRX & FLTR UPDTE	ASC NAV	FT/S	
V_LAST_FILT(2)	V90L0622CA	Y-COMP VEL W COV MTRX & FLTR UPDTE	ASC NAV	FT/S	
V_LAST_FILT(3)	V90L0623CA	Z-COMP VEL W COV MTRX & FLTR UPDTE	ASC NAV	FT/S	
	V93J5013C	DRAG H A/I/F EDIT CMD	6.21		HXS
	V96U8555CB	NAV UPDATE DELTA Y POS UPLINK CMD	SYS S/W	FT	
	V96U8556CB	NAV UPDATE DELTA Z POS UPLINK CMD	SYS S/W	FT	
	V96U8558CB	NAV UPDATE DELTA Y VEL UPLINK CMD	SYS S/W	FT/S	
	V96U8559CB	NAV UPDATE DELTA Z VEL UPLINK CMD	SYS S/W	FT/S	

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
			TLM			
ACC_DRAG_SNAP	V90A8899C	SNAPPED DRAG DECEL ALPHA IN	TLM			
ALPHA_SNAP	V90U8932CB	SNAPPED CONVERTED ALPHA IN	TLM			
ALT_SNAP	V90H8897C	SNAPPED ALT ABOVE FISHER ELLIPSOID	TLM			
ALT_WHEELS_SNAP	V90H8898C	SNAPPED ALT WHEELS ABOVE RW	TLM			
BARO_AIF_RCVD	V90J0227CA	BARO AUT/INH FOR FLAG FDBK	TLM			
BARO_DATA_GOOD	V90X8861XA	DATA SNAP-ADTA DATA GOOD FLAG	TLM			
BARO_MARK_NUM	V90J8843CA	COUNTER-BARO MEAS BEING PROCESSED	TLM			
BETA	V90U8933CB	SNAPPED CONVERTED BETA IN	6.21,TLM	RAD		
DISP_DELS 1	V90H0212CA	TAC AZ OPTICS H X/AZ MEAS RESIDUAL	6.21,TLM	NM		
DISP_DELS 2	V90H0214CA	TAC R OPTICS V/Y/EL MEAS RESIDUAL	6.21,TLM	FT		
DISP_DELS 3	V90H0221CA	BARO ALT RR RNG MEAS RESIDUAL	6.21,TLM	FT		
DISP_DELS 4	V90A8711CB	DRAG ALT RR R DOT MEAS RESIDUAL	TLM			
DISP_DELS 5	V90U0223CB	MSBLS AZ SHAFT RATE MEAS RESIDUAL	TLM			
DISP_DELS 6	V90U0221CB	MSBLS R/TRUN RATE MEAS RESIDUAL	TLM			
DISP_DELS 7	V90U0223CB	MSBLS EL MEAS RESIDUAL	6.21,TLM			
DISP_SIG 1	V90H1123CA	TAC AZ/OPTICS H X/AZ EDIT MIST IND	6.21,TLM			
DISP_SIG 2	V90H1124CA	TAC R OPTICS V/Y EL EDIT MIST IND	6.21,TLM			
DISP_SIG 3	V90H1123CA	BARO ALT RR RNG EDIT MIST IND	6 21,TLM			
DISP_SIG 4	V90A1123CB	DRAG ALT/RR R DOT EDIT MIST IND	TLM			
DISP_SIG 5	V90U1223CB	MSBLS AZ/SHAFT RATE EDIT MIST IND	TLM			
DISP_SIG 6	V90U1221CB	MSBLS R/TRUN RATE EDIT MIST IND	TLM			
DISP_SIG 7	V90U1221CB	MSBLS EL EDIT MIST IND	6 21,TLM			
DO_BARO_NAV	V90U0121CA	TAC AZ/OPTICS H X/AZ RESID RATIO	6 21,TLM			
DO_DRAG_NAV	V90U0121 CA	TAC R/OPTICS V/Y/EL RESID RATIO	6 21,TLM			
DO_M S_NAV	V90U0222CA	BARO ALT/RR RNG RESID RATIO	6 21,TLM			
DO_TACAN_NAV	V90U0 123CB	DRAG ALT/RR R DOT RESID RATIO	TLM			
DR_RW(1)	V90U0253CB	MSB S AZ/SHAFT RATE RESID RATIO	TLM			
DR_RW(2)	V90U0254CB	MSBLS R/TRUN RATE RESID RATIO	TLM			
DR_RW(3)	V90U0255CB	MSBLS EL RESID RATIO	TLM			
DRAG_AIF_RCVD	V90X0259XB	FLAG IND BARO A T BEING PROCESSED	TLM			
DRAG_MARK_NUM	V90U8847CA	FLAG IND DRAG A T BEING PROCESSED	TLM			
DV_RW(1)	V90X0234XB	FLAG IND M S BEING PROCESSED	TLM			
DV_RW(2)	V90U8846CA	FLG IND TACAN DATA BEING PROCESSED	6.21	FT		
DV_RW(3)	V93H5010CD	NAV UPDATE DELTA X POSITION	6.21	FT		
ELEV_ANG	V93H5011CD	NAV UPDATE DELTA Y POSITION	6.21	FT		
FCME_DU(1,1)/E(1,1)	V93H5012CD	NAV UPDATE DELTA Z POSITION	6.21,TLM			
FCME_DU(2,2)/E(2,2)	V90J0714CB	DRAG H A/I/F EDIT IND	TLM			
FCME_DU(3,3)/E(3,3)	V90J8844CA	COUNTER-DRAG MEAS BEING PROCESSED	6.21	FT/S		
FCME_DU(4,4)/E(4,4)	V93L5020CD	NAV UPDATE DELTA X VELOCITY	6.21	FT/S		
FCME_DU(5,5)/E(5,5)	V93L5021CD	NAV UPDATE DELTA Y VELOCITY	6.21	FT/S		
FCME_DU(6,6)/E(6,6)	V93L5022CD	NAV UPDATE DELTA Z VELOCITY	TLM			
FI_T_UPDATE	V90U0720CC	TACAN/SHUTTLE ELEV ANG	TLM			
G_RESET 1)	V90U8887C	DIAG OF UPDATED FILT COV MAT(1,1)	TLM			
G_RESET(2)	V90U8888C	DIAG OF UPDATED FILT COV MAT(2,2)	TLM			
G_RESET 3)	V90U8889C	DIAG OF UPDATED FILT COV MAT(3,3)	TLM			
	V90U8890C	DIAG OF UPDATED FILT COV MAT(4,4)	TLM			
	V90U8891C	DIAG OF UPDATED FILT COV MAT(5,5)	TLM			
	V90U8892C	DIAG OF UPDATED FILT COV MAT(6,6)	TLM			
	V90X0224XG	FLAG IND NAV FILTER PROC COMPLETE	RTLS UPP,TLM			
	V90A0243CF	SEL X COMP OF GRAV ACCEL VCTR RST	RTLS UPP,TLM	FT/S2		
	V90A0244CF	SEL Y COMP OF GRAV ACCEL VCTR RST	RTLS UPP,TLM	FT/S2		
	V90A0245CF	SEL Z COMP OF GRAV ACCEL VCTR RST	RTLS UPP,TLM	FT/S2		

Table 4.3.2.9-1. RTLS Navigation (4.205) Input/Output Functional Parameters (Cont)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
GM_DEG	V90A8896C	ACCEL GRAV MODEL SPHER HARM DEG	TLM			
GM_ORD	V90A8895C	ACCEL GRAV MODEL SPHER HARM ORD	TLM			
MLS_MARK_NUM	V90J0242CB	COUNTER-MLS MEAS BEING PROCESSED	TLM			
MLSAZ_DATA_GOOD	V90X0275XB	SNAPPED MLS AZIMUTH DATA GOOD	TLM			
MLSEL_DATA_GOOD	V90X0274XB	SNAPPED MLS ELEVATION DATA GOOD	TLM			
MLSRANGE_DATA_GOOD	V90X0273XB	SNAPPED MLS RANGE DATA GOOD	TLM			
NAV_ALT_FLAG	V90X8901XC	NAV EDIT ALTITUDE CREW ALERT	E/L EV AN PROC,HUD PROC			
NAV_EDIT_IND	V95X0305XC	NAV EDIT INDICATOR FLAG	TLM			
NAV_MLS_FLAG	V90X8903XC	NAV EDIT MSBLS CREW ALERT	HUD PROC			
NAV_TAC_FLAG	V90X8902XC	NAV EDIT TACAN CREW ALERT	E/L EV AN PROC,HUD PROC			
ONE_BRG_LOCK	V90X0769XC	TACAN RM 1 LRU BRG LOCKON RQMT FLG	TACAN RM			
ONE_RNG_LOCK	V90X0768XC	TACAN RM 1 LRU RNG LOCKON RQMT FLG	TACAN RM			
PITCH_M	V90H8894C	SNAPPED VEHICLE PITCH ANGLE	TLM			
Q_AZMLS	V90H0265CB	SNAPPED SELECTED MLS AZIMUTH	TLM			
Q_BARO	V90P8871CA	DATA SNAP-ADS CORR PRESSURE ALT	TLM			
Q_DRAG	V90U8848CA	DRAG MEASUREMENT	TLM			
Q_ELMLS	V90H0266CB	SNAPPED SELECTED MLS ELEVATION	TLM			
Q_RANGE	V90H0264CB	SNAPPED SELECTED MLS RANGE	TLM			
Q_TAC_BRG	V90H8868CA	DATA SNAP-SELECTED TACAN BEARING	TLM			
Q_TAC_R	V90H8867CA	DATA SNAP-SELECTED TACAN RANGE	TLM			
R_RESET(1)	V90H0235CF	SEL X-COMP OF UPDATED POS VCTR RST	RTLS UPP,TLM	FT	DPL	
R_RESET(2)	V90H0236CF	SEL Y-COMP OF UPDATED POS VCTR RST	RTLS UPP,TLM	FT	DPL	
R_RESET(3)	V90H0237CF	SEL Z-COMP OF UPDATED POS VCTR RST	RTLS UPP,TLM	FT	DPL	
SEL_LRU_ID	V90J8864CA	DATA SNAP-TACAN LRU NUMBER	TLM			
SENSOR_EDIT(1)	V90U8841CC	TAC AZ/OPTICS H/X/AZ FILTER FLAG	TLM			
SENSOR_EDIT(2)	V90J8880CC	TAC R/OPTICS V/Y/EL FILTER FLAG	TLM			
SENSOR_EDIT(3)	V90J8881CC	BARO ALT/RR RNG FILTER FLAG	TLM			
SENSOR_EDIT(4)	V90J8882CB	DRAG ALT/RR R DOT FILTER FLAG	TLM			
SENSOR_EDIT(5)	V90J8883CB	MSBLS AZ/SHAFT RATE FILTER FLAG	TLM			
SENSOR_EDIT(6)	V90J8884CB	MSBLS R/TRUN RATE FILTER FLAG	TLM			
SENSOR_EDIT(7)	V90J8885CB	MSBLS EL FILTER FLAG	TLM			
T_BARO	V90W8870CA	DATA SNAP-ADS CORR P ALT TIME TAG	TLM			
T_EF_AZMLS	V90W0268CB	SNAPPED MLS AZIMUTH MEAS TIME	TLM			
T_EF_ELMLS	V90W0269CB	SNAPPED MLS ELEVATION MEAS TIME	TLM			
T_EF_RMLS	V90W0267CB	SNAPPED MLS RANGE MEAS TIME	TLM			
T_RESET	V90W0225CF	TIME OF FILTER STATE VCTR	RTLS UPP,TLM	S		
T_TACAN	V90W0716CC	TIME OF TACAN READ	TLM			
TAC_AIF_RCVD	V90J0226CA	TACAN AUT/INH/FOR FLAG FDBK	6.21,TLM			
TAC_BRG_DATA_GOOD	V90X0718XC	SNAPPED TAC BRG DATA GOOD	TLM			
TAC_R_DATA_GOOD	V90X0717XC	SNAPPED TAC RNG DATA GOOD	TLM			
TACAN_AIF	V90U0719CC	TACAN AUTO/INHIBIT/FORCE SWITCH	TLM			
TACAN_ID_FILT	V90U8850CA	DATA SNAP-SEL TAC CHANNEL W/MODE	TLM			
TACAN_MARK_NUM	V90J8842CA	COUNTER-TACAN MEAS BEING PROCESSED	TLM			
USE_IMU_DATA	V90X0538XC	FLAG TO USE IMU ACCUM VEL OR NOT	TLM			
V_CURRENT_FILT(1)	V90L8927CB	SNAPPED SEL TOTAL X VEL M50	TLM			
V_CURRENT_FILT(2)	V90L8928CB	SNAPPED SEL TOTAL Y VEL M50	TLM			
V_CURRENT_FILT(3)	V90L8929CB	SNAPPED SEL TOTAL Z VEL M50	TLM			
V_IMU_RESET(1)	V90L0247CF	SEL X-COMP OF ACCUM SENSED VEL RST	RTLS UPP	FT/S		
V_IMU_RESET(2)	V90L0248CF	SEL Y-COMP OF ACCUM SENSED VEL RST	RTLS UPP	FT/S		
V_IMU_RESET(3)	V90L0249CF	SEL Z-COMP OF ACCUM SENSED VEL RST	RTLS UPP	FT/S		
V_RESET(1)	V90L0239CF	SEL X-COMP OF UPDATED VEL VCTR RST	RTLS UPP,TLM	FT/S		
V_RESET(2)	V90L0240CF	SEL Y-COMP OF UPDATED VEL VCTR RST	RTLS UPP,TLM	FT/S		
V_RESET(3)	V90L0241CF	SEL Z-COMP OF UPDATED VEL VCTR RST	RTLS UPP,TLM	FT/S		

Table 4.3.2.9-1. RTLS Navigation (4.205) Input/Output Functional Parameters (Cont)

DBFN: D28031-A PN: VP707100026P00L
OUTPUT FUNCTIONAL PARAMETERS FROM RTLS NAVIGATION OCTOBER 16, 1987

RTLS NAV OI8B REV00 4.205 PAGE BOOK: 5 260

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
V_RESET(2)	V90L0240CF	SEL Y-COMP OF UPDATED VEL VCTR RST	RTLS UPP,TLM	FT/S		
V_RESET(3)	V90L0241CF	SEL Z-COMP OF UPDATED VEL VCTR RST	RTLS UPP,TLM	FT/S		

Table 4.3.2.9-2. RTLS Navigation (4.205) I-Loads

OI08B MISSIONS DBFN:0431
G4.205 - 0005 - RTLS NAVIGATION
ACTIVE MEMORY CONFIGURATIONS: 01

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
ALT_BARO_CUTOFF_HIGH	V99U8719C	FT	F	S	D	P	G4.144 G4.205	ZFT2
ALT_BARO_CUTOFF_LOW	V99U8720C	FT	F	S	D	P	G4.127 G4.144 G4.205	ZFT2
BASE_DEN(1)	V97U5235C	SLUGS/FT**3	V	DP	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
BASE_DEN(2)	V97U5236C	SLUGS/FT**3	V	DP	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
BASE_DEN(3)	V97U5237C	SLUGS/FT**3	V	DP	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
BASE_DEN(4)	V97U5238C	SLUGS/FT**3	V	DP	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
BIAS_DRAG_LAYER(1)	V97U5243C	FT	V	S	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
BIAS_DRAG_LAYER(2)	V97U5244C	FT	V	S	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
BIAS_DRAG_LAYER(3)	V97U5245C	FT	V	S	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
BIAS_DRAG_LAYER(4)	V97U5246C	FT	V	S	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
C_DRAG_ONE	V97U5277C	RAD**-1	F	S	M	C	G4.127 G4.144 G4.15 G4.205	DRNO

Table 4.3.2.9-2. RTLS Navigation (4.205) I-Loads (Cont)

OI088 MISSIONS DBFN:0431
G4.205 - 0005 - RTLS NAVIGATION
ACTIVE MEMORY CONFIGURATIONS: 01

FSSR NAME	MSID	ENG UNIT	DT	PR	B	S	PR FCTN	CAT
C_DRAG_TWO	V97U5278C	RAD**-2	F	S	M	C	G4.127 G4.144 G4.15 G4.205	DRM0
C_DRAG_ZERO	V97U5279C	ND	F	SP	M	C	G4.127 G4.144 G4.15 G4.205	DRM0
DEL_TIME_STEP	V97U6548C	SEC	F	S	D	C	G4.127 G4.144 G4.198 G4.15 G4.205	ZFT2 ZFT2
DENSITY_LIMIT 1	V97U5310C	FT	V	S	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
DENSITY_LIMIT(2	V97U5311C	FT	V	S	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
DENSITY_LIMIT(3)	V97U5312C	FT	V	S	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
DENSITY_LIMIT(4)	V97U5313C	FT	V	S	M	C	G4.127 G4.144 G4.15 G4.205	PR40 PE41
DRAG_CONST	V97U5317C	FT**2/SLUG	F	D	M	C	G4.127 G4.144 G4.223 G4.236 G4.15 G4.205	DRC0 DRC0
DRAG CONST RTLS	V97U9010C	FT**2/SLUG	F	DP	M	C	G4.15 G4.205	XS71
K MAX	V97U5348C	ND	I	S	D	C	G4.15 G4.205 G4.127 G4.144	ZFT2

Table 4.3.2.9-2. RTLS Navigation (4.205) I-Loads (Cont)

OI08B MISSIONS DBFN:0431
G4.205 - 0005 - RTLS NAVIGATION
ACTIVE MEMORY CONFIGURATIONS: 01

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
K_UNO_MGT	V97U5350C	ND	F	S	M	X	G4.126 G4.15 G4.205 G4.127 G4.144	ZFT2 ZPA0 ZFT2
M_M50TOEF_AT_EPOCH(1,1)	V97U5738C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(1,2)	V97U5739C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(1,3)	V97U5740C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(2,1)	V97U5741C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(2,2)	V97U5742C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(2,3)	V97U5743C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(3,1)	V97U5744C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(3,2)	V97U5745C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1
M_M50TOEF_AT_EPOCH(3,3)	V97U5746C	ND	M	DP	M	C	G4.15 G4.205 G4.224 G4.126	TEP1

Table 4.3.2.9 2. RTLS Navigation (4.205) I-Loads (Cont)

OI08B MISSIONS DBFN:0431
G4 205 - 0005 - RTLS NAVIGATION
ACTIVE MEMORY CONFIGURATIONS: 01

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
MS_POS_UNC_MGT	V97U5411C	FT**2	F	S	D	X	G4.126 G4.127 G4.144 G4.15 G4.205		ZFT2 ZPA0 ZFT2
MSBLS_EL_ANGLE_CUTOFF	V99U7593C	RAD	F	S	D	P	G4.205 G4.144		ZFV2
NAVBASE_ALT_ZERO	V97U5749C	FT	F	D	D	C	G4.15 G4.205		NVB0
NAVBASE_LAT_ZERO	V97U5750C	RAD	F	DP	D	C	G4.15 G4.19 G4.20 G4.205		NVB0
NAVBASE_LONG_ZERO	V97U5751C	RAD	F	DP	D	C	G4.15 G4.19 G4.20 G4.205		NVB0
RV_MAX	V99U7596C	FT/SEC	F	S	D	C	G4.15 G4.205		ZFT2
SCALE_HT(1)	V97U5501C	FT	V	S	N	C	G4 127 G4 144 G4 15 G4 205		PM40 PE41
SCALE_HT(2)	V97U5502C	FT	V	SP	N	C	G4 127 G4 144 G4 15 G4 205		PM40 PE41
SCA E_HT 3	V97U5503C	FT	V	SP	N	C	G4 127 G4 144 G4 15 G4 205		PM40 PE41
SCA E_HT 4	V97U5504C	FT	V	SP	N	C	G4 127 G4 144 G4 15 G4 205		PM40 PE41
[illegible]	[illegible]	[illegible]	F	DP	N	C	G4 15 G4 [illegible] G4 [illegible] G4 [illegible]		TEP1
[illegible]	[illegible]	[illegible]	F	S	D	C	G4 15 G4 205		ZFT2

Space Transportation Systems Division
Rockwell International

Table 4.3.2.9-2. RTLS Navigation (4.205) I-Loads (Cont)

OI088 MISSIONS DBFN:0431
G4.205 - 0005 - RTLS NAVIGATION
ACTIVE MEMORY CONFIGURATIONS: 01

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
VAR_H2	V99U7595C	ND	F	S	D	C	G4.15 G4.205		ZFT2

Table 4.3.2.9-3. RTLS Navigation (G4.205) K-Loads Return to Launch Site (RTLS) Navigation

OI88 MISSIONS

FSCB NAME / DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	BT	PR	S	PR FCTN	LAST CR EQTN MSID
ACC_DRAG MCH	V97U5208C	+1 1000000	E+01 FT/SEC**2	F	S	C	G4.127 G4.144 G4.15 G4.205	59971
ACC_DRAG MCH_REF								
ACC_MAG MCH_REF	V97U5700C	+3 20	E-02 FT/SEC**2	F	S	C	G4.15 G4.205	59971
ACCEL MAG ABOVE VENT & DRAG								
ALT_EL 1	V97U5212C	+1 4000000	E+05 FT	F	S	P	G4.23 G4.24 G4.25 G4.127 G4.144 G4.205	89661A
ALT REGIONS NAV EV LAMP PROCESSING								
ALT_EL 2	V97U5213C	+1.2000000	E+04 FT	F	S	P	G4.23 G4.24 G4.25 G4.127 G4.144 G4.205	89661A
ALT REGIONS NAV EV LAMP PROCESSING								
ALT_ZONE_CHANGE	V97U5718C	+5.0000000	E+05 FT	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
ALT MODEL ATMOS DEN CHANGED								
A3_TOL	V98U9425C	-3.0	E-03 RAD	F	S	C	G4.23 G4.19 G4.20 G4.144 G4.127 G4.205	89661A
BIAS BARO	V97U5242C	+0 0	E+00 FT	F	S	C	G4.127 G4.144 G4.205	89661A
BAROMETRIC DETERMINISTIC BIAS								
COEF COEFF UPDATE 1)	V97U5291C	+0 0	E+00 MD	F	D	C	G4.205 G4.127 G4.144	89661A
COEF CORRELATION COEFFICIENTS								

DEFN 0534 DATE 07/14/88

Table 4.3.2.9-3. RTLS Navigation (G4.205) K-Loads Return to Launch Site (RTLS) Navigation (Cont)

OI88 MISSIONS

FSSR NAME / DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT	PR	S	PR FCTN	LAST CR EQTN MSID
CORR_COEFF_UPDATE(2)	V97U5292C	+0.0	E+00 ND	F	D	C	G4.127 G4.144 G4.205	89661A
COVAR CORRELATION COEFFICIENTS								
CORR_COEFF_UPDATE(3)	V97U5293C	+0.0	E+00 ND	F	D	C	G4.127 G4.144 G4.205	89661A
COVAR CORRELATION COEFFICIENTS								
CORR_COEFF_UPDATE(4)	V97U5294C	+0.0	E+00 ND	F	D	C	G4.127 G4.144 G4.205	89661A
COVAR CORRELATION COEFFICIENTS								
CORR_COEFF_UPDATE(5)	V97U5295C	+0.0	E+00 ND	F	D	C	G4.127 G4.144 G4.205	89661A
COVAR CORRELATION COEFFICIENTS								
CORR_COEFF_UPDATE(6)	V97U5296C	+0.0	E+00 ND	F	D	C	G4.127 G4.144 G4.205	89661A
COVAR CORRELATION COEFFICIENTS								
CORR_COEFF_UPDATE(7)	V97U5297C	+0.0	E+00 ND	F	D	C	G4.127 G4.144 G4.205	89661A
COVAR CORRELATION COEFFICIENTS								
DENSE(1)	V97U5304C	-3.9570	E+01 ND	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
DENSITY MODEL CONST								
DENSE(2)	V97U5305C	+1.0440	E-05 FT**-1	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
DENSITY MODEL CONST								

DBFN:0534 DATE:07/14/88

Table 4.3.2.9-3. RTLS Navigation (G4.205) K-Loads Return to Launch Site (RTLS) Navigation (Cont)

OI88 MISSIONS

FSSR NAME / DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT	PR	S	PR	FCTN	LAST CR EQTN MSID
DENSE(3)	V97U5306C	+6.9560000	E+06 FT	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236		89661A
DENSITY MODEL CONST									
DENSE(4)	V97U5307C	-2.420	E+01 ND	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236		89661A
DENSITY MODEL CONST									
DENSE(5)	V97U5308C	-2.8890	E-06 FT**-1	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236		89661A
DENSITY MODEL CONST									
DENSE(6)	V97U5309C	+2.6050000	E+06 FT	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236		89661A
DENSITY MODEL CONST									
DIFCD1	V96U9743C	+3.9589	E-01 ND	F	S	C	G4.236 G4.223 G4.15 G4.127 G4.144 G4.205		89661A
DIFCD2	V96U9744C	+3.3962	E+00 ND	F	S	C	G4.236 G4.223 G4.15 G4.127 G4.144 G4.205		89661A

DBFN:0534 DATE:07/14/88

Table 4.3.2.9-3. RTLS Navigation (G4.205) K-Loads Return to Launch Site (RTLS) Navigation (Cont)

DI88 MISSIONS

FSSR NAME / DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT	PR	S	PR FCTN	LAST CR EQTN MSID	
DIFCD3	V96U9745C	+6.5414	E-01 RAD	F	S	C	G4.236 G4.223 G4.15 G4.127 G4.144 G4.205	89661A	
DIFCD4	V96U9746C	+8.3589	E-01 ND	F	S	C	G4.236 G4.223 G4.15 G4.127 G4.144 G4.205	89661A	
H_DRAG_LOW ALT BELOW DRAG DATA NOT PROC	V97U5336C	+8.5200000	E+04 FT	F	S	C	G4.127 G4.205	89661A	
K_EDIT_BARO	V98U7977C	+4	ND	I	S	X	G4.127 G4.144 G4.205	89661A	V99U8782C
K_EDIT_DRAG	V98U7978C	+64	ND	I	S	X	G4.127 G4.144 G4.205	89661A	V99U8783C
K_EDIT_MLSAZ	V98U7980C	+400	ND	I	S	P	G4.144 G4.205	89661A	
K_EDIT_MLSEL	V98U7981C	+400	ND	I	S	P	G4.144 G4.205	89661A	
K_EDIT_MLSR	V98U7979C	+400	ND	I	S	P	G4.144 G4.205	89661A	
K_EDIT_TACBR	V98U7976C	+1	ND	I	S	X	G4.127 G4.144 G4.205	89661A	V99U8804C
K_EDIT_TACR	V98U7975C	+64	ND	I	S	X	G4.127 G4.144 G4.205	89661A	V99U8803C
MLSANT_ANG ANGLE MLS AND X-BODY AXIS	V98U7434C	+3.2686	E-01 RAD	F	S	P	G4.205 G4.144	89661A	
MLSANT_NB_DIST DIST FROM NB TO MLS ANTENNA	V98U7433C	+1.389	E+01 FT	F	S	P	G4.205 G4.144	89661A	

DBFN:0534 DATE:07/14/88

Table 4.3.2.9 3. RTLS Navigation (G4.205) K Loads Return to Launch Site (RTLS) Navigation (Cont)

OI88 MISSIONS

FSSR NAME DESCRIPTION	MSID	MC	KLOAD VALUE	ENG UNIT	BT	PR	S	PR	FCTN	LAST CR EQTN MSID
R AZ_COUNT MAX DATA GOOD FAILS INHIB MLS PROC	V97U5429C	+2		NO	I	S	P	G4.205 G4.144		89661A
RNG VAR BEARING STEP RNG CRIT SEL TACAN AZ INSTR	V97U5467C	+9	1141700	E+05 FT	F	S	C	G4.127 G4.144 G4.205		89661A
RNG VAR RNG_STEP RNG CRIT SEL TACAN RNG VAR	V97U5468C	+3	0380500	E+05 FT	F	S	C	G4.205 G4.127 G4.144		89661A
SFA [illegible] DENSITY SFA [illegible] ATMOSPHERIC DENSITY	[illegible]	+2	3760940	E-03 SLUGS/FT**3	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236		89661A
S S J AG UPDATE VEH POS & VEL DEVIATIONS	V97U5506C	+2	0	E+03 FT	F	D	C	G4.127 G4.144 G4.205		89661A
SIG DIAG UPDATE 2 VEH POS & VEL DEVIATIONS	V97U5507C	+2	0	E+03 FT	F	D	C	G4.127 G4.144 G4.205		89661A
SIG DIAG UPDATE 3 VEH POS & VEL DEVIATIONS	V97U5508C	+2.0		E+03 FT	F	D	C	G4.127 G4.144 G4.205		89661A
SIG DIAG UPDATE(4) VEH POS & VEL DEVIATIONS	V97U5509C	+3.0		E+01 FT/SEC	F	D	C	G4.127 G4.144 G4.205		89661A
SIG DIAG UPDATE(5) VEH POS & VEL DEVIATIONS	V97U5510C	+3.0		E+01 FT/SEC	F	D	C	G4.127 G4.144 G4.205		89661A
SIG DIAG UPDATE(6) VEH POS & VEL DEVIATIONS	V97U5511C	+3.0		E+01 FT/SEC	F	D	C	G4.127 G4.144 G4.205		89661A

DBFN 0534 DATE:07/14/88

Table 4.3.2.9-3. RTLS Navigation (G4.205) K-Loads Return to Launch Site (RTLS) Navigation (Cont)

OI88 MISSIONS

FSSR NAME / DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT	PR	S	PR FCTN	LAST CR EQTN MSID
TACAN_BRG_CONVERG_TEST	V98U9807C	+1.0	E-02 RAD**2	F	S	P	G4.127 G4.144 G4.205	89661A
TACAN_RNG_CONVERG_TEST	V98U9808C	+4.0000000	E+07 FT**2	F	S	P	G4.205 G4.127 G4.144	89661A
TIME_BIAS_BARO	V97U5544C	+1.790	E-01 SEC	F	D	C	G4.205 G4.127 G4.144	89661A
PAD BIAS CORR BARO TIME TAG								
TIME_BIAS_MLS	V97U5545C	-1.0	E-01 SEC	F	D	P	G4.144 G4.205	89661A
PAD BIAS CORR MSBLS TIME TAG								
TIME_BIAS_TACAN	V97U5543C	+2.90	E-02 SEC	F	D	P	G4.205 G4.127 G4.144	89661A
PAD LOADED CORR TACAN TIME LAG								
VAR_ACC_QUANT	V97U9036C	+9.0	E-05 FT**2/SEC**4	F	S	P	G4.205	89661A
VAR_AZMLS	V97U5551C	+1.0	E-05 RAD**2	F	S	P	G4.205 G4.144	89661A
MSBLS AZIMUTH MEAS INSTRU VAR								
VAR_DRAG	V97U5552C	+1.0000000	E+08 FT**2	F	S	C	G4.127 G4.205	89661A
DRAG ALT MEASURE ERROR VARIANCE								
VAR_ELMLS	V97U5553C	+1.0	E-05 RAD**2	F	S	P	G4.144 G4.205	89661A
MSBLS ELEV INSTR VARIANCE								
VAR_RMLS	V97U5556C	+5.7500000	E+02 FT**2	F	S	P	G4.144 G4.205	89661A
MSBLS RANGE MEASURE INSTR VAR								
VAR_TAC_BRG_HIGH	V97U5557C	+1.0	E-02 RAD**2	F	S	C	G4.205 G4.127 G4.144	89661A
TACAN BRG INSTR VAR AT RANGE								
VAR_TAC_BRG_LOW	V97U5558C	+1.0	E-02 RAD**2	F	S	C	G4.205 G4.127 G4.144	89661A
VAR TACAN BRGN INSTRUMENT ERROR								

OBFN:0534 DATE:07/14/88

Table 4.3.2.9-3. RTLS Navigation (G4.205) K-Loads Return to Launch Site (RTLS) Navigation (Cont)

OI88 MISSIONS

FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT	PR	S	PR FCTN	LAST CR EQTN MSID
VAR_TAC_R_HIGH	V97U5559C	+3.6000000	E+05 FT**2	F	S	C	G4.205 G4.127 G4.144	89661A
TACAN RNG INSTR VAR AT RANGE								
VAR_TAC_R_LOW	V97U5560C	+3 6	E+05 FT**2	F	S	C	G4.205 G4.127 G4.144	89661A
VAR TACAN RANGE INSTR ERROR								
VAR UP#OD ACC DT VAR UP#OGELED ACCEL SCALE TIME	V97U5781C	+2 5000000	E-01 FT**2/SEC**3	F	S	P	G4 205	89661A

Table 4.3.2.9-4. RTLS Navigation (4.205) Constants

NROKRMM FSSR2.DATA(X04)BOOK5
PFS CONSTANTS UPDATE B/L

FSSR NAME / DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
C(01) TESSERAL HARMONIC COEFFICIENT			-.27635957 E-09	ND	F	D				
C(02) TESSERAL HARMONIC COEFFICIENT			+.15711423 E-05	ND	F	D				
C(03) TESSERAL HARMONIC COEFFICIENT			+.21907694 E-05	ND	F	D				
C(04) TESSERAL HARMONIC COEFFICIENT			+.30466825 E-06	ND	F	D				
C(05) TESSERAL HARMONIC COEFFICIENT			+.97966803 E-07	ND	F	D				
C(06) TESSERAL HARMONIC COEFFICIENT			+.50552749 E-06	ND	F	D				
C(07) TESSERAL HARMONIC COEFFICIENT			+.78842815 E-07	ND	F	D				
C(08) TESSERAL HARMONIC COEFFICIENT			+.59073749 E-07	ND	F	D				
C(09) TESSERAL HARMONIC COEFFICIENT			-.41542493 E-08	ND	F	D				
EARTH_MU EARTH GRAVITATIONAL CONSTANTS	V97U4378C		+.140764487566 E+17	FT**3/ SEC**2	F	D				
EARTH_POLE(1) X COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8460C		.28322844 E-02	ND	F	S				
EARTH_POLE(2) Y COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8461C		-.50279960 E-04	ND	F	S				
EARTH_POLE(3) Z COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8462C		.99999598 E+00	ND	F	S				
EARTH_RADIUS_EQUATOR EARTH EQUATORIAL RADIUS	V97U5324C		.209257414698 1630 E+08	FT	F	D				
EARTH_RADIUS_GRAV EARTH RADIUS (GRAV ACCEL)	V97U5325C		+.209256561680 E+08	FT	F	D				
EARTH_RATE EARTH'S ROTATIONAL RATE	V97U4379C		.7292115146460 000 E-04	RAD/SEC	F	D				
ELLIPT EARTH'S ELLIPTICITY CONSTANTS	V97U5332C		.3352329800000 000 E-002	ND	F	D				
EPS_TAG LIMIT FOR THE DIFFERENCE BETWEEN MEASUREMENT TIME TAG AND STATE VECTOR TIME TAG			.0005	SEC	F	S				
KN1 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT LESS THAN 400K FEET			-.17980000 E+01	ND	F	S				

CR89596C

Space Transportation Systems Division
Rockwell International
CR89596C

Table 4.3.2.9-4. RTLS Navigation (4.205) Constants (Cont)

NROKRMM FSSR2.DATA(X04)BOOK5
PFS CONSTANTS UPDATE B/L

FSSR NAME / DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
KN2 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT LESS THAN 400K FEET			.66670000 E-05	FT**-1	F	S				
KN3 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT LESS THAN 400K FEET			-.57890000 E-11	FT**-2	F	S				
KN4 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT BETWEEN 400K AND 600K FEET			.27518150 E-02	ND	F	S				
KN5 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT BETWEEN 400K AND 600K FEET			-.14990900 E-03	FT**-1	F	S				
KN6 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT BETWEEN 400K AND 600K FEET			.20490000 E-09	FT**-2	F	S				
ID_MATRIX_3X3(01) (1,1) COMPONENT OF 3X3 IDENTITY MATRIX			1.0	ND	F	S				
ID_MATRIX_3X3(02) (1,2) COMPONENT OF 3X3 IDENTITY MATRIX			.0	ND	F	S				
ID_MATRIX_3X3(03) (1,3) COMPONENT OF 3X3 IDENTITY MATRIX			.0	ND	F	S				
ID_MATRIX_3X3(04) (2,1) COMPONENT OF 3X3 IDENTITY MATRIX			.0	ND	F	S				
ID_MATRIX_3X3(05) (2,2) COMPONENT OF 3X3 IDENTITY MATRIX			1.0	ND	F	S				
ID_MATRIX_3X3(06) (2,3) COMPONENT OF 3X3 IDENTITY MATRIX			.0	ND	F	S				
ID_MATRIX_3X3(07) (3,1) COMPONENT OF 3X3 IDENTITY MATRIX			.0	ND	F	S				
ID_MATRIX_3X3(08) (3,2) COMPONENT OF 3X3 IDENTITY MATRIX			.0	ND	F	S				
ID_MATRIX_3X3(09) (3,3) COMPONENT OF 3X3 IDENTITY MATRIX			1.0	ND						
NAUTMI PER FT FEET TO NAUTICAL MILES CONVERSION FACTOR	V97U5423C		.16457884 E-03	NMI/FT	F	S				

CR89596C

CR89596C

Table 4.3.2.9-4. RTLS Navigation (4.205) Constants (Cont)

NROKRMM.FSSR2.DATA(X04)BOOK5
PFS CONSTANTS UPDATE B/L

FSSR NAME / DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
PI RATIO CIRCUMFERENCE TO DIAMETER	V98U8725C		3.1415926535897	ND	F	D				
RAD_PER_DEG DEGREES TO RADIANS CONVERSION FACTOR	V97U0383C		.17453293 E-01	RAD/DEG	F	S				
S(01) TESSERAL HARMONIC COEFFICIENT	V97U5492C		-.52357454 E-08	ND	F	D				
S(02) TESSERAL HARMONIC COEFFICIENT	V97U5493C		-.90231337 E-06	ND	F	D				
S(03) TESSERAL HARMONIC COEFFICIENT	V97U5494C		+.27267074 E-06	ND	F	D				
S(04) TESSERAL HARMONIC COEFFICIENT	V97U5495C		-.21259298 E-06	ND	F	D				
S(05) TESSERAL HARMONIC COEFFICIENT	V97U5496C		+.19681077 E-06	ND	F	D				
S(06) TESSERAL HARMONIC COEFFICIENT	V97U5497C		-.44125015 E-06	ND	F	D				
S(07) TESSERAL HARMONIC COEFFICIENT	V97U5498C		+.14718958 E-06	ND	F	D				
S(08) TESSERAL HARMONIC COEFFICIENT	V97U5499C		-.12140873 E-07	ND	F	D				
S(09) TESSERAL HARMONIC COEFFICIENT	V97U5500C		+.63163541 E-08	ND	F	D				
ZONAL(01) ZONAL HARMONIC COEFFICIENT	V97U5582C		.0	ND	F	D				
ZONAL(02) ZONAL HARMONIC COEFFICIENT	V97U5583C		+.10826271 E-02	ND	F	D				
ZONAL(03) ZONAL HARMONIC COEFFICIENT	V97U5584C		-.25358868 E-05	ND	F	D				
ZONAL(04) ZONAL HARMONIC COEFFICIENT	V97U5585C		-.16246180 E-05	ND	F	D				

CR89596C

Space Transportation Systems Division

CR89596C

Rockwell International

Table 4.3.2.9-5. RTLS Navigation
(4.205) Cross-References

FSSR Name	Source Name
V_CURRENT_FILT	SEL_V_M50
T_CURRENT_FILT	TIME_V
T_EF_ELMLS	MSBELEVTIM
T_EF_AZMLS	MSBAZIMTIM
T_EF_RMLS	MSBRANGTIM
BARO_DATA_GOOD	ALT_DG
T_BARO	T_HPC
Q_BARO	HPC
TAC_BRG_DATA_GOOD	OUT_BRG_DG
Q_TAC_BRG	OUT_SEL_BRG
TAC_RNG_DATA_GOOD	OUT_RNG_DG
Q_TAC_R	OUT_SEL_RNG
ALPHA	ALPHA_SNAP
ALPHAIN	ALPHA_N
BETAIN	BETA_N
THETAIN	THETA
M_EFTOTD_TACAN_SL(1)	M_EFTOTD_TACAN_SL1
M_EFTOTD_TACAN_SL(2)	M_EFTOTD_TACAN_SL2
M_EFTOTD_TACAN_SL(3)	M_EFTOTD_TACAN_SL3
R_TACAN_EF_SL(1)	R_TACAN_EF_SL1
R_TACAN_EF_SL(2)	R_TACAN_EF_SL2
R_TACAN_EF_SL(3)	R_TACAN_EF_SL3

Table 4.3.2.9-5. RTLS Navigation
(4.205) Cross-References

FSSR Name	Source Name
V_CURRENT_FILT	SEL_V_M50
T_CURRENT_FILT	TIME_V
T_EF_ELMLS	MSBELEVTIM
T_EF_AZMLS	MSBAZIMTIM
T_EF_RMLS	MSBRANGTIM
BARO_DATA_GOOD	ALT_DG
T_BARO	T_HPC
Q_BARO	HPC
TAC_BRG_DATA_GOOD	OUT_BRG_DG
Q_TAC_BRG	OUT_SEL_BRG
TAC_RNG_DATA_GOOD	OUT_RNG_DG
Q_TAC_R	OUT_SEL_RNG
ALPHA	ALPHA_SNAP
ALPHAIN	ALPHA_N
BETAIN	BETA_N
THETAIN	THETA
M_EFTOTD_TACAN_SL(1)	M_EFTOTD_TACAN_SL1
M_EFTOTD_TACAN_SL(2)	M_EFTOTD_TACAN_SL2
M_EFTOTD_TACAN_SL(3)	M_EFTOTD_TACAN_SL3
R_TACAN_EF_SL(1)	R_TACAN_EF_SL1
R_TACAN_EF_SL(2)	R_TACAN_EF_SL2
R_TACAN_EF_SL(3)	R_TACAN_EF_SL3

4.4 SUBFUNCTIONS COMMON TO SEVERAL NAVIGATION-RELATED PRINCIPAL FUNCTIONS

This section documents detailed requirements for subfunctions identified as being common to two or more navigation-related principal functions or their major subfunctions. The detailed requirements specified here will be referenced from the sections to which they are common and, where referenced, may be regarded as inserts to paragraph A, Detailed Requirements, in these sections.

4.4.1 User Parameter State Propagation

During the ascent/RTLS operational sequence (OPS-1, 6), the navigation state propagation subfunction advances the navigation state vector at relatively large intervals, at the end of which external measurement data processed by the filter are incorporated when appropriate. Users such as guidance and displays, however, require a knowledge of the state vector at shorter intervals. The user parameter state propagation subfunction will satisfy the requirements of its users by performing the integration of the equations of motion in an M50 coordinate system within the intervals of the navigation propagation, with use of the most recent navigation-computed acceleration vector in conjunction with a small step size and the accumulated sensed velocity snapped from the accelerometers. During those periods when drag accelerations are being modeled, the accelerometer readings shall be ignored. These integration processes shall be restarted at the completion of each navigation cycle with the navigation state.

On entry into the ascent operational sequence, the flag, FILT_UPDATE, will be set to ON by the ascent navigation sequencer principal function. The flag setting indicates that the user parameter state is to be initialized as in Item 2 below. Thereafter, the initial value of the state that is to be advanced (integrated forward in time) may be from either of two sources (the one used depends on the tested value of the flag FILT_UPDATE, which indicates the availability of an updated state from the navigation function):

1. If an update from the navigation function is not available (FILT_UPDATE = OFF), the propagated state, saved from the previous cycle, is to be advanced. A constant value of gravity acceleration is used between updates, and sensed acceleration is computed from IMU velocity data.

2. If an update from the navigation function is available (FILT_UPDATE = ON), the navigation updated state, together with its time tag, gravity acceleration and associated accumulated sensed velocity, replaces the previous propagated state, time tag, gravity acceleration and accumulated velocity. Advancement is to be the same as in Item 1.

This mechanism permits independent computation rates for IMU and gravity only propagation and the incorporation of usually less frequent external measurements data.

The general computational flow of the state propagator is to first compute derived sensed acceleration from IMU velocity data, incorporate the updated navigation state vector if FILT_UPDATE = ON, and then propagate the state to current time.

The derived sensed acceleration is computed as follows:

1. The accumulated sensed velocity and time tag are read and the time since the last IMU data are computed:

   SNAP_IMU(V_IMU_CURRENT, T_IMU)

   DT_IMU = T_IMU - T_IMU_LAST

2. If the data read in by the SNAP_IMU are new, defined by DT_IMU > 0, the derived sensed acceleration is computed and the 'last' IMU data are updated to the current values:

   DV_S = V_IMU_CURRENT - V_IMU_LAST

   A_SENSED = DV_S/DT_IMU

   T_IMU_LAST = T_IMU

   V_IMU_LAST = V_IMU_CURRENT

3. If a navigation state vector update is available (FILT_UPDATE = ON), the new state data are read in, the earth-relative velocity is computed, the FILT_UPDATE flag is turned OFF to inhibit a reset until it is again set to ON in the navigation function and the UPP_UPDATE flag is set ON to indicate that the UPP state has been updated by the navigation filter:

   G_OLD = G_RESET

   R_AVGG = R_RESET

   V_AVGG = V_RESET

   V_IMU_OLD = V_IMU_RESET

   T_STATE = T_RESET

   V_RHO = V_REL(V_AVGG, R_AVGG)

   FILT_UPDATE = OFF

   UPP_UPDATE = ON

4. On every pass through the state propagator the current time is obtained, the state vector, accumulated sensed velocity inertial velocity magnitude and earth-relative velocity magnitude are computed:

   READ CURRENT TIME (T_CURRENT)

   DT = T_CURRENT - T_STATE

$$\underline{DV} = DT\ (\underline{A}\_SENSED + \underline{G}\_OLD)$$

$$\underline{R}\_AVGG = \underline{R}\_AVGG + DT\ (\underline{V}\_AVGG + 0.5\ \underline{DV})$$

$$\underline{V}\_AVGG = \underline{V}\_AVGG + \underline{DV}$$

$$\underline{V}\_IMU\_OLD = \underline{V}\_IMU\_OLD + DT\ \underline{A}\_SENSED$$

$$V\_INERTIAL\_MAG = ABVAL(\underline{V}\_AVGG)$$

$$\underline{V}\_RHO = \underline{V}\_RHO + \underline{DV}$$

$$T\_STATE = T\_CURRENT$$

$$REL\_VEL\_MAG = ABVAL(\underline{V}\_RHO)$$

4.4.2 Coordinate Transformations

These nine subfunctions provide the capability to transform parameters specified (or computed) in one coordinate system to another coordinate system. Coordinate system definitions are provided in Section 5.3.

Each of the nine subfunctions described in Sections 4.4.2.1 through 4.4.2.9 may be executed separately. The subfunctions do not actually perform the coordinate transformation; only the transformation matrix is computed.

For consistency, it is assumed that all coordinate systems located on the surface of the earth are specified in terms of geodetic parameters (i.e., geodetic latitude, longitude, and altitude above the reference ellipsoid) and that all azimuth angles are referenced to true (not magnetic) north.

It should be noted that the coordinate transformation M50 to earth-fixed and earth-fixed to topodetic are also required for use by the IMU SOP and must be made available in any OPS load that allows IMU alignment, even if navigation is not active.

Input and output parameters for all subfunctions are listed in Tables 4.4.2-1 and 4.4.2-2.

4.4.2.1 Transformation From Aries-Mean-of 1950 to Earth-Fixed. The purpose of this subfunction is to provide a transformation matrix (M_M50TOEF_AT_EPOCH) from Aries M50 coordinates to earth-fixed coordinates that accounts for the rotation, nutation, and precession motion of the earth at a specified time, T_EPOCH. Also supplied is the vector EARTH_POLE, which is the direction of the true-of-date (earth-fixed) Z-axis in M50 coordinates. EARTH_POLE is defined to be

$$EARTH\_POLE(i) = M\_M50TOEF\_AT\_EPOCH\ (3,i),\ i = 1,3$$

The earth-fixed to M50 coordinate transformation (Section 4.4.2.2) is employed to rapidly propagate this transformation matrix between epoch times. This propagation accounts for the earth's daily rotational effects only.

All parameters needed by this subfunction will be premission determined for OPS-1. T_EPOCH will be in elapsed seconds from 0.0 hours 31 December prior to the year of launch to time of nominal liftoff plus 6 hours, to provide adequate accuracy with slips in the launch time or in the event of an ascent abort. In the case of ascent aborts, the I-load parameters needed by this subfunction will be passed from OPS-1 to OPS-6 or (for an AOA) carried across the computer memory reconfiguration for use by the OPS-3 flight software.

The software will not be designed to preclude any particular value of T_EPOCH, whether future or past.

The nutation/precession computations are lengthy, and it is assumed that suitable accuracy can be maintained by employing the approximation of earth motion used in EARTH_FIXED_TO_M50_COORD (Section 4.4.2.2).

4.4.2.2 Earth-Fixed to M50. The purpose of this subfunction is to propagate the matrix M_M50TOEF_AT_EPOCH from the last epoch time to the time of interest. This propagation accounts for the earth's rotation effects only.

Formulation: A simple Z-axis rotation is performed through the angle defined by the product of the earth's mean rotational rate (EARTH_RATE) relative to the mean-of-date system, and the difference between the time (T_EPOCH) associated with the matrix (M M50TOEF AT EPOCH) and the time (TIME) of this requested matrix. Thus, for the defined

DELT = TIME - T_EPOCH

the angle of rotation is

LAM = (EARTH_RATE) DELT

and the rotation matrix, $\bar{M}$, is defined by the equation

$$M = \begin{bmatrix} \text{COS (LAM)} & \text{-SIN (LAM)} & 0 \\ \text{SIN (LAM)} & \text{COS (LAM)} & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad \text{(F9)}$$

The matrix is then used to compute a current transformation matrix from earth-fixed to M50 coordinates:

$$\text{EARTH\_FIXED\_TO\_M50\_COORD} = \text{M\_M50TOEF\_AT\_EPOCH}^{T}M$$

[F9]This equation shall be protected against return value of sine or cosine with magnitude greater than unity (Section 3.5).

Because of the sparseness of the matrix M, both core and execution time will be conserved by use of the following formulation. For notational convenience, let N denote the matrix M_M50TOEF_AT_EPOCH. The sine and cosine of LAM will be computed once and denoted by CLAM = COS (LAM) and SLAM = SIN (LAM). Then EARTH_FIXED_TO_M50_COORD will be computed as follows:

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{1,1} = N_{1,1}\ \text{CLAM} + N_{2,1}\ \text{SLAM}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{1,2} = -N_{1,1}\ \text{SLAM} + N_{2,1}\ \text{CLAM}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{1,3} = N_{3,1}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{2,1} = N_{1,2}\ \text{CLAM} + N_{2,2}\ \text{SLAM}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{2,2} = -N_{1,2}\ \text{SLAM} + N_{2,2}\ \text{CLAM}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{2,3} = N_{3,2}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{3,1} = N_{1,3}\ \text{CLAM} + N_{2,3}\ \text{SLAM}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{3,2} = -N_{1,3}\ \text{SLAM} + N_{2,3}\ \text{CLAM}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{3,3} = N_{3,3}$$

This subfunction may be executed as needed. The time (TIME) for which the output transformation matrix (EARTH_FIXED_TO_M50_COORD) is valid must be supplied by the user in elapsed seconds from 0.0 hours 31 December prior to the launch year to the desired time.

A valid M_M50TOEF_AT_EPOCH must be available before this subfunction can be executed.

The Aries-mean-of-1950 and the earth-fixed coordinate systems are shown in Section 5.3.

Table 4.4.2-1. Coordinate Transformations Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
EARTH_FIXED_TO_M50_COORD							
Earth rotation rate	EARTH_RATE	(a)	F	DP			As needed
Time tag for M_M50TOEF_AT_EPOCH, Greenwich hour angle, and EARTH_POLE	T_EPOCH	(a)	F	DP		sec	As needed
Transformation matrix from M50 to earth-fixed at T_EPOCH	M_M50TOEF_AT_EPOCH	(a)	M	DP			As needed
General time variable	TIME	User sub-function	F	DP		sec	As needed
EF_TO_TOPDET							
Geodetic latitude of R_EF	LAT_GEOD	User sub-function	F	S		rad	As needed
Geodetic longitude of Shuttle's position vector	LON	User sub-function	F	S		rad	As needed
EF_TO_RUNWAY							
Geodetic latitude of R_EF	LAT_GEOD	User sub-function	F	S		rad	As needed
Geodetic longitude of Shuttle's position vector	LON	User sub-function	F	S		rad	As needed
Bearing from true north	AZ	User sub-function	F	S		rad	As needed
EF_TO_SCANNER							
Geodetic latitude of R_EF	LAT_GEOD	User sub-function	F	S		rad	As needed
Geodetic longitude of Shuttle's position vector	LON	User sub-function	F	S		rad	As needed
Bearing from true north	AZ	User sub-function	F	S		rad	As needed
EF_TO_GEODETIC							
General position vector in Earth-fixed coordinates	R_EF	User sub-function	V	DP		ft	As needed
Earth ellipticity constant	ELLIPT	(a)	F	DP			
Earth equatorial radius	EARTH_RADIUS_EQUATOR	(a)	F	DP		ft	As needed

[a]See ascent or RTLS navigation principal function I-load and constant tables.

Table 4.4.2-1. Coordinate Transformations Input Parameters (Cont)

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
GEODETIC_TO_EF							
Geodetic latitude of R_EF	LAT_GEOD	User subfunction	F	S		rad	As needed
Geodetic longitude of Shuttle's position vector	LON	User subfunction	F	S		rad	As needed
Current orbiter altitude above reference ellipsoid	ALT	User subfunction	F	S		ft	As needed
Earth ellipticity constant	ELLIPT	(a)	F	DP			As needed
Earth equatorial radius	EARTH_RADIUS_EQUATOR	(a)	F	DP		ft	As needed
UVW_TO_M50							
Input position vector in M50 coords	R	User subfunction	V	DP		ft	As needed
Input velocity vector in M50 coords	V	User subfunction	V	S		ft/sec	As needed
SBODY_TO_M50							
M50 to body coordinates transformation quaternion	Q_FIFTY_BODY	User subfunction	V	DP		—	As needed

[a]See ascent or RTLS navigation principal function constant table.

Table 4.4.2-2. Coordinate Transformations Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
EARTH_FIXED TO MSO_COORD							
Earth-fixed to MSO coordinate transformation matrix	M_EFTOMSO	User subfunction	M	DP			As needed
EF_TO_TOPOET							
Transformation from earth-fixed to topodetic	M_EFTOTD	User subfunction	M	S			As needed
EF_TO_RUNWAY							
Earth-fixed to prime RW transformation matrix	M_EFTORW	User subfunction	M	S			As needed
EF_TO_SCANNER							
Transformation matrix from earth-fixed to scanner coordinates	M_EFTOSCANNER	User subfunction	M	S			As needed
EF_TO_GEODETIC							
Geodetic latitude of R_EF	LAT_GEOD	User subfunction	F	S		rad	As needed
Geodetic longitude of Shuttle s position vector	LON	User subfunction	F	S		rad	As needed
Current orbiter altitude above reference ellipsoid	ALT	User subfunction	F	S		ft	As needed
GEODETIC_TO_EF							
General position vector in earth-fixed coordinates	R_EF	User subfunction	V	DP		ft	As needed
UVW_TO_MSO							
UVW to MSO coordinate transformation matrix	M_UVW_TO_MSO	User sub function	M	S			As needed
BODY_TO_MSO							
Structure body to MSO coord nate transformation	MAT	User sub function	M	S			As needed

4.4.2.3 Geodetic to Earth-Fixed. This submodule accepts the geodetic parameters of a point and computes the earth-fixed Cartesian coordinates of that point.

Formulation: The input angles must be in radians. The equations necessary to transform geodetic parameters to earth-fixed coordinates are as follows:

$$R\_EF_1 = \left[\frac{EARTH\_RADIUS\_EQUATOR}{(\cos^2 (LAT\_GEOD) + (1 - ELLIPT)^2 \sin^2 (LAT\_GEOD))^{1/2}} + ALT \right] \cos LAT\_GEOD \cos LON \quad (F3,F4,F9)$$

$$R\_EF_2 = \left[\frac{EARTH\_RADIUS\_EQUATOR}{(\cos^2 (LAT\_GEOD) + (1 - ELLIPT)^2 \sin^2 (LAT\_GEOD))^{1/2}} + ALT \right] \cos LAT\_GEOD \sin LON \quad (F3,F4,F9)$$

$$R\_EF_3 = \left[\frac{(1 - ELLIPT)^2 EARTH\_RADIUS\_EQUATOR}{(\cos^2 (LAT\_GEOD) + (1 - ELLIPT)^2 \sin^2 (LAT\_GEOD))^{1/2}} + ALT \right] \sin LAT\_GEOD \quad (F3,F4,F9)$$

4.4.2.4 Earth-Fixed to Topodetic. This subfunction accepts the geodetic latitude and longitude of a point and computes the rotation matrix from earth-fixed coordinates to a topodetic coordinate system for the input location.

Formulation: This subfunction creates the rotation matrix as an Euler Z, Y sequence through the longitude angle (LON) and the negative of geodetic latitude angle minus 90 degrees (i.e., LAT_GEOD + $\pi/2$, respectively. The necessary equation is

$$M = \begin{bmatrix} (-\cos LON \sin LAT\_GEOD) & (-\sin LON \sin LAT\_GEOD) & (\cos LAT\_GEOD) \\ (-\sin LON) & (\cos LON) & 0 \\ (-\cos LON \cos LAT\_GEOD) & (-\sin LON \cos LAT\_GEOD) & (-\sin LAT\_GEOD) \end{bmatrix} \begin{matrix} (F9) \\ (F9) \\ (F9) \end{matrix}$$

[F3] This equation shall be protected against division by zero (Section 3.5).
[F4] This equation shall be protected against square roots of a negative number (Section 3.5).
[F9] This equation shall be protected against return value of sine or cosine with magnitude greater than unity (Section 3.5).

4.4.2.5 Earth-Fixed to Runway. This subfunction accepts the geodetic latitude, longitude, and azimuth of the runway and computes the rotation matrix from the earth-fixed coordinate system to the runway coordinate system.

Formulation: The earth-fixed to topodetic subfunction is used to obtain an earth-fixed to topodetic rotation matrix. Then the earth-fixed to topodetic matrix is multiplied by an Euler Z rotation matrix through the runway azimuth angle (AZ). The equation is

$$M = \begin{bmatrix} (\cos AZ) & (\sin AZ) & 0 \\ (-\sin AZ) & (\cos AZ) & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad \text{(F9)}$$ (F9)

where AZ is the runway azimuth angle measured clockwise from true north to the +X-axis of the runway. Then the transformation matrix is computed by

$$EF\_TO\_RUNWAY = M\ EF\_TO\_TOPDET$$

Input angles must be in radians.

The runway and topodetic coordinate systems are shown in Section 5.3.

4.4.2.6 Earth-Fixed to Scanner. The purpose of this subfunction is to compute the rotation matrix from earth-fixed to scanner coordinates.

Formulation: The earth-fixed to runway subfunction is executed, with use of the geodetic latitude and longitude of the scanner and the azimuth of the scanner boresight (AZ) from the true north to obtain a rotation matrix. The rotation matrix is then multiplied by a rotation matrix representing a 180-degree rotation about the X-axis. The necessary equation is

$$EF\_TO\_SCANNER = M\_XROTPI\ EF\_TO\_RUNWAY$$

where

$$M\_XROTPI = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

and EF_TO_RUNWAY is the rotation matrix computed by the earth-fixed to runway subfunction.

All computations are performed in double precision.

Input angles must be in radians.

[F9] This equation shall be protected against return value of sine or cosine with magnitude greater than unity (Section 3.5).

The scanner and earth-fixed coordinates systems are shown in Section 5.3.

4.4.2.7 Body to M50. The transformation matrix from structural body to M50 coordinates (MAT) is computed by postmultiplying the transformation matrix from body to M50 coordinates by a matrix representing a 180° rotation about the y-axis.

The transformation from body to M50 coordinates is derived from the inlisted quaternion Q_FIFTY_BODY by employing the general purposes matrix function QUAT_TO_MAT.

QUAT_TO_MAT computes the transformation matrix, A, associated with a quaternion, Q, as QUAT_TO_MAT (Q) = A, where A is computed by

$P2 = Q_2 + Q_2$

$P3 = Q_3 + Q_3$

$P4 = Q_4 + Q_4$

$P5 = P2\ Q_2$

$P6 = P4\ Q_4$

$Temp = 1.0 - P3\ Q_3$

$A_{1,1} = Temp - P6$

$A_{2,2} = 1.0 - P5 - P6$

$A_{3,3} = Temp - P5$

$P5 = P2\ Q_3$

$P6 = P4\ Q_1$

$A_{1,2} = P5 - P6$

$A_{2,1} = P5 + P6$

$P5 = P2\ Q_4$

$P6 = P3\ Q_1$

$A_{1,3} = P5 + P6$

$A_{3,1} = P5 - P6$

$P5 = P3\ Q_4$

$$P6 = P2\ Q_1$$

$$A_{2,3} = P5 - P6$$

$$A_{3,2} = P5 + P6$$

The structural body to M50 coordinates, MAT, is then computed as

$$MATRIX = QUAT\_TO\_MAT\ (Q\_FIFTY\_BODY)$$

$$MAT_{1,1} = -MATRIX_{1,1}$$

$$MAT_{1,2} = MATRIX_{2,1}$$

$$MAT_{1,3} = -MATRIX_{3,1}$$

$$MAT_{2,1} = -MATRIX_{1,2}$$

$$MAT_{2,2} = MATRIX_{2,2}$$

$$MAT_{2,3} = -MATRIX_{3,2}$$

$$MAT_{3,1} = -MATRIX_{1,3}$$

$$MAT_{3,2} = MATRIX_{2,3}$$

$$MAT_{3,3} = -MATRIX_{3,3}$$

This subfunction may be executed as needed.

Coordinate system definitions and the suggested implementation are shown in Section 5.3.

4.4.2.8 Earth-Fixed to Geodetic. This function is required to transform a Cartesian position vector in the earth-fixed (Greenwich) coordinate system to the geodetic parameters: geodetic altitude, longitude, and geodetic latitude.

Formulation: The equations necessary to transform the Cartesian position vector to geodetic parameters are as follows.

The computation for longitude is:

$$LON = \tan^{-1}\frac{\underline{R}\_EF_2}{\underline{R}\_EF_1} \quad ;0 \leq LON < 2\pi \qquad (F3,F7)$$

Computations for geodetic latitude, LAT_GEOD, and height above the reference ellipsoid, ALT, are as follows:

$$R\_XY = \underline{R}\_EF_1^2 + \underline{R}\_EF_2^2$$

$$R = (R\_XY + \underline{R}\_EF_3^2)^{1/2}$$

$$SIN\_P = \underline{R}\_EF_3/R \qquad F3)$$

$$COS\_P = (R\_XY)^{1/2}/R \qquad (F3)$$

$$RAD\_P = RE/\sqrt{1 + FLATCON\ SIN\_P^2/(1.0 - FLATCON)} \qquad (F3,F4)$$

$$DEL = \frac{FLATCON\ SIN\_P\ COS\_P}{1.0 - FLATCON\ COS\_P^2} \qquad (F3)$$

$$DEL\_LAT = \frac{RAD\_P\ DEL}{R} \qquad (F3)$$

$$\phi = ARCTAN\ (SIN\_P/COS\_P)$$

$$LAT\_GEOD = \phi + DEL\_LAT\ ;\ (in\ radians)$$

$$ALT = (R - RAD\_P)\ (1.0 - 0.5\ DEL\ DEL\_LAT)\ ;\ (in\ feet)$$

F3 This equation shall be protected against division by zero (Section 3.5).
F4 This equation shall be protected against square roots of a negative number (Section 3.5).
F7 This equation shall be protected against arc tangents with both arguments equal to zero (Section 3.5).

where

FLATCON = 1.0 - (1.0 - ELLIPT)^2,the eccentricity squared of the ellipsoic

LAT_GEOD = geodetic latitude

LON = longitude

ALT = geodetic altitude

ELLIPT = flattening of the reference ellipsoid (ELLIPT)

RE = equatorial radius of the reference ellipsoid (EARTH_RADIUS_EQUATOR)

This subfunction may be executed on demand.

The earth-fixed coordinate system and geodetic parameters are defined in Section 5.3.

4.4.2.9 UVW to M50. The purpose of this subfunction is to compute the transformation matrix from UVW coordinates to Aries M50 coordinates, given the position and velocity of the vehicle.

Formulation: The orientation of the U, V, W system is determined by the orbiter inertial position and velocity vectors ($\underline{R}$, $\underline{V}$) at the point (or time) of interest. Define

$$\underline{U} = \underline{R}/\ |\underline{R}| \qquad \text{(F3)}$$

$$\underline{W} = (\underline{R} \times \underline{V})/\ |\underline{R} \times \underline{V}| \qquad \text{(F3)}$$

$$\underline{Z} = \underline{W} \times \underline{U}$$

All computations are to be performed in double precision.

The transformation matrix from UVW coordinates to Aries-mean-of-1950 is then given by

$$(\underline{U} \mid \underline{Z} \mid \underline{W})$$

The UVW coordinate system and the Aries M50 system are defined in Section 5.3.

[F3]This equation shall be protected against division by zero (Section 3.5).

4.4.3 User Parameter Ascent/RTLS Computations

There are several variables, more specifically, altitude and altitude rate, which are required in both first and second stage ascent as well as in powered and glide RTLS; furthermore, dynamic pressure, equivalent airspeed and the magnitude of the total sensed acceleration are needed in first stage ascent, second stage ascent and powered RTLS. It is the purpose of this section to unify all of these requirements in one subfunction called ASCENT_RTLS_COMPS.

The altitude, altitude rate and vertical acceleration will be calculated by employing position and velocity vectors in M50 coordinates as input data. First, the absolute value of the position vector R_AVGG is computed and renamed for output purposes:

R_VEH_MAG = ABVAL(R_AVGG)

R_VEH_MAG_UPP = R_VEH_MAG

Then, a unit vector along the Shuttle position vector is determined:

VNOR = - R_AVGG/R_VEH_MAG

Next, certain quantities are computed in order to obtain a topodetic unit vector in the Z_{TD} - direction:

UK = VNOR · EARTH_POLE

TEMP = $(A\_0 + FLATCON\ UK^2)$

RAD_P = EARTH_RADIUS_EQUATOR $(A\_0/TEMP)^{1/2}$

The parameters A_0 and FLATCON are related to the earth ellipticity, ELLIPT, and are defined by

A_0 = $(1.0 - ELLIPT)^2$

FLATCON = 1 - A_0

The parameter ELLIPT is a constant whose value is specified in the level A CPDS.

The altitude above the ellipsoid is then computed:

ALT = R_VEH_MAG - RAD_P

Since the altitude rate is referenced to different directions in ascent and RTLS, a major mode test is required at this point to differentiate the

forms employed. If the major mode is either 102 or 103, denoted by the major mode flags being set ON;

MM_CODE_102 = ON

or

MM_CODE_103 = ON

then the altitude rate is given by

H_DOT = -V_RHO · VNOR

If the current OPS is either OPS 1 or OPS 6, then computations are made to calculate altitude rate relative to the ellipsoid. In this case one quantity varies slowly with time and, hence, is calculated only when the UPP state is updated by the navigation filter; that is, when

UPP_UDPATE = ON

then

UX = (EARTH_POLE - UK VNOR) (FLATCON UK RAD_P/(TEMP R_VEH_MAG))

If UPP_UPDATE = OFF, UX is held to its previous value.

H_DOT_ELLIPSOID = -V_RHO · (UX + VNOR)

If the major mode is neither 102 nor 103, the altitude with reference to the runway is computed from

ALT_WHEELS = ALT - ALT_RW

If the major mode is either 602 or 603 denoted by MM_CODE_602 = ON or MM_CODE_603 = ON, then the altitude and altitude rate are modified to account for the rotation of the nav base with respeot to the c.g. in the following manner:

ALT_WHEELS = ALT_WHEELS - (X_NB_WH SINTH + Z_NB_WH COSTH)

H_DOT_ELLIPSOID = H_DOT_ELLIPSOID - WBR_2 RAD_PER_DEG (X_NB_CG COSTH - Z_NB_CG SINTH)

where X_NB_CG and Z_NB_CG are the positive X and Z structural body axis distances between the navigation base and the vehicle c.g. and X_NB_WH and Z_NB_WH are the (positive) X and Z structural body axis distance between the navigation base and the bottom of the rear wheels. The term WBR_2 is the vehicle pitch rate in degrees per second, and SINTH and COSTH are the sine and cosine of the pitch angle.

Furthermore, for the glide RTLS phases, the vertical acceleration must be calculated; therefore the following scheme must be incorporated. The vertical acceleration will be determined in one of two ways: (a) if the navigation filter has updated the state, denoted by UPP_UPDATE = ON, then the vertical acceleration will be computed by extrapolating the previous values:

$$ACC\_VERT = ACC\_VERT\_OLD + \left(\frac{DELTA\_ACC\_VERT}{DELTA\_T}\right)(T\_STATE - T\_STATE\_LAST)$$

where ACC_VERT_OLD is the previous value of ACC_VERT, DELTA_ACC_VERT is the difference between the two most recent values of ACC_VERT excluding any navigation filter update value and DELTA_T is the difference between the times associated with those values of ACC_VERT employed to compute DELTA_ACC_VERT; and (b) if the update flag UPP_UPDATE = OFF, indicating no navigation update of the state, then, vertical acceleration is computed as follows:

ACC_VERT = (H_DOT_ELLIPSOID - H_DOT_LAST)/(T_STATE - T_STATE_LAST)

Also, when UPP_UPDATE = OFF, the values of ACC_VERT and T_STATE are employed to calculate values of DELTA_ACC_VERT and DELTA_T as well as values of T_STATE_OLD and ACC_VERT_OLD

DELTA_ACC_VERT = ACC_VERT - ACC_VERT_OLD

DELTA_T = T_STATE - T_STATE_OLD

T_STATE_OLD = T_STATE

ACC_VERT_OLD = ACC_VERT

Finally, previous values of altitude rate and state time are set to current values:

H_DOT_LAST = H_DOT_ELLIPSOID

T_STATE_LAST = T_STATE

During MM's 102, 103 and 601, the dynamic pressure, equivalent airspeed, and total sensed acceleration will be calculated. First, the dynamic pressure, based on an exponential atmosphere model, will be computed as a function of atmospheric density and earth-relative velocity. Local density is calculated by using the premission-determined constants RHO_B_I and ALT_S_I, the exponential atmosphere base density, and scale height, respectively. A premission-determined table of altitudes is compared with the current altitude, ALT, to find the index I for the altitude region of interest. The index I is determined as follows:

Increment I from 1 to IMAX until ALT < ALT_TAB_I or I = IMAX

Local density is then calculated by

$$RHO\_A = RHO\_B_I \; EXP(-ALT/ALT\_S_I)$$

The dynamic pressure will then be calculated:

$$Q\_BAR\_A = 0.5 \; RHO\_A \; REL\_VEL\_MAG^2$$

where the REL_VEL_MAG is the magnitude of the vehicle's earth-relative velocity vector.

The equivalent airspeed and total sensed acceleration follow from

$$EAS = SQRT(Q\_BAR\_A/(0.5 \; RHO\_B(1)))$$

$$LOAD\_TOTAL = ABVAL(A\_SENSED)/(GRAV\_SEA\_LEVEL)$$

Finally, independent of major mode, the update flag, UPP_UPDATE is reset to OFF.

Supplemental Information. Constants defining the exponential atmosphere can be determined as follows:

$$ALT\_S_I = (h_{I-1} - h_I)/\ln(\rho_I/\rho_{I-1})$$

$$RHO\_B_I = \rho_{I-1}/EXP(-h_{I-1}/ALT\_S_I)$$

where h_{I-1} and h_I are the lower and upper geometric altitudes defining the desired range of applicability of the exponential atmosphere and ρ_{I-1} and ρ_I are the corresponding densities at those altitudes. Note that $h_o = 0$ and $\rho_o = \rho_{h=o}$. Seven layers are used to approximate the atmospheric density from sea level to about 400,000 feet. Tabular values for RHO_B_I and ALT_S_I must be computed and premission stored with corresponding altitudes, ALT_TAB_I.

Tables of density versus geometric altitude are available at the launch site (such as the Patrick reference atmosphere) or can be found in the U. S. Standard Atmosphere, 1962, and in the U. S. Standard Atmosphere Supplements, 1966.

These calculations have been simplified to conserve memory locations and execution time. The assumptions are as follows:

1. Position and velocity are defined with respect to the vehicle navigation base rather than the c.g.

2. A correction factor has been applied to the altitude and altitude rate calculation to correct for pitch and pitch rate errors introduced because of the first assumption. Roll and roll rate are not included.

The terms X_NB_CG and Z_NB_CG used in the altitude rate correction are positive numbers equal to the X and Z structural body axis distance between the navigation base and the vehicle c.g.

X_NB_CG = X_CG - X_NB

Z_NB_CG = Z_NB - Z_CG

The terms X_NB_WH and Z_NB_WH used in the rear wheel altitude correction are positive numbers equal to the X and Z structural body axis distance between the navigation base and the bottom of the rear wheels.

X_NB_WH = X_WHEELS - X_NB

Z_NB_WH = Z_NB - Z_WHEELS

4.4.4 Powered HSI Computations

During first and second stage ascent as well as powered RTLS, the HSI will be employed to present to the crew angular relationships formed by certain vectors and the orbit plane. This plane, which is defined by the unit vector I_YD_M50, is used as the reference direction on the HSI throughout MM 102, 103 and 601.

The following computations shall be performed throughout MM 102, 103 and 601.

The secondary bearing pointer will be used to indicate the angle formed by the inertial velocity vector and the orbit plane. Since this angle is small, it is assumed that the angle and the sine of the angle are equivalent; hence, the heading of the inertial velocity vector is given by

HEADING_V_I = (V_AVGG · I_YD_M50)/V_INERTIAL_MAG

The course pointer will be used to indicate the angle formed by the relative velocity vector and the orbit plane. In order to avoid computational problems at lift-off, a test is made on the relative velocity. If the relative velocity is greater than 200 ft/sec, that is, if REL_VEL_MAG > 200, then the heading of the relative velocity vector is given by

HEADING_V_REL = (V_RHO · I_YD_M50)/REL_VEL_MAG

Again the small angle approximation for the sine has been employed in this formula.

The remaining computations are made only if the major mode is 601 or if a TAL abort has been declared. First, if MM_CODE_601 = ON or TAL_ABORT_DECLARED = ON then, a unit vector contained in the orbit plane and directed downrange is calculated:

IX = R_AVGG x I_YD_M50/ABVAL(R_AVGG x I_YD_M50)

Then, the landing site position vector, R_LS_EF, will be transformed from earth-fixed coordinates to M50 coordinates:

R_LS_M50 = EARTH_FIXED_TO_M50_COORD(T_STATE) R_LS_EF

Next, a vector normal to the great circle plane containing the Shuttle and the landing site position vectors is computed:

VNORM = R_AVGG x R_LS_M50

Then, the bearing from the Shuttle position to the landing site referenced to the orbit plane is determined:

HEADING_RW = ARCTAN2(VNORM · IX, - VNORM · I_YD_M50)

Finally, a test is made to determine if the velocity vectors have reversed direction, that is, if V_RHO · IX < 0, then the heading of relative velocity will be modified as follows:

HEADING_V_REL = PI - HEADING_V_REL

Furthermore, if V_AVGG · IX < 0, then the heading of the inertial velocity will be changed in a similar manner:

HEADING_V_I = PI - HEADING_V_I

4.4.5 Utility Subfunctions

The following subfunctions are utilized by various users. They are mutually independent, that is, the execution of any one of these functions neither requires the previous execution nor precludes the future execution of another. They may be utilized at regular intervals or only upon request.

Input and output parameters for these subfunctions are contained in Tables 4.4.5-1 and 4.4.5-2, respectively.

4.4.5.1 Altitude Above the Reference Ellipsoid. The purpose of this subfunction is to calculate the altitude, above the Fisher ellipsoid, of a point with M50 position vector R. The altitude obtained is approximate, with the error increasing with altitude. The accuracy obtained in near-earth work (and this covers the range of orbiter altitudes) is considered adequate. The equation is

$$H\_ELLIPSOID\ (\underline{R}) = |\underline{R}| - \frac{(1 - ELLIPT)\ EARTH\_RADIUS\_EQUATOR}{\sqrt{1 + [\ (1 - ELLIPT)^2 - 1]\ [1 - (\underline{UNIT}(\underline{R}) \cdot \underline{EARTH\_POLE})^2]}}$$

where ELLIPT and EARTH_RADIUS_EQUATOR are the ellipticity constant (or "flattening") and the equatorial radius of the 1960 Fisher ellipsoid, respectively, and EARTH_POLE is the unit vector in the direction of the earth's spin axis, expressed in M50 coordinates.

A flow chart for this function may be found in Section 5.2, under the name H_ELLIPSOID.

Table 4.4.5-1. Utility Subfunctions Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Earth's gravitational constant	EARTH_MU	(a)	F	DP		ft^3/sec^2	As needed
Unit vector in the direction of the earth's axis of rotation	EARTH_POLE	(a)	V	S		—	As needed
Equatorial radius of the earth	EARTH_RADIUS_EQUATOR	(a)	F	DP		ft	As needed
Rotational rate of the earth	EARTH_RATE	(a)	F	DP		rad/sec	As needed
Earth's ellipticity constant	ELLIPT	(a)	F	DP		—	As needed
Identity matrix (3x3)	ID_MATRIX_3x3	(a)	M	S		—	As needed
Unit vector of reference direction	I_Z	User function	V	S		—	As needed
Generic position vector	R	User function	V	DP		ft	As needed
Position vector of vehicle at time of measurement	R_RESID	User function	V	DP		ft	As needed
Position vector of sensor at time of measurement	R_SENSOR	User function	V	DP		ft	As needed
Generic velocity vector	V	User function	V	S		ft/sec	As needed

[a]See ascent or RTLS navigation prinicipal function constant table.

CR89963C

Table 4.4.5-2. Utility Subfunctions Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Sample Rate
Partial derivative of angular measurement WRT state vector	B	User function	V	DP		vary	As needed
Gradient of central gravity WRT position vector	GRAVITY_GRADIENT	User function	M	DP		sec^{-2}	As needed
Altitude above reference ellipsoid	H_ELLIPSOID	User function	F	S		ft	As needed
Velocity relative to rotating, windless atmosphere	V_REL	User function	V	S		ft/sec	As needed

4.4.5.2 Velocity Relative to the Windless, Rotating Atmosphere. This function computes the velocity, relative to the atmosphere, of a vehicle with M50 position and velocity vectors respectively $\underline{R}$ and $\underline{V}$. The following assumptions are made: there are no winds and the atmosphere rotates rigidly with the earth at all altitudes. The relative velocity is expressed in M50 coordinates.

The equation that accomplishes this is:

$$\underline{V}\_REL(\underline{V}, \underline{R}) = \underline{V} \cdot EARTH\_RATE\ (\underline{EARTH\_POLE} \times \underline{R})$$

where EARTH_RATE is the earth's angular velocity with respect to the M50 (inertial) axes and EARTH_POLE is the unit vector in the direction of the earth's axis of rotation, expressed in M50 coordinates.

A flow chart for this function may be found in Section 5.2 under the name V_REL.

4.4.5.3 Partial Derivatives of an Angular Measurement with Respect to the State Vector. This routine calculates a 6 component vector, $\underline{B}$, the components of which are the partial derivatives of an angular measurement (a scalar) with respect to the components of the position and velocity vectors of the vehicle relative to the measurement device.

The function takes as inputs the M50 position vector of the vehicle at the time of the measurement ($\underline{R}$_RESID), the M50 position vector of the measurement device at the same time ($\underline{R}$_SENSOR) and a unit vector ($\underline{I}$_Z) that represents, in the M50 coordinate system, the direction relative to which the angular measurement is taken (local north for azimuth, the zenith direction for the complement of elevation).

The following calculations are then made:

$$\underline{REL\_R} = \underline{R}\_RESID - \underline{R}\_SENSOR$$

$$\underline{REL\_R\_HORZ} = \underline{REL\_R} - (\underline{REL\_R} \cdot \underline{I}\_Z)\ \underline{I}\_Z$$

$$\underline{B}_{1 \text{ to } 3} = (\underline{I}\_Z \times \_REL\_R\_HORZ)/\ REL\_R\_HORZ^{\,2}$$

The other three components of the 6-vector $\underline{B}$ are identically zero.

$$\underline{B}_{4 \text{ to } 6} = \underline{0}.$$

A flow chart for this function, with the name ANGLE_PARTIALS, may be found in Section 5.2. The flow chart contains equations derived from those above but optimized for computation in that they eliminate the calculation of the intermediate vector REL_R_HORZ and thereby avoid the calculation of the zero vector obtained by the cross product of $\underline{I}$_Z and ($\underline{REL_R} \cdot \underline{I}$_Z) $\underline{I}$_Z.

4.4.5.4 Derivative of the Gravitational Acceleration Vector With Respect to the Position Vector. This function calculates a 3 x 3 matrix, the components of which are the partial derivatives of the gravitational acceleration vector with respect to the position vector $\underline{R}$. This is used in the generation of the state transition matrix, which is required for covariance matrix propagation. The dominant part of the gravitational acceleration vector is the central term, which computes the earth's attraction as if all its mass were concentrated at the center. This is the only term utilized in the calculation of the partial derivatives. A vehicle moving under the influence of such a gravity field would travel in a conic orbit. The state transition matrix obtained is based on Keplerian motion as the reference trajectory.

The equation is

$$\text{GRAVITY\_GRADIENT}(\underline{R}) = (\text{EARTH\_MU}/|R|^5)\ (3\ \underline{R}\ \underline{R}^T - |R|^2\ \text{ID\_MATRIX\_3x3})$$

where EARTH_MU is the earth's gravitational constant and ID_MATRIX_3x3 is the 3x3 identity matrix.

A flow chart for this function, with the name GRAVITY_GRADIENT, may be found in Section 5.2.

4.5 GENERAL REQUIREMENT PRINCIPAL FUNCTIONS

This section delineates software requirements in the category of service, single use or multiple use, that are not specifically function related. The general requirement principal functions include, but are not limited to, the following:

1. Ascent precise predictor principal function (sec. 4.5.1)

2. Ascent site lookup principal function (sec. 4.5.2)

4.5.1 Ascent Precise Predictor

A capability will be provided for predicting the position and velocity of the orbiter at some time in the future or past when an initial state and time are given, provided an OPS transition has not been requested.

The ascent precise predictor principal function will make no use of the IMU-accumulated sensed velocities and therefore is a free-flight prediction process even though it may be performed during periods of flight in which navigation is using accumulated sensed velocities.

A. Detailed Requirements. The position and velocity of the orbiter at the end of a given interval of time shall be computed in an M50 coordinate system by integration of the equations of motion, including gravity and drag accelerations (when appropriate).

The accuracy requirements and type of the atmosphere and gravity potential models used by this prediction function may vary according to the orbiter's distance to the surface of the earth and utilization for the prediction being requested. The user of the predictor function specifies the environmental models desired by means of input parameters, as described in the paragraphs that follow.

The predictor function will be called with the following input parameters:

1. T_FINAL, the time at which the final state is desired.

2. GMD_PRED,GMO_PRED, indicators of the gravitational and drag acceleration models that will be considered valid for the duration of the prediction interval.

3. R_INIT, V_INIT, and T_INIT, the initial state and time.

4. DT_MAX, an upper bound for the integration step size.

It will then perform as follows:

1. Obtain R_INIT, V_INIT, and rename them as R_FINAL, V_FINAL.

2. Proceed only if an OPS transition has not been requested (OPS_TRANS_REQUEST).

3. Obtain T_INIT and rename as T.

4. Establish the fixed integration STEP_SIZE by dividing the time interval into the smallest number (NUMBER_STEPS) of subintervals consistent with DT_MAX:

$$\text{NUMBER\_STEPS} = \text{MAX}\left(\text{ROUND}\left(\frac{|\text{T\_FINAL} - \text{T\_INIT}|}{\text{DT\_MAX}}\right), 1\right)$$

$$\text{STEP\_SIZE} = \frac{\text{T\_FINAL} - \text{T\_INIT}}{\text{NUMBER\_STEPS}}$$

5. Check the input parameter GMD_PRED. If the value of this parameter is zero (a setting which indicates the user wants to use a conic approximation), the acceleration vector G_PREVIOUS will contain only the central force term. This will be achieved by a call to a special routine, CENTRAL (which is documented in Section 4.2.1.2).

   CALL: CENTRAL

   INLIST: R_FINAL

   OUTLIST: G_PREVIOUS, R_INV

If GMD_PRED has a non-zero value (a setting that indicates a more complete gravity model and possibly a drag model are desired by the user), the angles of attack and sideslip will be obtained from the attitude processing principal function and converted to radians:

   SNAP ATTITUDE: ALPHAIN, BETAIN

   ALPHA = ALPHAIN RAD_PER_DEG

   BETA = BETAIN RAD_PER_DEG

and the acceleration vector G _PREVIOUS will be obtained by a call to the ACCEL function (instead of the function CENTRAL). Detailed requirements for the ACCEL function are contained in Section 4.2.1.2.

$$\underline{G}\_PREVIOUS = ACCEL\ (GMD\_PRED, GMO\_PRED, \underline{R}\_FINAL, \underline{V}\_FINAL, T, ALPHA, BETA)$$

Next, for the necessary number of times to cover the whole prediction interval, this function will perform as follows:

1. Should an OPS transition occur during a prediction, terminate the prediction.

2. Advance the time by an amount equal to STEP_SIZE

$$T = T + STEP\_SIZE$$

and advance the position by means of the equation

$$\underline{R}\_FINAL = \underline{R}\_FINAL + STEP\_SIZE\ \underline{V}\_FINAL + 0.5\ (STEP\_SIZE)^2\ \underline{G}\_PREVIOUS$$

3. Obtain a new value (G _FINAL) for the acceleration corresponding to the new position. Again, the subfunction called to provide this acceleration will depend on the value of the flag GMD_PRED: if GMD_PRED = 0, the function CENTRAL will be called. Otherwise, the function ACCEL will compute the acceleration. In this last case, if a drag acceleration is required, it will be computed on the basis of the ALPHA and BETA angles obtained previously. In other words, the model assumes a fixed attitude.

4. Advance the velocity:

$$\underline{V}\_FINAL = \underline{V}\_FINAL + STEP\_SIZE\ 0.5\ (\underline{G}\_PREVIOUS + \underline{G}\_FINAL)$$

5. Obtain a corrected value for the position by the "super-g" algorithm:

$$\underline{R}\_FINAL = \underline{R}\_FINAL + STEP\ SIZE^2\ (\underline{G}\_FINAL - \underline{G}\_PREVIOUS)/6$$

6. Save the value of G _FINAL for the next cycle: G _PREVIOUS = G _FINAL. The values of R _FINAL, V _FINAL, and G _FINAL, after these operations have been performed the appropriate number of times (NUMBER STEPS), being the desired position, velocity and approximate acceleration vectors at T_FINAL, will be output.

B. Interface Requirements. Input and output parameters are listed in Tables 4.5.1-1 and 4.5.1-2, respectively. The principal function input and output parameter table along with the I-load, K-load, constant, and cross-reference tables, are presented in Section 4.5.1.1.

C. Processing Requirements. None.

D. Constraints. If the precision prediction algorithm is not implemented as a reentrant procedure, execution of the algorithm may not be interrupted by calls from subsequent users. Users of the precision prediction algorithm are required to initialize the input parameters DT_MAX, GMD_PRED, GMO_PRED, R_INIT, V_INIT, T_INIT, and T_FINAL prior to the call, and are required to off load or snap the output parameters R_FINAL, V_FINAL, and G_FINAL after execution is complete. The parameter DT_MAX must be greater than zero.

The acceleration consisting of the central force term alone (required in conic prediction cases) could be obtained by calling the function ACCEL with the parameter GMD_PRED set equal to zero. The reason for the existence of the special routine CENTRAL for conic prediction is that its use will optimize the predictor of CPU (if the ACCEL function is implemented as a reentrant procedure, additional CPU would be involved in a call to ACCEL instead of a call to CENTRAL). This CPU optimization is a requirement only in the conic prediction mode.

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart may be found in Section 5.3.

The following table is intended for general information concerning how to set up the various flags for use of the predictor:

Type of Prediction Desired	GMD_PRED	GMO_PRED	DT_MAX (sec)
Conic (central gravity, only)	0	0	4.
Simplified (central + J_2 gravity, only)	2	0	4.
Precise (4 x 4 gravity plus drag)	4	4	4.

Table 4.5.1-1. Ascent Precise Predictor Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Maximum allowable step size	DT_MAX	(a)	F	S		sec	As needed
Flag indicating the degree of the gravity potential model	GMD_PRED	(a)	I	S	0-4	—	As needed
Shuttle position vector at T_INIT	R_INIT	(a)	V	DP		ft	As needed
Flag indicating the order of the gravity potential model	GMO_PRED	(a)	I	S	0-4	—	As needed
Time at which state is desired	T_FINAL	(a)	F	DP		sec	As needed
Time at beginning of prediction	T_INIT	(a)	F	DP		sec	As needed
Shuttle velocity vector at T_INIT	V_INIT	(a)	V	S		ft/sec	As needed
Angle of attack	ALPHAIN	(a)	F	S		deg	As needed
Angle of sideslip	BETAIN	(a)	F	S		deg	As needed
Degrees to radians conversion	RAD_PER_DEG	(b)	F	S		rad/deg	As needed
Flag indicating that an OPS transition has been requested	OPS_TRANS_REQUEST	(a)	D		ON OFF	--	As needed

[a]See ascent precise predictor principal function input parameter table.
[b]See ascent precise predictor principal function constant table.

Table 4.5.1-2. Ascent Precise Predictor Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Shuttle position vector at end of prediction	R_FINAL	(a)	V	DP		ft	As needed
Shuttle velocity vector at end of prediction	V_FINAL	(a)	V	S		ft/sec	As needed
Flag indicating that an OPS transition has been requested	OPS TRANS_REQUEST	(a)	D		ON OFF	N A	As needed

[a]See ascent precise principal function output parameter table

4.5.1.1 Ascent Precise Predictor (4.236) Principal Function Tables. The ascent precise predictor principal function input and output parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.5.1.1-1 through 4.5.1.1-5.

The values for the I-loads are contained in the I-loads requirements document (JSC-19350).

Table 4.5.1.1-1. Ascent Precise Predictor (4.236) Input/Output Functional Parameters

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
ALPHA_N	V90H2246C	NAV DERIVED ANGLE OF ATTACK	A/E ATT PROC	DEG	SPL	
BETA_N	V90H2249C	INERTIAL SIDESLIP ANGLE	A/E ATT PROC	DEG	SPL	
DT_MAX	V90U8500CA	MAX ALLOW TIME STEP SIZE	ASC 2STG GUID	S		
DT_MAX	V90U8500CB	MAX ALLOW TIME STEP SIZE	ORB INS GUID	S		
DT_MAX	V90U8500CC	MAX ALLOW TIME STEP SIZE	AOA/ATO TGT	S		
DT_MAX	V90U8500CE	MAX ALLOW TIME STEP SIZE	ASC MNVR DIP	S		
DT_MAX	V90U8500CG	MAX ALLOW TIME STEP SIZE	PW RTLS GUID	S		
DT_MAX	V90U8500CK	MAX ALLOW TIME STEP SIZE	ASC NAV	S		
GMD_PRED	V90U8501CA	GRAVITY MODEL DEGREE	ASC 2STG GUID			
GMD_PRED	V90U8501CB	GRAVITY MODEL DEGREE	ORB INS GUID			
GMD_PRED	V90U8501CC	GRAVITY MODEL DEGREE	AOA/ATO TGT			
GMD_PRED	V90U8501CE	GRAVITY MODEL DEGREE	ASC MNVR DIP			
GMD_PRED	V90U8501CH	GRAVITY MODEL DEGREE	PW RTLS GUID			
GMD_PRED	V90U8501CK	GRAVITY MODEL DEGREE	ASC NAV			
GMO_PRED	V90U8502CH	GRAVITY MODEL ORDER	PW RTLS GUID			
GMO_PRED	V90U8502CA	GRAVITY MODEL ORDER	ASC 2STG GUID			
GMO_PRED	V90U8502CB	GRAVITY MODEL ORDER	ORB INS GUID			
GMO_PRED	V90U8502CC	GRAVITY MODEL ORDER	AOA/ATO TGT			
GMO_PRED	V90U8502CE	GRAVITY MODEL ORDER	ASC MNVR DIP			
GMO_PRED	V90U8502CK	GRAVITY MODEL ORDER	ASC NAV			
OPS_TRANS_REQUEST	V90X0892XC	OPS TRANSITION REQUEST FLAG	MSC			
R_INIT(X)	V90H8508CA	X-COMP SHUTTLE POS VECTR AT T_INIT	ASC 2STG GUID	FT		
R_INIT(X)	V90H8508CB	X-COMP SHUTTLE POS VECTR AT T_INIT	ORB INS GUID	FT		
R_INIT(X)	V90H8508CC	X-COMP SHUTTLE POS VECTR AT T_INIT	PW RTLS GUID	FT		
R_INIT(X)	V90H8508CD	X-COMP SHUTTLE POS VECTR AT T_INIT	AOA/ATO TGT	FT		
R_INIT(X)	V90H8508CE	X-COMP SHUTTLE POS VECTR AT T_INIT	ASC MNVR DIP	FT		
R_INIT(X)	V90H8508CK	X-COMP SHUTTLE POS VECTR AT T_INIT	ASC NAV	FT		
R_INIT(Y)	V90H8509CA	Y-COMP SHUTTLE POS VECTR AT T_INIT	ASC 2STG GUID	FT		
R_INIT(Y)	V90H8509CB	Y-COMP SHUTTLE POS VECTR AT T_INIT	ORB INS GUID	FT		
R_INIT(Y)	V90H8509CC	Y-COMP SHUTTLE POS VECTR AT T_INIT	PW RTLS GUID	FT		
R_INIT(Y)	V90H8509CD	Y-COMP SHUTTLE POS VECTR AT T_INIT	AOA/ATO TGT	FT		
R_INIT(Y)	V90H8509CE	Y-COMP SHUTTLE POS VECTR AT T_INIT	ASC MNVR DIP	FT		
R_INIT(Y)	V90H8509CK	Y-COMP SHUTTLE POS VECTR AT T_INIT	ASC NAV	FT		
R_INIT(Z)	V90H8510CA	Z-COMP SHUTTLE POS VECTR AT T_INIT	ASC 2STG GUID	FT		
R_INIT(Z)	V90H8510CB	Z-COMP SHUTTLE POS VECTR AT T_INIT	ORB INS GUID	FT		
R_INIT(Z)	V90H8510CC	Z-COMP SHUTTLE POS VECTR AT T_INIT	PW RTLS GUID	FT		
R_INIT(Z)	V90H8510CD	Z-COMP SHUTTLE POS VECTR AT T_INIT	AOA/ATO TGT	FT		
R_INIT(Z)	V90H8510CE	Z-COMP SHUTTLE POS VECTR AT T_INIT	ASC MNVR DIP	FT		
R_INIT(Z)	V90H8510CK	Z-COMP SHUTTLE POS VECTR AT T_INIT	ASC NAV	FT		
T_FINAL	V90W8506CA	TIME AT WHICH STATE IS DESIRED	ASC 2STG GUID	SSSSSSSSSSSSSSS		
T_FINAL	V90W8506CB	TIME AT WHICH STATE IS DESIRED	ORB INS GUID	SSSSSSSSSSSSSSS		
T_FINAL	V90W8506CD	TIME AT WHICH STATE IS DESIRED	AOA/ATO TGT	SSSSSSSSSSSSSSS		
T_FINAL	V90W8506CE	TIME AT WHICH STATE IS DESIRED	ASC MNVR DIP	SSSSSSSSSSSSSSS		
T_FINAL	V90W8506CG	TIME AT WHICH STATE IS DESIRED	PW RTLS GUID	SSSSSSSSSSSSSSS		
T_FINAL	V90W8506CK	TIME AT WHICH STATE IS DESIRED	ASC NAV	SSSSSSSSSSSSSSS		
T_INIT	V90W8512CA	TIME AT BEGINNING OF PRED	ASC 2STG GUID	SSSSSSSSSSSSSSS		
T_INIT	V90W8512CB	TIME AT BEGINNING OF PRED	ORB INS GUID	SSSSSSSSSSSSSSS		
T_INIT	V90W8512CD	TIME AT BEGINNING OF PRED	AOA/ATO TGT	SSSSSSSSSSSSSSS		
T_INIT	V90W8512CG	TIME AT BEGINNING OF PRED	PW RTLS GUID	SSSSSSSSSSSSSSS		
T_INIT	V90W8512CK	TIME AT BEGINNING OF PRED	ASC NAV	SSSSSSSSSSSSSSS		
T_INIT/T_NAV,TGD	V90W8512CE	TIME AT BEGINNING OF PRED	ASC MNVR DIP	SSSSSSSSSSSSSSS		
V_INIT(X)	V90L8513CA	X-COMP SHUTTLE VEL VECTR AT T_INIT	ASC 2STG GUID	FT/S		

Space Transportation Systems Division
Rockwell International

Table 4.5.1.1-1. Ascent Precise Predictor (4.236) Input/Output Functional Parameters (Cont)

DBFN: D3B008-D PN: VP707100037P00L JULY 17, 1989 OI8D REV00 PAGE 318
INPUT FUNCTIONAL PARAMETERS FOR ASCENT PRECISE PREDICTOR ASC PREC PRED G4.236 BOOK: 5

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
V_INIT(X)	V90L8513CB	X-COMP SHUTTLE VEL VECTR AT T_INIT	ORB INS GUID	FT/S		
V_INIT(X)	V90L8513CC	X-COMP SHUTTLE VEL VECTR AT T_INIT	PW RTLS GUID	FT/S		
V_INIT(X)	V90L8513CD	X-COMP SHUTTLE VEL VECTR AT T_INIT	AOA/ATO TGT	FT/S		
V_INIT(X)	V90L8513CE	X-COMP SHUTTLE VEL VECTR AT T_INIT	ASC MNVR DIP	FT/S		
V_INIT(X)	V90L8513CK	X-COMP SHUTTLE VEL VECTR AT T_INIT	ASC NAV	FT/S		
V_INIT(Y)	V90L8514CA	Y-COMP SHUTTLE VEL VECTR AT T_INIT	ASC 2STG GUID	FT/S		
V_INIT(Y)	V90L8514CB	Y-COMP SHUTTLE VEL VECTR AT T_INIT	ORB INS GUID	FT/S		
V_INIT(Y)	V90L8514CC	Y-COMP SHUTTLE VEL VECTR AT T_INIT	PW RTLS GUID	FT/S		
V_INIT(Y)	V90L8514CD	Y-COMP SHUTTLE VEL VECTR AT T_INIT	AOA/ATO TGT	FT/S		
V_INIT(Y)	V90L8514CE	Y-COMP SHUTTLE VEL VECTR AT T_INIT	ASC MNVR DIP	FT/S		
V_INIT(Y)	V90L8514CK	Y-COMP SHUTTLE VEL VECTR AT T_INIT	ASC NAV	FT/S		
V_INIT(Z)	V90L8515CA	Z-COMP SHUTTLE VEL VECTR AT T_INIT	ASC 2STG GUID	FT/S		
V_INIT(Z)	V90L8515CB	Z-COMP SHUTTLE VEL VECTR AT T_INIT	ORB INS GUID	FT/S		
V_INIT(Z)	V90L8515CC	Z-COMP SHUTTLE VEL VECTR AT T_INIT	PW RTLS GUID	FT/S		
V_INIT(Z)	V90L8515CD	Z-COMP SHUTTLE VEL VECTR AT T_INIT	AOA/ATO TGT	FT/S		
V_INIT(Z)	V90L8515CE	Z-COMP SHUTTLE VEL VECTR AT T_INIT	ASC MNVR DIP	FT/S		
	V90L8515CK	Z-COMP SHUTTLE VEL VECTR AT T_INIT	ASC NAV	FT/S		

Table 4.5.1.1-1. Ascent Precise Predictor (4.236) Input/Output Functional Parameters (Cont)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
OPS_TRANS_REQUEST	V98X0892XB	OPS TRANSITION REQUEST FLAG	AOA/ATO TGT,ASC MNVR DIP, ASC 2STG GUID,ORB INS GUID, ASC NAV			
R_FINAL(1)	V98H0881CB	X-COMP PREDICTED SHUTTLE POS VECTR	AOA/ATO TGT,ASC MNVR DIP, ASC 2STG GUID,ORB INS GUID, PW RTLS GUID,ASC NAV	FT		
R_FINAL(2)	V98H0882CB	Y-COMP PREDICTED SHUTTLE POS VECTR	AOA/ATO TGT,ASC MNVR DIP, ASC 2STG GUID,ORB INS GUID, PW RTLS GUID,ASC NAV	FT		
R_FINAL(3)	V98H0883CB	Z-COMP PREDICTED SHUTTLE POS VECTR	AOA/ATO TGT,ASC MNVR DIP, ASC 2STG GUID,ORB INS GUID, PW RTLS GUID,ASC NAV	FT		
V_FINAL(1)	V98L0885CB	X-COMP PREDICTED SHUTTLE VEL VECTR	AOA/ATO TGT,ASC MNVR DIP, ASC 2STG GUID,ORB INS GUID, PW RTLS GUID,ASC NAV	FT/S		
V_FINAL(2)	V98L0886CB	Y-COMP PREDICTED SHUTTLE VEL VECTR	AOA/ATO TGT,ASC MNVR DIP, ASC 2STG GUID,ORB INS GUID, PW RTLS GUID,ASC NAV	FT/S		
V_FINAL(3)	V98L0887CB	Z-COMP PREDICTED SHUTTLE VEL VECTR	AOA/ATO TGT,ASC MNVR DIP, ASC 2STG GUID,ORB INS GUID, PW RTLS GUID,ASC NAV	FT/S		

Table 4.5.1.1-2. Ascent Precise Predictor (4.236) I-Loads

OI08B MISSIONS DBFN:0431
G4.236 - 0005 - ASCENT PRECISE PREDICTOR
ACTIVE MEMORY CONFIGURATIONS: 01

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
CDA	V97U5281C	ND	F	DP	D	X	G4.126	ZFJ2
							G4.223	ZFJ2
							G4.224	ZFJ2
							G4.236	ZFJ2
CDF	V97U6002C	ND	V	DP	D	X	G4.223	ZFJ2
							G4.224	ZFJ2
							G4.236	ZFJ2
							G4.126	ZFJ2
CDN	V97U5282C	ND	F	DP	D	X	G4.223	ZFJ2
							G4.224	ZFJ2
							G4.236	ZFJ2
							G4.126	ZFJ2
CDS	V97U6010C	ND	V	DP	D	X	G4.223	ZFJ2
							G4.224	ZFJ2
							G4.236	ZFJ2
							G4.126	ZFJ2
DRAG_CONST	V97U5317C	FT**2/SLUG	F	D	M	C	G4.127	DRC0
							G4.144	DRC0
							G4.223	
							G4.236	
							G4.15	
							G4.205	
EXP_SHAPE_FACTOR	V97U5334C	ND	F	DP	D	X	G4.223	ZFJ2
							G4.224	ZFJ2
							G4.236	ZFJ2
							G4.126	ZFJ2

Space Transportation Systems Division
Rockwell International

Table 4.5.1.1-3. Ascent Precise Predictor (G4.236) K-Loads Ascent Precise Predictor

OI88 MISSIONS

FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT	PR	S	PR FCTN	LAST CR EQTN MSID
ALT_ZONE_CHANGE	V97U5718C	+5.0000000	E+05 FT	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
ALT MODEL ATMOS DEN CHANGED								
DENSE(1)	V97U5304C	-3.9570	E+01 ND	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
DENSITY MODEL CONST								
DENSE(2)	V97U5305C	+1.0440	E-05 FT**-1	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
DENSITY MODEL CONST								
DENSE(3)	V97U5306C	+6.9560000	E+06 FT	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
DENSITY MODEL CONST								
DENSE(4)	V97U5307C	-2.420	E+01 ND	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
DENSITY MODEL CONST								
DENSE(5)	V97U5308C	-2.8890	E-06 FT**-1	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
DENSITY MODEL CONST								

DBFN:0534 DATE:07/14/88

Table 4.5.1.1-3. Ascent Precise Predictor (G4.236) K-Loads Ascent Precise Predictor (Cont)

OI88 MISSIONS

FSSR NAME / DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT	PR	S	PR FCTN	LAST CR EQTN MSID
DENSE(6)	V97U5309C	+2.6050000	E+06 FT	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
DENSITY MODEL CONST								
DIFCD1	V96U9743C	+3.9589	E-01 ND	F	S	C	G4.236 G4.223 G4.15 G4.127 G4.144 G4.205	89661A
DIFCD2	V96U9744C	+3.3962	E+00 ND	F	S	C	G4.236 G4.223 G4.15 G4.127 G4.144 G4.205	89661A
DIFCD3	V96U9745C	+6.5414	E-01 RAD	F	S	C	G4.236 G4.223 G4.15 G4.127 G4.144 G4.205	89661A
DIFCD4	V96U9746C	+8.3589	E-01 ND	F	S	C	G4.236 G4.223 G4.15 G4.127 G4.144 G4.205	89661A
SEA_LEVEL_DENSITY	V97U5505C	+2.3768840	E-03 SLUGS/FT**3	F	S	C	G4.127 G4.144 G4.15 G4.205 G4.223 G4.236	89661A
SEA LEVEL ATOMOSPHERIC DENSITY								

DBFN:0534 DATE:07/14/88

Table 4.5.1.1-4. Ascent Precise Predictor (G4.236) Constants

NROKRMM.FSSR2.DATA(X05)BOOK5
PFS CONSTANTS UPDATE B/L

FSSR NAME / DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
C(01) TESSERAL HARMONIC COEFFICIENT			-.27635957 E-09	ND	F	D				
C(02) TESSERAL HARMONIC COEFFICIENT			+.15711423 E-05	ND	F	D				
C(03) TESSERAL HARMONIC COEFFICIENT			+.21907694 E-05	ND	F	D				
C(04) TESSERAL HARMONIC COEFFICIENT			+.30466825 E-06	ND	F	D				
C(05) TESSERAL HARMONIC COEFFICIENT			+.97966803 E-07	ND	F	D				
C(06) TESSERAL HARMONIC COEFFICIENT			+.50552749 E-06	ND	F	D				
C(07) TESSERAL HARMONIC COEFFICIENT			+.78842815 E-07	ND	F	D				
C(08) TESSERAL HARMONIC COEFFICIENT			+.59073749 E-07	ND	F	D				
C(09) TESSERAL HARMONIC COEFFICIENT			-.41542493 E-08	ND	F	D				
EARTH_MU EARTH GRAVITATIONAL CONSTANTS	V97U4378C		+.140764487566 E+17	FT**3/ SEC**2	F	D				
EARTH_POLE(1) X COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8460C		.28322844 E-02	ND	F	S				
EARTH_POLE(2) Y COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8461C		-.50279960 E-04	ND	F	S				
EARTH_POLE(3) Z COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8462C		.99999598 E+00	ND	F	S				
EARTH_RADIUS_EQUATOR EARTH EQUATORIAL RADIUS	V97U5324C		.209257414698 1630 E+08	FT	F	D				
EARTH_RADIUS_GRAV EARTH RADIUS (GRAV ACCEL)	V97U5325C		+.209256561680 E+08	FT	F	D				
EARTH_RATE EARTH'S ROTATIONAL RATE	V97U4379C		.7292115146460 000 E-04	RAD/SEC	F	D				
ELLIPT EARTH'S ELLIPTICITY CONSTANTS	V97U5332C		.3352329800000 008 E-02	ND	F	D				
KN1 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT LESS THAN 400K FEET			-.17980000 E+01	ND	F	S				
KN2 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT LESS THAN 400K FEET			.66670000 E-05	FT**-1	F	S				

CR89596C

Table 4.5.1.1-4. Ascent Precise Predictor (4.236) Constants (Cont)

FSSR NAME / DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
KN3 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT LESS THAN 400K FEET			-.57890000 E-11	FT**-2	F	S				
KN4 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT BETWEEN 400K AND 600K FEET			.27518150 E-02	ND	F	S				
KN5 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT BETWEEN 400K AND 600K FEET			-.14990900 E-03	FT**-1	F	S				
KN6 CONSTANTS USED TO COMPUTE LOG OF KNUDSEN NUMBER, ALT BETWEEN 400K AND 600K FEET			.20490000 E-09	FT**-2	F	S				
PI RATIO CIRCUMFERENCE TO DIAMETER	V98U8725C		3.1415926535897	ND	F	D				
RAD_PER_DEG DEGREES TO RADIANS CONVERSION FACTOR	V97U0383C		.17453293 E-01	RAD/DEG	F	S				
S(01) TESSERAL HARMONIC COEFFICIENT	V97U5492C		-.52357454 E-08	ND	F	D				
S(02) TESSERAL HARMONIC COEFFICIENT	V97U5493C		-.90231337 E-06	ND	F	D				
S(03) TESSERAL HARMONIC COEFFICIENT	V97U5494C		+.27267074 E-06	ND	F	D				
S(04) TESSERAL HARMONIC COEFFICIENT	V97U5495C		-.21259298 E-06	ND	F	D				
S(05) TESSERAL HARMONIC COEFFICIENT	V97U5496C		+.19681077 E-06	ND	F	D				
S(06) TESSERAL HARMONIC COEFFICIENT	V97U5497C		-.44125015 E-06	ND	F	D				
S(07) TESSERAL HARMONIC COEFFICIENT	V97U5498C		+.14718958 E-06	ND	F	D				
S(08) TESSERAL HARMONIC COEFFICIENT	V97U5499C		-.12140873 E-07	ND	F	D				
S(09) TESSERAL HARMONIC COEFFICIENT	V97U5500C		+.63163541 E-08	ND	F	D				
ZONAL(01) ZONAL HARMONIC COEFFICIENT	V97U5582C		.0	ND	F	D				
ZONAL(02) ZONAL HARMONIC COEFFICIENT	V97U5583C		+.10826271 E-02	ND	F	D				
ZONAL(03) ZONAL HARMONIC COEFFICIENT	V97U5584C		-.25358868 E-05	ND	F	D				
ZONAL(04) ZONAL HARMONIC COEFFICIENT	V97U5585C		-.16246180 E-05	ND	F	D				

CR89596C

CR89596C

CR89596C

Space Transportation Systems Division
Rockwell International

Table 4.5.1.1-5. Ascent Precise Predictor (4.236) Cross-Reference

FSSR Name	Source Name
No requirements	

4.5.2 Ascent Site Lookup (4.238)

This principal function provides the capability to retrieve specified information from an appropriate site location table and to perform necessary computations to obtain the site position vector(s) and/or associated transformation matrices. The design of the site data management principal function is based on an area concept. An area is defined as any potential landing site which is appropriate for either Western Test Range (WTR) or Eastern Test Range (ETR) or both launches. Associated with each area are two runways called primary and secondary, two MSBLS's (if existing) each one supporting one of the two runways, and two TACAN's called primary and secondary. It is permissible to have more than one area associated with a given ground location, such as Edwards Air Force Base, whenever more than two runways must be supported (for example, one area might have EDW 04 and EDW 22 runways while a second area might have EDW 17 and EDW 35 runways). A maximum of 15 areas ($1 \leq$ AREA_SEL ≤ 15) have been allocated for OPS 3 while for OPS 1/6 there are five areas ($1 \leq$ AREA_SEL ≤ 5) allocated. This means that a total of 30 runways and 30 TACAN's exist in OPS 3 while a total of 10 runways and 10 TACAN's exist in OPS 1/6. For OPS 3 a maximum of 10 MSBLS's will be supported, while for OPS 1/6 there will be four MSBLS's. There are three subfunctions which make up this principal function, and they are described in Sections 4.5.2.1 through 4.5.2.3. Section 4.5.2.1 describes the site lookup initialization subfunction, which provides initialization of the selected area, runway/MSBLS parameters for the selected runway and auto TACAN channel command which is output to the TACAN SOP. Also, it provides for crew interface to support area redesignation, runway selection within a given area, and TACAN changes within a given area. Section 4.5.2.2 describes the entry runway lookup subfunction, which retrieves all necessary information related to a selected runway including runway parameters and MSBLS parameters (if existing). Section 4.5.2.3 describes the ascent TACAN lookup subfunction, which retrieves all necessary information related to a specified TACAN receiver (that is, information is output as a function of LRU number as well as TACAN station channel number). Notably, the TACAN site lookup function executes on the basis of which channel each of the three LRU's is actually tuned to receive, regardless of whether the LRU is tuned by GPC (auto) mode or by thumbwheel (manual) mode. There are, however, only two TACAN channels in any selected area; consequently, valid TACAN site data is restricted to either of two possible TACAN's in each selected area. Section 4.5.2.4 presents the input and output parameter table, along with the I-loads, K-loads, constants, and cross-references, of this principal function.

4.5.2 Ascent Site Lookup (4.238)

This principal function provides the capability to retrieve specified information from an appropriate site location table and to perform necessary computations to obtain the site position vector(s) and/or associated transformation matrices. The design of the site data management principal function is based on an area concept. An area is defined as any potential landing site which is appropriate for either Western Test Range (WTR) or Eastern Test Range (ETR) or both launches. Associated with each area are two runways called primary and secondary, two MSBLS's (if existing) each one supporting one of the two runways, and two TACAN's called primary and secondary. It is permissible to have more than one area associated with a given ground location, such as Edwards Air Force Base, whenever more than two runways must be supported (for example, one area might have EDW 04 and EDW 22 runways while a second area might have EDW 17 and EDW 35 runways). A maximum of 15 areas ($1 \leq$ AREA_SEL ≤ 15) have been allocated for OPS 3 while for OPS 1/6 there are five areas ($1 \leq$ AREA_SEL ≤ 5) allocated. This means that a total of 30 runways and 30 TACAN's exist in OPS 3 while a total of 10 runways and 10 TACAN's exist in OPS 1/6. For OPS 3 a maximum of 10 MSBLS's will be supported, while for OPS 1/6 there will be four MSBLS's. There are three subfunctions which make up this principal function, and they are described in Sections 4.5.2.1 through 4.5.2.3. Section 4.5.2.1 describes the site lookup initialization subfunction, which provides initialization of the selected area, runway/MSBLS parameters for the selected runway and auto TACAN channel command which is output to the TACAN SOP. Also, it provides for crew interface to support area redesignation, runway selection within a given area, and TACAN changes within a given area. Section 4.5.2.2 describes the entry runway lookup subfunction, which retrieves all necessary information related to a selected runway including runway parameters and MSBLS parameters (if existing). Section 4.5.2.3 describes the ascent TACAN lookup subfunction, which retrieves all necessary information related to a specified TACAN receiver (that is, information is output as a function of LRU number as well as TACAN station channel number). Notably, the TACAN site lookup function executes on the basis of which channel each of the three LRU's is actually tuned to receive, regardless of whether the LRU is tuned by GPC (auto) mode or by thumbwheel (manual) mode. There are, however, only two TACAN channels in any selected area; consequently, valid TACAN site data is restricted to either of two possible TACAN's in each selected area. Section 4.5.2.4 presents the input and output parameter table, along with the I-loads, K-loads, constants, and cross-references, of this principal function.

4.5.2.1 Ascent Site Lookup Initialization. The purpose of this subfunction is to provide a crew interface to support selection of any of 15 (five for RTLS) landing areas and, further, to support the choice of either of two runways within that area. Appropriate landing aids (two TACAN's and up to two MSBLS's) are supported in each area. Upon OPS 3 and OPS 1 initialization, a default choice for area is automatically selected in order to support nominal end-of-mission (or TAL) and RTLS as appropriate. Furthermore, this subfunction provides runway/MSBLS site data value assignments by means of a call to the Ascent Site Lookup subfunction. These data are used by all other software elements including CRT and dedicated displays, guidance, navigation, and SOP's (subsystem operating programs). Finally, auto TACAN channel commands are supported by initialization and crew requested changes. MSC will invoke the site lookup initialization subfunction after transition to OPS 3 or OPS 1 or whenever a TAL abort is declared at such a time so that initialization of parameters is completed before first execution of any user of those parameters. This subfunction will also be invoked whenever the crew selects a new area, selects the other runway, or switches TACAN's by means of HSD item entries.

A. Detailed Requirements. The design of this subfunction is based on the following considerations. Whenever OPS 1 is entered, the default value for the area will be an I-load value (AREA_SEL = RTLS_PRIME_AREA) which represents the designated RTLS site. In addition, if a TAL abort has been declared, the initial TAL site value will be the TAL selected area (AREA_SEL = TAL_SELECT*). The default value for the selected runway will be the primary runway (the first of two choices) associated with the given area. The default value for the auto TACAN channel will be the primary TACAN (the first of the two possible choices) associated with the given area. Subsequent to the default initialization, the crew may select by means of an item entry on the HSD a new area at any time. For each new area selected, the values of the runway and TACAN will again be the primary runway and TACAN (the first of two possible choices). Since each area contains two runways and two TACAN's, the crew may at any time, independently, select either runway and either TACAN by means of any of three item entries on the HSD. With these design concepts in mind, the detailed requirements can be expressed under the following four headings: (1) first pass logic when entering OPS 1 and when a TAL abort is declared, (2) landing area redesignation, (3) runway selection, and (4) TACAN switch.

1. First pass logic when entering OPS 1 or a TAL abort is declared.

   If the first pass flag, FIRST_PASS, or the TAL abort declared first pass flag, TAL_DECLARED_FIRST_PASS, is set equal to an I-load value, RTLS_PRIME_AREA (TAL_SELECT), the selected runway index, PRIME_RUNWAY_INDEX, is set equal to one; and the first pass flag is reset. Therefore, if

*Initially, TAL_SELECT is set to an I-load value and, thereafter, can be changed to another TAL area prior to the setting of TAL_DECLARED_FIRST_PASS by means of an item entry 40 on the HSD.

FIRST_PASS = ON or TAL_DECLARED_FIRST_PASS = ON

then

AREA_SEL = RTLS_PRIME_AREA

PRIME_RUNWAY_INDEX = 1

FIRST_PASS = OFF

Next, the TAL abort declared first pass flag is tested and, if set, then the selected area is set equal to the TAL selected area, TAL_SELECT, and the OPS transition carryover value for the selected area, AREA_SEL_OPS1, is defined; that is, if

TAL_DECLARED_FIRST_PASS = ON

then

TAL_DECLARED_FIRST_PASS = OFF

AREA_SEL= TAL_SELECT

AREA_SEL_OPS1 = AREA_SEL

Regardless of the value of the selected area, the selected TACAN index, TAC_SEL, is always the first of the two possible choices of TACAN's. The auto TACAN channel number, AUTO_CHANNEL_ID, is set to the selected channel number. Also, the primary and secondary runway names, which are area dependent, are defined at this point for display on the HSD. Therefore,

$$TAC\_SEL = 2\ AREA\_SEL - 1$$

$$AUTO\_CHANNEL\_ID = TACAN\_ID\_MAXI(TAC\_SEL)$$

$$RW\_NAME\_PSL = RUNWAY\_NAME(2\ AREA\_SEL - 1)$$

$$RW\_NAME\_SSL = RUNWAY\_NAME(2\ AREA\_SEL)$$

Finally, the ascent runway site lookup subfunction is called in order to assign values to all necessary runway/MSBLS parameters used by other software functions, that is,

CALL ASCENT_RUNWAY_SITE_LOOKUP

2. Landing area redesignation.

Whenever the crew desires to select a new area they will make an item entry on the HSD along with the value for the desired area, AREA_SEL. The HSD will in turn set the flag, NEW_AREA. In response to this request, the selected runway index, PRIME_RUNWAY_INDEX, will be set

to the first of the two possible choices for the new area, the selected TACAN index, TAC_SEL, will be set to the first of two possible choices, the overhead TAEM targeting initialization flag, RW_ID_UPP, will be set to zero, and the auto TACAN channel number, AUTO_CHANNEL_ID, is set to the selected channel number. The primary and secondary runway names, which are area dependent, are defined at this point for display on the HSD; the TACAN SOP parameters, $TAC\_CHAN\_OLD_1$, $TAC\_CHAN\_OLD_2$, and $TAC\_CHAN\_OLD_3$, are set in order to ensure that the SOP will invoke the TACAN site lookup subfunction*; the OPS transition carryover value for the selected area, AREA_SEL_OPS1, is defined; and the flag, NEW_AREA, is reset OFF. Therefore, if

NEW_AREA = ON

then

PRIME_RUNWAY_INDEX = 1

TAC_SEL = 2 AREA_SEL - 1

RW_ID_UPP = 0

AUTO_CHANNEL_ID = TACAN_ID_MAXI(TAC_SEL)

RW_NAME_PSL = RUNWAY_NAME(2 AREA_SEL - 1)

RW_NAME_SSL = RUNWAY_NAME(2 AREA_SEL)

$TAC\_CHAN\_OLD_1$ = 0

$TAC\_CHAN\_OLD_2$ = 0

$TAC\_CHAN\_OLD_3$ = 0

AREA_SEL_OPS1 = AREA_SEL

NEW_AREA = OFF

Finally, the ascent runway site lookup subfunction is called to complete the runway/MSBLS value assignments, that is,

CALL ASCENT_RUNWAY_SITE_LOOKUP

*This is necessary in order to handle the case where a new uplinked TACAN channel number is identical to the current channel number of one of the LRU's. If the area which has this uplinked TACAN is requested by the crew, the TACAN SOP would not be able to recognize that the TACAN station had changed without this artifice.

3. Runway selection.

For each given area, there are two runways which may be selected for landing. The primary, which is the first of two, is the default selection whenever a new area is requested, but either primary or secondary runway may be selected by the crew at any time. The appropriate item entry on the HSD will cause the setting of the flag, PRI_SEL, which in turn will result in the selection of the primary runway. Another item entry on the HSD will cause the setting of the flag, SEC_SEL, which in turn will result in the selection of the secondary runway. If the flag, PRI_SEL, is set ON, then the selected runway index, PRIME_RUNWAY_INDEX, is set to one and the flag, PRI_SEL, is reset OFF; that is, if

PRI_SEL = ON

then

PRIME_RUNWAY_INDEX = 1

PRI_SEL = OFF

Finally, the ascent runway site lookup function is called in order to complete the runway/MSBLS value assignments, that is,

CALL ASCENT_RUNWAY_SITE_LOOKUP

If, on the other hand, the flag, SEC_SEL, is set on, then the selected runway index, PRIME_RUNWAY_INDEX, is set to two and the flag, SEC_SEL is reset OFF; that is, if

SEC_SEL = ON

then

PRIME_RUNWAY_INDEX = 2

SEC_SEL = OFF

Finally the ascent runway site lookup function is called in order to complete the runway/MSBLS value assignments; that is,

CALL ASCENT_RUNWAY_SITE_LOOKUP

4. TACAN switch. For each given area, there are two TACAN stations which may be selected for the auto TACAN channel command. The first TACAN is the default selection whenever a new area is selected, but either one may be selected by the crew at any time. The appropriate item entry on the HSD will cause the setting of the flag, TAC_CHANGE, which in turn will result in the selection of the other TACAN by testing on the current value of the selected TACAN index, TAC_SEL. If TAC_SEL is equal to the first TACAN index, denoted by 2 AREA_SEL-1, then TAC_SEL is set

equal to the second TACAN index, denoted by 2 AREA_SEL; otherwise, it is set equal to the first index, 2 AREA_SEL -1. The auto TACAN channel command, AUTO_CHANNEL_ID, is set to the selected TACAN channel number and the flag, TAC_CHANGE, is reset OFF. Therefore, if

TAC_CHANGE = ON

then, test the selected TACAN index. If

TAC_SEL = 2 AREA_SEL -1

then

TAC_SEL = 2 AREA_SEL

otherwise

TAC_SEL = 2 AREA_SEL -1

Finally,

AUTO_CHANNEL_ID = TACAN_ID_MAXI(TAC_SEL)

TAC_CHANGE = OFF

B. Interface Requirements. The input and output parameters are shown in Tables 4.5.2.1-1 and 4.5.2.1-2.

C. Processing Requirements. All necessary initialization will be completed before execution of any user of site lookup data. The parameter AREA_SEL_OPS1 must be protected and carried over during OPS transition from OPS 1 to OPS 3.

Additionally, site parameter updates, that is, data for new areas, runways, MSBLS, TACAN's, should be computed as a homogeneous set and should not be available to users until the entire set is compatible. The value of the TAL area selection parameter, TAL_SELECT, is initialized to an I-load value (TAL_PRIME_AREA) by the HSD.

D. Constraints. The OPS 3 and OPS 1/6 versions are identical with the following exceptions:

1. In OPS 1, the default value for the prime RTLS landing site area is an I-load value, RTLS_PRIME_AREA, whereas in OPS 3, the default value for a non-TAL landing site area is one. In OPS 1, the value of the TAL landing site area is initially an I-load value but, subsequently, can be changed by an item entry 40 on the HSD prior to the setting of the TAL abort declared flag. In OPS 3, the value of the TAL landing site area is the value of the selected area carried over from OPS 1, AREA_SEL_OPS1.

2. The OPS 3 version must support an uplink capability (see Sections 4.11.3.1 and 4.11.3.2) to change any parameter associated with runway data and TACAN data whereas the OPS 1/6 version has no such requirement.

3. The OPS 3 version must support 15 areas resulting in a total of 30 runways and 30 TACAN's; also, a total of 10 MSBLS's must be supported. The OPS 1/6 version supports only 5 areas resulting in a total of 10 runways and 10 TACAN's; also, a total of 4 MSBLS's must be supported.

4. The OPS 1 version sends the selected area, AREA_SEL, and the landing site position vector, R_LS_EF, to the guidance principal function 4.2 and 4.4. The OPS 3 version does not require this interface.

E. Supplemental Information. A suggested implementation of these requirements is illustrated in Section 5.3 in the flow chart ASCENT_SITE_LOOKUP_INIT.

In OPS 1, the prime RTLS landing site area is initially an I-load value, RTLS_PRIME_AREA. The crew may, subsequently, select another RTLS site by means of an item entry 41 on the HSD. Item entry 41 will cause the flag NEW_AREA to be set, and the keyboard interface processor will call ASCENT_SITE_LOOKUP_INIT in order to process the request for the new area. In OPS 1, the prime TAL landing site area, TAL_SELECT, is initialized to an I-load value and, subsequently, can be changed by an item entry 40 on the HSD until the TAL abort declared flag is set. After this time, a different TAL landing site area is selected in the same manner as the RTLS landing site area, that is, by means of an item entry 41 on the HSD.

The OPS 1/6 and OPS 3 area tables must have an identical sequence of loading of areas supporting TAL. For example, if OPS 1/6 areas 2, 4, and 5 are loaded with certain TAL sites, then OPS 3 areas 2, 4, and 5 must be loaded in the same manner.

External to the site lookup function, certain "illegal entry" logic may exist to preclude selection of a TAL site for RTLS or an RTLS site for a TAL. There is no such lockout in the site lookup function.

Two guidance I-loads, RTLS_PRIME_AREA and TAL_PRIME_AREA, are used to designate the prime RTLS landing area and the prime TAL landing area. In ASCENT_SITE_LOOKUP_INIT, the I-load RTLS_PRIME_AREA is used, whereas the I-load TAL_PRIME_AREA is used by the HSD to initialize the parameter TAL_SELECT.

Table 4.5.2.1-1. Ascent Site Lookup Initialization Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Selected area	AREA_SEL	(a)	I	—	1-5	—	As needed
New landing area request flag	NEW_AREA	(a)	D	—	OFF/ON	—	As needed
Primary runway select command	PRI_SEL	(a)	D	—	OFF/ON	—	As needed
Name of the selected landing site	RUNWAY_NAME(L)	(b)	CHAR	—	—	—	As needed
Secondary runway select command	SEC_SEL	(a)	D	—	OFF/ON	—	As needed
Three-digit channel/mode designation unique for each TACAN station	TACAN_ID_MAXI(I)	(b)	V(10)	—	±126	—	As needed
Primary/secondary TACAN select commands	TAC_CHANGE	(a)	D	—	OFF/ON	—	As needed
Desired TAL landing site area	TAL_SELECT	(a)	I	—	1-5	—	As needed
Prime RTLS landing site area	RTLS_PRIME_AREA	(c)	I	—	1-5	—	As needed
TAL abort declared first pass flag	TAL_DECLARED_FIRST_PASS	(a)	D	—	OFF/ON	—	As needed

[a]See ascent site lookup principal function input parameter table.
[b]See ascent site lookup principal function I-load table.
[c]This is a guidance I-load

Table 4.5.2.1-2. Ascent Site Lookup Initialization Output Parameters

Description	Symbol	Destination	Type	Precision	Range	Units	Rate
Selected area	AREA_SEL	ASCENT_RUNWAY_SITE_LOOKUP, ASCENT_TACAN_SITE_LOOKUP, (a)	I	—	1-5	—	As needed
Value of AREA_SEL which is carried over from OPS 1 to 3	AREA_SEL_OPS1	(a)	I	—	1-5	—	As needed
Channel/mode identifier for the automatically selected TACAN station	AUTO_CHANNEL_ID	(a)	I	—	±126	—	As needed
New landing area request flag	NEW_AREA	(a)	D	—	OFF/ON	—	As needed
Indicator of which landing site choice is selected	PRIME_RUNWAY INDEX	ASCENT_RUNWAY_SITE_LOOKUP	I	—	1-2	—	As needed
Primary runway select command	PRI_SEL	(a)	D	—	OFF/ON	—	As needed
Local runway index parameter; also first pass flag	RW_ID_UPP	(a)	I	—	0-10	—	As needed
Primary runway name for the selected area which is used for display	RW_NAME_PSL	(a)	CHAR	—	—	—	As needed

[a]See ascent site lookup principal function output parameter table.

Table 4.5.2.1-2. Ascent Site Lookup Initialization Output Parameters (Cont)

Description	Symbol	Destination	Type	Precision	Range	Units	Rate
Secondary runway name for the selected area which is used for display	RW_NAME_SSL	(a)	CHAR	—	—	—	As needed
Secondary runway select command	SEC_SEL	(a)	D	—	OFF/ON	—	As needed
Primary/secondary TACAN select command	TAC_CHANGE	(a)	D	—	OFF/ON	—	As needed
Previous value of channel/ mode indicator for each TACAN station	TAC_CHAN_OLD(I)	(a)	V	—	±126	—	As needed

[a]See ascent site lookup principal function output parameter table.

4.5.2.2 Ascent Runway/MSBLS Site Lookup. The purpose of this subfunction is to retrieve information related to a specified runway for a given selected area. For purposes of designation, there are 5 choices of areas and, for each area, there are two choices of runways available referred to as the primary and the secondary. Either one of these two may be identified as the selected runway; however, the default designation will be the primary. The primary and secondary runway data shall include a parameter which is a pointer indicating which one of 4 MSBLS's is associated with the selected runway.

A. Detailed Requirements. This subfunction will accept from the ascent site lookup initialization subfunction a parameter, AREA_SEL, whose value indicates the area that has been selected and a parameter, PRIME_RUNWAY_INDEX, which indicates which one of the two runway choices has been identified as the selected runway. If PRIME_RUNWAY_INDEX = 1, then the primary runway is selected. If PRIME_RUNWAY_INDEX = 2, then the secondary runway is selected.

First, the local area parameter, J, is set equal to the selected area, AREA_SEL. Next, the local site table index parameter, L, is determined based on the value of the selected runway index. If PRIME_RUNWAY_INDEX is equal to one, then L is set equal to 2J-1 and RW_SELECT is set to ON, otherwise L is equal to 2J and RW_SELECT is set to OFF; therefore,

J = AREA_SEL

if

PRIME_RUNWAY_INDEX =1

then

L = 2J -1 and RW_SELECT = ON

otherwise

L = 2J and RW_SELECT = OFF

Once the site table index parameter, L, is determined, then the runway parameters are redefined for the selected runway

RW_NAME = L

LAT = RW_LAT(L)

LON = RW_LON(L)

ALT_RW = RUNWAY_ALT(L)

AZIMUTH_RW = RW_AZIMUTH(L)

LENGTH_RW = RW_LENGTH(L)

DELH_MSL_ELLIPSOID_RW = RW_DELH(L)

ANGLE_CORR_TNTOMAG_RW = RW_MAG_VAR(L)

K = RW_MSBLS_INDEX(L)

and the flag, MLS_AVAIL, is initially reset OFF, that is,

MSL_AVAIL = OFF

Next, the earth-fixed position vector and earth-fixed to selected runway transformation matrix shall be computed:

$\underline{R}$ _ LS_EF = GEODETIC_TO_EF(LAT,LON,ALT_RW)

M_EFTORW = EF_TO_RUNWAY(LAT,LON,AZIMUTH_RW)

Then, the position vector (originating at the origin of the EF coordinate system) of the HAC center for both sides of the runway centerline will be determined in earth-fixed coordinates:

$$\underline{R}\_CC\_L\_PRI = \underline{R}\_LS\_EF + M\_EFTORW^T \underline{R}\_HAC\_RW\_L$$

$$\underline{R}\_CC\_R\_PRI = \underline{R}\_LS\_EF + M\_EFTORW^T \underline{R}\_HAC\_RW\_R$$

where $\underline{R}$ _HAC_RW_L and $\underline{R}$ _HAC_RW_R are the position vectors (originating at the origin of the RW coordinate system) of these two points in runway coordinates (see Section 4.9).

Then, the magnitude of these two position vectors will be determined:

R_CC_LMAG_PRI = $|\underline{R}$ _CC_L_PRI$|$

R_CC_RMAG_PRI = $|\underline{R}$ _CC_R_PRI$|$

Next, a test will be made to determine if the selected runway has a MSBLS. If the selected runway MSBLS pointer, K, is zero, then the runway has no MSBLS. However, if K is a positive integer ($1 \leq K \leq 4$), then the parameters associated with the MSBLS site will be redefined for the designated selection and an earth-fixed position vector and an earth-fixed to scanner transformation matrix shall be computed for the MSBLS range-azimuth antenna and the MSBLS elevation antenna locations; therefore if

K > 0

then

LAT_MLS_R_AZ = LAT_MLS_R_AZ(K)

```
LONG_MLS_R_AZ = LONG_MLS_R_AZ(K)

ALT_MLS_R_AZ = ALT_MLS_R_AZ(K)

R_AZ_SCANNER_BEARING = R_AZ_RADAR_BEARING(K)

LAT_MLSEL = LAT_MLSEL(K)

LONG_MLSEL = LONG_MLSEL(K)

ALT_MLSEL = ALT_MLSEL(K)

EL_SCANNER_BEARING = EL_SCANNER_BEARING(K)

BIAS_MLS_RANGE = BIAS_MLS_RANGE(K)

BIAS_ELMLS = BIAS_ELMLS(K)

BIAS_AZMLS = BIAS_AZMLS(K)

X_DMEAZ_RW = X_DMEAZ_RW(K)

X_EL_RW = X_EL_RW(K)

Y_DMEAZ_RW = Y_DMEAZ_RW(K)

MLS_AVAIL = ON

M_EFTORAD_R_AZ = EF_TO_SCANNER(LAT_MLS_R_AZ, LONG_
                 MLS_R_AZ, R_AZ_SCANNER_BEARING)

M_EFTORAD_EL = EF_TO_SCANNER(LAT_MLSEL, LONG_MLSEL,
               EL_SCANNER_BEARING)

R_RMLS_EF = GEODETIC_TO_EF(LAT_MLS_R_AZ, LONG_
            MLS_R_AZ, ALT_MLS_R_AZ)

R_AZMLS_EF = R_RMLS_EF

R_ELMLS_EF = GEODETIC_TO_EF(LAT_MLSEL, LONG_
             MLSEL, ALT_MLSEL)
```

B. Interface Requirements. The input and output parameters are shown in Tables 4.5.2.2-1 and 4.5.2.2-2.

C. Processing Requirements. Parameters output from this subfunction should be provided as a homogeneous set and not be available to users until the entire set is compatible.

D. Constraints. No error checking is performed. The selected runway must be indicated by an integer from 1 to 2 and the selected area by an integer from 1 to 5. Both must be properly derived and limited by software external to this subfunction.

E. Supplementary Information. A suggested implementation of these requirements is illustrated in Section 5.3, ASCENT_RUNWAY_SITE_LOOKUP.

Table 4.5.2.2-1. Ascent Runway/MSBLS Site Lookup Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Current landing site selection	PRIME_RUNWAY_INDEX	ASCENT_SITE_LOOKUP_INIT	I	S	1-2	—	As needed
Selected area	AREA_SEL	ASCENT_SITE_LOOKUP_INIT	I	S	1-5	—	As needed
Bearing from true north of runway coordinate system +X axis	RW_AZIMUTH(L)	(b)	V(10)	S	—	rad	As needed
Altitude above reference ellipsoid of runway reference point	RUNWAY_ALT(L)	(b)	V(10)	S	—	ft	As needed
Altitude of mean sea-level above reference ellipsoid of the runway	RW_DELH(L)	(b)	V(10)	S	—	ft	As needed
Variation of runway magnetic north from true north	RW_MAG_VAR(L)	(b)	V(10)	S	—	rad	As needed
Runway geodetic latitude	RW_LAT(L)	(b)	V(10)	S	—	rad	As needed
Runway longitude	RW_LON(L)	(b)	V(10)	S	—	rad	As needed
Length of runway	RW_LENGTH(L)	(b)	V(10)	S	—	ft	As needed
Runway MSBLS pointer index	RW_MSBLS_INDEX(L)	(b)	V(10)	S	0-4	—	As needed
MSBLS azimuth antenna measurement bias	BIAS_AZMLS(K)	(b)	V(4)	S	—	rad	As needed
MSBLS elevation antenna measurement bias	BIAS_ELMLS(K)	(b)	V(4)	S	—	rad	As needed
MSBLS range antenna measurement bias	BIAS_MLSRANGE(K)	(b)	V(4)	S	—	ft	As needed
X component of range/azimuth antenna in runway coordinates	X_DMEAZ_RW(K)	(b)	V(4)	S	—	ft	As needed
Y component of range/azimuth antenna in runway coordinates	Y_DMEAZ_RW(K)	(b)	V(4)	S	—	ft	As needed
X component of elevation antenna in runway coordinates	X_EL_RW(K)	(b)	V(4)	S	—	ft	As needed
MSBLS range/azimuth geodetic latitude	LAT_MLS_R_AZ(K)	(b)	V(4)	S	—	rad	As needed
MSBLS range/azimuth longitude	LONG_MLS_R_AZ(K)	(b)	V(4)	S	—	rad	As needed
MSBLS range/azimuth geodetic altitude	ALT_MLS_R_AZ(K)	(b)	V(4)	S	—	ft	As needed
MSBLS azimuth boresight relative to true north	R_AZ_RADAR_BEARING(K)	(b)	V(4)	S	—	rad	As needed
MSBLS elevation geodetic latitude	LAT_MLS_EL(K)	(b)	V(4)	S	—	rad	As needed
MSBLS elevation longitude	LONG_MLS_EL(K)	(b)	V(4)	S	—	rad	As needed
MSBLS elevation geodetic altitude	ALT_MLS_EL(K)	(b)	V(4)	S	—	ft	As needed
MSBLS elevation boresight relative to true north	EL_SCANNER_BEARING (K)	(b)	V(4)	S	—	rad	As needed

[b] See ascent site lookup principal function I-load table.

Table 4.5.2.2-1. Ascent Runway/MSBLS Site Lookup Input Parameters (Cont)

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Position vector of HAC center for the left side of the runway centerline	R_HAC_RW_L	(b)	V	S	—	ft	As needed
Position vector of HAC center for the right side of the runway centerline	R_HAC_RW_R	(b)	V	S	—	ft	As needed

[b]See ascent site lookup principal function I-load table.

Table 4.5.2.2-2. Ascent Runway/MSBLS Site Lookup Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Completion Rate
Current landing site selection index	RW_NAME	(a)	P	S	1-10	—	As needed
Altitude above reference ellipsoid of runway reference point	ALT_RW	(a)	P	S	—	ft	As needed
Bearing from true north of runway coordinate system +X axis	AZIMUTH_RW	(a)	P	S	—	rad	As needed
Length of runway	LENGTH_RW	(a)	P	S	—	ft	As needed
Altitude of mean sea-level above reference ellipsoid at the runway	DELH_MSL_ELLIPSOID_RW	(a)	P	S	—	ft	As needed
Variation of runway magnetic north from true north	ANGLE_CORR_TWTOMAG_RW	(a)	P	S	0-2	rad	As needed
Earth-fixed to select runway transformation matrix	M_EFTORW	(a)	M	S	—	—	As needed
Position vector of landing site in earth-fixed coordinates	R_LS_EF	(a)	V	DP	—	ft	As needed
Position vector of HAC center on the left-side of the runway centerline in earth-fixed coordinates	R_CC_L_PRI	(a)	V	S	—	ft	As needed
Position vector of HAC center on the right-side of the runway centerline in earth-fixed coordinates	R_CC_R_PRI	(a)	V	S	—	ft	As needed
Magnitude of R_CC_L_PRI	R_CC_LMAG_PRI	(a)	F	S	—	ft	As needed
Magnitude of R_CC_R_PRI	R_CC_RMAG_PRI	(a)	F	S	—	ft	As needed
Flag indicating (ON) the availability of MSBLS sites at the currently chosen runway	MLS_AVAIL	(a)	D		OFF ON		As needed
MSBLS azimuth antenna measurement bias	BIAS_AZMLS	(a)	F	S	—	rad	As needed
MSBLS elevation antenna measurement bias	BIAS_ELMLS	(a)	F	S	—	rad	As needed
MSBLS range antenna measurement bias	BIAS_MLSRANGE	(a)	F	S	—	ft	As needed
X component of range/azimuth antenna in runway coordinates	X_DMEAZ_RW	(a)	F	S	—	ft	As needed
Y component of range/azimuth antenna in runway coordinates	Y_DMEAZ_RW	(a)	F	S	—	ft	As needed
X component of elevation antenna in runway coordinates	X_EL_RW	(a)	F	S	—	ft	As needed
Earth-fixed position vector of MSBLS range scanner	R_RMLS_EF	(a)	V	DP	—	ft	As needed
Earth-fixed position vector of MSBLS azimuth scanner	R_AZMLS_EF	(a)	V	DP		ft	As needed

[a]See ascent site lookup principal function output parameter table.

Table 4.5.2.2-2. Ascent Runway/MSBLS Site Lookup Output Parameters (Cont)

Description	Symbol	Output Destination	Type	Precision	Range	Units	Completion Rate
Earth-fixed position vector of MSBLS elevation scanner	R_ELMLS_EF	(a)	V	DP	—	ft	As needed
Transformation matrix from earth-fixed to MSBLS range azimuth radar coordinate frame	M_EFTORAD_R_AZ	(a)	M	DP	—	—	As needed
Transformation matrix from earth-fixed to MSBLS elevation radar coordinate frame	M_EFTORAD_EL	(a)	M	S	—	ft	As needed
Runway Selection Indicator	RW_SELECT	(a)	D	—	ON/OFF	—	As needed

[a]See ascent site lookup principal function output parameter table.

4.5.2.3 Ascent TACAN Site Lookup. The purpose of this subfunction is to retrieve information for a specified TACAN channel, NEW_STATION_ID, associated with a given TACAN receiver, LRU_ID, from the TACAN site location table and to compute the corresponding geodetic radius at the site, an earth-fixed position vector and an earth-fixed to topodetic transformation matrix. There will be a maximum of two TACAN sites available for each selected area.

A. Detailed Requirements. This subfunction will accept from the ascent site lookup initialization subfunction an index, AREA_SEL, which indicates the selected area; furthermore, it will accept from the TACAN SOP the current TACAN channel number, NEW_STATION_ID, and its associated receiver number, LRU_ID. First, the local area parameter, J, is set equal to the selected area, AREA_SEL, the TACAN channel valid flag, $TAC\_CHAN\_VALID\_SL_{LRU\_ID}$, is initially reset OFF and the local TACAN channel number, $TACAN\_ID_{LRU\_ID}$, set equal to the current channel number, NEW_STATION_ID. Then, a search is performed to determine if the specified channel, $TACAN\_ID_{LRU\_ID}$, is one of the two possible choices which are fixed by means of the selected area, AREA_SEL. If the channel, $TACAN\_ID_{LRU\_ID}$, is not one of the two possible TACAN's, then the flag, $TAC\_CHAN\_VALID\_SL_{LRU\_ID}$, remains OFF and the present TACAN information for this LRU is not updated. On the other hand, if the channel is one of the two possible choices, then the following parameters are redefined for the new TACAN from values supplied by the TACAN site location table

$$LAT\_TACAN\_SL_{LRU\_ID} = LATITUDE\_GEODETIC\_MAXI(I)$$

$$LONG\_TACAN\_SL_{LRU\_ID} = LONGITUDE\_EAST\_MAXI(I)$$

$$ALT\_TACAN\_SL_{LRU\_ID} = ALT\_ABOVE\_ELLIPSOID\_MAXI(I)$$

$$DH\_TACAN\_SL_{LRU\_ID} = MSL\_ABOVE\_ELLIPSOID\_MAXI(I)$$

$$ANGLE\_CORR\_TNTOMAG\_SL_{LRU\_ID} = MAGNETIC\_VARIATION\_MAXI(I)$$

Furthermore, the corresponding geodetic radius at the site, an earth-fixed position vector and an earth-fixed to topodetic transformation matrix are computed

$$RD\_TAC\_MSL\_SL_{LRU\_ID} = (1.-ELLIPT)^2\ EARTH\_RADIUS\_EQUATOR/$$
$$..(1. + SIN^2\ (LAT\_TACAN\_SL_{LRU\_ID})\ ELLIPT$$
$$(ELLIPT-2))^{1/2} + DH\_TACAN\_SL_{LRU\_ID}$$

$$\underline{R}\_TACAN\_EF\_SL_{LRU\_ID} = GEODETIC\_TO\_EF(LAT\_TACAN\_SL_{LRU\_ID},$$
$$LONG\_TACAN\_SL_{LRU\_ID}, ALT\_TACAN\_SL_{LRU\_ID})$$

$$M\_EFTOTD\_TACAN\_SL_{LRU\_ID} = EF\_TO\_TOPDET(LAT\_TACAN\_SL_{LRU\_ID},$$
$$LONG\_TACAN\_SL_{LRU\_ID})$$

Finally, the TACAN channel valid flag is set ON, that is,

$$TAC\_CHAN\_VALID\_SL_{LRU\_ID} = ON$$

B. Interface Requirements. The input and output parameters are shown in Tables 4.5.2.3-1 and 4.5.2.3-2, respectively.

C. Processing Requirements. Output parameters from this subfunction are employed by a variety of users. Consequently, this subfunction is invoked only by the TACAN SOP. Parameters output from this subfunction should be provided as a homogeneous set and not be available to users until the entire set is compatible.

D. Constraints. None

E. Supplementary Information. A suggested implementation of these requirements is illustrated in Section 5.3, ASCENT_TACAN_SITE_LOOKUP. TACAN site lookup constraints: The TACAN transmitters/receivers (T/R) provide a selection of 126 X-mode channels and 126 Y-mode channels; the TACAN control head permits the crew to manually select anyone of these 252 T/R frequency pairs. However, a selection is of no value to certain of the onboard software unless the ground station location for the tuned channel is also available. Consequently, a table of limited size is provided to supply this information for two unique channels/modes for each area. The parameters, TAC_CHAN_VALID_SL_{LRU_ID} serve as the indicators of whether the station location is known or not known.

Table 4.5.2.3-1. Ascent TACAN Site Lookup Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Selected area	AREA_SEL	ASCENT_SITE_LOOKUP_INIT, (a)	I	S	1-5	—	As needed
Current TACAN channel/mode identifier	NEW_STATION_ID	(a)	I	S	±126	—	As needed
LRU number for output parameters	LRU_ID	(a)	I	S	1-3	—	As needed
TACAN channel/mode identifier	TACAN_ID_MAXI (I)	(b)	V(10)	S	±126	—	As needed
TACAN site geodetic latitude	LATITUDE_GEOETIC_MAXI(I)	(b)	V(10)	S	$-\frac{\pi}{2}, \frac{\pi}{2}$	rad	As needed
TACAN site longitude	LONGITUDE_EAST_MAXI(I)	(b)	V(10)	S	$-\pi, \pi$	rad	As needed
TACAN station altitude	ALT_ABOVE_ELLIPSOID_MAXI(I)	(b)	V(10)	S	—	ft	As needed
Altitude of mean sea-level above reference ellipsoid at TACAN station	MSL_ABOVE_ELLIPSOID_MAXI(I)	(b)	V(10)	S	—	ft	As needed
Variation of magnetic north from true north at TACAN site	MAGNETIC_VARIATION_MAXI(I)	(b)	V(10)	S	$0-2\pi$	rad	As needed
Earth ellipticity constant	ELLIPT	(b)	F	DP	—	—	As needed
Earth equatorial radius	EARTH_RADIUS_EQUATOR	(b)	F	DP	—	ft	As needed

[a]See ascent site lookup principal function input parameter table.
[b]See ascent site lookup principal function I-load and constant tables.

Table 4.5.2.3-2. Ascent TACAN Site Lookup Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Completion Rate
TACAN station identifier code	$TACAN\_ID_{LRU\_ID}$	(a)	I	S	±126	—	As needed
TACAN site geodetic latitude	$LAT\_TACAN\_SL_{LRU\_ID}$	(a)	P	S	$\frac{\pi}{2},\frac{\pi}{2}$	rad	As needed
TACAN site longitude	$LONG\_TACAN\_SL_{LRU\_ID}$	(a)	P	S	$-\pi,\pi$	rad	As needed
TACAN station altitude	$ALT\_TACAN\_SL_{LRU\_ID}$	(a)	P	S	—	ft	As needed
Altitude of mean sea-level above reference ellipsoid at TACAN station	$DH\_TACAN\_SL_{LRU\_ID}$	(a)	P	S	—	ft	As needed
Variation of magnetic north from true north at TACAN site	$ANGLE\_CORR\_TNTOMAG\_SL_{LRU\_ID}$	(a)	P	S	0-2π	rad	As needed
Geodetic radius at TACAN site	$RD\_TAC\_MSL\_SL_{LRU\_ID}$	(a)	P	DP	—	ft	As needed
TACAN station earth-fixed position vector	$R\_TACAN\_EF\_SL_{LRU\_ID}$	(a)	V	DP	—	ft	As needed
Transformation matrix from earth-fixed to topodetic coordinates at the TACAN site	$M\_EFTOTD\_TACAN\_SL_{LRU\_ID}$	(a)	M	S	—	—	As needed
TACAN channel validity flag	$TAC\_CHAN\_VALID\_SL_{LRU\_ID}$	(a)	D	—	OFF ON	—	As needed

(a) See ascent site lookup principal function output parameter table.

4.5.2.4 Ascent Site Lookup (4.238) Principal Function Tables. The ascent site lookup principal function input and output parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.5.2.4-1 through 4.5.2.4-5.

The values for the I-loads are contained in the I-loads requirements document (JSC-19350).

Table 4.5.2.4-1. Ascent Site Lookup (4.238) Input/Output Functional Parameters

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
LRU ID	V95J5021C	TACAN LRU NUMBER	TACAN SOP			
NEW STATION_ID	V95J5020CB	TACAN 1,2,OR 3 NEW STATION CHAN NO	ORB TAC SOP			
NEW AREA	V93X4398X	NEW LANDING AREA SELECT IND	6.21			
NEW STATION_ID	V95J5020CA	TACAN 1,2,OR 3 NEW STATION CHAN NO	TACAN SOP			
PRI SEL	V93X4393X	PRIMARY RUNWAY SEL CMD	6.21			
SEC_SEL	V93X4394X	SECONDARY RUNWAY SEL CMD	6.21			
TAC_CHANGE	V93X4395X	PRI/SEC TACAN SELECT CMD	6.21			
TAL_DECL_FRST_PASS	V90X8657X	TAL ABORT DECLARED FIRST PASS FLAG	MSC			
TAL_SELECT CMD	V93J4399C	TAL SELECT CMD	6.21		HXS	

Space Transportation Systems Division
Rockwell International

Table 4.5.2.4-1. Ascent Site Lookup (4.238) Input/Output Functional Parameters (Cont)

DBFN: D3B008-D PN: VP707100037P00L JULY 17, 1989 OI8D REV00 PAGE 235
OUTPUT FUNCTIONAL PARAMETERS FROM ASCENT SITE LOOKUP ASC SITE LOOKUP G4.238 BOOK: 5

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
ALT_RW	V90H1818CB	ALTITUDE OF RW WRT REF ELLIPSOID	ASC AREA NAV,AVVI PROC,RTLS UPP	FT		
ALT_TACAN_SL(1)	V90H1846CB	ALTITUDE OF TACAN 1 STATION	ASC AREA NAV	FT		
ALT_TACAN_SL(2)	V90H1847CB	ALTITUDE OF TACAN 2 STATION	ASC AREA NAV	FT		
ALT_TACAN_SL(3)	V90H1848CB	ALTITUDE OF TACAN 3 STATION	ASC AREA NAV	FT		
ANGLE_CORR_TNTOMAG_RW	V90H1820CB	MAGNETIC VARIATION OF RW	A/E ATT PROC,ASC AREA NAV, HSI PROC,HUD PROC,TLM	RAD		
ANGLE_CORR_TNTOMAG_S1	V90H1843CB	MAGNETIC VARIATION AT TACAN 1 SITE	RTLS UPP,ASC AREA NAV,RTLS NAV	RAD		
ANGLE_CORR_TNTOMAG_S2	V90H1844CB	MAGNETIC VARIATION AT TACAN 2 SITE	RTLS UPP,ASC AREA NAV,RTLS NAV	RAD		
ANGLE_CORR_TNTOMAG_S3	V90H1845CB	MAGNETIC VARIATION AT TACAN 3 SITE	RTLS UPP,ASC AREA NAV,RTLS NAV	RAD		
AREA_SEL	V93J4392CB	SELECTED AREA	6.21,ASC 2STG GUID,TLM, PW RTLS GUID			
AREA_SEL_OPS1	V93U4389C	AREA-SEL CARRYOVER TO OPS 3	ENT SITE LOOKUP			
AUTO_CHANNEL_ID	V95J5022CB	AUTO TACAN CHANNEL SELECTION	6.21,TACAN SOP			
AZIMUTH_RW	V90H1817CB	AZIMUTH OF RW FROM TRUE NORTH	ASC AREA NAV,HSI PROC,RTLS UPP, HUD PROC	RAD		
BIAS_AZMLS	V90H1886CB	MSBLS AZIMUTH MEASUREMENT BIAS	RTLS NAV	RAD		
BIAS_ELMLS	V90H1887CB	MSBLS ELEVATION MEASUREMENT BIAS	RTLS NAV,RTLS UPP	RAD		
BIAS_RMLS	V90H1885CB	MSBLS RANGE MEASUREMENT BIAS	RTLS NAV	FT		
DELH_MSL_ELLIPSOID_RW	V90H1819CB	ALT OF MSL ABOVE REF ELLIP AT RW	ASC AREA NAV,AVVI PROC,RTLS NAV	FT		
DH_TACAN_SL(1)	V90H1849CB	ALT OF MSL ABV REF ELLIP AT TAC 1	ASC AREA NAV	FT		
DH_TACAN_SL(2)	V90H1850CB	ALT OF MSL ABV REF ELLIP AT TAC 2	ASC AREA NAV	FT		
DH_TACAN_SL(3)	V90H1851CB	ALT OF MSL ABV REF ELLIP AT TAC 3	ASC AREA NAV	FT		
HUD_RW_LENGTH	V72H4163CB	HUD RUNWAY LENGTH	HUDE1,HUDE2	FT		
M_EFTORAD_EL(1-1)	V90U1875CB	EF TO MSBLS EL COORD, ELE 1-1	RTLS NAV			
M_EFTORAD_EL(1-2)	V90U1876CB	EF TO MSBLS EL COORD, ELE 1-2	RTLS NAV			
M_EFTORAD_EL(1-3)	V90U1877CB	EF TO MSBLS EL COORD, ELE 1-3	RTLS NAV			
M_EFTORAD_EL(2-1)	V90U1878CB	EF TO MSBLS EL COORD, ELE 2-1	RTLS NAV			
M_EFTORAD_EL(2-2)	V90U1879CB	EF TO MSBLS EL COORD, ELE 2-2	RTLS NAV			
M_EFTORAD_EL(2-3)	V90U1880CB	EF TO MSBLS EL COORD, ELE 2-3	RTLS NAV			
M_EFTORAD_EL(3-1)	V90U1881CB	EF TO MSBLS EL COORD, ELE 3-1	RTLS NAV			
M_EFTORAD_EL(3-2)	V90U1882CB	EF TO MSBLS EL COORD, ELE 3-2	RTLS NAV			
M_EFTORAD_EL(3-3)	V90U1883CB	EF TO MSBLS EL COORD, ELE 3-3	RTLS NAV			
M_EFTORAD_R_AZ(1-1)	V90U1865CB	EF TO RNG/AZ MSBLS RDR COORD/1-1	RTLS NAV			
M_EFTORAD_R_AZ(1-2)	V90U1866CB	EF TO RNG/AZ MSBLS RDR COORD/1-2	RTLS NAV			
M_EFTORAD_R_AZ(1-3)	V90U1867CB	EF TO RNG/AZ MSBLS RDR COORD/1-3	RTLS NAV			
M_EFTORAD_R_AZ(2-1)	V90U1868CB	EF TO RNG/AZ MSBLS RDR COORD/2-1	RTLS NAV			
M_EFTORAD_R_AZ(2-2)	V90U1869CB	EF TO RNG/AZ MSBLS RDR COORD/2-2	RTLS NAV			
M_EFTORAD_R_AZ(2-3)	V90U1870CB	EF TO RNG/AZ MSBLS RDR COORD/2-3	RTLS NAV			
M_EFTORAD_R_AZ(3-1)	V90U1871CB	EF TO RNG/AZ MSBLS RDR COORD/3-1	RTLS NAV			
M_EFTORAD_R_AZ(3-2)	V90U1872CB	EF TO RNG/AZ MSBLS RDR COORD/3-2	RTLS NAV			
M_EFTORAD_R_AZ(3-3)	V90U1873CB	EF TO RNG/AZ MSBLS RDR COORD/3-3	RTLS NAV			
M_EFTORW(1-1)	V90U1805CB	EF TO PRIME RW XFORM MTRX ELE 1-1	RTLS UPP,RTLS NAV,ASC AREA NAV, ASC NAV			
M_EFTORW(1-2)	V90U1806CB	EF TO PRIME RW XFORM MTRX ELE 1-2	RTLS UPP,RTLS NAV,ASC AREA NAV, ASC NAV			
M_EFTORW(1-3)	V90U1807CB	EF TO PRIME RW XFORM MTRX ELE 1-3	RTLS UPP,RTLS NAV,ASC AREA NAV, ASC NAV			
M_EFTORW(2-1)	V90U1808CB	EF TO PRIME RW XFORM MTRX ELE 2-1	RTLS UPP,RTLS NAV,ASC AREA NAV, ASC NAV			
M_EFTORW(2-2)	V90U1809CB	EF TO PRIME RW XFORM MTRX ELE 2-2	RTLS UPP,RTLS NAV,ASC AREA NAV, ASC NAV			
M_EFTORW(2-3)	V90U1810CB	EF TO PRIME RW XFORM MTRX ELE 2-3	RTLS UPP,RTLS NAV,ASC AREA NAV,			

Table 4.5.2.4-1. Ascent Site Lookup (4.238) Input/Output
Functional Parameters (Cont)

FIELD NAME	MS ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
			ASC NAV			
M_EFTOPW 3 1	V90U[illegible]CB	EF TO PRIME RW XFORM MTRX ELE 3-1	RTLS UPP,RTLS NAV,ASC AREA NAV, ASC NAV			
M_EFTOPW 3 2	V90U1812CB	EF TO PRIME RW XFORM MTRX ELE 3-2	RTLS UPP,RTLS NAV,ASC AREA NAV, ASC NAV			
M EFTOPW 3 3	V90U[illegible]3CB	EF TO PRIME RW XFORM MTRX ELE 3-3	RTLS UPP,RTLS NAV,ASC AREA NAV, ASC NAV			
M EFTOTD TACAN S 1(1-1	V90U1775CB	EF TO TOPO COORD AT TA SITE 1/1-1	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD TACAN S 1 1-2	V90 7 6CB	EF TO TO O CC D AT TA SITE 1/1-2	RT S UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD TACAN S 1(1-3	V90 7 CB	EF TO TOPO CO D AT TA SITE 1/1 3	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFT TD TA AN SL1 2 1	V90 778 B	EF TO TOPO CO RD AT TA SITE 1/2-1	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFT TD TACAN S 1(2 2)	V90 7 9CB	EF TO TOPO COORD AT TA SITE 1/2-2	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOT TACAN SL1(2-3)	V90U 78[illegible]B	EF TO TOPO CO RD AT TA SI E 1/2-3	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFT TD TA AN SL1(3-1)	V90U1781CB	EF TO TOPO COORD AT TA SITE 1/3-1	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOT TACAN SL1(3 2)	V90U1782 B	EF TO TOPO COORD AT TA SITE 1/3-2	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD_TA AN_SL1(3-3)	V90U1783CB	EF TO TOPO COORD AT TA SITE 1/3-3	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD TACAN SL2(1-1)	V90U1784CB	EF TO TOPO COORD AT TA SITE 2/1-1	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD TACAN SL2(1-2)	V90U1785CB	EF TO TOPO CO RD AT TA SITE 2/1-2	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD_TACAN_SL2(1-3)	V90 1786CB	EF TO TOPO COORD AT TA SITE 2/1-3	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFT TD_TACAN_SL2(2-1)	V90U1787CB	EF TO TOPO COORD AT TA SITE 2/2-1	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD_TACAN_SL2(2-2)	V90U1788CB	EF TO TOPO COORD AT TA SITE 2/2-2	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD_TACAN_SL2(2-3)	V90U1789CB	EF TO TOPO COORD AT TA SITE 2/2-3	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD_TACAN_SL2(3-1)	V90U1790CB	EF TO TOPO COORD AT TA SITE 2/3-1	RTLS UPP,ASC AREA NAV,RTLS NAV			
M_EFTOTD_TACAN_SL2(3-2)	V90U1791CB	EF TO TOPO COORD AT TA SITE 2/3-2	RTLS UPP,ASC AREA NAV,RTLS NAV			
M_EFTOTD_TACAN_SL2(3-3)	V90U1792CB	EF TO TOPO COORD AT TA SITE 2/3-3	RTLS UPP,ASC AREA NAV,RTLS NAV			
M_EFTOTD_TACAN_SL3(1-1)	V90U1793CB	EF TO TOPO COORD AT TA SITE 3/1-1	RTLS UPP,ASC AREA NAV RTLS NAV			
M EFTOTD_TACAN_SL3 1-2)	V90U1794CB	EF TO TOPO COORD AT TA SITE 3/1-2	RTLS UPP,ASC AREA NAV RTLS NAV			
M EFTOTD_TACAN_SL3 1-3)	V90U1795CB	EF TO TOPO COORD AT TA SITE 3/1-3	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD TACAN S 3 2-1)	V90U1796CB	EF TO TOPO COORD AT TA SITE 3/2-1	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD_TACAN SL3 2-2)	V90U1797CB	EF TO TOPO COORD AT TA SITE 3/2-2	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD_TACAN S 3 2-3)	V90U1798CB	EF TO TOPO COORD AT TA SITE 3/2-3	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD_TACAN SL3 3-1)	V90U1799CB	EF TO TOPO COORD AT TA SITE 3/3-1	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD_TACAN S 3 3 2)	V90U1800CB	EF TO TOPO COORD AT TA SITE 3/3-2	RTLS UPP,ASC AREA NAV,RTLS NAV			
M EFTOTD_TACAN_SL3 3-3)	V90J1801CB	EF TO TOPO COORD AT TA SITE 3/3 3	RTLS UPP,ASC AREA NAV,RTLS NAV			
MLS_AVAI[illegible]	V90[illegible]3720[illegible]B	MLS AVAILABILITY	RTLS NAV,A/RTLS NAV SEQ, RTLS UPP			
R_AZ[illegible]S EF	V90H1828CB	X COMP EF POS VCT OF MLS AZ ANT	RTLS NAV			
R_A[illegible]S_EF 2	V90H1829CB	Y COMP EF POS VCT OF MLS AZ ANT	RTLS NAV			
R_A[illegible]S EF 3	V90H1830CB	Z COMP EF POS VCT OF MLS AZ ANT	RTLS NAV			
R [illegible] PRI 1	V90H1925CB	X COMP POS VCT HAC LFT SIDE RW	ASC AREA NAV	FT		
R CC PRI 2	V90H1926CB	Y COMP POS VCT HAC LFT SIDE RW	ASC AREA NAV	FT		
R CC PRI 3	V90H1927CB	Z COMP POS VCT HAC LFT SIDE RW	ASC AREA NAV	FT		
R CC MAG PRI	V90H1931CB	MAG OF POS VCT HAC LFT SIDE RW	ASC AREA NAV	FT		
R CC R PRI 1	V90H1928CB	X COMP POS VCT HAC RHT SIDE RW	ASC AREA NAV	FT		
R CC R PRI 2)	V90H1929CB	Y COMP POS VCT HAC RHT SIDE RW	ASC AREA NAV	FT		
R CC_R_PRI 2	V90H1930CB	Z COMP POS VCT HAC RHT SIDE RW	ASC AREA NAV	FT		
R CC_RMAG_PRI	V90H1932CB	MAG OF POS VCT HAC RHT SIDE RW	ASC AREA NAV	FT		
R E M S EF 1)	V90H1825CB	X COMP EF POS VCT MLS ELEV ANT	RTLS NAV	FT		
R E M S EF(2)	V90H1826CB	Y COMP EF POS VCT MLS ELEV ANT	RTLS NAV	FT		
R_E M S_EF(3)	V90H1827CB	Z COMP EF POS VCT MLS ELEV ANT	RTLS NAV	FT		
R_ S_EF(1)	V90H1900CB	X COMP LDG SITE POS VCT EF COORD	ASC UPP,ASC AREA NAV,RTLS UPP, ASC 2STG GUID	FT		
R_LS_EF(2)	V90H1901CB	Y-COMP LDG SITE POS VCT-EF COORD	ASC UPP,ASC AREA NAV,RTLS UPP,	FT		

Space Transportation Systems Division
Rockwell International

Table 4.5.2.4-1. Ascent Site Lookup (4.238) Input/Output Functional Parameters (Cont)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
R_LS_EF(3)	V90H1902CB	Z-COMP LDG SITE POS VCT-EF COORD	ASC 2STG GUID ASC UPP,ASC AREA NAV,RTLS UPP,	FT		
R_RMLS_EF(1)	V90H1831CB	X-COMP EF POS VCT OF MLS RNG ANT	ASC 2STG GUID RTLS NAV			
R_RMLS_EF(2)	V90H1832CB	Y-COMP EF POS VCT OF MLS RNG ANT	RTLS NAV			
R_RMLS_EF(3)	V90H1833CB	Z-COMP EF POS VCT OF MLS RNG ANT	RTLS NAV			
R_TACAN_EFSL1(1)	V90H1834CB	X-COMP EF POS VECTOR OF TACAN 1	RTLS UPP,ASC AREA NAV,TACAN RM, RTLS NAV	FT		
R_TACAN_EFSL1(2)	V90H1835CB	Y-COMP EF POS VECTOR OF TACAN 1	RTLS UPP,ASC AREA NAV,TACAN RM, RTLS NAV	FT		
R_TACAN_EFSL1(3)	V90H1836CB	Z-COMP EF POS VECTOR OF TACAN 1	RTLS UPP,ASC AREA NAV,TACAN RM, RTLS NAV	FT		
R_TACAN_EFSL2(1)	V90H1837CB	X-COMP EF POS VECTOR OF TACAN 2	RTLS UPP,ASC AREA NAV,TACAN RM, RTLS NAV	FT		
R_TACAN_EFSL2(2)	V90H1838CB	Y-COMP EF POS VECTOR OF TACAN 2	RTLS UPP,ASC AREA NAV,TACAN RM, RTLS NAV	FT		
R_TACAN_EFSL2(3)	V90H1839CB	Z-COMP EF POS VECTOR OF TACAN 2	RTLS UPP,ASC AREA NAV,TACAN RM, RTLS NAV	FT		
R_TACAN_EFSL3(1)	V90H1840CB	X-COMP EF POS VECTOR OF TACAN 3	RTLS UPP,ASC AREA NAV,TACAN RM, RTLS NAV	FT		
R_TACAN_EFSL3(2)	V90H1841CB	Y-COMP EF POS VECTOR OF TACAN 3	RTLS UPP,ASC AREA NAV,TACAN RM, RTLS NAV	FT		
R_TACAN_EFSL3(3)	V90H1842CB	Z-COMP EF POS VECTOR OF TACAN 3	RTLS UPP,ASC AREA NAV,TACAN RM, RTLS NAV	FT		
RD_TAC_SL(1)	V90H1861CB	GEODETIC RADIUS AT TACAN SITE 1	ASC AREA NAV	FT		
RD_TAC_SL(2)	V90H1862CB	GEODETIC RADIUS AT TACAN SITE 2	ASC AREA NAV	FT		
RD_TAC_SL(3)	V90H1863CB	GEODETIC RADIUS AT TACAN SITE 3	ASC AREA NAV	FT		
RUNWAY_NAME_PSL	V97U5681CB	RUNWAY NAME PRIME LND SITE	6.21			
RUNWAY_NAME_SSL	V97U5682CB	RUNWAY NAME SEC LND SITE	6.21			
RW_ID_UPP	V95X0234XB	OTT FIRST PASS FLAG	RTLS UPP			
RW_NAME	V90U1916CB	CURRENT LANDING SITE SELECTED	RTLS UPP			
RW_SELECT	V93X4523XB	PRI/SEC RUNWAY SELECTION INDICATOR	6.21			
TAC_CHAN_OLD(1)	V95U5023CB	PREV VALUE TAC CHAN FOR LRU 1	TACAN SOP			
TAC_CHAN_OLD(2)	V95U5024CB	PREV VALUE TAC CHAN FOR LRU 2	TACAN SOP			
TAC_CHAN_OLD(3)	V95U5025CB	PREV VALUE TAC CHAN FOR LRU 3	TACAN SOP			
TAC_CHANGE	V93J4464CB	SELECTED TACAN CHANNEL	6.21			
TACAN_CHAN_VALID_SL1	V90X1858XB	TACAN CHANNEL VALIDITY FLAG(TAC 1)	RTLS UPP,ASC AREA NAV,RTLS NAV			
TACAN_CHAN_VALID_SL2	V90X1859XB	TACAN CHANNEL VALIDITY FLAG(TAC 2)	RTLS UPP,ASC AREA NAV,RTLS NAV			
TACAN_CHAN_VALID_SL3	V90X1860XB	TACAN CHANNEL VALIDITY FLAG(TAC 3)	RTLS UPP,ASC AREA NAV,RTLS NAV			
TACAN_ID(1)	V90U1802CB	TACAN 1 GND STA CHAN	RTLS NAV,6.21,TLM			
TACAN_ID(2)	V90U1803CB	TACAN 2 GND STA CHAN	RTLS NAV,6.21,TLM			
TACAN_ID(3)	V90U1804CB	TACAN 3 GND STA CHAN	RTLS NAV,6.21,TLM			
X_DMEAZ_RW	V90H1815CB	X-COMP RNG/AZ ANTENNA IN RW COORD	ASC AREA NAV	FT		
X_EL_RW	V90H1910CB	X-COMP OF ELEV ANTENNA IN RW COORD	ASC AREA NAV	FT		
Y_DMEAZ_RW	V90H1816CB	Y-COMP RNG/AZ ANTENNA IN RW COORD	ASC AREA NAV	FT		

Table 4.5.2.4-2. Ascent Site Lookup (4.238) I-Loads

OI8D MISSIONS FSSR NAME	MSID	ENG UNIT	DT PR D S PR FCTN	CAT
ALT_ABOVE_ELLIPSOID_MAXI(01)	V98U8021C	FT	F S D C G4.124 G4.238	A011 E011
ALT_ABOVE_ELLIPSOID_MAXI(02)	V98U8022C	FT	F S D C G4.124 G4.238	A011 E011
ALT_ABOVE_ELLIPSOID_MAXI(03)	V98U8023C	FT	F S D C G4.124 G4.238	A021 E021
ALT_ABOVE_ELLIPSOID_MAXI(04)	V98U8024C	FT	F S D C G4.124 G4.238	A021 E021
ALT_ABOVE_ELLIPSOID_MAXI(05)	V98U8025C	FT	F S D C G4.124 G4.238	A031 E031
ALT_ABOVE_ELLIPSOID_MAXI(06)	V98U8026C	FT	F S D C G4.124 G4.238	A031 E031
ALT_ABOVE_ELLIPSOID_MAXI(07)	V98U8027C	FT	F S D C G4.124 G4.238	A041 E041
ALT_ABOVE_ELLIPSOID_MAXI(08)	V98U8028C	FT	F S D C G4.124 G4.238	A041 E041
ALT_ABOVE_ELLIPSOID_MAXI(09)	V98U8029C	FT	F S D C G4.124 G4.238	A051 E052
ALT_ABOVE_ELLIPSOID_MAXI(10)	V98U8030C	FT	F S D C G4.124 G4.238	A051 E052
ALT_MLS_R_AZ(01)	V98U8064C	FT	F S D P G4.124 G4.238	AML0 EML0
ALT_MLS_R_AZ(02)	V98U8065C	FT	F S D P G4.124 G4.238	AML0 EML0
ALT_MLS_R_AZ(03)	V98U8066C	FT	F S D P G4.124 G4.238	AML0 EML0
ALT_MLS_R_AZ(04)	V98U8067C	FT	F S D P G4.124 G4.238	AML0 EML0
ALT_MLSEL(01)	V98U8052C	FT	F S D P G4.124 G4.238	AML0 EML0
ALT_MLSEL(02)	V98U8053C	FT	F S D P G4.124 G4.238	AML0 EML0
ALT_MLSEL(03)	V98U8054C	FT	F S D P G4.124 G4.238	AML0 EML0

DBFN:0470 DATE:01/23/89

IDR87019

Table 4.5.2.4-2. Ascent Site Lookup (4.238) I-Loads (Cont)

OI8D MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
ALT_MLSEL(04)	V98U8055C	FT	F	S	D	P	G4.124 G4.238	AML0 EML0
BIAS_AZMLS(01)	V98U8268C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
BIAS_AZMLS(02)	V98U8269C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
BIAS_AZMLS(03)	V98U8270C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
BIAS_AZMLS(04)	V98U8271C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
BIAS_ELMLS(01)	V98U8280C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
BIAS_ELMLS(02)	V98U8281C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
BIAS_ELMLS(03)	V98U8282C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
BIAS_ELMLS(04)	V98U8283C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
BIAS_MLSRANGE(01)	V98U8292C	FT	F	S	D	P	G4.124 G4.238	AML0 EML0
BIAS_MLSRANGE(02)	V98U8293C	FT	F	S	D	P	G4.124 G4.238	AML0 EML0
BIAS_MLSRANGE(03)	V98U8294C	FT	F	S	D	P	G4.124 G4.238	AML0 EML0
BIAS_MLSRANGE(04)	V98U8295C	FT	F	S	D	P	G4.124 G4.238	AML0 EML0
EL_SCANNER_BEARING(01)	V98U8463C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
EL_SCANNER_BEARING(02)	V98U8464C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
EL_SCANNER_BEARING(03)	V98U8465C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
EL_SCANNER_BEARING(04)	V98U8466C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0

DBFN:0470 DATE:01/23/89

Table 4.5.2.4-2. Ascent Site Lookup (4.238) I-Loads (Cont)

OI8D MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
LAT_MLS_R_AZ(01)	V98U8486C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LAT_MLS_R_AZ(02)	V98U8487C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LAT_MLS_R_AZ(03)	V98U8488C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LAT_MLS_R_AZ(04)	V98U8489C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LAT_MLSEL(01)	V98U8498C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LAT_MLSEL(02)	V98U8499C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LAT_MLSEL(03)	V98U8500C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LAT_MLSEL(04)	V98U8501C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LATITUDE_GEODETIC_MAXI(01)	V98U8520C	RAD	F	S	D	C	G4.124 G4.238	A011 E011
LATITUDE_GEODETIC_MAXI(02)	V98U8521C	RAD	F	S	D	C	G4.124 G4.238	A011 E011
LATITUDE_GEODETIC_MAXI(03)	V98U8522C	RAD	F	S	D	C	G4.124 G4.238	A021 E021
LATITUDE_GEODETIC_MAXI(04)	V98U8523C	RAD	F	S	D	C	G4.124 G4.238	A021 E021
LATITUDE_GEODETIC_MAXI(05)	V98U8524C	RAD	F	S	D	C	G4.124 G4.238	A031 E031
LATITUDE_GEODETIC_MAXI(06)	V98U8525C	RAD	F	S	D	C	G4.124 G4.238	A031 E031
LATITUDE_GEODETIC_MAXI(07)	V98U8526C	RAD	F	S	D	C	G4.124 G4.238	A041 E041
LATITUDE_GEODETIC_MAXI(08)	V98U8527C	RAD	F	S	D	C	G4.124 G4.238	A041 E041
LATITUDE_GEODETIC_MAXI(09)	V98U8528C	RAD	F	S	D	C	G4.124 G4.238	A051 E052

DBFN:0470 DATE:01/23/89

Table 4.5.2.4-2. Ascent Site Lookup (4.238) I-Loads (Cont)

OI8D MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
LATITUDE_GEODETIC_MAXI(10)	V98U8529C	RAD	F	S	D	C	G4.124 G4.238	A051 E052
LONG_MLS_R_AZ(01)	V98U8551C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LONG_MLS_R_AZ(02)	V98U8552C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LONG_MLS_R_AZ(03)	V98U8553C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LONG_MLS_R_AZ(04)	V98U8554C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LONG_MLSEL(01)	V98U8563C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LONG_MLSEL(02)	V98U8564C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LONG_MLSEL(03)	V98U8565C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LONG_MLSEL(04)	V98U8566C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0
LONGITUDE_EAST_MAXI(01)	V98U8585C	RAD	F	S	D	C	G4.124 G4.238	A011 E011
LONGITUDE_EAST_MAXI(02)	V98U8586C	RAD	F	S	D	C	G4.124 G4.238	A011 E011
LONGITUDE_EAST_MAXI(03)	V98U8587C	RAD	F	S	D	C	G4.124 G4.238	A021 E021
LONGITUDE_EAST_MAXI(04)	V98U8588C	RAD	F	S	D	C	G4.124 G4.238	A021 E021
LONGITUDE_EAST_MAXI(05)	V98U8589C	RAD	F	S	D	C	G4.124 G4.238	A031 E031
LONGITUDE_EAST_MAXI(06)	V98U8590C	RAD	F	S	D	C	G4.124 G4.238	A031 E031
LONGITUDE_EAST_MAXI(07)	V98U8591C	RAD	F	S	D	C	G4.124 G4.238	A041 E041
LONGITUDE_EAST_MAXI(08)	V98U8592C	RAD	F	S	D	C	G4.124 G4.238	A041 E041

DBFN:0478 DATE:01/23/89

IDR87019

IDR87019

Table 4.5.2.4-2. Ascent Site Lookup (4.238) I-Loads (Cont)

OI8D MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
LONGITUDE_EAST_MAXI(09)	V98U8593C	RAD	F	S	D	C	G4.124 G4.238	A051 E052
LONGITUDE_EAST_MAXI(10)	V98U8594C	RAD	F	S	D	C	G4.124 G4.238	A051 E052
MAGNETIC_VARIATION_MAXI(01)	V98U8639C	RAD	F	S	D	C	G4.124 G4.238	A011 E011
MAGNETIC_VARIATION_MAXI(02)	V98U8640C	RAD	F	S	D	C	G4.124 G4.238	A011 E011
MAGNETIC_VARIATION_MAXI(03)	V98U8641C	RAD	F	S	D	C	G4.124 G4.238	A021 E021
MAGNETIC_VARIATION_MAXI(04)	V98U8642C	RAD	F	S	D	C	G4.124 G4.238	A021 E021
MAGNETIC_VARIATION_MAXI(05)	V98U8643C	RAD	F	S	D	C	G4.124 G4.238	A031 E031
MAGNETIC_VARIATION_MAXI(06)	V98U8644C	RAD	F	S	D	C	G4.124 G4.238	A031 E031
MAGNETIC_VARIATION_MAXI(07)	V98U8645C	RAD	F	S	D	C	G4.124 G4.238	A041 E041
MAGNETIC_VARIATION_MAXI(08)	V98U8646C	RAD	F	S	D	C	G4.124 G4.238	A041 E041
MAGNETIC_VARIATION_MAXI(09)	V98U8647C	RAD	F	S	D	C	G4.124 G4.238	A051 E052
MAGNETIC_VARIATION_MAXI(10)	V98U8648C	RAD	F	S	D	C	G4.124 G4.238	A051 E052
MSL_ABOVE_ELLIPSOID_MAXI(01)	V98U8692C	FT	F	S	D	C	G4.124 G4.238	A011 E011
MSL_ABOVE_ELLIPSOID_MAXI(02)	V98U8693C	FT	F	S	D	C	G4.124 G4.238	A011 E011
MSL_ABOVE_ELLIPSOID_MAXI(03)	V98U8694C	FT	F	S	D	C	G4.124 G4.238	A021 E021
MSL_ABOVE_ELLIPSOID_MAXI(04)	V98U8695C	FT	F	S	D	C	G4.124 G4.238	A021 E021
MSL_ABOVE_ELLIPSOID_MAXI(05)	V98U8696C	FT	F	S	D	C	G4.124 G4.238	A031 E031

DDFN 0470 DATE:01/23/89

IDR87019

Table 4.5.2.4-2. Ascent Site Lookup (4.238) I-Loads (Cont)

OI8D MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT	
MSL_ABOVE_ELLIPSOID_MAXI(06)	V98U8697C	FT	F	S	D	C	G4.124 G4.238	A031 E031	IDR87019
MSL_ABOVE_ELLIPSOID_MAXI(07)	V98U8698C	FT	F	S	D	C	G4.124 G4.238	A041 E041	IDR87019
MSL_ABOVE_ELLIPSOID_MAXI(08)	V98U8699C	FT	F	S	D	C	G4.124 G4.238	A041 E041	IDR87019
MSL_ABOVE_ELLIPSOID_MAXI(09)	V98U8700C	FT	F	S	D	C	G4.124 G4.238	A051 E052	IDR87019
MSL_ABOVE_ELLIPSOID_MAXI(10)	V98U8701C	FT	F	S	D	C	G4.124 G4.238	A051 E052	IDR87019
R_AZ_RADAR_BEARING(01)	V98U8729C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0	
R_AZ_RADAR_BEARING(02)	V98U8730C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0	
R_AZ_RADAR_BEARING(03)	V98U8731C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0	
R_AZ_RADAR_BEARING(04)	V98U8732C	RAD	F	S	D	P	G4.124 G4.238	AML0 EML0	
R_HAC_RW_L(1)	V98U9801C	FT	F	S	D	C	G4.124 G4.238	XS80 XS80	
R_HAC_RW_R(1)	V98U9804C	FT	F	S	D	C	G4.124 G4.238	XS80 XS80	
RTLS_PRIME_AREA	V99U8961C	ND	I	S	M	C	G4.2 G4.4 G4.238	AAP0	
RUNWAY_ALT(1)	V98U9795C	FT	F	S	D	C	G4.124 G4.238	A011 E011	IDR87019
RUNWAY_ALT(10)	V97U6570C	FT	F	S	D	C	G4.124 G4.238	A051 E052	IDR87019
RUNWAY_ALT(2)	V97U6562C	FT	F	S	D	C	G4.124 G4.238	A011 E011	IDR87019
RUNWAY_ALT(3)	V97U6563C	FT	F	S	D	C	G4.124 G4.238	A021 E021	IDR87019
RUNWAY_ALT(4)	V97U6564C	FT	F	S	D	C	G4.124 G4.238	A021 E021	IDR87019

DBFN:0470 DATE:01/23/89

Table 4.5.2 4 2. A nt te Lookup (4.238) I-Loads (Cont)

OI8D MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
RUNWAY_ALT(5)	V97U6565C	FT	F	S	D	C	G4.124 G4.238	A031 E031
RUNWAY_ALT(6)	V97U6566C	FT	F	S	D	C	G4.124 G4.238	A031 E031
RUNWAY_ALT(7)	V97U6567C	FT	F	S	D	C	G4.124 G4.238	A041 E041
RUNWAY_ALT(8)	V97U6568C	FT	F	S	D	C	G4.124 G4.238	A041 E041
RUNWAY_ALT(9)	V97U6569C	FT	F	S	D	C	G4.124 G4.238	A051 E052
RUNWAY_NAME(01)	V98U8767C	ND	CH		D	C	G4.124 G4.238	A011 E011
RUNWAY_NAME(02)	V98U8768C	ND	CH		D	C	G4.124 G4.238	A011 E011
RUNWAY_NAME(03)	V98U8769C	ND	CH		D	C	G4.124 G4.238	A021 E021
RUNWAY_NAME(04)	V98U8770C	ND	CH		D	C	G4.124 G4.238	A021 E021
RUNWAY_NAME(05)	V98U8771C	ND	CH		D	C	G4.124 G4.238	A031 E031
RUNWAY_NAME(06)	V98U8772C	ND	CH		D	C	G4.124 G4.238	A031 E031
RUNWAY_NAME(07)	V98U8773C	ND	CH		D	C	G4.124 G4.238	A041 E041
RUNWAY_NAME(08)	V98U8774C	ND	CH		D	C	G4.124 G4.238	A041 E041
RUNWAY_NAME(09)	V98U8775C	ND	CH		D	C	G4.124 G4.238	A051 E052
RUNWAY_NAME(10)	V98U8776C	ND	CH		D	C	G4.124 G4.238	A051 E052
RW_AZIMUTH(01)	V98U8794C	RAD	F	S	D	C	G4.124 G4.238	A011 E011
RW_AZIMUTH(02)	V98U8795C	RAD	F	S	D	C	G4.124 G4.238	A011 E011

IDR87019

DBFN:0470 DATE:01/23/89

Table 4.5.2.4-2. Ascent Site Lookup (4.238) I-Loads (Cont)

OI8D MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
RW_AZIMUTH(03)	V98U8796C	RAD	F	S	D	C	G4.124 G4.238	A021 E021
RW_AZIMUTH(04)	V98U8797C	RAD	F	S	D	C	G4.124 G4.238	A021 E021
RW_AZIMUTH(05)	V98U8798C	RAD	F	S	D	C	G4.124 G4.238	A031 E031
RW_AZIMUTH(06)	V98U8799C	RAD	F	S	D	C	G4.124 G4.238	A031 E031
RW_AZIMUTH(07)	V98U8800C	RAD	F	S	D	C	G4.124 G4.238	A041 E041
RW_AZIMUTH(08)	V98U8801C	RAD	F	S	D	C	G4.124 G4.238	A041 E041
RW_AZIMUTH(09)	V98U8802C	RAD	F	S	D	C	G4.124 G4.238	A051 E052
RW_AZIMUTH(10)	V98U8803C	RAD	F	S	D	C	G4.124 G4.238	A051 E052
RW_DELH(01)	V98U8807C	FT	F	S	D	C	G4.124 G4.238	A011 E011
RW_DELH(02)	V98U8808C	FT	F	S	D	C	G4.124 G4.238	A011 E011
RW_DELH(03)	V98U8809C	FT	F	S	D	C	G4.124 G4.238	A021 E021
RW_DELH(04)	V98U8810C	FT	F	S	D	C	G4.124 G4.238	A021 E021
RW_DELH(05)	V98U8811C	FT	F	S	D	C	G4.124 G4.238	A031 E031
RW_DELH(06)	V98U8812C	FT	F	S	D	C	G4.124 G4.238	A031 E031
RW_DELH(07)	V98U8813C	FT	F	S	D	C	G4.124 G4.238	A041 E041
RW_DELH(08)	V98U8814C	FT	F	S	D	C	G4.124 G4.238	A041 E041
RW_DELH(09)	V98U8815C	FT	F	S	D	C	G4.124 G4.238	A051 E052

DBFN:0470 DATE:01/23/89

IDR87019

Space Transportation Systems Division
Rockwell International

Table 4.5.2.4-2. Ascent Site Lookup (4.238) I-Loads (Cont)

OI8D MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
RW_DELH(10)	V98U8816C	FT	F	S	D	C	G4.124 G4.238	A051 E052
RW_LAT(01)	V98U8820C	RAD	F	S	D	C	G4.124 G4.238	A011 E011
RW_LAT(02)	V98U8821C	RAD	F	S	D	C	G4.124 G4.238	A011 E011
RW_LAT(03)	V98U8822C	RAD	F	S	D	C	G4.124 G4.238	A021 E021
RW_LAT(04)	V98U8823C	RAD	F	S	D	C	G4.124 G4.238	A021 E021
RW_LAT(05)	V98U8824C	RAD	F	S	D	C	G4.124 G4.238	A031 E031
RW_LAT(06)	V98U8825C	RAD	F	S	D	C	G4.124 G4.238	A031 E031
RW_LAT(07)	V98U8826C	RAD	F	S	D	C	G4.124 G4.238	A041 E041
RW_LAT(08)	V98U8827C	RAD	F	S	D	C	G4.124 G4.238	A041 E041
RW_LAT(09)	V98U8828C	RAD	F	S	D	C	G4.124 G4.238	A051 E052
RW_LAT(10)	V98U8829C	RAD	F	S	D	C	G4.124 G4.238	A051 E052
RW_LENGTH(1)	V99U7121C	FT	I	S	D	P	G4.124 G4.238	A011 E011
RW_LENGTH(10)	V99U7130C	FT	I	S	D	P	G4.124 G4.238	A051 E052
RW_LENGTH(2)	V99U7122C	FT	I	S	D	P	G4.124 G4.238	A011 E011
RW_LENGTH(3)	V99U7123C	FT	I	S	D	P	G4.124 G4.238	A021 E021
RW_LENGTH(4)	V99U7124C	FT	I	S	D	P	G4.124 G4.238	A021 E021
RW_LENGTH(5)	V99U7125C	FT	I	S	D	P	G4.124 G4.238	A031 E031

DBFN:0470 DATE:01/23/89

IDR87019

Table 4.5.2.4-2. Ascent Site Lookup (4.238) I-Loads (Cont)

OI8D MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT	IDR87019
RW_LENGTH(6)	V99U7126C	FT	I	S	D	P	C4.124 C4.238		A031 E031	
RW_LENGTH(7)	V99U7127C	FT	I	S	D	P	C4.124 C4.238		A041 E041	
RW_LENGTH(8)	V99U7128C	FT	I	S	D	P	C4.124 C4.238		A041 E041	
RW_LENGTH(9)	V99U7129C	FT	I	S	D	P	C4.124 C4.238		A051 E052	
RW_LON(01)	V98U8833C	RAD	F	S	D	C	C4.124 C4.238		A011 E011	
RW_LON(02)	V98U8834C	RAD	F	S	D	C	C4.124 C4.238		A011 E011	
RW_LON(03)	V98U8835C	RAD	F	S	D	C	C4.124 C4.238		A021 E021	
RW_LON(04)	V98U8836C	RAD	F	S	D	C	C4.124 C4.238		A021 E021	
RW_LON(05)	V98U8837C	RAD	F	S	D	C	C4.124 C4.238		A031 E031	
RW_LON(06)	V98U8838C	RAD	F	S	D	C	C4.124 C4.238		A031 E031	
RW_LON(07)	V98U8839C	RAD	F	S	D	C	C4.124 C4.238		A041 E041	
RW_LON(08)	V98U8840C	RAD	F	S	D	C	C4.124 C4.238		A041 E041	
RW_LON(09)	V98U8841C	RAD	F	S	D	C	C4.124 C4.238		A051 E052	
RW_LON(10)	V98U8842C	RAD	F	S	D	C	C4.124 C4.238		A051 E052	
RW_MAG_VAR(01)	V98U8846C	RAD	F	S	D	C	C4.124 C4.238		A011 E011	
RW_MAG_VAR(02)	V98U8847C	RAD	F	S	D	C	C4.124 C4.238		A011 E011	
RW_MAG_VAR(03)	V98U8848C	RAD	F	S	D	C	C4.124 C4.238		A021 E021	

DATE:01/23/89

DBFN:0470

Space Transportation Systems Division
Rockwell International

Table 4.5.2.4 2. Ascent Site Lookup (4.238) I-Loads (Cont)

OI&D MISSIONS

FSSR NAME	NSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
RW_MAG_VAR(04)	V98U8849C	RAD	F	S	D	C	G4.124 G4.238	A021 E021
RW_MAG_VAR 05)	V98U8850C	RAD	F	S	D	C	G4.124 G4.238	A031 E031
RW_MAG_VAR 06)	V98U8851C	RAD	F	S	D	C	G4.124 G4.238	A031 E031
RW_MAG_VAR 07	V98U8852C	RAD	F	S	D	C	G4.124 G4.238	A041 E041
RW_MAG_VAR 08	V98U8853C	RAD	F	S	D	C	G4.124 G4.238	A041 E041
RW_MAG_VAR 09)	V98U8854C	RAD	F	S	D	C	G4.124 G4.238	A051 E052
RW_MAG_VAR(10)	V98U8855C	RAD	F	S	D	C	G4.124 G4.238	A051 E052
RW_MSBLS_INDEX(01)	V99U7610C	ND	I	S	D	P	G4 124 G4 238	A011 E011
RW_MSBLS_INDEX(02)	V99U7611C	ND	I	S	D	P	G4 124 G4 238	A011 E011
RW_MSBLS_INDEX(03)	V99U7612C	ND	I	S	D	P	G4 124 G4 238	A021 E021
RW_MSBLS_INDEX(04)	V99U7613C	ND	I	S	D	P	G4 124 G4 238	A021 E021
RW_MSBLS_INDEX(05)	V99U7614C	ND	I	S	D	P	G4 124 G4.238	A031 E031
RW_MSBLS_INDEX(06)	V99U7615C	ND	I	S	D	P	G4 124 G4.238	A031 E031
RW_MSBLS_INDEX(07)	V99U7616C	ND	I	S	D	P	G4.124 G4.238	A041 E041
RW_MSBLS_INDEX(08)	V99U7617C	ND	I	S	D	P	G4.124 G4.238	A041 E041
RW_MSBLS_INDEX(09)	V99U7618C	ND	I	S	D	P	G4.124 G4.238	A051 E052
RW_MSBLS_INDEX(10)	V99U7619C	ND	I	S	D	P	G4.124 G4.238	A051 E052

IDR87019

DBFN:0470 DATE:01/23/89

Space Transportation Systems Division
Rockwell International

Table 4.5.2.4-2. Ascent Site Lookup (4.238) I-Loads (Cont)

OI8D MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
TACAN_ID_MAXI(01)	V98U8893C	ND	I	S	D	C	G4.124 G4.238	A011 E011
TACAN_ID_MAXI(02)	V98U8894C	ND	I	S	D	C	G4.124 G4.238	A011 E011
TACAN_ID_MAXI(03)	V98U8895C	ND	I	S	D	C	G4.124 G4.238	A021 E021
TACAN_ID_MAXI(04)	V98U8896C	ND	I	S	D	C	G4.124 G4.238	A021 E021
TACAN_ID_MAXI(05)	V98U8897C	ND	I	S	D	C	G4.124 G4.238	A031 E031
TACAN_ID_MAXI(06)	V98U8898C	ND	I	S	D	C	G4.124 G4.238	A031 E031
TACAN_ID_MAXI(07)	V98U8899C	ND	I	S	D	C	G4.124 G4.238	A041 E041
TACAN_ID_MAXI(08)	V98U8900C	ND	I	S	D	C	G4.124 G4.238	A041 E041
TACAN_ID_MAXI(09)	V98U8901C	ND	I	S	D	C	G4.124 G4.238	A051 E052
TACAN_ID_MAXI(10)	V98U8902C	ND	I	S	D	C	G4.124 G4.238	A051 E052
X_DMEAZ_RW(01)	V98U9207C	FT	F	S	D	P	G4.124 G4.238	AML0 EML0
X_DMEAZ_RW(02)	V98U9208C	FT	F	S	D	P	G4.124 G4.238	AML0 EML0
X_DMEAZ_RW(03)	V98U9209C	FT	F	S	D	P	G4.124 G4.238	AML0 EML0
X_DMEAZ_RW(04)	V98U9210C	FT	F	S	D	P	G4.124 G4.238	AML0 EML0
X_EL_RW(01)	V98U9219C	FT	F	S	D	P	G4.124 G4.238	AML0 EML0
X_EL_RW(02)	V98U9220C	FT	F	S	D	P	G4.124 G4.238	AML0 EML0
X_EL_RW(03)	V98U9221C	FT	F	S	D	P	G4.124 G4.238	AML0 EML0

DBFN:0470 DATE:01/23/89

IDR87019

Table 4.5.2.4-2. Ascent Site Lookup (4.238) I-Loads

OI8D MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
X_EL_RW(04)	V98U9222C	FT	F	S	D	P	G4.124 G4.238		AML0 EML0
Y_DMEAZ_RW(01)	V98U9231C	FT	F	S	D	P	G4.124 G4.238		AML0 EML0
Y_DMEAZ_RW(02)	V98U9232C	FT	F	S	D	P	G4.124 G4.238		AML0 EML0
Y_DMEAZ_RW(03)	V98U9233C	FT	F	S	D	P	G4.124 G4.238		AML0 EML0
Y_DMEAZ_RW(04)	V98U9234C	FT	F	S	D	P	G4.124 G4.238		AML0 EML0

DBFN:0470 DATE:01/23/89

Space Transportation Systems Division
Rockwell International

STS 83-0005B
PCN-4 OI-8D
July 31, 1989

Table 4.5.2.4-3. Ascent Site Lookup (G4.238) K-Loads Ascent Site Lookup

OI8B MISSIONS

FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT	PR	S	PR	FCTN	LAST CR EQTN MSID
R_HAC_RW_L(2)	V98U9802C	-1.55	E+04 FT	F	S	C	G4.124 G4.238		89661A
R_HAC_RW_L(3)	V98U9803C	+0.0	E+00 FT	F	S	C	G4.124 G4.238		59960
R_HAC_RW_R(2)	V98U9805C	+1.55	E+04 FT	F	S	C	G4.124 G4.238		89661A
R_HAC_RW_R(3)	V98U9806C	+0.0	E+00 FT	F	S	C	G4.238 G4.124		59960

DBFN:0534 DATE:07/14/88

STS 83-0005B
March 25, 1988
NASA-JSC

Space Transportation Systems Division
Rockwell International

Table 4.5.2.4-4. Ascent Site Lookup (4.238) Constants

NROKRMM.FSSR2.DATA(X06)BOOK5
PFS CONSTANTS UPDATE B/L

FSSR NAME / DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
ELLIPT EARTH'S ELLIPTICITY CONSTANT	V97U5332C		.335232980000 0000 E-02	ND	F	D				
EARTH RADIUS EQUATOR EARTH EQUATORIAL RADIUS	V97U5324C		.209257414698 1630 E+08	FT	F	D				

CR89596C

Table 4.5.2.4-5. Ascent Site Lookup (4.238)
Cross-Reference

FSSR Name	Source Name
TAL_DECLARED_FIRST_PASS	TAL_DECL_FRST_PASS
TAL_ABORT_DECLARED	TAL_SELECT_CMD
M_EFTOTD_TACAN_SL(1)	M_EFTOTD_TACAN_SL1
M_EFTOTD_TACAN_SL(2)	M_EFTOTD_TACAN_SL2
M_EFTOTD_TACAN_SL(3)	M_EFTOTD_TACAN_SL3
R_TACAN_EF_SL(1)	R_TACAN_EFSL1
R_TACAN_EF_SL(2)	R_TACAN_EFSL2
R_TACAN_EF_SL(3)	R_TACAN_EFSL3

CR89947A

4.6 USER PARAMETER PROCESSING PRINCIPAL FUNCTIONS

The purpose of the user parameter processing principal functions is to maintain an estimate of the vehicle state (position and velocity) and to derive from that state various related parameters required by systems such as guidance, displays, flight control, targeting, payloads, and navigation.

Within each user parameter processing principal function, the state from which the user parameters are derived is maintained by the user parameter state propagation subfunction. This subfunction utilizes a simple, fast-acting, single-step integrator to rapidly advance the user parameter state. The propagation interval is smaller than that used by the navigation principal functions, thus avoiding the need to wait for the next external sensor measurement processing to occur. At the end of each navigation propagation and external sensor measurement incorporation step, the navigation state is passed to the user parameter propagator, which then resets itself to that state. The value of the gravitational acceleration vector calculated by the navigation state propagator is used as a constant by the user parameter propagator between resets. Sensed changes in velocity are rapidly incorporated in the user parameter state at each integration step. In this way, the user parameter state propagation function maintains an accurate current state between navigation filter state computations.

The user parameters that are derived from the user parameter state typically provide expressions of the vehicle state in frames of reference dictated by the user; for example, positions expressed in non-Cartesian frames related to landmarks, radar beacons, or selected way points for easy crew interpretation and aerodynamic parameters for guidance, displays and flight control derived from the state through the use of environmental models.

The systems that require user parameters vary as a function of mission phase, major mode, and event cues recognized by the user parameter processing sequencers. The rates at which user parameters must be calculated also vary according to these criteria. This forces the user parameter state propagation subfunction to be performed at a rate supportive to the user parameter having the highest rate requirement during any particular user parameter phase.

The user parameter processing principal functions that perform the computations of the user parameters correspond to the major ascent/RTLS operations mission phases: ascent and RTLS. The detailed requirements for these phase-related principal functions are provided in their individual subsections.

Because the user parameter propagator supports all phases, the rate requirements of these phase-related user parameter processing principal functions implicitly place scheduling and rate requirements upon the user parameter state propagation subfunction. These scheduling and rate requirements are defined in those subsections of Section 4.1 that correspond to the user parameter processing sequencer principal functions.

4.6.1 Ascent User Parameter Processing (4.19)

This principal function will serve as the interface between navigation and users of navigation-related data during the ascent operational sequence. This function will maintain the vehicle state within the user parameter state propagation subfunction and shall:

- Provide this state to users who require vehicle state parameters in mean-of-fifty (M50) coordinates
- Provide the software to transform this state for users who require nav state related parameters

This function is composed of the following subfunctions:

1. User parameter state propagation (Section 4.6.1.1).
2. Ascent/RTLS user parameter calculations (Section 4.6.1.2).
3. Ascent user parameter processing initialization (Section 4.6.1.3).
4. Ascent user parameter HSI calculations (Section 4.6.1.4).

This function is controlled by the ascent user parameter processing sequencer (Section 4.1.3).

CR8596C The principal function input and output parameter tables, along with I-load, K-load, constant, and cross-reference tables, are presented in Section 4.6.1.5, in Tables 4.6.1.5-1 through 4.6.1.5-5.

4.6.1.1 User Parameter State Propagation. This subfunction will provide state vector information to users such as guidance and displays during the ascent phase.

A. Detailed Requirements. The detailed requirements for this subfunction are contained in Section 4.4.1.

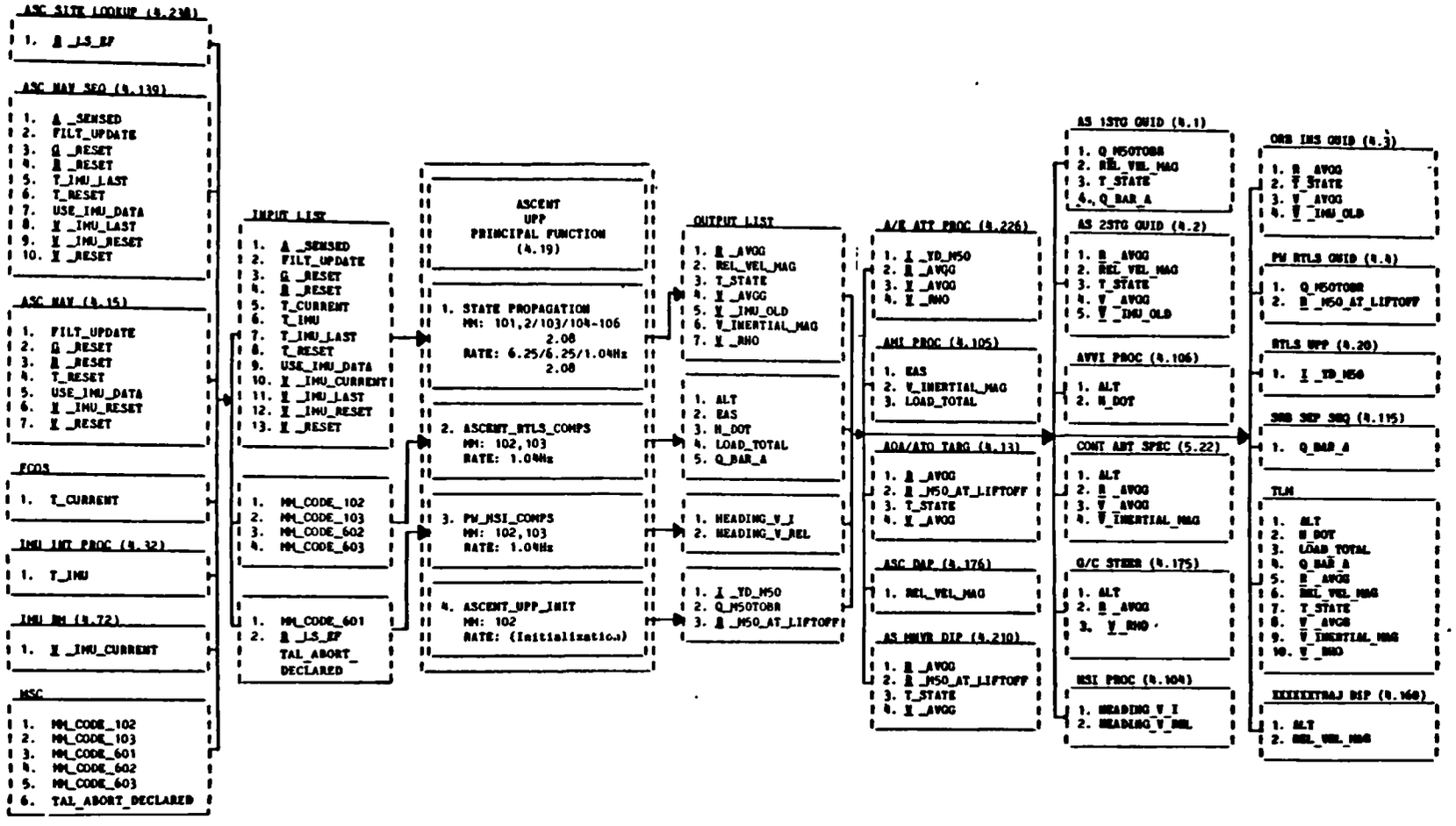
B. Interface Requirements. The input and output parameters required are listed in Tables 4.6.1.1-1 and 4.6.1.1-2.

C. Processing Requirements. None.

D. Constraints. None.

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart is to be found in Section 5.6, USER_PARAM_PROPAGATOR_ASCENT_AND_RTLS.

Table 4.6.1. Ascent User Parameter Processing Principal Function Interface Diagram



STS 83-0005B
PCN-4 OI-8D
July 31, 1989

Space Transportation
Systems Division
Rockwell
International

Table 4.6.1.1-1. Ascent User Parameter State Propagation Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Switch indicating (ON) that current Nav cycle is complete	FILT_UPDATE	(a)	D		OFF/ON		NAV rate
Vehicle position vector after all navigation updates reserved for reset of user parameter integrator position vector R_AVGG	R_RESET	(a)	V	DP		ft	NAV rate
Time associated with currently read IMU velocity counts from the IMU selection filter (RM)	T_IMU	(a)	F	DP		sec	As per sequencer
Time associated with reserved reset state	T_RESET	(a)	F	DP		sec	NAV rate
Current selected accumulated IMU velocity	V_IMU_CURRENT	(a)	V	DP		ft/sec	As per sequencer
Copy of V_CURRENT_FILT reserved as velocity count at start of extrapolation interval when user parameter integrator is reset	V_IMU_RESET	(a)	V	DP		ft/sec	NAV rate
Vehicle velocity vector after all navigation updates reserved for reset of user parameter integrator velocity vector V_AVGG	V_RESET	(a)	V	S		ft/sec	NAV rate
Previous value of T_IMU	T_IMU_LAST	(a)	F	DP		sec	First pass only
Previous value of V_IMU_CURRENT	V_IMU_LAST	(a)	V	DP		ft sec	First pass only
Sensed acceleration	A_SENSED	(a)	V	S		$\frac{ft}{sec^2}$	First pass only
Current time	T_CURRENT	(a)	F	DP		sec	As per sequencer
Gravitational acceleration vector reserved for reset of user parameter integrator gravity vector	G_RESET	(a)	V	S		$\frac{ft}{sec^2}$	NAV rate

[1]See ascent UPP principal function input parameter table.

Table 4.6.1.1-2. Ascent User Parameter State Propagation Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
IMU-sensed acceleration	A_SENSED	ASCENT_RTLS_COMPS	V	S		ft/sec^2	As per sequencer
Current Shuttle position vector	R_AVGG	(a), ASCENT_RTLS_COMPS, ASCENT_UPP_INIT	V	DP		ft	As per sequencer
Time tag for current user parameter state vector	T_STATE	(a), ASCENT_UPP_INIT	F	DP		sec	As per sequencer
Shuttle current velocity vector	V_AVGG	(a), PW_HSI_COMPS	V	S		ft/sec	As per sequencer
Earth-relative velocity	V_RHO	(a), ASCENT_RTLS_COMPS, PW_HSI_COMPS	V	S		ft/sec	As per sequencer
Earth-relative velocity magnitude	REL_VEL_MAG	(a), ASCENT_RTLS_COMPS, PW_HSI_COMPS	F	S		ft/sec	As per sequencer
Inertial velocity magnitude	V_INERTIAL_MAG	(a)	F	S		ft/sec	As per sequencer
Current selected accumulated IMU velocity	V_IMU_OLD	(a)	V	DP		ft/sec	As per sequencer

[a]See ascent UPP principal function output parameter table.

4.6.1.2 Ascent/RTLS User Parameter Calculations. This subfunction will compute the navigation-related parameters required by users during MM's 102 and 103 of the ascent operational sequence.

A. Detailed Requirements. The detailed requirements for this subfunction are contained in Section 4.4.3.

B. Interface Requirements. Input and output parameters required are listed in Tables 4.6.1.2-1 and 4.6.1.2-2.

C. Processing Requirements. Cyclic execution and repetition rate for this subfunction are controlled by the ascent users parameter processing sequencer (Section 4.1.3).

D. Constraints. The computations from RHO_A will be valid for altitudes ALT < ALT_TAB_{IMAX} where ALT_TAB_{IMAX} is the last altitude in the premission-loaded table.

E. Supplemental Information. A suggested implementation of the ascent calculations, in the form of a detailed flow chart, is shown in Section 5.6, flow chart ASCENT_RTLS_COMPS.

Table 4.6.1.2-1. Inputs for Ascent/RTLS User Parameter Calculations

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Exponential atmosphere scale height I = 1, 7	ALT_S_I	Design Dependent	F	S		ft	As per sequencer
Current Shuttle position vector	R_AVGG	Ascent UPP state prop	V	DP		ft	As per sequencer
Exponential atmosphere base density I = 1, 7	RHO_B_I	(b)	F	S		slugs/ft^3	As per sequencer
Magnitude of vehicle relative velocity	REL_VEL_MAG	Ascent UPP state prop	F	S		ft/sec	As per sequencer
Altitude regions I = 1, 7	ALT_TAB_I	(b)	F	S		ft	As per sequencer
Number of altitude regions	IMAX	(b)	I	S			As per sequencer
IMU-sensed acceleration	A_SENSED	Ascent UPP state	V	S		ft/sec^2	As per sequencer
Acceleration of gravity at sea level	GRAV_SEA_LEVEL	(b)	F	S		ft/sec^2	As per sequencer
Major mode 102 flag	MM_CODE_102	(a)	D		ON/OFF		As per sequencer
Major mode 103 flag	MM_CODE_103	(a)	D		ON/OFF		As per sequencer
Unit vector in direction of earth's axis of rotation	EARTH_POLE		V	DP			As per sequencer
Earth equatorial radius	EARTH_RADIUS_EQUATOR	(b)	F	DP		ft	As per sequencer
Flag indicating (ON) that the UPP state has been updated by the navigation filter	UPP_UPDATE	Ascent UPP state prop	D		OFF/ON		As per sequencer
Altitude of runway with respect to reference ellipsoid	ALT_RW	(a)	F	S		ft	As per sequencer
Earth ellipticity constant	ELLIPT	(b)	F	DP			As per sequencer
Shuttle Earth-relative velocity vector in M50 coordinates	V_RHO	Ascent UPP state prop	V	S		ft/sec	As per sequencer
Major mode 602 flag	MM_CODE_602	(a)	D		ON/OFF		As per sequencer
Major mode 603 flag	MM_CODE_603	(a)	D		ON/OFF		As per sequencer

[a]See ascent UPP principal function input parameter table.

[b]See ascent UPP principal function I-load, K-load, and constant tables.

Table 4.6.1.2-2. Outputs From Ascent/RTLS User Parameter Calculations

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Vehicle's current dynamic pressure	Q_BAR_A	(a)	F	S		PSF	As per sequencer
Current Orbiter altitude above reference ellipsoid	ALT	(a)	F	S		ft	As per sequencer
Radial component of the relative velocity	H_DOT	(a)	F	S		ft/sec	As per sequencer
Total load factor	LOAD_TOTAL	(a)	F	S		g's	As per sequencer
Equivalent air speed	EAS	(a)	F	S		ft/sec	As per sequencer

[a]See ascent UPP principal function output parameter table.

4.6.1.3 Ascent User Parameter Processing Initialization.

A. Detailed Requirements. The following initial calculations are required to properly initialize the ascent user parameter processing principal function.

The M50 position vector of the navigation base will be snapped and renamed at this time to provide a vector approximating the M50 position of the launch site at liftoff:

R_M50_AT_LIFTOFF = R_AVGG

An earth-fixed to topodetic coordinate system transformation matrix will be determined:

M_EFTOTD = EF_TO_TOPDET(NAVBASE_LAT_ZERO, NAVBASE_LONG_ZERO)

where NAVBASE_LAT_ZERO and NAVBASE_LONG_ZERO are premission-loaded coordinates of the navigation base at the launch pad reference point.

A matrix to transform M50 coordinates to Earth-fixed at the time associated with the current vehicle M50 state will be generated:

M_TEMP_TXPOS = EARTH_FIXED_TO_M50_COORD(T_STATE)^T

where T_STATE is obtained from the user parameter state propagator.

A matrix to transform M50 coordinates to the boost reference coordinate system (topodetic coordinate system at launch site) at this time of initialization will be computed as:

M_M50TOBR = M_EFTOTD M_TEMP_TXPOS

Next, the general utility routine MAT_TO_QUAT will be evoked to convert the matrix M_M50TOBR to an equivalent quaternion.

CALL: MAT_TO_QUAT(M_M50TOBR)

ASSIGN (Q_M50TOBR)

Finally, the unit vector normal to the plane of the orbit is computed as follows:

If the orbital plane constraint is earth fixed (i e , EF PLANE_SW = ON), then the unit vector normal to the EF orbital plane is transformed from EF coordinates to M50 coordinates:

I_YD_M50 = M_TEMP_TXPOS^T I_YD,

else (i.e., EF_PLANE_SW = OFF) a node adjustment matrix is computed, and the unit vector normal to the M50 orbital plane is rotated to account for nodal regression between nominal and actual launch times:

DELTA_NODE = NODE_SLOPE (T_STATE - T_GMTLO_REF)

CNODE = COS(DELTA_NODE)

SNODE = SIN(DELTA_NODE)

M_NODE_ADJ = (CNODE, SNODE, 0, -SNODE, CNODE, 0, 0, 0, 1)

I_YD_M50 = M_NODE_ADJ I_YD

B. Interface Requirements. The input and output parameters required are listed in Tables 4.6.1.3-1 and 4.6.1.3-2.

C. Processing Requirements. None.

D. Constraints. None.

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart may be found in Section 5.6, ASCENT_UPP_INIT.

Table 4.6.1.3-1. Ascent User Parameter Processing Initialization Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Latitude of nav base at launch reference point	NAVBASE_LAT_ZERO	(a)	F	DP		rad	Once
Longitude of nav base at launch reference point	NAVBASE_LONG_ZERO	(a)	F	DP		rad	Once
Time tag associated with current user parameter state vector	T_STATE	UPP state prop	F	DP		sec	Once
Current nav base M50 position vector	R_AVOO	UPP state prop	V	DP			Once
Unit vector normal to orbit plane in earth-fixed or M50 coordinates	I_YD	(a)	V	S			Once
Nominal lift-off time	TGNTLO_REF	(a)	F	DP		sec	Once
Nodal regression slope	NODE_SLOPE	(a)	F	SP		rad/sec	Once
Earth-fixed plane constraint switch	EF_PLANE_SW	(a)	D		OFF ON		Once

[a]See ascent UPP principal function I-load table.

Table 4.6.1.3-2. Ascent User Parameter Processing Initialization Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Update Rate
Mean of 50 to boost reference quaternion	Q_M50TOBR	(a)	V(4)	DP			Once
M50 position of navbase at SRB ignition command (approximates M50 position of launch pad at liftoff)	R_M50_AT_LIFTOFF	(a)	V	DP			Once
Unit vector normal to orbit plane in M50 coordinates	I_YD_M50	(a), PW_MSI_COMPS	V	S			Once
Node adjustment matrix	M_NODE_ADJ	(a)	M				Once

[a]See ascent UPP principal function output parameter table.

4.6.1.4 Ascent User Parameter HSI Calculations. This subfunction will calculate certain parameters required to support the HSI processing principal function during MM's 102 and 103 of the ascent operational sequence.

A. Detailed Requirements. The detailed requirements of this subfunction are presented in Section 4.4.4.

B. Interface Requirements. The input and output parameters required are listed in Tables 4.6.1.4-1 and 4.6.1.4-2.

C. Processing Requirements. None.

D. Constraints. The parameter HEADING_V_REL shall be initialized to a value of zero.

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart may be found in Section 5.6, PW_HSI_COMPS.

Table 4.6.1.4-1. Inputs for Ascent HSI Calculations

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Position vector of runway in earth-fixed coordinates	R_LS_EF	(a)	V	DP		ft	As per sequencer
Time tag associated with current upper parameter state vector	T_STATE	UPP state prop	F	DP		sec	As per sequencer
Current navbase M50 position vector	R_AVGG	UPP state prop	V	DP		ft	As per sequencer
Unit vector perpendicular to the orbit plane and directed in the opposite sense to that of the angular momentum	I_YD_M50	ASCENT_UPP_INIT	V	S			As per sequencer
Inertial velocity in M50	V_AVGG	UPP state prop	V	S		ft/sec	As per sequencer
Relative velocity in M50	V_RMO	UPP state prop	V	S		ft/sec	As per sequencer
Magnitude of the inertial velocity	V_INERTIAL_MAG	UPP state prop	F	S		ft/sec	As per sequencer
Magnitude of the relative velocity	REL_VEL_MAG	UPP state prop	F	S		ft/sec	As per sequencer
Major mode 601 flag	MM_CODE_601	(a)	D		ON/OFF		As per sequencer
TAL abort declared flag	TAL_ABORT_DECLARED	(a)	D		ON/OFF		As per sequencer

[a]See ascent UPP principal function input parameter table

Table 4.6.1.4 2. Outputs For Ascent HSI Calculations

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Angle formed by the inertial velocity vector and the orbit plane	HEADING_V I	(a)	F	S	-π,π	rad	As per sequencer
Angle formed by the relative velocity vector and the orbit plane	HEADING_V REL	(a)	F	S	-π,π	rad	As per sequencer
Bearing of Shuttle position to landing site referenced to the orbit plane	HEADING_RW	(a)	F	S	-π,π	rad	As per sequencer

[a]See ascent UPP principal function output parameter table

4.6.1.5 Ascent User Parameter Processing (4.19) Principal Function Tables. The ascent user parameter processing principal function input and output parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.6.1.5-1 through 4.6.1.5-5.

The values for the I-loads are contained in the I-loads requirements document (JSC-19350).

Table 4.6.1.5-1. Ascent User Parameters Processing (4.19) Input/Output Functional Parameters

DBFN D3B008-D PN: VP70710037P00L JULY 17, 1989
INPUT FUNCTIONAL PARAMETERS FOR ASCENT USER PARAMETER PROCESSING — ASC UPP — OI8D REV00 — 04.19 — PAGE 307 BOOK: 5

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
A_SENSED 1)	V90A8946C	X-COMP OF SENSED ACCELERATION	ASC NAV SEQ	FT/S2		
A_SENSED 2)	V90A8947C	Y-COMP OF SENSED ACCELERATION	ASC NAV SEQ	FT/S2		
A_SENSED 3	V90A8948C	Z-COMP OF SENSED ACCELERATION	ASC NAV SEQ	FT/S2		
CLOCK_CLOCKTIME	V91W5000C2	CLOCK-COMPUTER(GMT)	FCOS	S		
FILT_UPDATE	V90X0224XA	FLAG IND NAV FILTER PROC COMPLETE	ASC NAV			
FILT_UPDATE	V90X0224XB	FLAG IND NAV FILTER PROC COMPLETE	ASC NAV SEQ			
G_RESET 1	V90A0243CA	SEL X-COMP OF GRAV ACCEL VCTR RST	ASC NAV	FT/S2		
G_RESET 1	V90A0243CB	SEL X-COMP OF GRAV ACCEL VCTR RST	ASC NAV SEQ	FT/S2		
G_RESET 2	V90A0244CA	SEL Y-COMP OF GRAV ACCEL VCTR RST	ASC NAV	FT/S2		
G_RESET 2	V90A0244CB	SEL Y-COMP OF GRAV ACCEL VCTR RST	ASC NAV SEQ	FT/S2		
G_RESET 3	V90A0245CA	SEL Z-COMP OF GRAV ACCEL VCTR RST	ASC NAV	FT/S2		
G_RESET 3	V90A0245CB	SEL Z-COMP OF GRAV ACCEL VCTR RST	ASC NAV SEQ	FT/S2		
MM_CODE_102/MM_102	V90X8158X	MAJOR MODE 102 FLAG	MSC			
MM_CODE_103/MM_103	V90X8156X	MAJOR MODE 103 FLAG	MSC			
MM_CODE_603/MM_603	V90X8122X	MAJOR MODE 603 FLAG	MSC			
R_LS_VEC 1	V90W1901CB	X-COMP LDG SITE POS VCT-EF COORD	ASC SITE LOOKUP	FT		
R_LS_VEC 2	V90W1902CB	Y-COMP LDG SITE POS VCT-EF COORD	ASC SITE LOOKUP	FT		
R_LS_VEC 3	V90W1903CB	Z-COMP LDG SITE POS VCT-EF COORD	ASC SITE LOOKUP	FT		
R_RESET 1	V90W0235CA	SEL X-COMP OF UPDATED POS VCTR RST	ASC NAV	FT	DPL	
R_RESET 1	V90W0235CB	SEL X-COMP OF UPDATED POS VCTR RST	ASC NAV SEQ	FT	DPL	
R_RESET 2	V90W0236CA	SEL Y-COMP OF UPDATED POS VCTR RST	ASC NAV	FT	DPL	
R_RESET 2	V90W0236CB	SEL Y-COMP OF UPDATED POS VCTR RST	ASC NAV SEQ	FT	DPL	
R_RESET 3	V90W0237CA	SEL Z-COMP OF UPDATED POS VCTR RST	ASC NAV	FT	DPL	
R_RESET 3	V90W0237CB	SEL Z-COMP OF UPDATED POS VCTR RST	ASC NAV SEQ	FT	DPL	
SEL_V_M50 1	V90L2557C	SEL TOTAL X VEL M50	IMU RM	FT/S	DPL	
SEL_V_M50 2	V90 2558C	SEL TOTAL Y VEL M50	IMU RM	FT/S	DPL	
SEL_V_M50 3	V90 2559C	SEL TOTAL Z VEL M50	IMU RM	FT/S	DPL	
SRB_SEP_CMD_FLAG	V90X8331XB	SRB SEPARATION COMMAND FLAG	ET SEP SEQ			
T_GMTLO_REF	V99U7442C	NOMINAL LIFTOFF IGN REF	UL			
T_IMU_LAST	V90W8941C	PREVIOUS VALUE OF T_IMU	ASC NAV SEQ	$$$$	DPL	
T_IMUS	V95W0002C	IMU INPUT TRANS TIME TAG	IMU INT PROC			
T_RESET	V90W0225CA	TIME OF FILTER STATE VCTR	ASC NAV			
T_RESET	V90W0225CB	TIME OF FILTER STATE VCTR	ASC NAV SEQ	$$		
TAL_ABORT_DECLARED	V90X8658X	TAL ABORT DECLARED	MSC			
V_IMU_LAST(1)	V90L8942C	X-COMP OF PREVIOUS V_IMU_CURRENT	ASC NAV SEQ	FT/S		
V_IMU_LAST(2)	V90L8943C	Y-COMP OF PREVIOUS V_IMU_CURRENT	ASC NAV SEQ	FT/S		
V_IMU_LAST(3)	V90L8944C	Z-COMP OF PREVIOUS V_IMU_CURRENT	ASC NAV SEQ	FT/S		
V_IMU_RESET(1)	V90L0247CA	SEL X-COMP OF ACCUM SENSED VEL RST	ASC NAV	FT/S		
V_IMU_RESET(1)	V90L0247CB	SEL X-COMP OF ACCUM SENSED VEL RST	ASC NAV SEQ	FT/S		
V_IMU_RESET(2)	V90L0248CA	SEL Y-COMP OF ACCUM SENSED VEL RST	ASC NAV	FT/S		
V_IMU_RESET(2)	V90L0248CB	SEL Y-COMP OF ACCUM SENSED VEL RST	ASC NAV SEQ	FT/S		
V_IMU_RESET(3)	V90L0249CA	SEL Z-COMP OF ACCUM SENSED VEL RST	ASC NAV	FT/S		
V_IMU_RESET(3)	V90L0249CB	SEL Z-COMP OF ACCUM SENSED VEL RST	ASC NAV SEQ	FT/S		
V_RESET(1)	V90L0239CA	SEL X-COMP OF UPDATED VEL VCTR RST	ASC NAV	FT/S		
V_RESET(1)	V90L0239CB	SEL X-COMP OF UPDATED VEL VCTR RST	ASC NAV SEQ	FT/S		
V_RESET(2)	V90L0240CA	SEL Y-COMP OF UPDATED VEL VCTR RST	ASC NAV	FT/S		
V_RESET(2)	V90L0240CB	SEL Y-COMP OF UPDATED VEL VCTR RST	ASC NAV SEQ	FT/S		
V_RESET(3)	V90L0241CA	SEL Z-COMP OF UPDATED VEL VCTR RST	ASC NAV	FT/S		
V_RESET(3)	V90L0241CB	SEL Z COMP OF UPDATED VEL VCTR RST	ASC NAV SEQ	FT/S		

Table 4.6.1.5-1. Ascent User Parameters Processing (4.19) Input/Output Functional Parameters (Cont)

DBFN: D3B008-D PN: VP707100037P00L JULY 17, 1989
OUTPUT FUNCTIONAL PARAMETERS FROM ASCENT USER PARAMETER PROCESSING ASC UPP OI8D REV08 G4.19

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
ALT	V95H0175CB	CURR ORB ALT ABOVE REF ELLIPSOID	AVVI PROC,XXXXXX TRAJ DIP, G/C STEER,TLM	KFT		
EAS	V95L0514CA	EQUIVALENT AIRSPEED	AMI PROC	FT/S		
H_DOT	V95L0511C	RADIAL CMPNT OF INERTIAL VELOCITY	AVVI PROC,TLM	FT/S		
H_DOT_ELLIPSOID/H_DOT	V95L0265CE	EST ALTITUDE RATE	ASC 1STG GUID,ASC 2STG GUID	FT/S	VAR	
HEADING_RW	V95H0461CA	BEAR VEH TO RW WRT ORB PL	HSI PROC	RAD		
HEADING_V_I	V95H0515CA	ANG BETWN INER VEL AND ORB PL	HSI PROC	RAD		
HEADING_V_REL	V95H0516CA	ANG BETWN REL VEL AND ORB PL	HSI PROC	RAD		
I_YD_M50(1)	V95U0494C	M50 INSERTION TARGET UNIT VECTOR-1	A/E ATT PROC,RTLS UPP			
I_YD_M50(2)	V95U0495C	M50 INSERTION TARGET UNIT VECTOR-2	A/E ATT PROC,RTLS UPP			
I_YD_M50(3)	V95U0496C	M50 INSERTION TARGET UNIT VECTOR-3	A/E ATT PROC,RTLS UPP			
LOAD_TOTAL	V95U0163CB	TOTAL LOAD FACTOR	AMI PROC,TLM	G		
M_NODE_ADJ	V95U0512C	NODAL ADJUSTMENT MATRIX	ASC 2STG GUID,ORB INS GUID			
Q_BAR_A	V95P0500C	DERIVED ASCENT DYNAMIC PRESS	SRB SEP SEQ,ASC 1STG GUID,TLM	LB/FT2	SPL	
Q_M50TOBR(1)	V95U0503C	M50-TO BOOST REF QUATERNION ELE 1	ASC 1STG GUID,PW RTLS GUID			
Q_M50TOBR(2)	V95U0504C	M50-TO BOOST REF QUATERNION ELE 2	ASC 1STG GUID,PW RTLS GUID			
Q_M50TOBR(3)	V95U0505C	M50-TO BOOST REF QUATERNION ELE 3	ASC 1STG GUID,PW RTLS GUID			
Q_M50TOBR(4)	V95U0506C	M50-TO BOOST REF QUATERNION ELE 4	ASC 1STG GUID,PW RTLS GUID			
R_AVGG(1)	V95H0185CB	X-COMP OF CURRENT SHUTTLE POS VCTR	ASC 2STG GUID,ORB INS GUID, A/E ATT PROC,AOA/ATO TGT, G/C STEER,ASC MNVR DIP,TLM	FT	DPL	
R_AVGG(2)	V95H0186CB	Y-COMP OF CURRENT SHUTTLE POS VCTR	ASC 2STG GUID,ORB INS GUID, A/E ATT PROC,AOA/ATO TGT, G/C STEER,ASC MNVR DIP,TLM	FT	DPL	
R_AVGG(3)	V95H0187CB	Z-COMP OF CURRENT SHUTTLE POS VCTR	ASC 2STG GUID,ORB INS GUID, A/E ATT PROC,AOA/ATO TGT, G/C STEER,ASC MNVR DIP,TLM	FT	DPL	
R_M50_AT_LIFTOFF(1)	V95U0507C	X-M50 POS OF NB AT LIFTOFF	AOA/ATO TGT,PW RTLS GUID, ASC MNVR DIP	FT		
R_M50_AT_LIFTOFF(2)	V95U0508C	Y-M50 POS OF NB AT LIFTOFF	AOA/ATO TGT,PW RTLS GUID, ASC MNVR DIP	FT		
R_M50_AT_LIFTOFF(3)	V95U0509C	Z-M50 POS OF NB AT LIFTOFF	AOA/ATO TGT,PW RTLS GUID, ASC MNVR DIP	FT		
REL_VEL_MAG	V95L0151CE	GND REL VEL MAGNITUDE IN M50 SYS	ASC 1STG GUID,ASC 2STG GUID, ASC DAP,AOA/ATO TGT, XXXXXX TRAJ DIP,SPTI SOP, AVVI PROC,TLM	FT/S		
T_STATE	V95W0200CD	TIME TAG ASSOC WITH CURRENT STATE	ASC 1STG GUID,ASC 2STG GUID, ORB INS GUID,AOA/ATO TGT, ASC MNVR DIP,TLM	S		
V_AVGG(1)	V95L0190CB	X-COMP OF CURRENT SHUTTLE VEL VCTR	ASC 2STG GUID,ORB INS GUID, AOA/ATO TGT,A/E ATT PROC, ASC MNVR DIP,TLM	FT/S	SPL	
V_AVGG(2)	V95L0191CB	Y-COMP OF CURRENT SHUTTLE VEL VCTR	ASC 2STG GUID,ORB INS GUID, AOA/ATO TGT,A/E ATT PROC, ASC MNVR DIP,TLM	FT/S	SPL	
V_AVGG(3)	V95L0192CB	Z-COMP OF CURRENT SHUTTLE VEL VCTR	ASC 2STG GUID,ORB INS GUID, AOA/ATO TGT,A/E ATT PROC, ASC MNVR DIP,TLM	FT/S	SPL	
V_IMU_OLD(1)	V95L0210CB	X-COMP OF CURRENT ACCUM IMU VEL	ASC 2STG GUID,ORB INS GUID, ASC MNVR DIP	FT/S		
V_IMU_OLD(2)	V95L0211CB	Y-COMP OF CURRENT ACCUM IMU VEL	ASC 2STG GUID,ORB INS GUID,	FT/S		

CR89461
CR89150H
Space Transportation Systems Division
Rockwell International

Table 4.6.1.5-1. Ascent User Parameters Processing (4.19) Input/Output Functional Parameters (Cont)

DBFN: D3B008-D PN: VP707100037P00L JULY 17, 1989 OI8D REV00 PAGE 228
OUTPUT FUNCTIONAL PARAMETERS FROM ASCENT USER PARAMETER PROCESSING ASC UPP G4.19 BOOK: 5

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
V_IMU_OLD(3)	V95L0212CB	Z-COMP OF CURRENT ACCUM IMU VEL	ASC MNVR DIP ASC 2STG GUID,ORB INS GUID, ASC MNVR DIP	FT/S		
V_INERTIAL_MAG	V95L0510CA	MAG OF VEHICLE INERTIAL VELOCITY	AMI PROC,TLM	FT/S		
V_RHO(1)	V95L0215CE	X-COMP OF RELATIVE VEL IN M50	A/E ATT PROC,G/C STEER,TLM	FT/S		
V_RHO(2)	V95L0216CE	Y-COMP OF RELATIVE VEL IN M50	A/E ATT PROC,G/C STEER,TLM	FT/S		
V_RHO(3)	V95L0217CE	Z-COMP OF RELATIVE VEL IN M50	A/E ATT PROC,G/C STEER,TLM	FT/S		

Space Transportation Systems Division
Rockwell International

Table 4.6.1.5-2. Ascent User Parameters Processing (4.19) I-Loads

OI8D MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
ALT_S(1)	V97U5706C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_S(2)	V97U5707C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_S(3)	V97U5708C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_S(4)	V97U5709C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_S(5)	V97U5710C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_S(6)	V99U6878C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_S(7)	V99U6879C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_TAB(1)	V97U5712C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_TAB(2)	V97U5713C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_TAB(3)	V97U5714C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_TAB(4)	V97U5715C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_TAB(5)	V97U5716C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_TAB(6)	V99U6874C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_TAB(7)	V99U6875C	FT	F	S	D	C	G4.19 G4.20	PAE0
EF_PLANE_SW	V99U7441C	ND	D		M	C	G4.2 G4.3 G4.19 G4.20 G4.210 G4.226	A2N2

CR89461A

DBFN:0470 DATE:01/23/89

Table 4.6.1.5 2. Ascent User Parameters Processing (4.19) I-Loads (Cont)

OI6D MISSIONS

FSSR NAME	MSID	ENG UNIT	BT	PR	D	S	PR FCTN	CAT
IVD(1)	V97U6413C	MD	F	B	M	C	G4.226 G4.2 G4.3 G4.19 G4.20 G4.210	A2M2
IVD 2	V97U6414C	MD	F	B	M	C	G4.226 G4.2 G4.3 G4.19 G4.20 G4.210	A2M2
IVD 3	V97U6415C	MD	F	B	M	C	G4.226 G4.2 G4.3 G4.19 G4.20 G4.210	A2M2
MAUBASE_LAT_ZERO	V97U5750C	RAD	F	B	D	C	G4.15 G4.19 G4.20 G4.205	MVB0
MAUBASE_LONG_ZERO	V97U5751C	RAD	F	B	D	C	G4.15 G4.19 G4.20 G4.205	MVB0
NODE_SLOPE	V99U7443C	RAD/SEC	F	S	M	C	G4.19 G4.20	ARC0
PSHARS	V96U8647C	DEG	F	S	D	C	G4.9 G4.23 G4.24 G4.25 G4.19 G4.20 G4.204	ZFU2 ZFU2
R_GO_RAMP	V97U5438C	FT	F	S	D	P	G4.19 G4.20 G4.23 G4.24 G4.25	ZFV2
RADIUS_MEP	V97U5458C	FT	F	S	D	C	G4.19 G4.20 G4.4	ZFV2

DBFN:0478 DATE:01/23/89

CR89461A

Table 4.6.1.5-2. Ascent User Parameters Processing (4.19) I-Loads (Cont)

OI08B MISSIONS DBFN:0431
G4.19 - 0005 - ASCENT USER PARAMETER PROCESSING
ACTIVE MEMORY CONFIGURATIONS: 01

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
RHO_B(1)	V97U5765C	SLUG/FT**3	F	S	D	C	G4.19 G4.20	PAE0
RHO_B(2)	V97U5766C	SLUG/FT**3	F	S	D	C	G4.19 G4.20	PAE0
RHO_B(3)	V97U5767C	SLUG/FT**3	F	S	D	C	G4.19 G4.20	PAE0
RHO_B(4)	V97U5768C	SLUG/FT**3	F	S	D	C	G4.19 G4.20	PAE0
RHO_B(5)	V97U5769C	SLUG/FT**3	F	S	D	C	G4.19 G4.20	PAE0
RHO_B(6)	V99U6876C	SLUG/FT**3	F	S	D	C	G4.19 G4.20	PAE0
RHO_B(7)	V99U6877C	SLUG/FT**3	F	S	D	C	G4.19 G4.20	PAE0
START_POSITION	V99U9569C	FT	F	S	D	P	G4.23 G4.24 G4.25 G4.19 G4.20	ZFV2
STOP_POSITION	V99U9570C	FT	F	S	D	P	G4.23 G4.24 G4.25 G4.19 G4.20	ZFV2
T_GMTLO_REF	V99U7442C	SEC	F	D	M	C	G4.19 G4.20	ARC0
X_NEP	V97U5575C	FT	F	S	M	X	G4.4 G4.19 G4.20 G5.7	XS60 XS60

Table 4.6.1.5-3. Ascent User Parameter Processing (G4.19) K-Loads
Ascent User Parameter Processing

OIBB MISSIONS

FSSR NAME / DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT	PR	S	PR FCTN	LAST CR EQTN MSID
AS TOL	V90U9425C	-3 0	E-03 RAD	F	S	C	G4.23 G4.19 G4.20 G4.144 G4.127 G4.205	89661A
IMAX NO OF ALTITUDE REGIONS	V97U5729C	07	NO	I	S	C	G4.19 G4.20	59972

Table 4.6.1.5-3. Ascent User Parameters Processing (4.19) K-Loads (Cont)

OI8B MISSIONS DBFN:0509
G4.19 - 0005 - ASCENT USER PARAMETER PROCESSING
ACTIVE MEMORY CONFIGURATIONS: 01

FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT PR S PR FCTN	LAST CR EQTN MSID
TIME_BIAS_RADALT	V97U5546C	+1.50	E-02 SEC	F D P G4.19 G4.20 G4.23 G4.24 G4.25	59972
PAD LOAD CORR RAD ALT TIME					
X_NB_CG	V97U5573C	+5.61360	E+01 FT	F S C G4.23 G4.24 G4.25 G4.19 G4.20	59972
X_STRUCT_BODY DIST NAV BASE CG					
Z_NB_CG	V97U5580C	+4.0580	E+00 FT	F S C G4.20 G4.19 G4.23 G4.24 G4.25	59972
Z_STRUCT_BODY DIS CG NAV BASE					

Space Transportation Systems Division
Rockwell International

Table 4.6.1.5-4. Ascent User Parameter Processing (4.19) Constants

NROKRMH.FSSR2.DATA(X07)BOOK5
PFS CONSTANTS UPDATE B/L

FSSR NAME / DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
EARTH_RADIUS_EQUATOR EARTH EQUATORIAL RADIUS	V97U5324C		.209257414698 1630 E+08	FT	F	D				
EARTH_RATE EARTH'S ROTATIONAL RATE	V97U4379C		.729211514646 0000 E-04	RAD/SEC	F	D				
EARTH_POLE(1) X COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8460C		.28322844 E-02	ND	F	S				
EARTH_POLE(2) Y COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8461C		-.5027996 E-04	ND	F	S				
EARTH_POLE(3) Z COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8462C		.99999598 E+00	ND	F	S				
ELLIPT *EARTH'S ELLIPTICITY CONSTANTS*	*V97U5332C*		.335232980000 0000 E-02	ND	F	D				
GRAV_SEA_LEVEL EARTH GRAVITATIONAL ACCELERATION AT SEA LEVEL			.32174049 E+02	FT/ SEC**2	F	S				
PI RATIO CIRCUMFERENCE TO DIAMETER	V98U8725C		3.1415926535897	ND	F	D				
X_NB_WH DISTANCE FROM THE NAVIGATION BASE TO THE WHEELS IN THE X STRUCTURAL BODY DIRECTION			.62784 E+02	FT	F	S				
Z_NB_WH DISTANCE FROM THE WHEEL TO THE NAVIGATION BASE IN THE Z STRUCTURAL BODY DIRECTION			.22405 E+02	FT	F	S				

CR89596C

Table 4.6.1.5-5. Ascent User Parameter Processing (4.19) Cross-Reference

FSSR Name	Source Name
T_IMU	T_IMUS
V _IMU_CURRENT	SEL_V_M50
T_CURRENT	CLOCK

4.6.2 RTLS User Parameter Processing (4.20)

This principal function will serve as the interface between navigation and users of navigation-related data during the RTLS operational sequence. This function will maintain the vehicle state within the user parameter state propagation subfunction and shall:

- Provide this state to users who require vehicle state parameters in mean-of-fifty (M50) coordinates
- Provide the software to transform this state for users who require nav state related parameters

This function is composed of the following subfunctions:

1. User parameter state propagation (Section 4.6.2.1).
2. Powered RTLS user parameter calculations (Section 4.6.2.2).
3. Glide RTLS user parameter calculations (Section 4.6.2.3).
4. Ascent/RTLS user parameter calculations (Section 4.6.2.4).
5. RTLS user parameter processing HSI calculations (Section 4.6.2.5).
6. TACAN display computations (Section 4.6.2.6).

This function is controlled by the RTLS user parameter processing sequencer (Section 4.1.4).

The principal function input and output parameter tables, along with the I-load, K-load, constant, and cross-reference tables, are presented in Section 4.6.2.7, Tables 4.6.2.7-1 through 4.6.2.7-5. CR89596C

4.6.2.1 User Parameter State Propagation. This subfunction will provide state vector information to users such as guidance and displays during the ascent phase.

A. Detailed Requirements. The detailed requirements for this subfunction are contained in Section 4.4.1, ascent/RTLS operations (OPS-1, 6).

B. Interface Requirements. The input and output parameters required are listed in Tables 4.6.2.1-1 and 4.6.2.1-2. CR89596C

C. Processing Requirements. None.

D. Constraints. None.

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart is to be found in Section 5.6, subfunction USER_PARAM_PROPAGATOR_ASCENT_AND_RTLS.

CR89150H

Table 4.6.2. RTLS User Parameter Processing Principal Function Interface Diagram

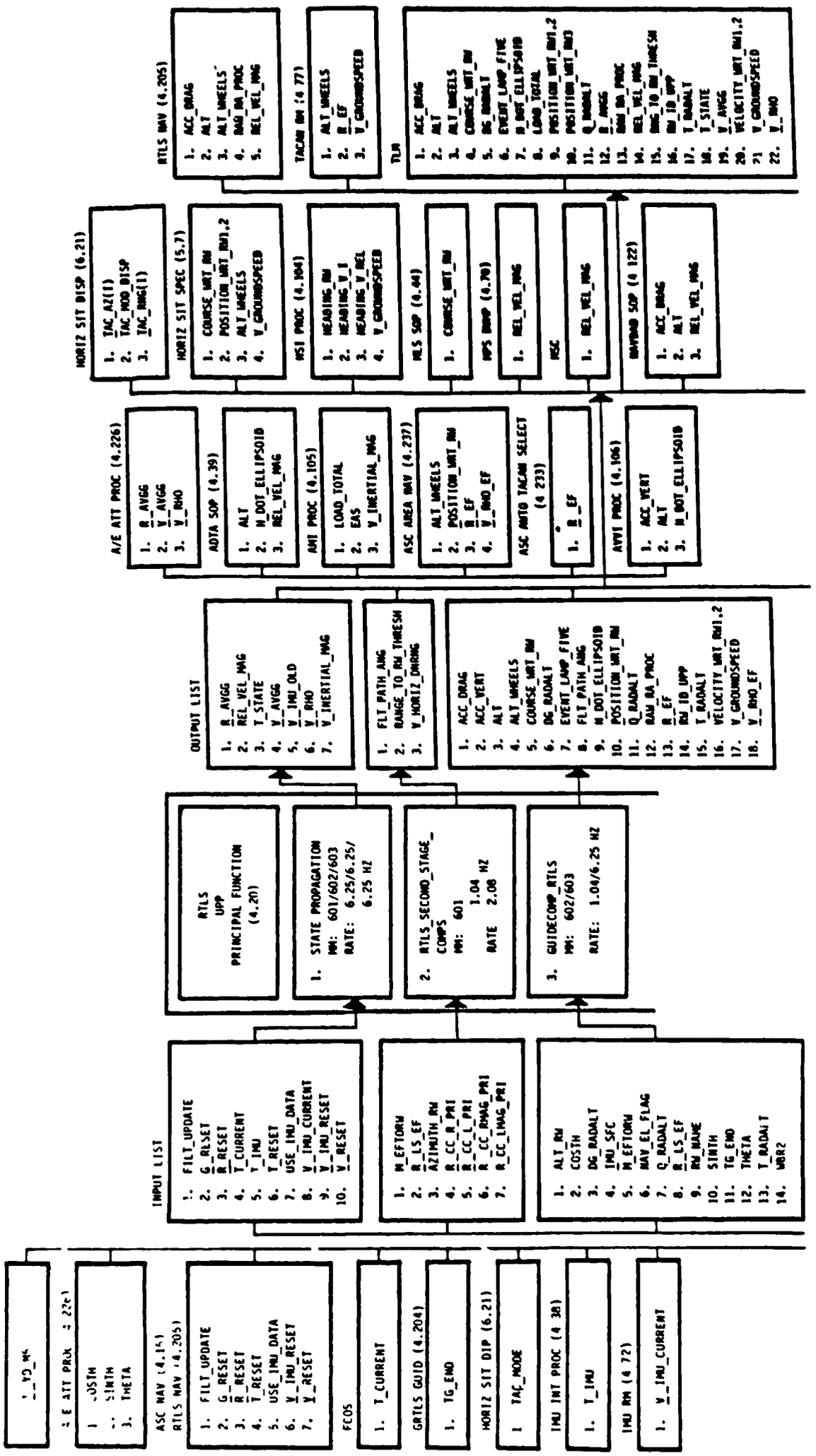
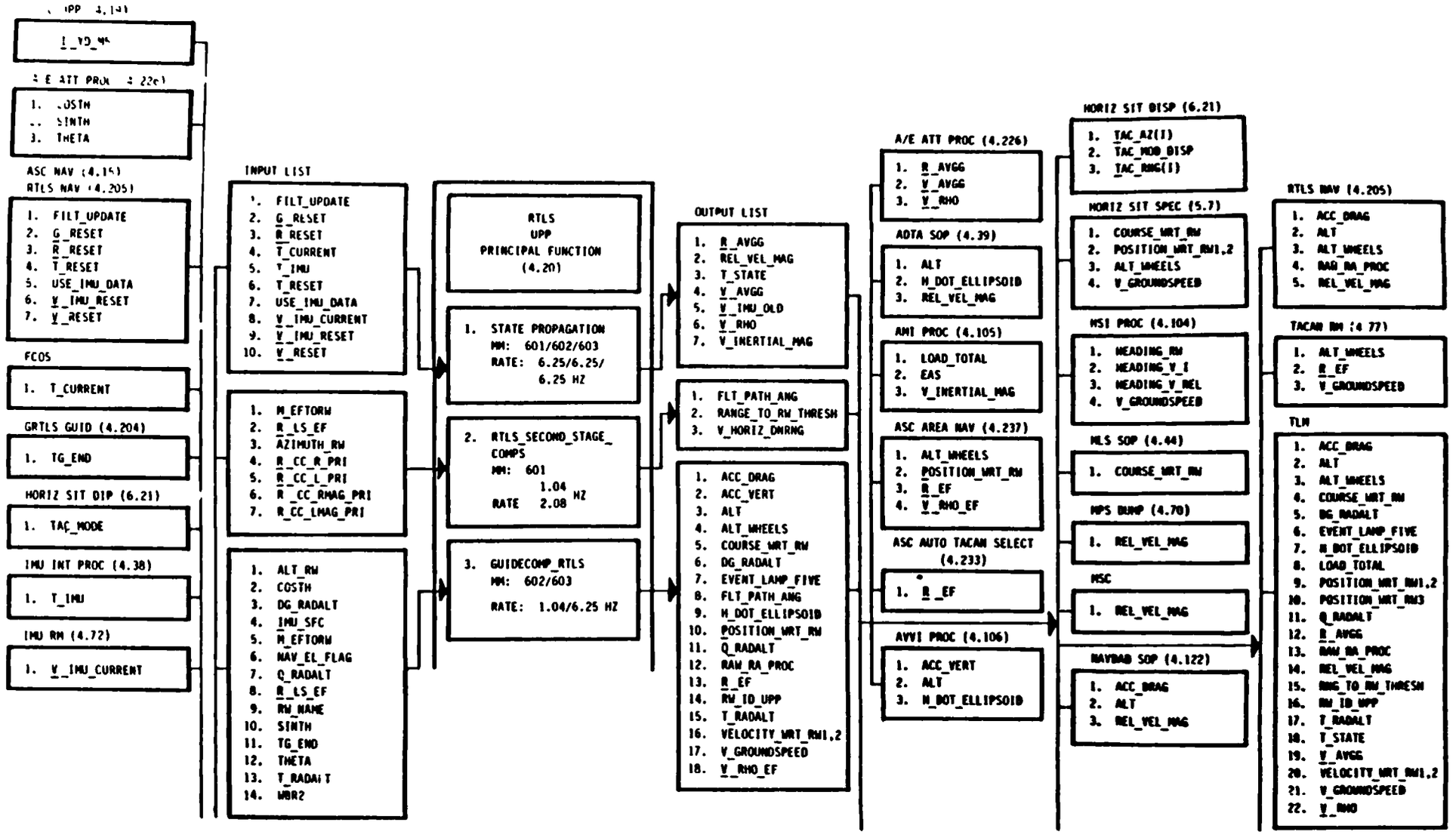


Table 4.6.2. RTLS User Parameter Processing Principal Function Interface Diagram



CR89150H

Table 4.6.2. RTLS User Parameter Processing Principal Function Interface Diagram (Cont)

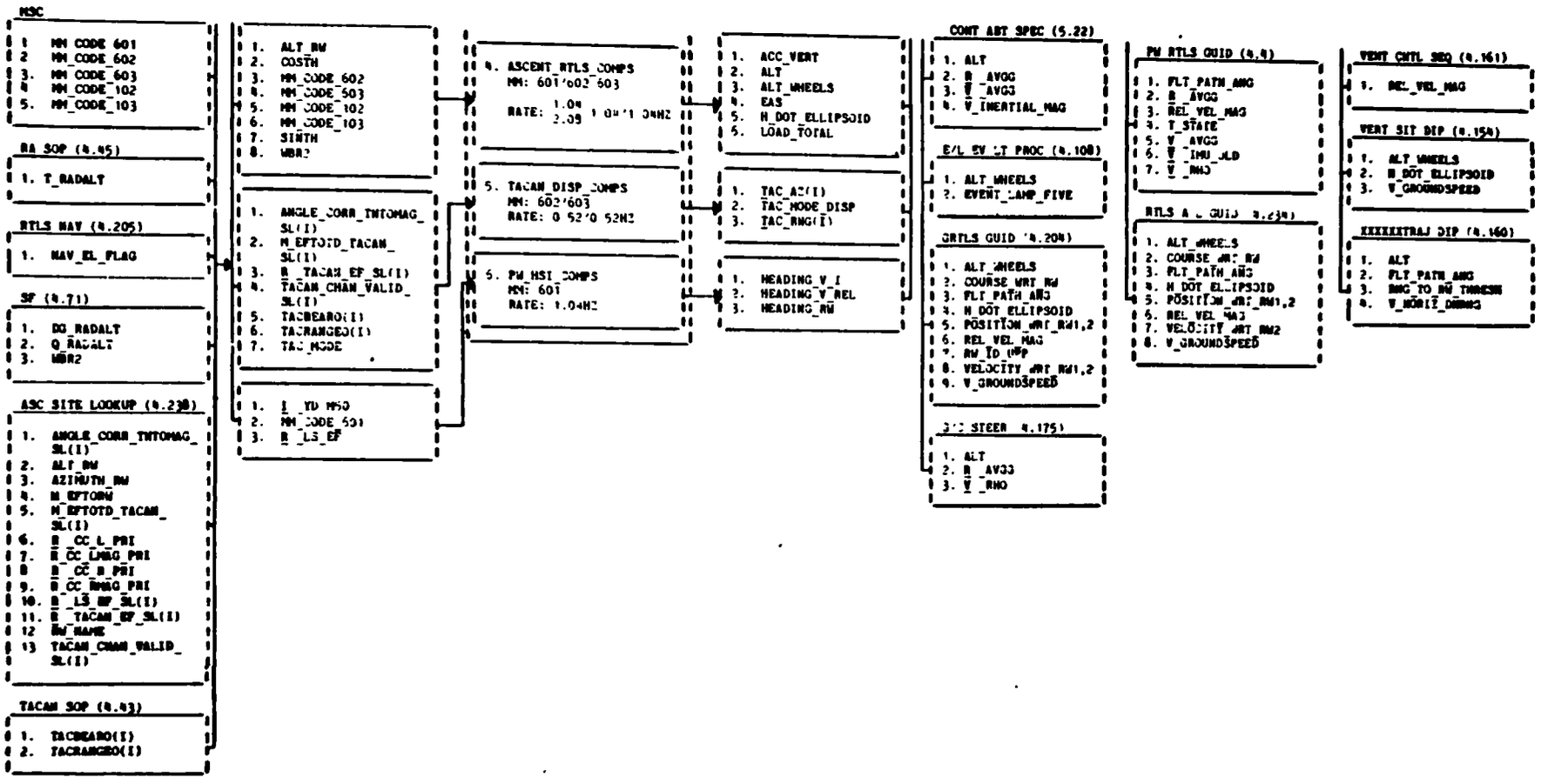


Table 4.6.2.1-1. Ascent/RTLS User Parameter State Propagation Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Switch indicating (ON) that current nav cycle is complete	FILT_UPDATE	(a)	D		OFF/ON		Nav rate
Vehicle position vector after all navigation updates reserved for reset of user parameter integrator position vector R_AVGG	R_RESET	(a)	V	DP		ft	Nav rate
Time associated with currently read IMU velocity counts from the IMU selection filter (RM)	T_IMU	(a)	F	DP		sec	As per sequencer
Time associated with reserved reset state	T_RESET	(a)	F	DP		sec	Nav rate
Current selected accumulated IMU velocity	V_IMU_CURRENT	(a)	V	DP		ft/sec	As per sequencer
Copy of V_CURRENT_FILT reserved as velocity count at start of extrapolation interval when user parameter integrator is reset	V_IMU_RESET	(a)	V	DP		ft/sec	Nav rate
Vehicle velocity vector after all navigation updates reserved for reset of user parameter integrator velocity vector V_AVGG	V_RESET	(a)	V	S		ft/sec	Nav rate
Gravitational acceleration vector reserved for reset of user parameter integrator gravity vector	G_RESET	(a)	V	S		ft/s^2	NAV rate
Current time	T_CURRENT	(a)	F	DP		sec	As per sequencer

[a]See RTLS UPP principal function input parameter table.

Table 4.6.2.1-2. Ascent/RTLS User Parameter State Propagation Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
IMU-sensed acceleration	A_SENSED	ASCENT_RTLS_COMPS	V	S		ft/sec^2	As per sequencer
Current Shuttle position vector	R_AVGG	(a), ASCENT_RTLS_COMPS, PW_HSI_COMPS, RTLS_SECOND_STAGE_COMPS, GUIDECOMP_RTLS	V	DP		ft	As per sequencer
Time tag for current user parameter state vector	T_STATE	(a), ASCENT_RTLS_COMPS, PW_HSI_COMPS, RTLS_SECOND_STAGE_COMPS, GUIDECOMP_RTLS	F	DP		sec	As per sequencer
Shuttle current velocity vector	V_AVGG	(a), PW_HSI_COMPS	V	S		ft/sec	As per sequencer
Current IMU accumulated velocity	V_IMU_OLD	(a), GUIDECOMP_RTLS	V	DP		ft/sec	As per sequencer
Shuttle earth-relative velocity vector in M50 coordinates	V_RHO	(a), ASCENT_RTLS_COMPS, PW_HSI_COMPS, RTLS_SECOND_STAGE_COMPS, GUIDECOMP_RTLS	V	S		ft/sec	As per sequencer
Magnitude of Shuttle earth-relative velocity	REL_VEL_MAG	(a), ASCENT_RTLS_COMPS, PW_HSI_COMPS, RTLS_SECOND_STAGE_COMPS, GUIDECOMP_RTLS	F	S		ft/sec	As per sequencer
Inertial velocity magnitude	V_INERTIAL_MAG	(a), PW_HSI_COMPS	F	S		ft/sec	As per sequencer
Flag indicating (ON) that the UPP state has been updated by navigation	UPP_UPDATE	ASCENT_RTLS_COMPS	D		ON/OFF		As per sequencer

[a]See RTLS UPP principal function output parameter table.

4.6.2.2 Powered RTLS User Parameter Calculations. This subfunction will provide the required software to transform the user parameter state into related parameters required to support the RTLS TRAJ 2 CRT display during the RTLS second stage MM 601. Since the altitude and the vertical velocity are also computed for glide RTLS, a common subfunction ASCENT_RTLS_COMPS is designed to handle these parameters and is presented in Section 4.6.2.4.

A. Detailed Requirements. This subfunction shall first generate a matrix to transform from M50 to earth-fixed coordinates at the time of the current vehicle state vector and determine the earth-fixed position and relative velocity of the Shuttle.

$$M\_TEMP\_TXPOS = EARTH\_FIXED\_TO\_M50\_COORD(T\_STATE)^T$$

$$\underline{R}\_EF = M\_TEMP\_TXPOS\ \underline{R}\_AVGG$$

$$\underline{V}\_RHO\_EF = M\_TEMP\_TXPOS\ \underline{V}\_RHO$$

The y-component of the Shuttle position vector in runway coordinates will then be computed:

$$R\_VEH\_RW_2 = (M\_EFTORW_{2,\ 1\ to\ 3}) \cdot (\underline{R}\_EF - \underline{R}\_LS\_EF)$$

where $\underline{R}\_LS\_EF$ is the position vector of the primary runway in earth-fixed coordinates. This subfunction will then determine which side of the runway centerline the Shuttle is on, and the parameter YSGNP will be established accordingly:

$$YSGNP = -SIGN\ (R\_VEH\_RW_2)$$

The flag TOGHAC is monitored to determine which runway approach type (overhead or straight in) has been selected by the crew. Whenever TOGHAC has the value OFF, an overhead approach is commanded, and YSGNP will retain its value established above. Whenever TOGHAC has the value ON, a straight-in approach is commanded, and YSGNP is set to the negative of its previously determined value. That is, if

TOGHAC = ON

then

YSGNP = -YSGNP

If YSGNP is positive, then the HAC center position vector and associated magnitude will be set equal to the following site lookup input parameters

$$\underline{R}\_CC\_EF = \underline{R}\_CC\_R\_PRI$$

$$R\_CC\_MAG = R\_CC\_RMAG\_PRI$$

If YSGNP is negative, then they will be set equal to

$$R\_CC\_EF = R\_CC\_L\_PRI$$

$$R\_CC\_MAG = R\_CC\_LMAG\_PRI$$

The vector, V_NORM, normal to the great circle plane containing the Shuttle and heading alignment circle center and its absolute value will be determined:

$$V\_NORM = R\_EF \times R\_CC\_EF$$

$$UNIT = ABVAL(V\_NORM)$$

Next, the bearing of this great circle plane with respect to true north at the circle center is determined:

$$BEAR\_CC = ARCTAN2\ [V\_NORM_3\ R\_CC\_MAG,\ (V\_NORM_1\ R\_CC\_EF_2 - V\_NORM_2\ R\_CC\_EF_1)] \quad (F7)$$

If BEAR_CC < 0, then BEAR_CC = BEAR_CC + 2 PI. The sine of the central angle between the position of the Shuttle and the center of the heading alignment circle is determined:

$$SIN\_THET\_VEH\_CC = UNIT/\ (R\_VEH\_MAG\ R\_CC\_MAG)$$

The great-circle surface range from the Shuttle to WP-1 is determined:

$$DIST\_VEH\_WP1 = ARCSIN(SIN\_THET\_VEH\_CC)\ R\_CC\_MAG$$

Next, the angle defined by the intersection of the two great circle planes (one passing through the Shuttle position and the HAC center and the other through the Shuttle position and WP1) is given by

$$A2 = RADIUS\_NEP/\ DIST\_VEH\_WP1$$

The arc length around the heading alignment circle from WP-1 to the normal entry point will be determined:

$$A3 = A2 + YSGNP\ (AZIMUTH\_RW - BEAR\_CC)$$
If A3 < A3_TOL, then A3 = A3 + 2 PI and
$$D\_ARC = A3\ RADIUS\_NEP$$

[F7] This equation shall be protected against arc tangents with both arguments equal to zero (Section 3.5).

Next, the surface range from the Shuttle to the primary runway threshold is computed via way point 1 and converted for output:

RNG_TO_RW_THRESH = (DIST_VEH_WP1 +D_ARC - X_NEP) NAUTMI_PER_FT

The flight path angle is given by

FLT_PATH_ANG = H_DOT_ELLIPSOID/ REL_VEL_MAG

FLT_PATH_ANG_TIME = T_STATE

The downrange component of groundspeed will then be determined by first defining the unit vector normal to the position vector and directed downrange in the plane containing the vehicle and the heading alignment circle:

$$\underline{I}\_DR = \underline{R}\_EF \times \underline{V}\_NORM / (R\_VEH\_MAG\ UNIT)$$

Downrange velocity follows from:

$$V\_HORIZ\_DNRNG = \underline{V}\_RHO\_EF \cdot \underline{I}\_DR$$

B. Interface Requirements. The input and output requirements for the guidance and displays way point computations are listed in Tables 4.6.2.2-1 and 4.6.2.2-2, respectively.

C. Processing Requirements. The performance of this subfunction and its cyclic repetition rate are under the control of the ascent/RTLS user parameter processing sequencer, as described in Section 4.1.4.

D. Constraints. None.

E. Supplemental Information. A suggested implementation of the guidance and displays way point computation subfunction may be found in Section 5.6, subfunction RTLS_SECOND_STAGE_COMPS.

Table 4.6.2.2-1. Input Parameters for Powered RTLS User Parameter Calculations

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Time tag for current user parameter state vector	T_STATE	UPP state prop	F	DP		sec	As per sequencer
Current Shuttle position vector	R_AVGG	UPP state prop	V	DP		ft	As per sequencer
Earth-fixed to prime RW transformation matrix	M_EFTORW	(a)	M	S			As per sequencer
Feet to nautical miles	NAUTMI_PER_FT	Constant	F	S		nm/ft	As per sequencer
Constant PI	PI	Constant	F	DP			As per sequencer
Radius of nominal entry point heading alignment circle	RADIUS_NEP	Mission dependent	F	S		ft	As per sequencer
Position vector of landing site in earth-fixed coordinates	R_LS_EF	(a)	V	DP		ft	As per sequencer
Runway X-component of the HAC center	X_NEP	Mission dependent	F	S		ft	As per sequencer
Bearing from true north of runway coordinate system +X-axis	AZIMUTH_RW	(a)	F	S	0-2 PI	rad	As per sequencer
Tolerance for correcting the range of the angle A3	A3_TOL	Design dependent	F	S		rad	As per sequencer
Shuttle earth-relative velocity vector in M50 coordinates	V_RHO	UPP state prop	V	S		ft/sec	As per sequencer
Position vector of the HAC center on the left-side (-Y) of the runway centerline	R_CC_L_PRI	(a)	V	S		ft	As per sequencer
Position vector of the HAC center on the right-side (+Y) of the runway centerline	R_CC_R_PRI	(a)	V	S		ft	As per sequencer
Magnitude of the vector R_CC_L_PRI	R_CC_LMAG_PRI	(a)	F	S		ft	As per sequencer
Magnitude of the vector R_CC_R_PRI	R_CC_RMAG_PRI	(a)	F	S		ft	As per sequencer
Estimated topodetic altitude rate	H_DOT_ELLIPSOID	ASCENT_RTLS_COMPS	F	S		ft/sec	As per sequencer
Magnitude of Shuttle position vector	R_VEH_MAG	ASCENT_RTLS_COMPS	F	S		ft	As per sequencer
Magnitude of Shuttle earth-relative velocity	REL_VEL_MAG	UPP state prop	F	S		ft/sec	As per sequencer
Flag denoting HAC approach type	TOGHAC	(a)	D			ON/OFF	

[a]See RTLS UPP principal function input parameter table.

Table 4.6.2.2-2. Outputs From Powered RTLS User Parameter Calculations

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Surface range from Shuttle to runway target point	RNG_TO_RW_THRESH	(a)	F	S		nmi	As per sequencer
Downrange component of the Shuttle's horizontal, earth-relative velocity	V_HORIZ_DWRNG	(a)	F	S		ft/sec	As per sequencer
Ground relative flight path angle	FLT_PATH_ANG	(a)	F	S		rad	As per sequencer
Time at calculation of flight path angle	FLT_PATH_ANG_TIME	(a)	F	D		sec	As per sequencer
HAC center position vector	R_CC_FF	(a)	V	DP		ft	As per sequencer
Arc length around HAC from WP1 to NEP	D_ARC	(a)	F	S		ft	As per sequencer
Indicator of vehicle position with respect to runway	YSGNP	(a)	I	S			As per sequencer

[a]See RTLS UPP principal function output parameter table.

4.6.2.3 Glide RTLS User Parameter Calculations. Guidance and other systems require that certain navigation-related calculations to be accomplished during the glide phases of the RTLS operational sequence. Since many of the required parameters are common to all points along the trajectory, one subfunction called GUIDECOMP_RTLS (4.6.2.3) is designed to handle the calculations. It should be expected that the commonality existing during this phase of RTLS is not perfect and, therefore, it is found that certain parameters are computed in different ways along different portions of the trajectory. The main difference is that the calculation of h, $\dot{h}$, and $\ddot{h}$ is with reference to runway coordinates when RTLS Approach/Land is active; while for RTLS TAEM Guidance, calculation is with reference to topodetic coordinates. The latter computations are made in a separate subfunction called ASCENT_RTLS_COMPS (4.6.2.4).

A. Detailed Requirements. First, the earth-fixed-to-M50 coordinate transformation will be transposed to form an M50 to earth-fixed transformation:

$$M\_TEMP\_TXPOS = EARTH\_FIXED\_TO\_M50\_COORD(T\_STATE)^T$$

The earth-fixed position and relative velocity vectors are:

$$\underline{R}\_EF = M\_TEMP\_TXPOS\ \underline{R}\_AVGG$$

$$\underline{V}\_RHO\_EF = M\_TEMP\_TXPOS\ \underline{V}\_RHO$$

and by using the earth-fixed-to-runway transformation, the position and velocity in runway coordinates will be computed:

$$\underline{POSITION\_WRT\_RUNWAY} = M\_EFTORW(\underline{R}\_EF - \underline{R}\_LS\_EF)$$

$$\underline{VELOCITY\_WRT\_RUNWAY} = M\_EFTORW(\underline{V}\_RHO\_EF)$$

where $\underline{R}\_LS\_EF$ is the radius vector to the landing site reference point. The components of these vectors are

$$\text{downrange position} = POSITION\_WRT\_RUNWAY_1$$

$$\text{crossrange position} = POSITION\_WRT\_RUNWAY_2$$

$$\text{altitude position} = -\ POSITION\_WRT\_RUNWAY_3$$

$$\text{downrange velocity} = VELOCITY\_WRT\_RUNWAY_1$$

$$\text{crossrange velocity} = VELOCITY\_WRT\_RUNWAY_2$$

$$\text{altitude rate} = -\ VELOCITY\_WRT\_RUNWAY_3$$

4.6.2.3 Glide RTLS User Parameter Calculations. Guidance and other systems require that certain navigation-related calculations to be accomplished during the glide phases of the RTLS operational sequence. Since many of the required parameters are common to all points along the trajectory, one subfunction called GUIDECOMP_RTLS (4.6.2.3) is designed to handle the calculations. It should be expected that the commonality existing during this phase of RTLS is not perfect and, therefore, it is found that certain parameters are computed in different ways along different portions of the trajectory. The main difference is that the calculation of h, $\dot{h}$, and $\ddot{h}$ is with reference to runway coordinates when RTLS Approach/Land is active; while for RTLS TAEM Guidance, calculation is with reference to topodetic coordinates. The latter computations are made in a separate subfunction called ASCENT_RTLS_COMPS (4.6.2.4).

A. Detailed Requirements. First, the earth-fixed-to-M50 coordinate transformation will be transposed to form an M50 to earth-fixed transformation:

$$M\_TEMP\_TXPOS = EARTH\_FIXED\_TO\_M50\_COORD(T\_STATE)^T$$

The earth-fixed position and relative velocity vectors are:

$$\underline{R}\_EF = M\_TEMP\_TXPOS\ \underline{R}\_AVGG$$

$$\underline{V}\_RHO\_EF = M\_TEMP\_TXPOS\ \underline{V}\_RHO$$

and by using the earth-fixed-to-runway transformation, the position and velocity in runway coordinates will be computed:

$$\underline{POSITION\_WRT\_RUNWAY} = M\_EFTORW(\underline{R}\_EF - \underline{R}\_LS\_EF)$$

$$\underline{VELOCITY\_WRT\_RUNWAY} = M\_EFTORW(\underline{V}\_RHO\_EF)$$

where $\underline{R}\_LS\_EF$ is the radius vector to the landing site reference point. The components of these vectors are

$$\text{downrange position} = POSITION\_WRT\_RUNWAY_1$$

$$\text{crossrange position} = POSITION\_WRT\_RUNWAY_2$$

$$\text{altitude position} = -\ POSITION\_WRT\_RUNWAY_3$$

$$\text{downrange velocity} = VELOCITY\_WRT\_RUNWAY_1$$

$$\text{crossrange velocity} = VELOCITY\_WRT\_RUNWAY_2$$

$$\text{altitude rate} = -\ VELOCITY\_WRT\_RUNWAY_3$$

4.6.2.3 Glide RTLS User Parameter Calculations. Guidance and other systems require that certain navigation-related calculations to be accomplished during the glide phases of the RTLS operational sequence. Since many of the required parameters are common to all points along the trajectory, one subfunction called GUIDECOMP_RTLS (4.6.2.3) is designed to handle the calculations. It should be expected that the commonality existing during this phase of RTLS is not perfect and, therefore, it is found that certain parameters are computed in different ways along different portions of the trajectory. The main difference is that the calculation of h, $\dot{h}$, and $\ddot{h}$ is with reference to runway coordinates when RTLS Approach/Land is active; while for RTLS TAEM Guidance, calculation is with reference to topodetic coordinates. The latter computations are made in a separate subfunction called ASCENT_RTLS_COMPS (4.6.2.4).

A. Detailed Requirements. First, the earth-fixed-to-M50 coordinate transformation will be transposed to form an M50 to earth-fixed transformation:

$$M\_TEMP\_TXPOS = EARTH\_FIXED\_TO\_M50\_COORD(T\_STATE)^T$$

The earth-fixed position and relative velocity vectors are:

$$\underline{R}\_EF = M\_TEMP\_TXPOS\ \underline{R}\_AVGG$$

$$\underline{V}\_RHO\_EF = M\_TEMP\_TXPOS\ \underline{V}\_RHO$$

and by using the earth-fixed-to-runway transformation, the position and velocity in runway coordinates will be computed:

$$\underline{POSITION\_WRT\_RUNWAY} = M\_EFTORW(\underline{R}\_EF - \underline{R}\_LS\_EF)$$

$$\underline{VELOCITY\_WRT\_RUNWAY} = M\_EFTORW(\underline{V}\_RHO\_EF)$$

where $\underline{R}\_LS\_EF$ is the radius vector to the landing site reference point. The components of these vectors are

$$\text{downrange position} = POSITION\_WRT\_RUNWAY_1$$

$$\text{crossrange position} = POSITION\_WRT\_RUNWAY_2$$

$$\text{altitude position} = -\ POSITION\_WRT\_RUNWAY_3$$

$$\text{downrange velocity} = VELOCITY\_WRT\_RUNWAY_1$$

$$\text{crossrange velocity} = VELOCITY\_WRT\_RUNWAY_2$$

$$\text{altitude rate} = -\ VELOCITY\_WRT\_RUNWAY_3$$

Because of targeting requirements, the sign of the vehicle side of the runway centerline for the selected runway is next determined:

$$SIGNY = SIGN\ (POSITION\_WRT\_RW_2)$$

In order to target to the proper point in preparation for landing at the selected runway, it is necessary to determine which type of targeting (either overhead approach or straight-in approach) has been selected as well as the associated heading alignment cone (HAC). The nominal targeting is initially set to the overhead approach on the selected runway which would therefore place the HAC on the opposite side of the runway centerline to that of the Shuttle. Since weather changes as well as energy level may cause the crew to select some combination of runway and approach type other than the nominal choice (by means of item entries on the HSD), it is necessary to monitor these changes and respond with the proper command both to guidance and the displays (HSD and HSI). Basically, there are four parts to the logic which handle the aforementioned problem: (a) initialization of parameters, (b) response to crew item entry which changes the approach type, (c) response to crew item entry which causes a runway redesignation, and (d) particular case of crossing runway centerline for a straight-in approach. Each part is now treated separately.

(a) Initialization of Parameters - The parameter RW_ID_UPP will be initialized to zero and employed as a single pass flag in order to initialize the required variables. Since the nominal approach will be overhead to the selected runway, the overhead flag, OVHD, will be turned ON and the commanded HAC side for the selected runway YSGNP, will be set equal to the negative of the Shuttle side of the runway centerline, that is,

$$OVHD = ON$$

$$YSGNP = -SIGNY$$

In addition, the runway parameter RW_ID_UPP will be set equal to the selected runway number and the radius of the HAC, R_NEP, as well as the turn angle along the cone, PSHA, will be initialized for the selected runway:

$$RW\_ID\_UPP = RW\_NAME$$

$$R\_NEP = RI$$

$$PSHA = PSHARS$$

The initial values of the radius, RI, and the turn angle, PSHARS, are design dependent constants.

Finally, one flag corresponding to TAEM guidance downmoding is initialized to OFF and one flag corresponding to AREA NAV is initialized to ON:

OHALRT = OFF

FIRST_PASS = ON

The flag, FIRST_PASS, when turned ON, allows AREA NAV to initialize the HAC indicators to those used by guidance.

(b) Response to Change of Approach Type - Since an item entry on the HSD commands a change in approach type, the flag TOGHAC is monitored in order to detect this crew request. Whenever TOGHAC is turned ON by the HSD, the turn angle PSHA will be re-initialized, and the HSD flag TOGHAC is turned OFF; that is:

PSHA = PSHARS

TOGHAC = OFF

The next step is to determine the status of the overhead flag, OVHD, and the commanded HAC side, YSGNP. If the current status of the overhead flag, OVHD, is ON, then it is set to OFF indicating a straight-in approach. The commanded HAC side for the selected runway is set equal to the vehicle side of the corresponding runway centerlines; that is, if

OVHD = ON

then

OVHD = OFF

YSGNP = SIGNY

If the current status of the overhead flag, OVHD, is OFF, then it is set to ON indicating an overhead approach. The commanded HAC side for the selected runway is set equal to the opposite sign of the vehicle side of the corresponding runway centerlines, that is, if

OVHD = OFF

then

OVHD = ON

YSGNP = -SIGNY

(c) Response to Runway Change - Since two item entries on the HSD provide the crew with the capability to change the designated runway, the parameter RW_NAME is monitored to detect this crew request. Since the variable RW_ID_UPP is set equal to the current runway number, it is employed to detect a change in runway designation. If RW_ID_UPP is not equal to the new value of RW_NAME, then this indicates a change of selected runway and

hence, the value of the commanded HAC side must be once more determined. The rule for determining this parameter for runway redesignation is as follows: (i) if the primary runway or the secondary runway are redesignated as selected, then the current status of the OVHD flag is to be retained and the value of the commanded HAC side will be determined based on this flag. Therefore, if

RW_ID_UPP ≠ RW_NAME

then the current status of the OVHD flag is tested. If it is ON, then the commanded HAC side is set equal to the negative of the vehicle side for the selected runway - otherwise it is set equal to the vehicle side, that is, if

OVHD = ON

then

YSGNP = -SIGNY

otherwise

YSGNP = SIGNY

Regardless of the current status of the OVHD flag, the flag FIRST_PASS is turned ON, the runway parameter RW_ID_UPP is set equal to the current value of RW_NAME and the turn angle PSHA is re-initialized:

FIRST_PASS = ON

RW_ID_UPP = RW_NAME

PSHA = PSHARS

(d) Particular Case for Straight-In Approach - Whenever the straight-in approach is required, it is necessary to change the commanded HAC side to be compatible with the vehicle side. A test is made on the overhead flag, OVHD, to determine if the approach is straight-in. If the OVHD is OFF, then a test is made on the phase counter IPHASE. For the vehicle not yet on the HAC (IPHASE ≠ 2 and IPHASE ≠ 3), the commanded HAC side is set equal to the vehicle side, that is, if

IPHASE ≠ 2 and IPHASE ≠ 3

then

YSGNP = SIGNY

A flag will be tested to determine if transition to RTLS Autoland guidance has occurred. If TG_END = ON, RTLS Autoland guidance is in effect and all subsequent calculations will be done with respect to the landing runway coordinate system. Radar altimeter data, altitude of the Shuttle, the data good flag, and the time tag will be collected:

SNAP RADAR ALTIMETER (Q_RADALT, DG_RADALT, T_RADALT)

All data are to be saved in one uninterrupted operation by the transfer of the parameters from working locations that are constantly being updated by hardware data reads and other operations into special locations. It will then be determined whether the third component of the vector, POSITION_WRT_RUNWAY, will be replaced with a value derived directly from the radar altimeter measurement of altitude. If RAW_RA_PROC = ON and DG_RADALT = ON, the following computations will be performed:

$$T\_RADALT = T\_RADALT - TIME\_BIAS\_RADALT$$

$$POSITION\_WRT\_RUNWAY_3 = - Q\_RADALT + BIAS\_RADALT + (T\_STATE - T\_RADALT)\ VELOCITY\_WRT\_RUNWAY_3 - SIN(RADALT\_ANG - THETA\ RAD\_PER\_DEG)\ RADALT\_NB\_DIST,$$

where DG_RADALT is the data validity indicator for the radar altimeter altitude measurement and RAW_RA_PROC indicates whether the vehicle position is within the zone of radar altimeter use.

If the first part of the test fails, that is RAW_RA_PROC = OFF, then the following test shall be made to determine whether the vehicle is close enough to the runway threshold to permit radar altimeter utilization:

If

$$POSITION\_WRT\_RUNWAY_1^2 + POSITION\_WRT\_RUNWAY_2^2 < R\_GO\_RAMP^2,$$

then set

$$RAW\_RA\_PROC = ON.$$

For some sloping runways, the MSBLS will be aligned parallel with the sloping runway rather than horizontally. In these instances, it will be necessary to correct the vertical components of the position and velocity with reference to runway vectors to account for this bias. These corrections will be made gradually beginning at the x-runway position, START_POSITION. The amount of correction will increase linearly so that the components are fully corrected at the x-runway position, STOP_POSITION. A small angle approximation will be used for the transformation from horizontal to sloping coordinates. The runway slope, BIAS_ELMLS, is obtained from the site lookup principal function.

First test to determine if MSBLS is available at the runway, that is, if

MLS_AVAIL = ON

then calculate the vertical components of the position and velocity vectors relative to the sloping runway:

TEMP = (POSITION_WRT_RUNWAY$_1$-START_POSITION)/

(STOP_POSITION-START_POSITION)

RAMP = MIDVAL (0, TEMP, 1)

TEMP = RAMP BIAS_ELMLS

POSITION_WRT_RUNWAY$_3$ = POSITION_WRT_RUNWAY$_3$ +

TEMP POSITION_WRT_RUNWAY$_1$

VELOCITY_WRT_RUNWAY$_3$ = VELOCITY_WRT_RUNWAY$_3$ +

TEMP VELOCITY_WRT_RUNWAY$_1$

The altitude of the rear wheels (corrected for the pitch plane altitude difference between the navigation base and the rear wheels), the altitude above the ellipsoid and the altitude rate (corrected for pitch rate of the navigation base with respect to the c.g.) shall be calculated:

$$\text{ALT\_WHEELS} = -\text{POSITION\_WRT\_RUNWAY}_3 - (\text{X\_NB\_WH SINTH} + \text{Z\_NB\_WH COSTH})$$

$$\text{ALT} = \text{ALT\_WHEELS} + \text{ALT\_RW}$$

$$\text{H\_DOT\_ELLIPSOID} = -\text{VELOCITY\_WRT\_RUNWAY}_3 - \text{WBR}_2\ \text{RAD\_PER\_DEG}\ (\text{X\_NB\_CG COSTH} - \text{Z\_NB\_CG SINTH})$$

where X_NB_CG and Z_NB_CG are the (positive) X and Z structural body axis distances between the navigation base and the vehicle c.g. and X_NB_WH and Z_NB_WH are the (positive) X and Z structural body axis distances between the navigation base and the bottom of the rear wheels. The term WBR_2 is the vehicle pitch rate in degrees per second, and SINTH and COSTH are the sine and cosine of the pitch angle. These last three terms are obtained from the attitude processing principal function.

The vertical acceleration is then obtained from

$$\text{ACC\_VERT} = (\text{H\_DOT\_ELLIPSOID} - \text{H\_DOT\_LAST}) / (\text{T\_STATE} - \text{T\_STATE\_LAST})$$

Subsequently, previous values are set to current values:

$$\text{H\_DOT\_LAST} = \text{H\_DOT\_ELLIPSOID}$$

$$\text{T\_STATE\_LAST} = \text{T\_STATE}$$

Returning now to calculations common to the entire glide phase, the heading of the Shuttle navigation base with respect to the runway centerline will be computed:

$$\text{COURSE\_WRT\_RW} = \text{ARCTAN2}(\text{VELOCITY\_WRT\_RUNWAY}_2, \text{VELOCITY\_WRT\_RUNWAY}_1)$$

A test will be made to determine if the computed course is a negative number:

$$\text{COURSE\_WRT\_RW} < 0$$

If this statement is true, 2 π radians will be added to the computed value:

$$\text{COURSE\_WRT\_RW} = \text{COURSE\_WRT\_RW} + 2\text{PI}$$

Finally, the value is converted to degrees

$$\text{COURSE\_WRT\_RW} = \text{COURSE\_WRT\_RW DEG\_PER\_RAD}$$

Next, the vehicle groundspeed will be determined:

$$V\_GROUNDSPEED = (REL\_VEL\_MAG^2 - H\_DOT\_ELLIPSOID^2)^{1/2}$$

A test will be made to determine if there has been a change in status of the IMU's (for instance, an IMU failure). If the current value of IMU_SFC is the same as the previous value, IMU_SFC_PREV, indicating no change in the status of the IMU's, that is,

if

$$\underline{IMU\_SFC} = \underline{IMU\_SFC\_PREV}$$

then the total sensed acceleration vector $\underline{TCG}$ is computed from the IMU-measured velocities:

$$\underline{TCG} = (\underline{V}\_IMU\_OLD - \underline{V}\_IMU\_PREV)/ (T\_STATE - T\_STATE\_PREV)$$

Next, the drag acceleration magnitude follows from

$$ACC\_DRAG = - (\underline{TCG} \cdot \underline{V}\_RHO)/ REL\_VEL\_MAG$$

CR89596C

ACC_DRAG should be limited between 1.0 E-4 and 1.0 E+3.

Then, the angle of attack is averaged over the last cycle in order to time synchronize this parameter with drag acceleration computations for use in the NAVDAD SOP (PF 4.122).

$$ALPHA\_NAVDAD = (ALPHA\_OLD + ALPHA\_N)/2$$

$$ALPHA\_OLD = ALPHA\_N$$

Next, previous values are set equal to current values:

$$T\ STATE\ PREV = T\_STATE$$

$$V\ \ IMU\ PREV = \underline{V}\_IMU\_OLD$$

$$IMU\ SFC\ PREV = IMU\_SFC$$

The flight path angle shall be calculated as

$$FLT\ PATH\ ANG = SIN^{-1}(H\ DOT\_ELLIPSOID\ \ REL\ VEL\ MAG)$$

Next the value of the radar altimeter alert flag will be established. If ALT_WHEELS < $ALT\_NAV\_EVLT_3$, then the value of the discrete, DG_RADALT, shall be tested, and if the value is ON, then the value of the discrete, RA_FLAG, shall be set to OFF and the sequential counter, N_SEQ_RA, shall be initialized to one. Otherwise, the sequential counter, N_SEQ_RA, shall be incremented by one and its value tested to see if it exceeds the maximum allowable value, N_SEQ_MAX. If it does, then the discrete, RA_FLAG, shall be set to the value ON. Whenever ALT_WHEELS $\geq$ $ALT\_NAV\_EVLT_3$, the discrete, RA_FLAG, shall retain its initial value of OFF.

B. Interface Requirements. The input and output required for the RTLS guidance parameters are listed in Tables 4.6.2.3-1 and 4.6.2.3-2.

C. Processing Requirements. The performance and cyclic repetition rate of this subfunction will be under the control of the Ascent/RTLS user parameter processing sequencer (Section 4.1.4). Minimum required computation rates for parameters computed by this subfunction are indicated in Table 4.6.2.3-2.

D. Constraints. It is required that N_SEQ_RA be initialized to one, T_STATE_PREV be initialized to an extremely large negative number, V_IMU_PREV be initialized to (0,0,0) and IMU_SFC_PREV to (1, 1, 1). The flag VNT_DR_SEQ_INIT must be initialized to OFF and the flag TEST_VNT_DR to ON. The parameter RW_ID_UPP must be initialized to zero. The flag, RA_FLAG, must be initialized to OFF.

E. Supplemental Information. These calculations have been simplified to conserve memory locations and execution time. The assumptions are as follows:

1. Position and velocity are defined with respect to the vehicle navigation base rather than the c.g.

2. A correction factor has been applied to the altitude and altitude rate calculation to correct for pitch and pitch rate errors introduced because of the first assumption. Roll and roll rate are not included.

3. Flight path angle is computed at the navigation base. Thus, errors will be introduced whenever pitch rate is not zero.

A suggested implementation in the form of a detailed flow chart is shown in Section 5.6, subfunction GUIDECOMP_RTLS.

Table 4.6.2.3-1. Input Parameters for Glide RTLS User Parameter Calculations

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
The constant PI	PI	(b)	F	S			As per sequencer
Cosine of Shuttle's pitch Euler angle (TD to body)	COSTH	(a)	F	S			As per sequencer
Sine of Shuttle's pitch Euler angle (TD to body)	SINTH	(a)	F	S			As per sequencer
Current Shuttle position vector	R_AVGG	UPP state prop	V	DP		ft	As per sequencer
Present value of horizontal distance of vehicle from RW reference point below which radar altimeter measurements will be incorporated into altitude position WRT runway	R_GO_RAMP	(b)	F	S		ft	As per sequencer
Position vector of runway in earth-fixed coordinates	R_LS_EF	(a)	V	DP		ft	As per sequencer
Altitude of runway WRT reference ellipsoid	ALT_RW	(a)	F	S		ft	As per sequencer
Time tag for current user parameter state vector	T_STATE	UPP state prop	F	DP		sec	As per sequencer
Shuttle earth-relative velocity vector in M50 coordinates	V_RHO	UPP state prop	V	S		ft/sec	As per sequencer
RGA-derived body rate in degrees/second	WBR	(a)	V	S		deg/sec	As per sequencer
X_STRUCT_BODY distance from navigation base to c.g.	X_NB_CG	(b)	F	S		ft	As per sequencer
X_STRUCT_BODY distance from navigation base to rear wheels	X_NB_WH	(b)	F	S		ft	As per sequencer
Z_STRUCT_BODY distance from c.g. to navigation base	Z_NB_CG	(b)	F	S		ft	As per sequencer
Z_STRUCT_BODY distance from rear wheels to navigation base	Z_NB_WH	(b)	F	S		ft	As per sequencer
Pitch angle	THETA	(a)	F	S		deg	As per sequencer
Conversion from radians to degrees	DEG_PER_RAD	(b)	F	S		deg/rad	As per sequencer
Selected runway ID	RW_NAME	(a)	I	S	1-10		As per sequencer
Altitude regions for nav event lamp processing	ALT_NAV_EVLT	(b)	V	S		ft	As per sequencer

[a] See RTLS UPP principal function input parameter table.
[b] See RTLS UPP principal function K-load and constant tables.

Table 4.6.2.3-1. Input Parameters for Glide RTLS User Parameter Calculations (Cont)

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Number of sequential failures of the test criteria allowed before activating the nav event lamp	N_SEQ_MAX	(b)	I	S			As per sequencer
Conversion from degrees to radians	RAD_PER_DEG	(b)	F	S		rad/deg	As per sequencer
Angle between body X-axis and c.g. to RA antenna vector	RADALT_ANG	(b)	F	S		rad	As per sequencer
Radar altimeter measurement	Q_RADALT	(a)	F	S		ft	As per sequencer
Radar altitude bias	BIAS_RADALT	(b)	F	S		ft	As per sequencer
Radar measurement time tag	T_RADALT	(a)	F	DP		sec	As per sequencer
Navigation base to antenna distance	RADALT_NB_DIST	(b)	F	S		ft	As per sequencer
Pad loaded bias used to correct radar altimeter time tag	TIME_BIAS_RADALT	(b)	F	DP		sec	As per sequencer
Data good flag for radar altimeter	DG_RADALT	(a)	D		ON/OFF		As per sequencer
Value of T_STATE at previous pass through user parameter processing	T_STATE_LAST	ASCENT_RTLS_COMPS	F	DP		sec	As per sequencer
Previous value of H_DOT_ELLIPSOID	H_DOT_LAST	ASCENT_RTLS_COMPS	F	S		ft/sec	As per sequencer
Magnitude of Shuttle earth-relative velocity	REL_VEL_MAG	UPP state prop	F	S		ft/sec	As per sequencer
RTLS TAEM guidance termination flag	TG_END	(a)	D		ON/OFF		As per sequencer
Estimated topodetic altitude rate	H_DOT_ELLIPSOID	ASCENT_RTLS_COMPS	F	S		ft/sec	As per sequencer
Altitude of Shuttle nav base above runway altitude	ALT_WHEELS	ASCENT_RTLS_COMPS	F	S		ft	As per sequencer
IMU selection filter control vector	IMU_SFC	(a)	I		0,7		As per sequencer
Current IMU accumulated velocity	V_IMU_OLD	UPP state prop	V	DP		ft/sec	As per sequencer

[a]See RTLS UPP principal function input parameter table.
[b]See RTLS UPP principal function K-load and constant tables.

Table 4.6.2.3-1. Input Parameters for Glide RTLS User Parameter Calculations (Cont)

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
NAV derived angle of attack	ALPHA_N	(a)	F	S		deg	As per sequencer
Earth-fixed to secondary RW transformation matrix	M_EFTORW_SEC	(a)	M	S			As per sequencer
Initial value for spiral radius	RI	(b)	F	S		ft	As per sequencer
Inital value of HAC turn angle	PSHARS	I-loads	F	S		deg	As per sequencer
Flag denoting various phases of GRTLS TAEM guidance	IPHASE	(a)	I		0-6		As per sequencer
Flag denoting crew request to change approach type (OVHD/STRT)	TOGHAC	(a)	D		OFF/ ON		As per sequencer
Flag denoting GRTLS TAEM guidance request to downmode	OHALRT	(a)	D		OFF/ ON		As per sequencer
MSBLS elevation measurement bias	BIAS_KLMIS	(a)	F	S		rad	As per sequencer
MLS availability	MLS_AVAIL	(a)	D	S	OFF/ ON		As per sequencer
X-runway position where conversion from horizontal to sloping runway coordinates begins	START_POSITION	I-loads	F	S		ft	As per sequencer
X-runway position where conversion from horizontal to sloping runway coordinates is completed	STOP_POSITION	I-loads	F	S		ft	As per sequencer

[a]See RTLS UPP principal function input parameter table.
[b]See RTLS UPP principal function K-load table.

Table 4.6.2.3-2. Output Parameters from Glide RTLS User Parameter Calculations

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Vertical component of vehicle c.g. acceleration wrt earth rotating frame	ACC_VERT	(a)	F	S		ft/sec^2	As per sequencer
Current orbiter altitude above reference ellipsoid	ALT	(a)	F	S		ft	As per sequencer
Vehicle velocity direction wrt runway centerline	COURSE_WRT_RW	(a)	F	S	0 to 2 PI	rad	As per sequencer
Component of c.g. relative velocity normal to RW ellipsoid (A/L) or local ellipsoid (TAEM)	H_DOT_ ELLIPSOID	(a)	F	S		ft/sec	As per sequencer
Downrange position wrt the runway	POSITION_WRT_ $RUNWAY_1$	(a)	I	S		ft	As per sequencer

[a]See RTLS UPP principal function output parameter table.

Table 4.6.2.3-2. Output Parameters from Glide RTLS User Parameter Calculations (Cont)

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Primary runway ID	RW_ID_UPP	(a)	F	S	0-10	ft	As per sequencer
Crossrange position wrt the runway	POSITION_WRT_RUNWAY$_2$	(a)	F	S		ft	As per sequencer
Altitude position wrt the runway	POSITION_WRT_RUNWAY$_3$	(a)	F	S		ft	As per sequencer
Downrange velocity wrt the runway	VELOCITY_WRT_RUNWAY$_1$	(a)	F	S		ft/sec	As per sequencer
Crossrange velocity wrt the runway	VELOCITY_WRT_RUNWAY$_2$	(a)	F	S		ft/sec	As per sequencer
Flag sent to MSC to initiate VENT DOOR CNTL SEQ	VNT_DR_SEQ_INIT	(a)	D		OFF/ ON		As per sequencer
Vehicle c.g. groundspeed WRT runway (A/L), reference ellipsoid (TAEM)	V_GROUNDSPEED	(a)	F	S		ft/sec	As per sequencer
Drag acceleration	ACC_DRAG	(a)	F	S		ft/sec^2	As per sequencer
Flight path angle	FLT_PATH_ANG	(a)	F	S		rad	As per sequencer
Altitude above runway of rear wheels	ALT_WHEELS	(a)	F	S		ft	As per sequencer
Radar altimeter processing flag	RAW_RA_PROC	(a)	D		ON/ OFF		As per sequencer
Shuttle position vector in earth-fixed coordinates	R_EF	(a)	V	DP		ft	As per sequencer
Shuttle earth-relative velocity vector in EF coordinates	V_RHO_EF	(a)	V	S		ft/sec	As per sequencer
Radar measurement time tag	T_RADALT	(a)	F	DP		sec	As per sequencer
Data good flag for radar altimeter	DG_RADALT	(a)	D		ON/ OFF		As per sequencer
Radar altimeter measurement	Q_RADALT	(a)	F	S		ft	As per sequencer
NAV derived angle of attack for use in NAVDAD SOP	ALPHA_NAVDAD	(a)	F	S		deg	As per sequencer
Radar altimeter crew alert, HUD	RA_FLAG	(a)	D		OFF/ ON		As per sequencer
Flag denoting overhead or straight-in approach	OVHD	(a)	D		OFF/ ON		As per sequencer
Commanded HAC side of primary runway	YSGNP	(a)	I			±1	As per sequencer

[a]See RTLS UPP principal function output parameter table.

Table 4.6.2.3-2. Output Parameters from Glide RTLS User Parameter Calculations (Cont)

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Turn angle of HAC of primary runway	PSHA	(a)	F	S		deg	As per sequencer
Area Nav HAC indicator initialization flag	FIRST_PASS	(a)	B		OFF/ ON		As per sequencer
Radius of HAC	R_HCP	(a)	F	S		Ft	As per sequencer

[a]See RTLS UPP principal function output parameter table.

4.6.2.4 Ascent/RTLS User Parameter Calculations. For both powered RTLS and glide RTLS the altitude and the altitude rate are required output parameters. This subfunction will provide the required software to handle these calculations. Furthermore, for glide RTLS the additional requirement of providing vertical acceleration is also handled in this subfunction.

A. Detailed Requirements. The detailed requirements for this subfunction are contained in Section 4.4.3.

B. Interface Requirements. Input and output parameters required are listed in Tables 4.6.2.4-1 and 4.6.2.4-2.

C. Processing Requirements. Cyclic execution and repetition rates for this subfunction are controlled by the RTLS user parameter processing sequencer (Section 4.1.4). These calculations must be performed prior to those specified in Section 4.6.2.2, powered RTLS user parameter calculations.

D. Constraints. It is required that T_STATE_LAST, H_DOT_LAST, ACC_VERT_OLD, T_STATE_OLD and DELTA_ACC_VERT be initialized to zero and that DELTA_T be initialized to a non-zero value.

E. Supplemental Information. A suggested implementation in the form of a detailed flow chart is shown in Section 5.6, subfunction ASCENT_RTLS_COMPS.

Table 4.6.2.4-1. Ascent/RTLS Calculations Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Flag indicating UPP state has been updated by nav filter	UPP_UPDATE	UPP state prop	D		ON/OFF		As per sequencer
Unit vector in direction of earth's axis of rotation	EARTH_POLE	(b)	V	S			As per sequencer
Earth equatorial radius	EARTH_RADIUS_EQUATOR	(b)	F	DP		ft	As per sequencer
Earth ellipticity constant	ELLIPT	(b)	F	DP			As per sequencer
Altitude of runway wrt reference ellipsoid	ALT_RW	(a)	F	S		ft	As per sequencer
Time tag for current user parameter state vector	T_STATE	UPP state prop	F	DP		sec	As per sequencer
Shuttle earth-relative velocity vector in M50 coordinates	V_RHO	UPP state prop	V	S		ft/sec	As per sequencer
IMU-derived body rate in degrees/second	WBR	(a)	V	S		deg/sec	As per sequencer
X_STRUCT_BODY distance from navigation base to c.g.	X_NB_CG	(b)	F	S		ft	As per sequencer
X_STRUCT_BODY distance from navigation base to rear wheels	X_NB_WH	(b)	F	S		ft	As per sequencer
Z_STRUCT_BODY distance from c.g. to navigation base	Z_NB_CG	(b)	F	S		ft	As per sequencer
Z_STRUCT_BODY distance from rear wheels to navigation base	Z_NB_WH	(b)	F	S		ft	As per sequencer
Major mode 602 flag	MM_CODE_602	(a)	D		ON/OFF		As per sequencer
Major mode 603 flag	MM_CODE_603	(a)	D		ON/OFF		As per sequencer
Major mode 102 flag	MM_CODE_102	(a)	D		ON/OFF		As per sequencer
Major mode 103 flag	MM_CODE_103	(a)	D		ON/OFF		As per sequencer
Exponential atmosphere scale height I = 1, 7	ALT_S_I	(b)	V	S		ft	As per sequencer
Current Shuttle position vector	R_AVGG	UPP state prop	V	DP		ft	As per sequencer
Exponential atmosphere base density, I = 1, 7	RHO_B_I	(b)	F	S		slugs/ft^3	As per sequencer
Magnitude of vehicle relative velocity	REL_VEL_MAG	UPP state prop	F	S		ft/sec	As per sequencer

[a]See RTLS UPP principal function input parameter table.
[b]See RTLS UPP principal function I-load, K-load and constant tables.

Table 4.6.2.4-1. Ascent/RTLS Calculations Input Parameters (Cont)

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Number of altitude regions	IMAX	(b)	I	S			As per sequencer
Altitude region, I = 1, 7	ALT_TAB_I	(a)	V(7)	S		ft	As per sequencer
IMU-sensed acceleration	A_SENSED	UPP state	V	S		ft/sec^2	As per sequencer
Gravitational acceleration at sea level	GRAV_SEA_LEVEL	(b)	F	S		ft/sec^2	As per sequencer
Sine of Shuttle's pitch angle	SINTH	(a)	F	S			As per sequencer
Cosine of Shuttle's pitch angle	COSTH	(a)	F	S			As per sequencer
Conversion from degrees to radians	RAD_PER_DEG	(b)	F	S		rad/deg	As per sequencer

[a]See RTLS UPP principal function input parameter table.
[b]See RTLS UPP principal function I-load, K-load and constant tables.

Table 4.6.2.4-1. Ascent/RTLS Calculations Input Parameters (Cont)

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Number of altitude regions	IMAX	(b)	I	S			As per sequencer
Altitude region, I = 1, 7	ALT_TAB_I	(a)	V(7)	S		ft	As per sequencer
INU-sensed acceleration	A_SENSED	UPP state	V	S		ft/sec^2	As per sequencer
Gravitational acceleration at sea level	GRAV_SEA_LEVEL	(b)	F	S		ft/sec^2	As per sequencer
Sine of Shuttle's pitch angle	SINTH	(a)	F	S			As per sequencer
Cosine of Shuttle's pitch angle	COSTH	(a)	F	S			As per sequencer
Conversion from degrees to radians	RAD_PER_DEG	(b)	F	S		rad/deg	As per sequencer

[a]See RTLS UPP principal function input parameter table.
[b]See RTLS UPP principal function I-load, K-load and constant tables.

Table 4.6.2.4-2. Ascent/RTLS Calculations Output Parameters

Description	Symbol	Input Source	Type	Precision	Range	Sample Units	Rate
Vertical component of vehicle e.g. acceleration wrt earth rotating frame	ACC_VERT	(a)	F	S		ft/sec^2	As per sequencer
Current Orbiter altitude above reference ellipsoid	ALT	(a)	F	S		ft	As per sequencer
Component of e.g. relative velocity normal to local ellipsoid	H_DOT_ ELLIPSOID	(a), UPP_ PW_RTLS_ COMPS, RTLS_ GRTLS- COMPS	F	S		ft/ sec	As per sequencer
Previous value of H_DOT_ELLIPSOID	H_DOT_LAST	UPP_ GRTLS_ COMPS	F	S		ft/ sec	As per sequencer
Value of T_STATE at previous pass through user parameter processing	T_STATE_ LAST	UPP_ GRTLS_ COMPS	F	DP		sec	As per sequencer
Magnitude of the Shuttle position vector	R_VEH_MAG	UPP_PW_ RTLS_ COMPS	F	DP		ft	As per sequencer
Altitude of the bottom of the rear wheels above the runway altitude in MM602 and MM603. Altitude of the NAV base above the runway altitude in major modes other than 602 and 603	ALT_WHEELS	(a), UPP_ GRTLS_ COMPS	F	S		ft	As per sequencer
Equivalent airspeed	EAS	(a)	F	S		ft/ sec	As per sequencer
Total sensed acceleration	LOAD_TOTAL	(a)	F	S		g's	As per sequencer
Mag Shuttle pos vector	R_VEH_MAG_ UPP	ASC AREA NAV	F	DP		ft	As per sequencer

[a]See RTLS UPP principal function output parameter table.

4.6.2.5 RTLS User Parameter Processing HSI Calculations. This subfunction will calculate certain parameters required to support the HSI processing principal function during Major Mode 601 of the RTLS operational sequence.

A. Detailed Requirements. The detailed requirements for this subfunction are presented in Section 4.4.4.

B. Interface Requirements. The input and output parameters required are listed in Tables 4.6.2.5-1 and 4.6.2.5-2.

C. Processing Requirements. None.

D. Constraints. None.

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart may be found in Section 5.6, subfunction PW_HSI_COMPS.

Table 4.6.2.5-1. RTLS User Parameter Processing HSI Calculations Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Position vector of runway in earth-fixed coordinates	R_LS_EF	(a)	V	DP		ft	As per sequencer
Time tag associated with current user parameter state vector	T_STATE	UPP state prop	F	DP		sec	As per sequencer
Current navbase M50 position vector	R_AVGG	UPP state prop	V	DP		ft	As per sequencer
Unit vector perpendicular to the orbit plane and directed in the opposite sense to that of the angular momentum	I_YD_M50	(a)	V	S			As per sequencer
Inertial velocity in M50	V_AVGG	UPP state prop	V	S		ft/sec	As per sequencer
Relative velocity in M50	V_RHO	UPP state prop	V	S		ft/sec	As per sequencer
Magnitude of the inertial velocity	V_INERTIAL_MAG	UPP state prop	F	S		ft/sec	As per sequencer
Magnitude of the relative velocity	REL_VEL_MAG	UPP state prop	F	S		ft/sec	As per sequencer
The constant PI	PI	Constant	F	S			As per sequencer
Major Mode 601 flag	MM_CODE_601	(a)	D		OFF/ON		As per sequencer

[a]See RTLS UPP principal function input parameter table.

Table 4.6.2.5-2. RTLS User Parameter Processing HSI Calculations Output Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Angle formed by the inertial velocity vector and the orbit plane	HEADING_V_I	(a)	F	S	$-\pi,\pi$	rad	As per sequencer
Angle formed by the relative velocity vector and the orbit plane	HEADING_V_REL	(a)	F	S	$-\pi,\pi$	rad	As per sequencer
Bearing of Shuttle position to landing site referenced to the orbit plane	HEADING_RW	(a)	F	S	$-\pi,\pi$	rad	As per sequencer

[a]See RTLS UPP principal function output parameter table.

4.6.2.6 TACAN Display Computations. During the GLIDE RTLS portions of the Shuttle flight the horizontal situation display (HSD) provides the crew with spacecraft position and heading information with respect to the ground plane. In addition to the graphical display of the Shuttle's position with respect to the runway and heading alignment circle, other tabular data is displayed. This subfunction provides tabular data for the TACAN portion of the display. Data for each of the three TACAN LRU's are displayed.

For each TACAN, there is a display of TAC_AZ as either the absolute magnetic azimuth in degrees from the vehicle to the ground station as measured by the TACAN, or the delta azimuth in degrees formed by subtracting the nav derived azimuth to the ground station from the TACAN measured azimuth to the station. In addition, for each TACAN there is a display of range as either the absolute slant range in nautical miles from the vehicle to the ground station as measured by the TACAN, or the delta slant range in nautical miles formed by subtracting the nav derived range to the ground station from the TACAN measured range to the ground station. Two mutually exclusive items, ABS and DELTA, are provided on the HSD to allow the crew to select absolute or delta values of TACAN azimuth and range.

A. Detailed Requirements. The computational sequence for the ABS mode is to convert data from the TACAN SOP to the proper units for display as follows:

$$TAC\_AZ_I = TACBEARO_I \ DEG\_PER\_RAD$$

$$TAC\_RNG_I = TACRANGEO_I \ NAUTMI\_PER\_FT$$

If the TAC_MODE is not ABS and the $TACAN\_CHAN\_VALID\_SL_I$ is "OFF", then both TAC_AZ_I and TAC_RNG_I, shall be set to "BLANK" for display.

If the TAC_MODE is not ABS and the $TACAN\_CHAN\_VALID\_SL_I$ is "ON", then the computational sequence is for the DELTA_MODE and the differences between the nav derived range and azimuth and the TACAN measured range and azimuth are computed. The range difference for each TACAN is computed as follows:

$$\underline{R}\_EST = \underline{R}\_EF - \underline{R}\_TACAN\_EF\_SL_I$$

$$\underline{R}\_TEMP = M\_EFTOTD\_TACAN\_SL_I \ \underline{R}\_EST$$

$$TAC\_RNG_I = (TACRANGEO_I - ABVAL(\underline{R}\_EST)) \ NAUTMI\_PER\_FT$$

The azimuth difference for each TACAN is computed as follows:

$$TEMP = (TACBEARO_I \quad (ARCTAN2(R\_TEMP_2, R\_TEMP_1) \ ANGLE\ CORR\_TNTOMAG\_SL_I + PI)) \ DEG\_PER\_RAD$$

This base delta azimuth (TEMP) is then adjusted for the event where the two angles span the 360° or 0° radial as follows:

If ABVAL(TEMP) >180°

then set,

$$TAC\_AZ_I = TEMP - SIGN(TEMP)\ 360°$$

If not, set

$$TAC\_AZ_I = TEMP$$

Finally, independently of the status of the TAC_MODE flag, it is renamed for output purposes as TAC_MODE_DISP.

B. Interface Requirements. The input and output are listed in Tables 4.6.2.6-1 and 4.6.2.6-2, respectively.

C. Processing Requirements. None

D. Constraints. None

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart is given in Section 5.6, subfunction TACAN_DISP_COMPS.

Table 4.6.2.6-1. TACAN Display Calculations Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Switch indicating ON when ABS_MODE is selected for HSD DISP and OFF when DELTA_MODE is selected	TAC_MODE	(a)	D		ON/OFF		As per sequencer
Switch indicating (ON) when a valid TACAN channel has been selected	TACAN_CHAN_VALID_SL$_I$	(a)	D		ON/OFF		As per sequencer
TACAN range data obtained from the SOP for each receiver, I = 1, 3	TACRANGEO$_I$	(a)	F	S		nmi	As per sequencer
TACAN bearing data obtained from the SOP for each receiver, I = 1, 3	TACBEARO$_I$	(a)	F	S	0-2π	rad	As per sequencer
Conversion factor from radians to degrees	DEG_PER_RAD	(b)	F	S		deg/rad	As per sequencer
Conversion factor from feet to nautical miles	NAUTMI_PER_FT	(b)	F	S		nmi/ft	As per sequencer
Shuttle position vector in earth-fixed coordinates	R_EF	GUIDE-COMP_RTLS	V	DP		ft	As per sequencer
TACAN station earth-fixed position vector obtained from site lookup for Ith receiver	R_TACAN_EF_SL$_I$	(a)	V	DP		ft	As per sequencer
Variation of magnetic north from true north at TACAN site obtained from site lookup for Ith receiver	ANGLE_CORR_TNTOMAG_SL$_I$	(a)	F	S		rad	As per sequencer
The constant PI	PI	(b)	F	DP			As per sequencer
Transformation matrix from earth-fixed to topodetic coordinates at the Ith TACAN site	M_EFTOTD_TACAN_SL$_I$	(a)	M	S			As per sequencer

[a]See RTLS UPP principal function input parameter table.
[b]See RTLS UPP principal function constant tables.

Table 4.6.2.6-2. TACAN Display Calculations Output Parameters

Description	Symbol	Input Source	Type	Precision	Range	Sample Units	Rate
Feedback switch indicating ON when ABS_MODE is selected on HSD DISP and OFF when DELTA_MODE is selected	TAC_MODE_DISP	(a)	D		ON/OFF		As per sequencer
TACAN azimuth for display in the ABS_MODE or DELTA azimuth when in DELTA_MODE	TAC_AZ$_I$	(a)	F	S	-180 - +360	deg	As per sequencer
TACAN range for display in the ABS_MODE or DELTA range when in the DELTA_MODE	TAC_RNG$_I$	(a)	F	S	0-400	nmi	As per sequencer

[a]RTLS UPP principal function output list.

4.6.2.7 RTLS User Parameter Processing (4.20) Principal Function Tables. The RTLS user parameter processing principal function input and output parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.6.2.7-1 through 4.6.2.7-5.

The values for the I-loads are contained in the I-loads requirements document (JSC-19350).

Table 4.6.2.7-1. RTLS User Parameter Processing (4.20) Input/Output Functional Parameters

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
	V90H2246C	NAV DERIVED ANGLE OF ATTACK	A/E ATT PROC	DEG	SPL	
ALPHA_N	V90H1818CB	ALTITUDE OF RW WRT REF ELLIPSOID	ASC SITE LOOKUP	FT		
ALT_RW	V90H1843CB	MAGNETIC VARIATION AT TACAN 1 SITE	ASC SITE LOOKUP	RAD		
ANGLE_CORR_TNTOMAG_S1	V90H1844CB	MAGNETIC VARIATION AT TACAN 2 SITE	ASC SITE LOOKUP	RAD		
ANGLE_CORR_TNTOMAG_S2	V90H1845CB	MAGNETIC VARIATION AT TACAN 3 SITE	ASC SITE LOOKUP	RAD		
ANGLE_CORR_TNTOMAG_S3	V90H1817CB	AZIMUTH OF RW FROM TRUE NORTH	ASC SITE LOOKUP	RAD		
AZIMUTH_RW	V90H1887CB	MSBLS ELEVATION MEASUREMENT BIAS	ASC SITE LOOKUP	RAD		
BIAS_ELALS	V91W5000C2	CLOCK-COMPUTER(GMT)	FCOS	S		
CLOCK/CLOCKTIME	V90H2215C	EULER ANGLE PITCH COSINE	A/E ATT PROC			
COSTH	V90X4003X	RALT HEIGHT DATA GOOD	SF		BD	
DG_RADALT	V90X0224XA	FLAG IND NAV FILTER PROC COMPLETE	ASC NAV			
FILT_UPDATE	V90X0224XG	FLAG IND NAV FILTER PROC COMPLETE	RTLS NAV			
FILT_UPDATE	V90A0243CA	SEL X-COMP OF GRAV ACCEL VCTR RST	ASC NAV	FT/S2		
G_RESET(1)	V90A0243CF	SEL X-COMP OF GRAV ACCEL VCTR RST	RTLS NAV	FT/S2		
G_RESET(1)	V90A0244CA	SEL Y-COMP OF GRAV ACCEL VCTR RST	ASC NAV	FT/S2		
G_RESET(2)	V90A0244CF	SEL Y-COMP OF GRAV ACCEL VCTR RST	RTLS NAV	FT/S2		
G_RESET(2)	V90A0245CA	SEL Z-COMP OF GRAV ACCEL VCTR RST	ASC NAV	FT/S2		
G_RESET(3)	V90A0245CF	SEL Z-COMP OF GRAV ACCEL VCTR RST	RTLS NAV	FT/S2		
G_RESET(3)	V95U0494C	M50 INSERTION TARGET UNIT VECTOR-1	ASC UPP			
I_YD_M50(1)	V95U0495C	M50 INSERTION TARGET UNIT VECTOR-2	ASC UPP			
I_YD_M50(2)	V95U0496C	M50 INSERTION TARGET UNIT VECTOR-3	ASC UPP			
I_YD_M50(3)	V90J2503C	IMU SELECTION FILTER COMMAND	IMU RM		BSU	
IMU_SFC	V90J1117CB	TAEM GUIDANCE PHASE INDICATOR	GRTLS TAEM GUID			
IPHASE	V97U4413CB	UNIT VEC NORM TRAJ PLANE X COMP	UL			
IYD(X)	V97U4414CB	UNIT VEC NORM TRAJ PLANE Y COMP	UL			
IYD(Y)	V97U4415CB	UNIT VEC NORM TRAJ PLANE Z COMP	UL			
IYD(Z)	V90U1805CB	EF TO PRIME RW XFORM MTRX ELE 1-1	ASC SITE LOOKUP			
M_EFTORW(1-1)	V90U1806CB	EF TO PRIME RW XFORM MTRX ELE 1-2	ASC SITE LOOKUP			
M_EFTORW(1-2)	V90U1807CB	EF TO PRIME RW XFORM MTRX ELE 1-3	ASC SITE LOOKUP			
M_EFTORW(1-3)	V90U1808CB	EF TO PRIME RW XFORM MTRX ELE 2-1	ASC SITE LOOKUP			
M_EFTORW(2-1)	V90U1809CB	EF TO PRIME RW XFORM MTRX ELE 2-2	ASC SITE LOOKUP			
M_EFTORW(2-2)	V90U1810CB	EF TO PRIME RW XFORM MTRX ELE 2-3	ASC SITE LOOKUP			
M_EFTORW(2-3)	V90U1811CB	EF TO PRIME RW XFORM MTRX ELE 3-1	ASC SITE LOOKUP			
M_EFTORW(3-1)	V90U1812CB	EF TO PRIME RW XFORM MTRX ELE 3-2	ASC SITE LOOKUP			
M_EFTORW(3-2)	V90U1813CB	EF TO PRIME RW XFORM MTRX ELE 3-3	ASC SITE LOOKUP			
M_EFTORW(3-3)	V90U1775CB	EF TO TOPO COORD AT TA SITE 1/1-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(1-1)	V90U1776CB	EF TO TOPO COORD AT TA SITE 1/1-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(1-2)	V90U1777CB	EF TO TOPO COORD AT TA SITE 1/1-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(1-3)	V90U1778CB	EF TO TOPO COORD AT TA SITE 1/2-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(2-1)	V90U1779CB	EF TO TOPO COORD AT TA SITE 1/2-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(2-2)	V90U1780CB	EF TO TOPO COORD AT TA SITE 1/2-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(2-3)	V90U1781CB	EF TO TOPO COORD AT TA SITE 1/3-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(3-1)	V90U1782CB	EF TO TOPO COORD AT TA SITE 1/3-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(3-2)	V90U1783CB	EF TO TOPO COORD AT TA SITE 1/3-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(3-3)	V90U1784CB	EF TO TOPO COORD AT TA SITE 2/1-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(1-1)	V90U1785CB	EF TO TOPO COORD AT TA SITE 2/1-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(1-2)	V90U1786CB	EF TO TOPO COORD AT TA SITE 2/1-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(1-3)	V90U1787CB	EF TO TOPO COORD AT TA SITE 2/2-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(2-1)	V90U1788CB	EF TO TOPO COORD AT TA SITE 2/2-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(2-2)	V90U1789CB	EF TO TOPO COORD AT TA SITE 2/2-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(2-3)	V90U1790CB	EF TO TOPO COORD AT TA SITE 2/3-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(3-1)	V90U1791CB	EF TO TOPO COORD AT TA SITE 2/3-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(3-2)						

Table 4.6.2.7-1. RTLS User Parameter Processing (4.20) Input/Output Functional Parameters (Cont)

DBFN: D3B008-D PN: VP707100037P00L JULY 17, 1989 OI8D REV00 PAGE 310
INPUT FUNCTIONAL PARAMETERS FOR RETURN TO LAUNCH SITE UPP RTLS UPP G4.20 BOOK: 5

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
M_EFTOTD_TACAN_SL2(3-3)	V90U1792CB	EF TO TOPO COORD AT TA SITE 2/3-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(1-1)	V90U1793CB	EF TO TOPO COORD AT TA SITE 3/1-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(1-2)	V90U1794CB	EF TO TOPO COORD AT TA SITE 3/1-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(1-3)	V90U1795CB	EF TO TOPO COORD AT TA SITE 3/1-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(2-1)	V90U1796CB	EF TO TOPO COORD AT TA SITE 3/2-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(2-2)	V90U1797CB	EF TO TOPO COORD AT TA SITE 3/2-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(2-3)	V90U1798CB	EF TO TOPO COORD AT TA SITE 3/2-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(3-1)	V90U1799CB	EF TO TOPO COORD AT TA SITE 3/3-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(3-2)	V90U1800CB	EF TO TOPO COORD AT TA SITE 3/3-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(3-3)	V90U1801CB	EF TO TOPO COORD AT TA SITE 3/3-3	ASC SITE LOOKUP			
MLS_AVAIL	V90X3720XB	MLS AVAILABILITY	ASC SITE LOOKUP			
MM_CODE_102/MM_102	V90X8158X	MAJOR MODE 102 FLAG	MSC			
MM_CODE_103/MM_103	V90X8156X	MAJOR MODE 103 FLAG	MSC			
MM_CODE_601/MM_601	V90X8194X	MAJOR MODE 601 FLAG	MSC			
MM_CODE_603/MM_603	V90X8122X	MAJOR MODE 603 FLAG	MSC			
Q_ORB/Q	V90R5321CA	SELECTED RGA PITCH RATE	SF	DEG/S		
Q_RADALT	V90H4002C	SELECTED RALT HEIGHT-RAW	SF	FT	SPL	
R_LS_EF(1)	V90H1900CB	X-COMP LDG SITE POS VCT-EF COORD	ASC SITE LOOKUP	FT		
R_LS_EF(2)	V90H1901CB	Y-COMP LDG SITE POS VCT-EF COORD	ASC SITE LOOKUP	FT		
R_LS_EF(3)	V90H1902CB	Z-COMP LDG SITE POS VCT-EF COORD	ASC SITE LOOKUP	FT		
R_RESET(1)	V90H0235CA	SEL X-COMP OF UPDATED POS VCTR RST	ASC NAV	FT	DPL	
R_RESET(1)	V90H0235CF	SEL X-COMP OF UPDATED POS VCTR RST	RTLS NAV	FT	DPL	
R_RESET(2)	V90H0236CA	SEL Y-COMP OF UPDATED POS VCTR RST	ASC NAV	FT	DPL	
R_RESET(2)	V90H0236CF	SEL Y-COMP OF UPDATED POS VCTR RST	RTLS NAV	FT	DPL	
R_RESET(3)	V90H0237CA	SEL Z-COMP OF UPDATED POS VCTR RST	ASC NAV	FT	DPL	
R_RESET(3)	V90H0237CF	SEL Z-COMP OF UPDATED POS VCTR RST	RTLS NAV	FT	DPL	
R_TACAN_EFSL1(1)	V90H1834CB	X-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP	FT		
R_TACAN_EFSL1(2)	V90H1835CB	Y-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP	FT		
R_TACAN_EFSL1(3)	V90H1836CB	Z-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP	FT		
R_TACAN_EFSL2(1)	V90H1837CB	X-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP	FT		
R_TACAN_EFSL2(2)	V90H1838CB	Y-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP	FT		
R_TACAN_EFSL2(3)	V90H1839CB	Z-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP	FT		
R_TACAN_EFSL3(1)	V90H1840CB	X-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP	FT		
R_TACAN_EFSL3(2)	V90H1841CB	Y-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP	FT		
R_TACAN_EFSL3(3)	V90H1842CB	Z-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP	FT		
RA_TIME	V95W7000C	RADAR ALTIMETER TIME	RA SOP	S	DPL	
RW_ID_UPP	V95X0234XB	OTT FIRST PASS FLAG	ASC SITE LOOKUP			
RW_NAME	V90U1916CB	CURRENT LANDING SITE SELECTED	ASC SITE LOOKUP			
SEL_V_M50(1)	V90L2557C	SEL TOTAL X VEL M50	IMU RM	FT/S	DPL	
SEL_V_M50(2)	V90L2558C	SEL TOTAL Y VEL M50	IMU RM	FT/S	DPL	
SEL_V_M50(3)	V90L2559C	SEL TOTAL Z VEL M50	IMU RM	FT/S	DPL	
SINTH	V90H2216C	EULER ANGLE PITCH SINE	A/E ATT PROC			
T_GMTLO_REF	V99U7442C	NOMINAL LIFTOFF IGN REF	UL			
T_IMUS	V95W0002C	IMU INPUT TRANS TIME TAG	IMU INT PROC	S	DPL	
T_RESET	V90W0225CA	TIME OF FILTER STATE VCTR	ASC NAV	SSS		
T_RESET	V90W0225CF	TIME OF FILTER STATE VCTR	RTLS NAV	SS		
TAC_MODE	V93X5015X	TACAN ABSOLUTE/DELTA DATA CMD	6.21		BD	
TACAN_CHAN_VALID_SL1	V90X1858XB	TACAN CHANNEL VALIDITY FLAG(TAC 1)	ASC SITE LOOKUP			
TACAN_CHAN_VALID_SL2	V90X1859XB	TACAN CHANNEL VALIDITY FLAG(TAC 2)	ASC SITE LOOKUP			
TACAN_CHAN_VALID_SL3	V90X1860XB	TACAN CHANNEL VALIDITY FLAG(TAC 3)	ASC SITE LOOKUP			
TACBEARO(1)	V95H5122CA	TACAN NO 1 BEARING OUT	TACAN SOP	RAD		
TACBEARO(2)	V95H5222CA	TACAN NO 2 BEARING OUT	TACAN SOP	RAD		
TACBEARO(3)	V95H5322CA	TACAN NO 3 BEARING OUT	TACAN SOP	RAD		

Table 4.6.2.7-1. RTLS User Parameter Processing (4.20) Input/Output Functional Parameters (Cont)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
TACRANGEO(1)	V95H5102CA	TACAN NO 1 RANGE OUT	TACAN SOP	FT		
TACRANGEO(2)	V95H5202CA	TACAN NO 2 RANGE OUT	TACAN SOP	FT		
TACRANGEO(3)	V95H5302CA	TACAN NO 3 RANGE OUT	TACAN SOP	FT		
TG_END	V90X1108XB	TAEM GUIDANCE TERMINATION FLAG	GRTLS TAEM GUID			
THETA	V90H2217C	BODY PITCH ATTITUDE EULER ANGLE	A/E ATT PROC	DEG		
TOGHAC	V93X4477X	R/L CONE CHG CMD	6.21		SPL BD	
V_IMU_RESET(1)	V90L0247CA	SEL X-COMP OF ACCUM SENSED VEL RST	ASC NAV	FT/S		
V_IMU_RESET(1)	V90L0247CF	SEL X-COMP OF ACCUM SENSED VEL RST	RTLS NAV	FT/S		
V_IMU_RESET(2)	V90L0248CA	SEL Y-COMP OF ACCUM SENSED VEL RST	ASC NAV	FT/S		
V_IMU_RESET(2)	V90L0248CF	SEL Y-COMP OF ACCUM SENSED VEL RST	RTLS NAV	FT/S		
V_IMU_RESET(3)	V90L0249CA	SEL Z-COMP OF ACCUM SENSED VEL RST	ASC NAV	FT/S		
V_IMU_RESET(3)	V90L0249CF	SEL Z-COMP OF ACCUM SENSED VEL RST	RTLS NAV	FT/S		
V_RESET(1)	V90L0239CA	SEL X-COMP OF UPDATED VEL VCTR RST	ASC NAV	FT/S		
V_RESET(1)	V90L0239CF	SEL X-COMP OF UPDATED VEL VCTR RST	RTLS NAV	FT/S		
V_RESET(2)	V90L0240CA	SEL Y-COMP OF UPDATED VEL VCTR RST	ASC NAV	FT/S		
V_RESET(2)	V90L0240CF	SEL Y-COMP OF UPDATED VEL VCTR RST	RTLS NAV	FT/S		
V_RESET(3)	V90L0241CA	SEL Z-COMP OF UPDATED VEL VCTR RST	ASC NAV	FT/S		
V_RESET(3)	V90L0241CF	SEL Z-COMP OF UPDATED VEL VCTR RST	RTLS NAV	FT/S		

Space Transportation Systems Division
Rockwell International
STS 83-0005B
PCN-4 OI-8D
July 31, 1989

Table 4.6.2.7-1. RTLS User Parameter Processing (4.20) Input/Output Functional Parameters (Cont)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
ACC_DRAG	V95A0160CA	DRAG DECEL	NAVDAD SOP,RTLS NAV,AMI PROC, HUD PROC,TLM			
ACC_VERT	V95A0170CA	VERTICAL ACCEL IN TOPODETIC COORD	AVVI PROC,TLM			
ALPHA_NAVDAD	V95H0233CD	AVG NAVDAD ANGLE OF ATTACK	NAVDAD SOP	DEG		
ALT	V95H0175CA	CURR ORB ALT ABOVE REF ELLIPSOID	NAVDAD SOP,XXXXXX TRAJ DIP, RTLS NAV,G/C STEER,ADTA SOP, AVVI PROC,GRTLS DAP,TLM	KFT		
ALT_WHEELS	V95H0165CA	ALT TO REAR WHEELS/NAV BASE(ENTRY)	VERT SIT DIP,ASC AREA NAV, RTLS NAV,GRTLS TAEM GUID,5.7, GRTLS A/L GUID,TACAN RM, E/L EV AN PROC,HYD SYS SOP, HUD PROC,TLM	FT		
COURSE_WRT_RUNWAY	V95H0225CD	COURSE WRT RW CENTER LINE	5.7,GRTLS TAEM GUID, GRTLS A/L GUID,MSBLS SOP,TLM			
D_ARC	V95H0477C	ARC LENGTH AROUND HAC(WPI TO NEP)	PW RTLS GUID			
DG_RADALT	V95X0460XA	SNAPPED RALT DATA GOOD	TLM			
EAS	V95L0514CB	EQUIVALENT AIRSPEED	TLM			
FIRST_PASS	V95X0184XC	AREA NAV HAC INIT FLAG	ASC AREA NAV			
FLT_PATH_ANG/GAMMA	V95H0261CC	GROUND-REL FLT PATH ANGLE	GRTLS TAEM GUID,GRTLS A/L GUID, PW RTLS GUID,XXXXXX TRAJ DIP, TLM	RAD		
FLT_PATH_ANG_TIME	V95W0464C	TIME OF COMPUTTING FLT PATH ANG	PW RTLS GUID			
H_DOT_ELLIPSOID/H_DOT	V95L0265CA	EST ALTITUDE RATE	VERT SIT DIP,ADTA SOP, GRTLS TAEM GUID,AVVI PROC, GRTLS A/L GUID,XXXXXX TRAJ DIP, 6.22,PW RTLS GUID,HUD PROC,TLM	FT/S		
HEADING_RW	V95H0461CB	BEAR VEH TO RW WRT ORB PL	HSI PROC	RAD		
HEADING_V_I	V95H0515CB	ANG BETWN INER VEL AND ORB PL	HSI PROC	RAD		
HEADING_V_REL	V95H0516CB	ANG BETWN REL VEL AND ORB PL	HSI PROC	RAD		
LAT_GEOD	V95H0455C	VEHICLE GEODETIC LATITUDE	TLM			
LOAD_TOTAL	V95U0163CC	TOTAL LOAD FACTOR	AMI PROC,TLM			
LON	V95H0456C	VEHICLE LONGITUDE	TLM			
OVHD	V95J0154CC	OVHD/STRT IND	ASC AREA NAV,6.21			
POSN_WRT_RW(VERT)	V95H0300CA	VERTICAL DISTANCE WRT RW	ASC AREA NAV,HUD PROC,TLM	FT		
POSN_WRT_RW(1)/X	V95H0220CA	DOWNRANGE DISTANCE WRT RW	ASC AREA NAV,5.7, GRTLS TAEM GUID,GRTLS A/L GUID, HUD PROC,TLM	FT		
POSN_WRT_RW(2)/Y	V95H0221CA	CROSSRANGE DISTANCE WRT RW	ASC AREA NAV,5.7, GRTLS TAEM GUID,GRTLS A/L GUID, HUD PROC,TLM	FT		
PSHA	V95H0181CB	TURN ANG HAC	GRTLS TAEM GUID	DEG		
Q_RADALT	V95H0458CA	SNAPPED RADAR ALT MEASUREMENT	TLM			
R_AVGG(1)	V95H0185CA	X-COMP OF CURRENT SHUTTLE POS VCTR	A/E ATT PROC,PW RTLS GUID, G/C STEER,TLM	FT	DPL	
R_AVGG(2)	V95H0186CA	Y-COMP OF CURRENT SHUTTLE POS VCTR	A/E ATT PROC,PW RTLS GUID, G/C STEER,TLM	FT	DPL	
R_AVGG(3)	V95H0187CA	Z-COMP OF CURRENT SHUTTLE POS VCTR	A/E ATT PROC,PW RTLS GUID, G/C STEER,TLM	FT	DPL	
R_CC_EF(1)	V95H0478C	HAC X_POSITION EF(TOD)	PW RTLS GUID			
R_CC_EF(2)	V95H0479C	HAC Y_POSITION EF(TOD)	PW RTLS GUID			
R_CC_EF(3)	V95H0480C	HAC Z_POSITION EF(TOD)	PW RTLS GUID			
R_EF(1)	V95H0155CB	ORBITER X POSITION EF(TOD)	ASC AREA NAV,TACAN RM	FT	DPL	

CR89805
CR89150H
Space Transportation Systems Division
Rockwell International

Table 4.6.2.7-1. RTLS User Parameter Processing (4.20) Input/Output Functional Parameters (Cont)

CBFM D33348-D PN VP707100037P00L JULY 17, 1989
OUTPUT FUNCTIONAL PARAMETERS FROM RETURN TO LAUNCH SITE UPP

RTLS UPP OI8D REV00 G4.20 PAGE 230 BOOK: 5

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
R_EF(2)	V95H0156CB	ORBITER Y POSITION EF(TOD)	ASC AREA NAV,TACAN RM	FT	DPL	
R_EF(3)	V95H0157CB	ORBITER Z POSITION EF(TOD)	ASC AREA NAV,TACAN RM	FT	DPL	
R_NEP_RTURN	V95U0183CB	HAC RADIUS	GRTLS TAEM GUID	FT		
R_VEH_MAG_UPP	V95H0167CA	MAG SHUTTLE POS VECTOR	ASC AREA NAV	FT		
RA_FLAG	V90X0450XC	RADAR ALTIMETER CREW ALERT	HUD PROC			
RAW_RA_PROC	V90X8865XA	RADAR ALTIMETER PROCESSING FLAG	TLM			
REL_VEL_MAG/V	V95L0151CA	GND REL VEL MAGNITUDE IN M50 SYS	NAVDAD SOP,ADTA SOP, VENT CNTL SEQ,MPS DUMP, VERT SIT DIP,GRTLS TAEM GUID, GRTLS A/L GUID,PW RTLS GUID, MSC,LDG GEAR VLV CNTL, XXXXXX TRAJ DIP,RTLS NAV,TLM	FT/S		
RNG_TO_RW_THRESH	V95H0176CB	RANGE TO RUNWAY THRESHOLD VIA WP1	XXXXXX TRAJ DIP,TLM	NMI		
RW_ID_UPP/RW_ID	V95U0205CA	INDEX OF CURRENT RW USED FOR UPP	GRTLS TAEM GUID,TLM			
RW_NAME	V90U1916CF	CURRENT LANDING SITE SELECTED	TLM			
T_RADALT	V95W0459CA	SNAPPED RADAR ALT TIME	TLM			
T_STATE	V95W0200CC	TIME TAG ASSOC WITH CURRENT STATE	PW RTLS GUID,TLM	S		
TAC_AZ(1)	V95H0207CD	TACAN 1 AZIMUTH	6.21	DEG		
TAC_AZ(2)	V95H0208CD	TACAN 2 AZIMUTH	6.21	DEG		
TAC_AZ(3)	V95H0209CD	TACAN 3 AZIMUTH	6.21	DEG		
TAC_MODE_DISP	V95X0227XD	TACAN ABS/DELTA DATA IND	6.21			
TAC_RNG(1)	V95H0201CD	TACAN 1 RANGE	6.21	NM		
TAC_RNG(2)	V95H0202CD	TACAN 2 RANGE	6.21	NM		
TAC_RNG(3)	V95H0203CD	TACAN 3 RANGE	6.21	NM		
V_AVGG(1)	V95 0190CA	X-COMP OF CURRENT SHUTTLE VEL VCTR	A/E ATT PROC,PW RTLS GUID,TLM	FT/S	SPL	
V_AVGG(2)	V95 0191CA	Y-COMP OF CURRENT SHUTTLE VEL VCTR	A/E ATT PROC,PW RTLS GUID,TLM	FT/S	SPL	
V_AVGG(3)	V95 0192CA	Z-COMP OF CURRENT SHUTTLE VEL VCTR	A/E ATT PROC,PW RTLS GUID,TLM	FT/S	SPL	
V_GROUNDSPEED/VN	V95 0178CA	GROUNDSPEED	HSI PROC,VERT SIT DIP,5.7, GRTLS TAEM GUID,GRTLS A/L GUID, TACAN RM,TLM			
V_HORIZ_DNRNG	V90 0474C	DOWNRANGE HORIZ EARTH REL VEL	XXXXXX TRAJ DIP	FT/S		
[illegible]	V95L0210CA	X COMP OF CURRENT ACCUM IMU VEL	PW RTLS GUID	FT/S		
[illegible]	V95 0211CA	Y COMP OF CURRENT ACCUM IMU VEL	PW RTLS GUID	FT/S		
[illegible]	V95L0212CA	Z-COMP OF CURRENT ACCUM IMU VEL	PW RTLS GUID	FT/S		
V_INERTIAL_MAG	V95L0510CB	MAG OF VEHICLE INERTIAL VELOCITY	AMI PROC	FT/S		
V_RHO(1)	V95L0215CA	X COMP OF RELATIVE VEL IN M50	A/E ATT PROC,PW RTLS GUID, G/C STEER,TLM			
V_RHO(2)	V95L0216CA	Y-COMP OF RELATIVE VEL IN M50	A/E ATT PROC,PW RTLS GUID, G/C STEER,TLM			
V_RHO(3)	V95L0217CA	Z-COMP OF RELATIVE VEL IN M50	A/E ATT PROC,PW RTLS GUID, G/C STEER,TLM			
V_RHO_EF(1)	V95L3884CB	X VELOCITY VECTOR EF(TOD)	ASC AREA NAV	FT/S		
V_RHO_EF(2)	V95 3885CB	Y VELOCITY VECTOR EF(TOD)	ASC AREA NAV	FT/S		
V_RHO_EF(3)	V95L3886CB	Z VELOCITY VECTOR EF(TOD)	ASC AREA NAV	FT/S		
VEL_WRT_RW(VERT)	V95L0257CA	VERTICAL VEL WRT RW	HUD PROC,TLM	FT/S		
VEL_WRT_RW(1)/XDOT	V95L0255CB	DOWNRANGE VEL WRT RW	GRTLS TAEM GUID,HUD PROC,TLM	FT/S		
VEL_WRT_RW(2)/YDOT	V95L0256CC	CROSSRANGE VEL WRT RW	GRTLS TAEM GUID,GRTLS A/L GUID, HUD PROC,TLM	FT/S		
YSGNP/YSGN	V95J0153CC	R/L CONE IND PRI RW	ASC AREA NAV,GRTLS TAEM GUID, 5.7,6.21,PW RTLS GUID			
	V95X0235XD	VENT DOOR SEQ INIT	MSC		BD	

STS 83-0005B
PCN 4 OI 8D
July 11, 1989

Space Transportation Systems Division
Rockwell International
CR8959C

Table 4.6.2.7-2. RTLS User Parameter Processing (4.20) I-Loads

OI8D MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	B	S	PR FCTN	CAT
ALT_S(1)	V97U5706C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_S(2)	V97U5707C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_S(3)	V97U5708C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_S(4)	V97U5709C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_S(5)	V97U5710C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_S(6)	V99U6878C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_S(7)	V99U6879C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_TAB(1)	V97U5712C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_TAB(2)	V97U5713C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_TAB(3)	V97U5714C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_TAB(4)	V97U5715C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_TAB(5)	V97U5716C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_TAB(6)	V99U6874C	FT	F	S	D	C	G4.19 G4.20	PAE0
ALT_TAB(7)	V99U6875C	FT	F	S	D	C	G4.19 G4.20	PAE0
EF_PLANE_SW	V99U7441C	ND	B		M	C	G4.2 G4.3 G4.19 G4.20 G4.210 G4.226	A2M2

CR89461A

DBFN 0470 DATE:01/23/89

Table 4.6.2.7-2. RTLS User Parameter Processing (4.20) I-Loads (Cont)

OI8D MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
IYD(1)	V97U4413C	ND	F	D	M	C	G4.226 G4.2 G4.3 G4.19 G4.20 G4.210	A2N2
IYD(2)	V97U4414C	ND	F	D	M	C	G4.226 G4.2 G4.3 G4.19 G4.20 G4.210	A2N2
IYD(3)	V97U4415C	ND	F	D	M	C	G4.226 G4.2 G4.3 G4.19 G4.20 G4.210	A2N2
NAVBASE_LAT_ZERO	V97U5750C	RAD	F	D	D	C	G4.15 G4.19 G4.20 G4.205	NVB0
NAVBASE_LONG_ZERO	V97U5751C	RAD	F	D	D	C	G4.15 G4.19 G4.20 G4.205	NVB0
NODE_SLOPE	V99U7443C	RAD/SEC	F	S	M	C	G4.19 G4.20	ARC0
PSHARS	V96U8647C	DEG	F	S	D	C	G4.9 G4.23 G4.24 G4.25 G4.19 G4.20 G4.204	ZFU2 ZFU2
R_GO_RAMP	V97U5438C	FT	F	S	D	P	G4.19 G4.20 G4.23 G4.24 G4.25	ZFV2
RADIUS_NEP	V97U5458C	FT	F	S	D	C	G4.19 G4.20 G4.4	ZFV2

DBFN:0470 DATE:01/23/89

CR89461A

STS 83-0005B
PCN-4 OI-8D
July 31, 1989

Space Transportation Systems Division
Rockwell International

Table 4.6.2.7-2. RTLS User Parameter Processing (4.20) I-Loads (Cont)

OI08B MISSIONS DBFN:0431
G4.20 - 0005 - RETURN TO LAUNCH SITE UPP
ACTIVE MEMORY CONFIGURATIONS: 01

FSSR NAME	MSID	ENG UNIT	DT	PR	B	S	PR FCTN	CAT
RHO_B(1)	V97U5765C	SLUG/FT**3	F	S	B	C	G4.19 G4.20	PAE0
RHO_B(2)	V97U5766C	SLUG/FT**3	F	S	B	C	G4.19 G4.20	PAE0
RHO_B(3)	V97U5767C	SLUG/FT**3	F	S	B	C	G4.19 G4.20	PAE0
RHO_B(4)	V97U5768C	SLUG/FT**3	F	S	B	C	G4.19 G4.20	PAE0
RHO_B(5)	V97U5769C	SLUG/FT**3	F	S	B	C	G4.19 G4.20	PAE0
RHO_B(6)	V99U6876C	SLUG/FT**3	F	S	B	C	G4.19 G4.20	PAE0
RHO_B(7)	V99U6877C	SLUG/FT**3	F	S	B	C	G4.19 G4.20	PAE0
START_POSITION	V99U9569C	FT	F	S	B	P	G4.23 G4.24 G4.25 G4.19 G4.20	ZFV2
STOP_POSITION	V99U9570C	FT	F	S	B	P	G4.23 G4.24 G4.25 G4.19 G4.20	ZFV2
T_GMTLO_REF	V99U7442C	SEC	F	D	M	C	G4.19 G4.20	ARC0
X_NEP	V97U5575C	FT	F	S	M	X	G4.4 G4.19 G4.20 G5.7	XS60 XS60

Table 4.6.2.7-3. RTLS UPP (G4.20) K-Loads Return to Launch Site UPP

OI8B MISSIONS

FSSR NAME / DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT	PR	S	PR FCTN	LAST CR EQTN MSID
A3 TOL	V98U9425C	-3.0	E-03 RAD	F	S	C	G4.23 G4.19 G4.20 G4.144 G4.127 G4.205	89661A
BIAS_RADALT	V97U5253C	+0.0	E+00 FT	F	S	P	G4.20 G4.23 G4.24 G4.25	89661A
RADAR ALTITUDE BIAS								
IMAX	V97U5729C	+7	ND	I	S	C	G4.19 G4.20	59972
NO OF ALTITUDE REGIONS								
N_SEQ_MAX	V98U9435C	+7	ND	I	S	P	G4.20 G4.24 G4.25	89661A
NO OF FAILURES BEFORE NAV EV LAMP								
RI	V96U8680C	+2.0	E+04 FT	F	S	C	G4.20 G4.23	89661A
TIME_BIAS_RADALT	V97U5546C	+1.50	E-02 SEC	F	D	P	G4.20 G4.23 G4.24 G4.25	89661A
PAD LOAD CORR RAD ALT TIME								
X_NB_CG	V97U5573C	+5.61360	E+01 FT	F	S	C	G4.23 G4.24 G4.25 G4.20	89661A
X_STRUCT_BODY DIST NAV BASE CG								
Z_NB_CG	V97U5580C	+4.0580	E+00 FT	F	S	C	G4.20 G4.23 G4.24 G4.25	89661A
Z_STRUCT_BODY DIS CG NAV BASE								

DBFN:0534 DATE:07/14/88

THIS PAGE INTENTIONALLY LEFT BLANK

Table 4.6.2.7-4. RTLS User Parameter Processing (4.20) Constants

NROKRMM.FSSR2.DATA(X08)BOOK5
PFS CONSTANTS UPDATE B/L

FSSR NAME DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
DEG_PER_RAD RADIANS TO DEGREES CONVERSION FACTOR	V97U0112C		57.2957795131	DEG/RAD	F	S				
EARTH_RADIUS_EQUATOR EARTH EQUATORIAL RADIUS	V97U5324C		.209257414698 1630 E+08	FT	F	D			CR89596C	
EARTH_RATE EARTH'S ROTATIONAL RATE	V97U4379C		.729211514646 0000 E-04	RAD/SEC	F	D				
EARTH_POLE(1) X COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8460C		.28322844 E-02	ND	F	S				
EARTH_POLE(2) Y COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8461C		-.5027996 E-04	ND	F	S				
EARTH_POLE(3) Z COMP OF UNIT VECTOR IN DIRECTION OF EARTH'S AXIS OF ROTATION IN M50	V98U8462C		.99999598 E+00	ND	F	S				
ELLIPT EARTH'S ELLIPTICITY CONSTANTS	V97U5332C		.335232980000 0000 E-02	ND	F	D				
GRAV_SEA_LEVEL EARTH GRAVITATIONAL ACCELERATION AT SEA LEVEL			.32174049 E+02	FT/ SEC**2	F	S				
NAUTMI_PER_FT FEET TO NAUTICAL MILES CONVERSION FACTOR	V97U5423C		.16457884 E-03	NMI/FT	F	S			CR89596C	
PI RATIO CIRCUMFERENCE TO DIAMETER	V98U8725C		3.1415926535897	ND	F	D				
RAD_PER_DEG DEGREES TO RADIANS CONVERSION FACTOR	V97U0383C		.17453293 E-01	RAD/DEG	F	S				
RADALT_ANG ANGLE BETWEEN BODY X-AXIS AND C.G. TO RADAR ALTIMETER ANTENNA VECTOR			2.005	RAD	F	S				
RADALT_NB_DIST DISTANCE FROM THE NAVIGATION BASE TO THE RADAR ALTIMETER			12.915	FT	F	S				
X_NB_WH DISTANCE FROM THE NAVIGATION BASE TO THE WHEELS IN THE X STRUCTURAL BODY DIRECTION			.62784 E+02	FT	F	S				
Z_NB_WH DISTANCE FROM THE WHEEL TO THE NAVIGATION BASE IN THE Z STRUCTURAL BODY DIRECTION			.22405 E+02	FT	F	S				

Table 4.6.2.7-5. RTLS User Parameter Processing (4.20) Cross-Reference

FSSR Name	Source Name
M_EFTOTD_TACAN_SL(1)	M_EFTOTD_TACAN_SL1
M_EFTOTD_TACAN_SL(2)	M_EFTOTD_TACAN_SL2
M_EFTOTD_TACAN_SL(3)	M_EFTOTD_TACAN_SL3
R_TACAN_EF_SL(1)	R_TACAN_EFSL1
R_TACAN_EF_SL(2)	R_TACAN_EFSL2
R_TACAN_EF_SL(3)	R_TACAN_EFSL3
T_CURRENT	CLOCK
T_IMU	T_IMUS
T_RADALT	RA_TIME
V _IMU_CURRENT	SEL_V_M50
WBR(1)	P_ORB
WBR(2)	Q_ORB
WBR(3)	R_ORB

4.7 ASCENT AREA NAVIGATION PRINCIPAL FUNCTION (4.237)

The area navigation principal function supports the horizontal situation indicators (HSI), which are dedicated display devices located in the Shuttle cockpit that provide visual outputs of certain navigation and guidance parameters for the crew. A separate HSI, together with its associated moding and selector switches, will be provided for both the commander and the pilot; the commander's panel and a larger view of an HSI are shown in Figures 4.7-1 and 4.7-2 (for reference only). The parameters to be displayed - fundamentally, directions, distances, and nominal course and glide path deviations to defined way points - have been chosen to permit the crew to adequately monitor and assess the automatic mode of GN&C on the basis of sources of data and computational software independent of that being employed in the automatic mode. Additionally, the choice of parameters provides the minimum necessary G&N information from this independent display to allow the crew to control the vehicle manually by using the HSI as a flight director. Any of three sets of display parameters will be provided (for entry, TAEM, or autoland) and selected for either HSI by its associated three-position mode switch together with certain auto switching logic. Other selector switches will provide for selection of data types used in navigationally related computations (e.g., TACAN/BARO, MSBLS, or NAV STATE) and for selection of a specific string in the case of redundant navigation sensors.[a] The three-position switches are shown in Figure 4.7-1 for the commander's HSI. The source selection will be independent of whatever source is currently being used in the automatic navigation; the string selection will precede and be independent of the redundancy management function (except in the case of the barometric altitude); and finally, the commander's and pilot's HSI switches will function appropriately for their HSI and cause computations and displays independent of each other. The display mode will be determined based upon either manual or automatic switching logic. If the three position mode switch is set to the entry position, then the display mode is automatically switched from entry to TAEM, based upon major mode, and from TAEM to autoland, based upon altitude above the runway. For the TAEM or approach switch settings, the display mode selection is manual and the TAEM or autoland display computations, respectively, will be performed.

The intent of the requirements for the HSI displays is to provide information derived primarily from raw navigation sensor data (for its navigation parameters) and to transform that derived navigation state into guidance related target parameters. The source selection, however, will permit use of the current navigation state vector. Generally, the targeting to waypoints is consistent with the current guidance targeting parameters. Overhead TAEM Targeting (OTT) has been implemented as an option (along with straight-in), with compatibility between crew displays and controls, guidance moding, user

---

[a]The barometric altitude used with the TACAN data will come from the redundancy management selection filter and, therefore will be unaffected by string selection.

parameter processing and the area navigation processing. In most instances, the same trajectory characteristics are supported, that is, overhead versus straight-in ground tracks, left/right heading alignment circles, and altitude versus range profiles. Exceptions are by design and are due to either unique functional requirements or trades and balances between compatibility and independence. Source/Receiver selections for area nav may produce somewhat different outputs compared to the guidance and user parameter processing which use only the navigation state vector. Computations based upon present positions determined from independent and different sources is a requirement, and differences are anticipated. Certain status flags will be displayed on the HSI to indicate cues regarding validity of selected source/string data: these include an ON/OFF flag, range flags, a bearing flag, course deviation flag, and glide slope deviation flag. The status setting of the flags will provide some means of rapid, real-time diagnosis of problems by the crew and will normally permit a crewman to select a good input source to drive the HSI. (That, incidentally, may permit isolation of bad sources, which he may inhibit for the automatic GN&C processing.)

Through the interpretation of the displayed parameters on the HSI, the crew will be provided an independent monitor of certain GN&C parameters critical to a safe arrival near the touchdown zone and through rollout. The HSI, together with other dedicated displays, will provide the primary backup to guidance and navigation as well as a flight director function for horizontal and vertical guidance for a similar safe arrival by manual control up to a region in which transition from the steep glide slope to a shallow glide is required. Thereafter, the glide slope deviation is not computed because its use as an altitude director in a manual landing is questionable (radar altimeter altitude being preferable). The horizontal flight direction will be validly applicable throughout rollout.

The UPP sequencer principal functions will schedule the area navigation principal function to be performed during the appropriate phases of Shuttle flight at a repetition rate commensurate with the HSI processing principal function.

Interface parameters, along with I-load, K-load, constant, and cross-reference tables, are presented in Section 4.7.1.

A. Detailed Requirements. In order for the area navigation to initialize with the same trajectory characteristics as the user parameter processing, guidance, and displays (that is, overhead versus straight-in, and turns around the same, either left or right, heading alignment circle the selected runway), it is required that the RTLS UPP principal function execute before the first pass through area nav processing and compute these necessary selection indicators. Area navigation processing tests a "first pass" indicator (FIRST PASS), which will be set to "ON" by RTLS UPP after its first execution in major mode 602, and also set to "ON" by RTLS UPP or TAEM UPP after any area or runway redesignation where new selection indicators are computed. Whenever area nav finds the "first pass" indicator set (ON), it copies (saves) the

overhead/straight-in indicator and the left/right heading alignment circle indicator for use in subsequent cycles, and resets the "first pass" indicator to OFF.

Provision for change in the overhead/straight-in indicator is provided elsewhere in the area nav (then left/right turn indicator is computed by A.N.), but only in this "first pass" is the left/right indicator accepted as input command. After the left/right heading alignment circle indicator is determined, it specifies a "selected HAC" for subsequent area nav computations. HSI computations will be based on inputs from either the tactical air navigation (TACAN) system with the air data system (ADS), the microwave scanning beam landing system (MSBLS), or the navigated state from a general-purpose computer (GPC). An HSI, with its associated switches, will be located at each side of the cockpit. Since each may be operated independently, computations will be executed independently for the left and right HSI. Cockpit switches will permit crew selection of data sources and will provide for either automatic or manual control over the display modes. A cockpit switch setting will determine which of three data sources is to be used for the computation of the HSI parameters. These data sources are (1) TACAN (range and azimuth), together with ADS (barometric altitude); (2) MSBLS (range, azimuth, and elevation); and (3) navigation solution of Shuttle's position and attitude.

Since the TACAN and MSBLS NAVAID sources are multiredundant, another cockpit switch will be used to select which of three subsources is to be used (i.e., there will be three TACAN's to choose from or three MSBLS transceivers to choose from). However, only one source for the navigated state will be used. When the source selection switch is set to the NAV position, the receiver selection switch will have no function, since the single source driving the HSI will be the user parameter state vector. Regardless of which data source is selected, the HSI parameter computation module will first transform the data to the coordinate system of the primary runway.

A third cockpit switch, together with major mode flags and altitude above the runway, will determine the display mode (ENTRY, TAEM, or A/L). The parameters computed for display will vary with the display mode selected. The parameters computed and the logic for determining the display mode are described in more detail below.

The HSI display and area navigation computation function will compute and output seven dynamic parameters for display on the HSI: primary bearing (PRI_BEAR), primary range (PRI_RANGE), secondary bearing (SEC_BEAR), secondary range (SEC_RANGE), course deviation (CDI), glide slope deviation (GSI), and the heading angle (HEADING). The definitions of these parameters vary according to the display mode as indicated briefly in Table 4.7-1. Their geometry is shown in Figures 4.7-3 and 4.7-4.

In the ENTRY display mode, these parameters are defined as follows:

PRI_BEAR	Spherical angle in degrees (measured positive eastward) between magnetic north and the great circle direction to Way Point 1[a] (WP-1) for the selected HAC at the selected landing runway.
PRI_RANGE	Great circle surface distance in nautical miles from the Shuttle to Way Point 2[a] (WP-2) on the selected landing runway via the selected HAC WP-1. This distance includes the distance from the Shuttle to WP-1, the arc length around the normal entry heading alignment circle (HAC) from WP-1 to the normal entry point (NEP), and the distance from the NEP to WP-2.
SEC_BEAR	Same as PRI_BEAR.
SEC_RANGE	Same as PRI_RANGE.
GSI	Not computed for entry mode. Validity indicator set OFF (invalid).
CDI	Valid zero
HEADING	Heading of the earth-relative velocity vector with respect to magnetic north.

In the TAEM display mode, these parameters are defined as follows:

PRI_BEAR	Angle in degrees (measured positive eastward) between the direction to magnetic north and the direction to WP-1[a] on the selected HAC as viewed from the Shuttle.
PRI_RANGE	Horizontal distance from the Shuttle to WP-2[a] via WP-1 on the selected HAC (see Figure 4.7-3). This distance includes the distance from the Shuttle to WP-1, the arc length around the selected HAC from WP-1 to the EP and the distance from the EP to WP-2.
SEC_BEAR	Bearing to center of selected HAC at the selected landing runway.

[a]Way Point 1 (WP-1) is defined as the tangential target point on the HAC. Way Point 2 (WP-2) is defined as the intersection with the runway centerline of the shallow glide slope. The runway X-component of WP-2 is a premission-determined value that nominally is expected to be on the order of 1,500 feet.

SEC_RANGE	Horizontal distance to center of selected HAC at the selected runway.
CDI	The deviation in degrees (measured positive to the pilot's left on approach to the runway) of the Shuttle from the extended runway centerline. (The apex of this angle is located on the runway centerline directly opposite the MSBLS AZ/DME antenna.) The CDI display full scale is 10 degrees.
GSI	The vertical deviation in feet of the Shuttle from the guidance reference altitude (positive when Shuttle is above glide path). The GSI display full scale deflection is 5,000 feet.
HEADING	Heading of the body X-axis with respect to magnetic north.

In the A/L display mode, the parameters are defined as follows:

PRI_BEAR	Angle in degrees (measured positive eastward) between the direction to magnetic north and the direction to WP-2 as viewed from the Shuttle.
PRI_RANGE	Horizontal distance from the Shuttle directly to WP-2.
SEC_BEAR	Same as PRI_BEAR.
SEC_RANGE	Same as PRI_RANGE.
CDI	Same as CDI in TAEM mode switch setting, with the exception that full scale is 2.5 degrees.
GSI	Vertical deviation in feet of the Shuttle from the linear segment reference altitude (positive when Shuttle is above glide path). Not computed for altitudes less than a prescribed value. The GSI display full scale deflection is 1,000 feet.
HEADING	Same as HEADING in TAEM mode switch setting.

Note: Scale factors in the HSI processing principal function provide conversion factors so that the least significant range digit corresponds to one nautical mile for entry; therefore, AREA NAV provides a decimal point shift for TAEM and A/L range values (by multiplying by TEN) so that the display's least significant digit indicates tenths of a nmi.

In addition to the seven dynamic parameters described above, the HSI display and area navigation computation function will compute OFF-ON values for four display validity indicator flags that are capable of being displayed on the HSI. These four flags are the bearing flag (BRG_FLAG), the course deviation flag (CDI_FLAG), the glide slope flag (GSI_FLAG), and the heading flag (HDG FLAG).

The meaning of the flags on the display varies according to flag grouping and the setting of the source switch as described in detail below.

The BRG and GSI flags presented as OFF: If the source switch is set to TACAN, either the TACAN range or azimuth data (or both) have been labeled invalid by the TACAN SOP. If the source switch is set to MSBLS, either the MSBLS range or azimuth data (or both) have been labeled invalid by the MSBLS SOP.

Only the GSI flag presented as OFF: If the source switch is set to TACAN, the barometric altitude data have been labeled invalid by the air data RM and a constant average altitude, or one derived from the navigation state, is being substituted for barometric altitude to drive the HSI. If the source switch is set to MSBLS, the MSBLS elevation data have been labeled invalid by the MSBLS SOP and a constant elevation angle is being substituted. Additionally, the GSI flag is OFF in the entry display mode and in the A/L display mode below a certain design dependent altitude.

The BRG, CDI, and GSI flags presented as OFF: This indicates to the crew that the station location of the beacon to which the selected TACAN receiver is tuned could not be found in the TACAN site table.

The HDG flag: This flag shall always indicate valid data (ON).

The detailed requirements for the HSI display and area navigation computation function may be described by breaking the function into the following nine subfunctions:

HSI_SEQUENCER

NAV_STATE_TO_RW

TAC_BARO_TO_RW

TAC_BARO_TO_TOPODETIC

MSBLS_TO_RW

ENTRY_HSI_COMP

TAEM_HSI_COMP

LAND_HSI_COMP

RANGE_BEAR_TO_HAC_ENTRY

The HSI-SEQUENCER subfunction performs a "first pass" test in order to initialize and save certain parameter values for subsequent processing: this is to insure that area nav computations are initially and following any area or runway redesignation based upon the same overhead/straight-in command and the same left/right heading alignment circle as the guidance, UPP, and displays. The parameters to be saved are equated to the values provided by the previously executed RTLS UPP. That is, if FIRST_PASS = ON; then:

P = YSGNP

OVHD_LAST = OVHD

This "first pass" code is not to be repeated unless a new area or runway is selected; hence,

FIRST_PASS = OFF

The remainder of the sequencing subfunction (HSI_SEQUENCER) will cycle through twice to perform the HSI computation function for both the left HSI and the right HSI.

If the cycle is for the left HSI, the source, mode, and receiver switch settings for the left HSI will be obtained from the GN&C switch processor principal function and renamed for subsequent processing:

SOURCE = SOURCE_LEFT

MODE = MODE_LEFT

RCVR = RCVR_LEFT

If the cycle is for the right HSI:

SOURCE = SOURCE_RIGHT

MODE = MODE_RIGHT

RCVR = RCVR_RIGHT

The data validity flags shall then be initialized to ON:

BRG_FLAG = ON

GSI_FLAG = ON

CDI_FLAG = ON

Next, the source, mode, and receiver indicators will be tested to control subsequent calculations. If the source indicated is navigation, the NAV_STATE_TO_RW subfunction will be performed to reduce navigation state data to the runway coordinate system. If the source indicated is not navigation, the receiver indicator will be tested to determine from which redundant receiver source data will be taken; in addition, the integer, N, will be set to the desired receiver number (1, 2, or 3) for data indexing purposes. If the source indicated is TACAN, all required TACAN data for the appropriate receiver will be obtained from the TACAN SOP and barometric data will be obtained from the redundancy management selection filter. All these data, along with their corresponding comm fault/lock-on or data-good indicators, will be used in subsequent processing. The parameters to be used are as follows:

TAC_CHAN_VALID_SL(N)

TACBEARO(N)

TACRANGEO(N)

TBRG_CMLK(N)

TRNG_CMLK(N)

HPC

ALT_DG

These data will be utilized in the TAC_BARO_TO_RW subfunction, where they will be transformed to the runway coordinate system.

If the source indicated is neither navigation nor TACAN, all appropriate MSBLS data and comm fault/lock-on indicators for the appropriate receiver will be obtained from the MSBLS SOP and used in subsequent processing. Then the MSBLS_TO_RW subfunction will be performed to reduce these data to the runway coordinate system.

The following parameters will be utilized:

MSBAZIMO(N)

MSBELEVO(N)

MSBRANGEO(N)

MRNG_CMLK(N)

MAZM_CMLK(N)

MELV_CMLK(N)

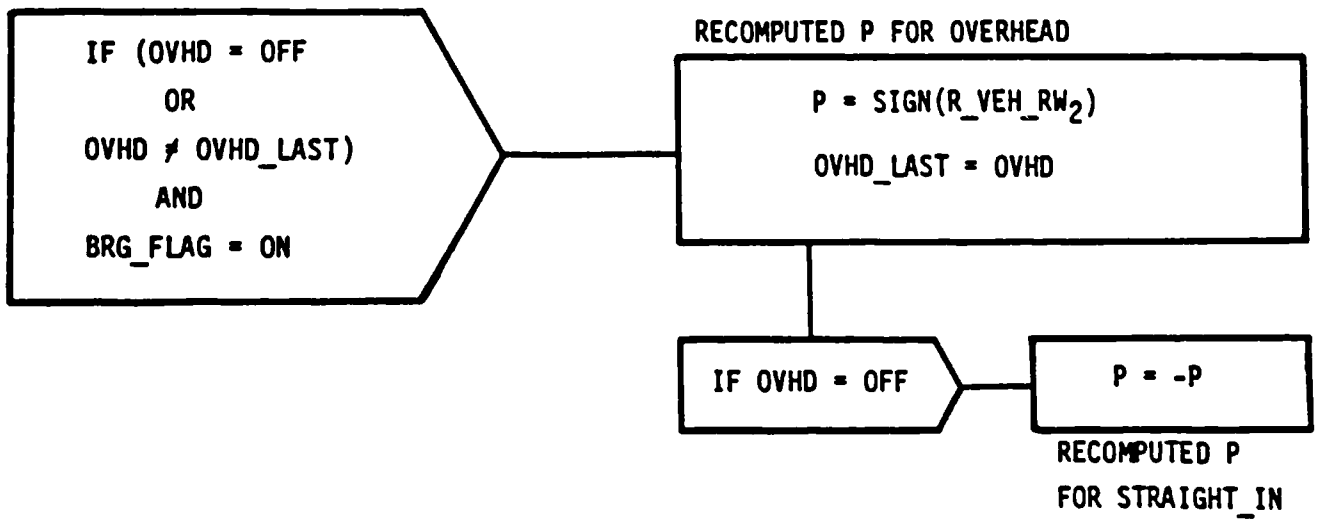
At this point, the selected data will have been reduced to the selected runway coordinate system, and mode-dependent processing will begin.

In order to respond to a change in the overhead/straight-in-command, (OVHD), it may or may not be required to recompute the left/right heading alignment indicator for the selected runway (the parameter P, where +1 signifies the right turn HAC and -1 signifies the left turn HAC). For the straight-in (OVHD = OFF), P must be computed each left cycle and each right cycle because its value depends upon present position derived from source and receiver switch positions for that side's display. This computation is not necessary in the case of invalid input data (BRG_FLAG = OFF).

If OVHD is "ON" but was not "ON" on the previous cycle, this condition indicates a command to transition from straight-in back to overhead, in which case it is necessary to compute the HAC indicator once and save for subsequent cycles (i.e., P corresponding to the HAC on the opposite side of the runway centerline from the current source/receiver derived present position).

However, this one-time computation will not be done until valid input data are available, (indicated by BRG_FLAG = ON ANDed with OVHD ≠ OVHD_LAST); once this computation is performed it will not be repeated (due to setting OVHD_LAST = OVHD) unless there is a subsequent transition from straight in to overhead and valid data are available.

Note that P is established by the first pass logic, and is unchanged as long as the initial OVHD indicator is "ON". A transition to OVHD = OFF causes P to be recomputed every left side and right side cycle. Then a further transition back to OVHD = ON causes a one-cycle recomputation of P on the first valid input data cycle, and this single cycle recomputation establishes the value of P as long as this OVHD indicator is "ON". Note also that regardless of OTT mode, the recomputation of P is not necessary if BRG_FLAG = OFF. Suggested logic (tests) and equations follow:



It will next be determined whether computations are to be performed for the entry display mode, the TAEM display mode or the autoland display mode. The "ENTRY" position on the mode switch provides automatic transitions of the display modes (ENTRY, TAEM, Approach/LAND). If the mode switch setting is entry and if the major mode is GLIDE RTLS 1 (MM_CODE_602 = ON) during OPS-6, then the ENTRY_HSI_COMP subfunction will be performed to generate display output parameters peculiar to the entry display mode. If the mode display is not entry, the angular deviation of the vehicle from the extended runway centerline (CDI) will be computed and the heading of the body X-axis with respect to magnetic north will be obtained from attitude processing and converted for output.

$$CDI = ARCTAN2(-R\_VEH\_RW_2, 16300 - R\_VEH\_RW_1)\ DEG\_PER\_RAD$$

$$HEADING = PSI\_HSIMV\ DEG\_PER\_RAD$$

Next, during OPS-3 two tests are made to determine certain constants which are dependent on vehicle mass and wind conditions, which are provided by crew interface. Depending on the mass of the vehicle, there are two distinct values for the final approach steep glide path angle. If the vehicle mass, M, is less than a threshold value, M_GSI, then the glide slope index IGS will be set equal to one corresponding to the nominal case; that is, if

$$M < M\_GSI$$

then

$$IGS = 1$$

If the mass of the vehicle is greater or equal to M_GSI, then the glide slope index IGS will be set equal to two corresponding to the high mass case; that is, if

$$M \geq M\_GSI$$

then

$$IGS = 2$$

During OPS-6, only one glide path is available. Therefore, set IGS = 1, without reference to vehicle mass.

The glide slope index is used to differentiate the constants employed in polynominal expressions relating the reference altitude and range for these two steep final approach glide path angles, as well as the cubic-fit higher altitude profile. (These coefficients are the same as those used by the onboard guidance reference altitude.)

Next, certain constants are calculated which are used later to compute the range-to-go and the reference altitude:

DELX_NEP = -HCO(IGS)/C1(IGS,1)

DELX_MEP = -HMEP(IGS)/C1(IGS,1)

DELX_REF = -CO(IGS,1)/C1(IGS,1)

Since the masses used in the comparison test do not change after AREA NAV begins operating, these calculations need be performed only once. In order to handle this, a flag (MASS_FLAG) is introduced which should be initialized to ON as a first pass flag; after this one time execution, it should be turned to the OFF position:

MASS_FLAG = OFF

A value of ALT_LAND, which is employed in the automatic switching logic, is initialized at this point to correspond to the desired altitude at the NEP; that is,

ALT_LAND = HCO(IGS)

Depending on the wind conditions, as defined by crew interface (keyboard entries on HSD), there are two distinct values for X_GSI (X_GSI is the distance from the glide slope intercept point on the extended runway centerline to the runway threshold). If the winds are normal, denoted by HI_WINDS = OFF, then the value for this parameter is set equal to its nominal value:

X_GSI = X_GSI_NOMINAL

If the winds are determined to be high headwinds, denoted by HI_WINDS = ON, then the value for this parameter is set equal to its HI_WIND value:

X_GSI = X_GSI_HI_WIND

The LAND_HSI_COMP subfunction will be performed to generate output parameters peculiar to the Approach/Landing display mode if any one or more of the following three conditions are true:

1. The mode switch setting indicates LANDING

2. The mode switch setting indicates ENTRY (auto-switching) and the altitude (H) is less than the altitude at the entry point (ALT_LAND)

3. The mode switch setting is ENTRY (auto-switching) and the altitude (H) is less than 6,000 ft above the entry point (ALT_LAND) and the absolute value of course deviation (CDI) is less than 0.044 radian.

If none of the conditions are true, additional parameters must be computed to support the TAEM display mode.

Depending on the vehicle's energy, there are two sets of distinct HACs which the crew may select via crew interface (HSD); the nominal circle indicated by the term NEP and the low energy circle indicated by the term MEP. If guidance determines that the vehicle has low energy, it will send a signal to the crew informing them to switch from the NEP to the MEP on the HSD (item entry). This switch will be received by AREA NAV as the NEP flag, which determines whether the nominal (NEP = ON) or the minimum energy (NEP = OFF) heading alignment circles shall be used. That is:

If NEP = ON, then

X_EP = X_GSI + DELX_NEP

Since the value of ALT_LAND depends on the selected HAC, the value associated with the nominal circle is computed at this point:

ALT_LAND = HCO(IGS)

If NEP = OFF, then

X_EP = X_GSI + DELX_MEP

The value of ALT_LAND associated with the low energy circle is computed at this point:

ALT_LAND = HMEP(IGS)

Next, the TAEM_HSI_COMP subfunction will be performed to generate display outputs peculiar to the TAEM display mode, and the CDI and GSI data will be scaled for desired display range.

CDI = 0.25 CDI

GSI = 0.2 GSI

Finally, all outputs generated will be renamed according to which of the HSI's (left or right) they were destined for, including the HAC indicator for the HSD which will be set for the left HSI:

If left

PRIBEAR_LEFT = PRI_BEAR

PRIRANGE_LEFT = PRI_RANGE

CDI_LEFT = CDI

GSI_FLAG_LEFT = GSI_FLAG

BRG_FLAG_LEFT = BRG_FLAG

CDI_FLAG_LEFT = CDI_FLAG

GSI_LEFT = GSI

HEADING_LEFT = HEADING

LHSI_ P = P

SECBEAR_LEFT = SEC_BEAR

SECRANGE_LEFT = SEC_RANGE

HDG_FLAG_LEFT = ON

If right

PRIBEAR_RIGHT = PRI_BEAR

PRIRANGE_RIGHT = PRI_RANGE

CDI_RIGHT = CDI

GSI_RIGHT = GSI

HEADING_RIGHT = HEADING

GSI_FLAG_RIGHT = GSI_FLAG

BRG_FLAG_RIGHT = BRG_FLAG

CDI_FLAG_RIGHT = CDI_FLAG

SECBEAR_RIGHT = SEC_BEAR

SECRANGE_RIGHT = SEC_RANGE
HDG_FLAG_RIGHT = ON

The NAV_STATE_TO_RW subfunction will establish the Shuttle position vector both in earth-fixed coordinates and in coordinates of the primary runway whenever the data source is navigation. Both vectors will be obtained from user parameter processing principal functions and renamed for HSI processing:

R_VEH_EF = R_EF

R_VEH_RW = POSITION_WRT_RUNWAY

The altitude of the Shuttle referenced to the runway altitude will be obtained from the appropriate UPP principal function and renamed for HSI processing:

H = ALT_WHEELS

The TAC_BARO_TO_RW subfunction, together with the TAC_BARO_TO_TOPODETIC subfunction, will transform TACAN data for the selected receiver into a vehicle position vector expressed in primary runway coordinates. To perform the required transformations, certain site-dependent parameters will be required that relate the TACAN data to the location of the TACAN beacon to which the selected (Nth) receiver is tuned. This site-dependent data will be obtained from the TACAN site look-up subfunction according to receiver number and will include the following parameters:

ALT_TACAN_SL(N), RD_TAC_SL(N), ANGLE_CORR_TNTOMAG_SL(N),

R_TACAN_EF_SL(N), DH_TACAN_SL(N), TACAN_CHAN_VALID_SL(N),

M_EFTOTD_TACAN_SL(N)

The TAC_BARO_TO_RW subfunction will first determine if either the TACAN bearing or TACAN range comm fault/lock-on indicator, TBRG_CMLK(N) or TRNG_CMLK(N), indicates invalid data. If so, both the HSI BRG and GSI flags will be set OFF accordingly:

BRG_FLAG = OFF

GSI_FLAG = OFF

and no further computations within this subfunction shall be performed.

Otherwise, the channel validity indicator, TACAN_CHAN_VALID_SL(N) will be tested by the HSI software; if it indicates that the beacon's location is not available, the HSI BRG, GSI, and CDI flags will be set to OFF. Thus, the crew will be notified of the situation, and all subsequent calculations utilizing beacon locations will be bypassed.

If the beacon's location is available, the TAC_BARO_TO_TOPODETIC subfunction will be performed to reduce the data to a topodetic coordinate system located at the TACAN beacon. The TAC_BARO_TO_TOPODETIC subfunction will compute the Shuttle position vector with respect to the TACAN site, $\underline{R}_{VEH\_TD\_TAC}$, and will also establish the condition of the flag, GSI_FLAG, that indicates the validity of the barometric altitude data.

Finally, the position of the Shuttle will be established in both earth-fixed and runway coordinates:

$$\underline{R}_{VEH\_EF} = M_{EFTOTD\_TACAN\_SL(N)}^{T}\ \underline{R}_{VEH\_TD\_TAC} + \underline{R}_{TACAN\_EF\_SL(N)}$$

$$\underline{R}_{VEH\_RW} = M_{EFTORW}\ (\underline{R}_{VEH\_EF} - \underline{R}_{LS\_EF})$$

The TAC_BARO_TO_TOPODETIC subfunction will convert TACAN range and azimuth for the selected (Nth) receiver, together with altitude data, to a vehicle position vector expressed in a topodetic system located at the TACAN beacon.

Barometric altitude data will be used for this purpose unless it is indicated to be invalid, in which case its value will be replaced with a corresponding, premission-determined, average value whenever the display mode is ENTRY. If the display mode is TAEM or approach/landing, an estimate of barometric altitude will be made on the basis of navigation-derived altitude above the runway. Also, the GSI_FLAG will be turned to OFF:

if ALT_DG = OFF, then GSI_FLAG = OFF

and if in ENTRY mode: if MM_CODE_602 = ON or MM_CODE_304 = ON, then H_BARO = 85000

Otherwise

H_BARO = ALT_WHEELS + ALT_RW - DELH_MSL_ELLIPSOID_RW

Whenever the barometric altitude data are indicated to be valid, barometric altitude, HPC, will be renamed for processing:

$$H\_BARO = HPC$$

Finally, all data will be reduced to the topodetic coordinate system as follows:

$$R\_TAC = RD\_TAC\_SL(N) + ALT\_TACAN\_SL(N) - DH\_TACAN\_SL(N)$$

$$R\_VEH = RD\_TAC\_SL(N) + H\_BARO$$

$$A = TACBEARO(N) + ANGLE\_CORR\_TNTOMAG\_SL(N) + PI$$

$$COSB = \frac{R\_TAC^2 + TACRANGEO(N)^2 - R\_VEH^2}{2\ R\_TAC\ TACRANGEO(N)} \qquad \text{(F3)}$$

If COSB < - 1, then COSB = -1

$$D = TACRANGEO(N)\ (1 - COSB^2)^{1/2}$$

$$R\_VEH\_TD\_TAC_1 = D\ COS(A) \qquad \text{(F9)}$$

$$R\_VEH\_TD\_TAC_2 = D\ SIN(A) \qquad \text{(F9)}$$

$$R\_VEH\_TD\_TAC_3 = TACRANGEO(N)\ COSB$$

Whatever the source for H_BARO, this value of the altitude will be transformed into an altitude referenced to the runway altitude and renamed for HSI processing:

$$H = H\_BARO - ALT\_RW + DELH\_MSL\_ELLIPSOID\_RW$$

The MSBLS_TO_RW subfunction will first determine if either the MLS range or MLS azimuth comm fault/lock-on indicator for the selected receiver (MRNG_CMLK(N) or MAZM_CMLK(N)) indicates invalid data. If so, both the HSI bearing (BRG) and glide slope (GSI) flags will be set accordingly to OFF:

$$BRG\_FLAG = OFF$$

$$GSI\_FLAG = OFF$$

and no further computations within this subfunction will be performed.

[F3] This equation shall be protected against division by zero (Section 3.5).
[F9] This equation shall be protected against return value of sine or cosine with magnitude greater than unity (Section 3.5).

Otherwise, the MSBLS elevation comm fault/lock-on indicator, MELV_CMLK(N), will be tested. If invalid data are indicated, the elevation angle will be set to one of two assumed values and the HSI GSI flag will be set OFF (GSI_FLAG = OFF) to indicate to the crew that invalid MSBLS elevation is being replaced with an assumed value - a change resulting in degraded performance of the HSI. The choice between the two assumed values for MSBLS elevation will depend upon the altitude relative to a predetermined reference value H_GSI_SHALLOW; that is,

if H > H_GSI_SHALLOW, then EL_MSBLS = 0.33281

otherwise EL_MSBLS = 0.0

Whenever the MSBLS elevation data are indicated to be valid, the elevation angle for the selected receiver, MSBELEVO(N), will be renamed for subsequent processing:

EL_MSBLS = MSBELEVO(N)

Finally, the MSBLS data will be reduced to the runway coordinate system according to the following equations:

TAZ = TAN(MSBAZIMO(N))

TEL = TAN(EL_MSBLS)

$TEL2 = TEL^2$

$A = 1 + TEL2 + TAZ^2$

B = 2 (X_EL_RW - X_DMEAX_RW) TEL2

$C = (X\_EL\_RW - X\_DMEAZ\_RW)^2\ TEL2 - MSBRANGEO(N)^2$

$$X\_VEH\_DMEAZ = \frac{B - \sqrt{B^2 - 4AC}}{2A} \qquad \text{(F4)}$$

$R\_VEH\_RW_1 = X\_DMEAZ\_RW + X\_VEH\_DMEAZ$

$R\_VEH\_RW_2 = (X\_DMEAZ\_RW - R\_VEH\_RW_1)\ TAZ + Y\_DMEAZ\_RW$

$R\_VEH\_RW_3 = (R\_VEH\_RW_1 - X\_EL\_RW)\ TEL$

[F4] This equation shall be protected against square roots of a negative number (Section 3.5).

The negative of the third component of the position vector R_VEH_RW will be renamed for HSI processing:

$$H = - R\_VEH\_RW_3$$

The ENTRY_HSI_COMP subfunction will compute the heading of the relative velocity vector with respect to magnetic north by utilizing the vehicle position vector and relative velocity in earth-fixed coordinates obtained from appropriate user parameter processing principal functions.

First, a vector, V_NORM, which is normal to the plane containing the position vector and the relative velocity is determined:

$$\underline{V}\_NORM = \underline{R}\_EF \times \underline{V}\_RHO\_EF$$

Then, the heading follows from

$$PSI = ARTCAN2(V\_NORM_3\ \underline{R}\_VEH\_MAG\_UPP,\ (V\_NORM_1\ R\_EF_2 - V\_NORM_2\ R\_EF_1))$$

$$HEADING = (PSI - ANGLE\_CORR\_TNTOMAG\_RW)\ DEG\_PER\_RAD$$

If HEADING < 0, then

$$HEADING = HEADING + 360$$

Then, the magnitude of the position vector from the selected source is calculated:

$$R\_VEH\_MAG = |\underline{R}\_VEH\_EF|$$

The RANGE_BEAR_TO_HAC_ENTRY subfunction will be performed with input parameters determined by the value of P. If P is positive, then the input parameters are

R_CC_R_PRI

R_CC_RMAG_PRI

If P is negative, then the input parameters are

R_CC_L_PRI

R_CC_LMAG_PRI

Regardless of the value of P, the following quantities are also required by this subfunction:

OVHD
P

R_VEH_EF

R_VEH_MAG

AZIMUTH_RW

ANGLE_CORR_TNTOMAG_RW

This action results in the calculation of the primary range (PRI_RANGE) and primary bearing (PRI_BEAR).

The secondary range (SEC_RANGE) and the secondary bearing (SEC_BEAR) are subsequently set equal to their corresponding values:

$$SEC\_RANGE = PRI\_RANGE$$

$$SEC\_BEAR = PRI\_BEAR$$

Finally, CDI and GSI are set to zero and the HSI glide slope valid flag is set to OFF.

$$CDI = 0$$

$$GSI = 0$$

$$GSI\_FLAG = OFF$$

The RANGE_BEAR_TO_HAC_ENTRY subfunction will accept as inputs the overhead/straight-in indicator (OVHD), the left/right HAC indicator (P), the position vector of the center of the HAC in EF coordinates, the magnitude of this vector, a parameter which is indicative of the position of the Shuttle with respect to the runway centerline, the position vector of the Shuttle in EF coordinates, the magnitude of this vector, the azimuth of the runway and the true north to magnetic north correction angle. It will then compute a range and bearing for the entry mode display.

The vector, $\underline{V}\_NORM$, normal to the great circle plane containing the Shuttle and HAC center will be determined:

$$\underline{V}\_NORM = \underline{R}\_VEH\_EF \times \underline{R}\_CC\_EF$$

The bearing of this great circle plane with respect to true north at the Shuttle position and at the circle center will be computed:

$$BEAR\_VEH = ARCTAN2(V\_NORM_3\ R\_VEH\_MAG,\ (V\_NORM_1\ R\_VEH\_EF_2 - V\_NORM_2\ R\_VEH\ EF_1)) \quad (F7)$$

$$BEAR\_CC = ARCTAN2(V\_NORM_3\ R\_CC\_MAG,\ (V\_NORM_1\ R\_CC\_EF_2 - V\_NORM_2\ R\_CC\_EF_1)) \quad (F7)$$

If BEAR_CC < 0 then BEAR_CC = BEAR_CC + 2 PI. The sine of the central angle between the position of the Shuttle and the center of the HAC will then be calculated:

$$SIN\_THET\_VEH\_CC = |\underline{V}\_NORM|/(R\_VEH\_MAG\ R\_CC\_MAG)$$

Then, the great circle surface range from the Shuttle to WP1 will be approximated by:

$$DIST\_VEH\_WP1 = ARCSIN(SIN\_THET\_VEH\_CC)\ R\_CC\_MAG \quad (F5)$$

Next, the angle defined by the intersection of the two great circle planes (one passing through the Shuttle position and the HAC center, and the other through the Shuttle position and WP1) is given by

$$A2 = RADIUS\_EP/\ DIST\_VEH\_WP1$$

and the bearing from the Shuttle to WP1 follows from

$$BEAR\_VEH\_WP1 = BEAR\_VEH - P\ A2$$

The arc length around the selected HAC from WP 1 to the entry point will be determined next:

$$A3 = A2 + P\ (AZIMUTH\_RW - BEAR\_CC)$$

If

$$A3 < -0.003,\ A3 = A3 + 2\ PI$$

If OVHD = ON and A3 < $\pi/2$, then 2π is added to A3 for an additional full turn around the heading alignment circle. Then:

$$D\_ARC = A3\ RADIUS\_EP$$

[F7] This equation shall be protected against arc tangents with both arguments equal to zero (Section 3.5).

[F5] This equation shall be protected against arc sine of arguments with magnitudes greater than unity (Section 3.5).

Finally, the display computations will be performed:

RANGE = (DIST_VEH_WP1 + D_ARC - X_NEP + X_WP2) NAUTMI_PER_FT

BEARING = (BEAR_VEH_WP1 - ANGLE_CORR_TNTOMAG_RW) DEG_PER_RAD

If

BEARING < 0, BEARING = BEARING + 360

The LAND_HSI_COMP subfunction will first compute the bearing to WP 2 according to the following:

$$D = X\_WP2 - R\_VEH\_RW_1$$

$$PRI\ BEAR = (ARCTAN2(-\ R\_VEH\_RW_2,\ D) + AZIMUTH\_RW - ANGLE\_CORR\_TNTOMAG\_RW)\ DEG\_PER\_RAD \quad (F7)$$

If

PRI_BEAR < 0, then PRI_BEAR = PRI_BEAR + 360

Otherwise, if PRI_BEAR > 360, then PRI_BEAR = PRI_BEAR - 360. Next, primary range will be computed:

$$DIST\_WP2 = (R\_VEH\_RW_2^2 + D^2)^{1/2}$$

PRI RANGE = (DIST_WP2 NAUTMI_PER_FT)10.

Secondary range and bearing are then set equal to primary range and bearing:

SEC_RANGE = PRI_RANGE

SEC_BEAR = PRI_BEAR

The multiply by 10. shifts the range decimal point to provide one-tenth nmi resolution on the display.

In order to compute the glide slope deviation for Shuttle altitudes greater than a premission-determined value, that is, H > H_GSI_SHALLOW, the reference altitude HREF must be calculated. The reference altitude is related to the distance (R) from the vehicle ground position to a reference point.

R = DIST_WP2 + X_GSI + DELX_REF - X_WP2

[F7] This equation shall be protected against arc tangents with both arguments equal to zero (Section 3.5).

by the following linear relation

$$HREF = C0(IGS,1) + C1(IGS,1)\ R$$

where C0, C1 are premission constants corresponding to guidance altitude coefficients and depend on the glide slope index. The glide slope deviation follows from

$$GSI = H - HREF$$

where H is the actual vehicle altitude above the runway threshold and HREF is the desired vehicle altitude. When the Shuttle altitude is less than the premission value, H_GSI_SHALLOW, the glide slope deviation is not computed and the HSI glide slope flag is set to OFF:

$$GSI\_FLAG = OFF$$

The TAEM_HSI_COMP subfunction will accept as inputs the runway X-component, X_EP, of a HAC associated with the crew selected entry point (EP) and the HAC radius, RADIUS_EP. This function will compute primary and secondary range, primary and secondary bearing, and glide slope deviation for the TAEM mode display. The primary bearing is the direction to WP1 on the selected heading alignment circle; the primary range is the distance to WP2 via the WP1; the glide slope deviation is the altitude error as compared to the reference altitude which is based on the guidance defined coefficients (a function of distance to go via the selected path). The secondary range and bearing are computed with respect to the center of the selected HAC. The ranges are scaled to represent range in tenths of nautical miles. The detailed requirements for this subfunction are as follows:

A coordinate system will be established whose origin is located at the Shuttle and the X-, Y-position of the center of the selected HAC will be expressed in Shuttle-centered coordinates. The distance and bearing to the center of the HAC will then be computed:

$$Y\_CC = RADIUS\_EP - P\ R\_VEH\_RW_2$$

$$X\_CC = X\_EP - R\_VEH\_RW_1$$

$$R\_CC = (X\_CC^2 + Y\_CC^2)^{1/2}$$

$$PHI = ARCTAN2(Y\_CC,\ X\_CC)$$

If PHI < 0, then PHI = PHI + 2 PI (PI = π)

Next, two cases will be distinguished: (1) the Shuttle is on or inside the HAC, and (2) the Shuttle is outside the HAC. In each of these cases, the distance from the Shuttle to WP 1 will be calculated, together with the bearing relative to the runway and the turn angle remaining around the HAC onto the runway centerline.

If R_CC ≤ RADIUS_EP, then case 1; otherwise, case 2.

Case 1:

$$DIST\_VEH\_WP1 = 0$$

$$BEAR\_RW = PHI - 0.5\ PI$$

In case 2, the nominal case, the angle THETA will be computed, which corrects the bearing from the center of the HAC to the tangent point WP 1.

Case 2:

$$THETA = ARCSIN(RADIUS\_EP/R\_CC)$$

$$DIST\_VEH\_WP1 = (R\_CC^2 - RADIUS\_EP^2)^{1/2}$$

$$BEAR\_RW = PHI - THETA$$

Next, for either Case 1 or 2, BEAR_RW will be tested and corrected if found to be negative. Then, the turn angle around the HAC will be determined:

If BEAR_RW < -.003, then BEAR_RW = BEAR_RW + 2 PI

$$ARC = 2\ PI - BEAR\_RW$$

Under certain conditions, it may be necessary to add 2π to ARC; i.e., an additional full turn to the arc around the heading alignment circle; specifically, if OVHD = ON and ARC < π/2 and H > (ALT_LAND + 25386); if all three conditions are true, then add 2π to ARC before computing D_ARC. (Note: The constant value corresponds roughly to the nominal altitude loss in a half turn.)

$$D\_ARC = ARC\ RADIUS\_EP$$

Finally, the parameter, P, will be tested; if it is found to be negative, the bearing to WP1 and to the center of the HAC will be corrected according to BEAR_RW = 2PI - BEAR_RW and PHI = 2PI - PHI. Then, the display computations will be performed:

$$RANGE\_FT = DIST\_VEH\_WP1 + D\_ARC - X\_EP + X\_WP2$$

$$PRI\_RANGE = (RANGE\_FT\ NAUTMI\_PER\_FT)\ 10$$

$$PRI\_BEAR = (BEAR\_RW + (AZIMUTH\_RW - ANGLE\_CORR\_TNTOMAG\_RW))\ DEG\_PER\_RAD$$

$$SEC\_BEAR = (PHI + (AZIMUTH\_RW - ANGLE\_CORR\_TNTOMAG\_RW))\ DEG\_PER\_RAD$$

$$SEC\_RANGE = 10\ R\_CC\ NAUTMI\_PER\_FT$$

If either of the bearings exceed 360°, they shall be reduced by 360°:

$$\text{If PRI\_BEAR} > 360, \text{PRI\_BEAR} = \text{PRI\_BEAR} - 360$$

$$\text{If SEC\_BEAR} > 360, \text{SEC\_BEAR} = \text{SEC\_BEAR} - 360$$

In order to compute the glide slope deviation, the reference altitude HREF is first calculated. This altitude is related to the ground distance (R) from the vehicle position to the reference along the selected path:

$$R = \text{RANGE\_FT} + \text{X\_GSI} + \text{DELX\_REF} - \text{X\_WP2}$$

Two different polynominal expressions are employed depending on the relative distance (DR) from a predetermined distance (CUBRC) from the MEP

$$DR = R - \text{CUBRC(IGS)}$$

If DR < 0, then the expression for HREF is given by a cubic in R

$$\text{HREF} = \text{C0(IGS,1)} + \text{C1(IGS,1)}\ R + \text{C2(IGS,1)}\ R^2 + \text{C3(IGS,1)}\ R^3$$

where C0, C1, C2, C3 are premission constants and depend on the glide slope index. If DR $\geq$ 0, then the expression for HREF is given by a cubic in DR

$$\text{HREF} = \text{C0(IGS, 2)} + \text{C1(IGS,2)}\ DR + \text{C2(IGS,2)}\ DR^2 + \text{C3(IGS,2)}\ DR^3$$

where C0, C1, C2, C3 are premission constants and depend on the glide slope index. Subsequently, the glide slope deviation is calculated:

$$\text{GSI} = H - \text{HREF}$$

B. Interface Requirements. The input and output variables are listed in Tables 4.7-3 and 4.7-4. For OPS-3, the vehicle mass is obtained from the DEORB Guidance principal function (4.209), while for OPS-6 it is not required. Targeting parameters, which may be mission dependent or design dependent, are defined by the appropriate guidance principal function; those parameters which are used by AREA NAV are shown in Table 4.7-2 for RTLS (OPS-6); this table shows the correspondence between AREA NAV symbols and the guidance symbols (FSSR names).

Interfacing between the submodules of the HSI computation function may consist of call/assign lists, name-scoping rules of HAL-structured programming, or other available techniques.

C. Processing Requirements. The left side (commander's) HSI and its associated switches will be independent of those on the right side (pilot's); thus, the HSI computations must be performed for each display. Crew interface inputs via spec functions, however, effect both displays.

It is required that all floating-point computations be in single precision to provide adequate computational speed.

D. Constraints. Computation rates will be dependent on requirements for the dedicated instrument drive rates and must be compatible with the independence of the right and left HSI requirements. There will be provision in this function to inhibit the processing of data if the sensor range or azimuth comm fault/lock-on flags indicate bad data. The HSI flags will provide an indication to the crew that the data may not be valid. These flags may be used as a cue to the crew that another receiver or source might be advisable.

Navigation state, TACAN, and MLS sensor measurements must be in appropriate sequence to ensure HSI input data availability when the GPC operation (navigation filter, etc.) is using other sources (e.g., provide TACAN for HSI while nav state is using MLS data).

Prior to activating area navigation, ASC site lookup (Section 4.5.2) is required to have been performed for the selected runway as well as for all TACAN ground stations currently tuned by the TACAN receivers.

It is also required that the RTLS UPP must have executed prior to the first pass through area nav because the overhead/straight-in indicator and the initial left/right HAC indicators for the selected runway are required inputs to be used, as well as saved for subsequent cycles.

E. Supplementary Information. A suggested implementation of the area navigation computation function may be found in Section 5.4 in the detailed flow charts.

The course deviation (CDI) and glide slope deviation (GSI) outputs from area navigation are utilized to drive "fly to" indicators on the HSI. Thus, a positive course deviation output will correspond to a "fly right" indication to the crew and a positive glide slope deviation output will correspond to a "fly down" indication to the crew.

Table 4.7-1. HSI Display Parameter/Mode Switch Matrix
HSI Output Identity

Display Mode	Primary Bearing	Primary Miles	Secondary Bearing	Secondary Miles	Course Deviation (CDI)	Glide Slope Deviation (GSI)	Compass Card (Heading)
ENTRY	Spherical bearing to WP 1 for NEP at selected landing runway	Spherical surface range to WP 2 on selected runway via WP 1 for NEP (LSB = 1. nmi)	Spherical bearing to WP 1 for NEP at selected landing runway	Spherical surface range to WP 2 on selected runway via WP 1 for NEP (LSB = 1. nmi)	A valid Software zero	Not computed GSI_FLAG set invalid	Magnetic heading of vehicle relative velocity vector
TAEM	Bearing to WP 1 on selected HAC for selected runway	Horizontal distance to WP 2 on selected runway via WP 1 for (LSB = 1/10 nmi)	Bearing to center of selected HAC for selected runway	Horizontal distance to center of selected runway centerline (LSB = 1/10 nmi)	Deviation from extended runway centerline = ±10 deg	Deviation from TAEM reference altitude (Full scale ±5,000 ft)	Magnetic heading of body X-axis
A/L	Bearing to WP 2 at selected runway	Horizontal distance to WP 2 on selected runway (LSB = 1/10 nmi)	Bearing to WP 2 at selected runway (Same as primary bearing)	Horizontal distance to WP 2 on selected runway (Same as primary miles) (LSB = 1/10 nmi)	Deviation from extended runway centerline (Full scale = ±2.5 deg)	Deviation from steep glide path; not computed for altitude less than prescribed value (full scale = ±1,000 ft)	Magnetic heading of body X-axis

CR89596C

Table 4.7-2. Correspondence of Ascent Area Navigation Mission Dependent Parameters and GRTLS TAEM A/L Guidance (4.204 and 4.234) Parameters

MSID	Description	Area NAV Symbol	GUID Symbol	Type	Precision	Range	Units	Rate
	Coefficients used in cubic for the reference altitude versus range	CO(1,J)[a]	CUBC1(1,J)	Arr	S		ft	1.04
	Coefficients used in cubic for the reference altitude versus range	C1(1,J)	CUBC2(1,J)	Arr	S			1.04
	Coefficients used in cubic for the reference altitude versus range	C2(1,J)	CUBC3(1,J)	Arr	S		ft^{-1}	1.04
	Coefficients used in cubic for the reference altitude versus range	C3(1,J)	CUBC4(1,J)	Arr	S		ft^{-2}	1.04
	Distance between reference point and the transition point for the reference altitude versus range	CUBRC(1)	CUBRC(1)	Arr	S		ft^{-2}	1.04
	Reference altitude evaluated at the NEP	HCO(1)	HFTC(1)	Arr	S		ft	1.04
	Glide slope intercept point on extended runway centerline for high-wind condition	X_GSI_HI_WIND	XA(2)	F	S		ft	1.04
	Glide slope intercept point on extended runway centerline for low wind condition	X_GSI_NOMINAL	XA(1)	F	S		ft	1.04
	Distance from threshold to WP2	X_WP2	X_AIM_PT	F	S		ft	1.04
	Altitude (AGL) of the minimum energy point	HMEP(1)	HMEP(1)	F	S		ft	1.04

[a] J refers to different range regions.

Table 4.7-3. Area Navigation Input Parameters

Description	Symbol	Source	Input Type	Precision	Range	Units	Sample Rate
Baro data good flag	ALT_DG	(a)	D		ON/OFF		1.04
Altitude above reference ellipsoid of runway reference point	ALT_RW	(a)	F	S		ft	1.04
Altitude above reference ellipsoid TACAN station obtained from site lookup for N'th receiver	ALT_TACAN_SL(N)	(a)	F	S		ft	1.04
Altitude of Orbiter c.g. (entry) or rear wheels (TAEM A/L) above runway altitude	ALT_WHEELS	(a)	F	S		ft	1.04
Angle of magnetic variation from true north at runway	ANGLE_CORR_ TNTOMAG_RW	(a)	F	S		rad	1.04
Variation of magnetic north from true north at TACAN site obtained from site lookup for N'th receiver	ANGLE_CORR_ TNTOMAG_SL(N)	(a)	F	S		rad	1.04
Bearing from true north of runway coordinate system +X-axis	AZIMUTH_RW	(a)	F	S		rad	1.04
Distance used for reference altitude versus range	CUBRC(1)	(b)	Arr	S		ft	1.04
Conversion factor from radians to degrees	DEG_PER_RAD	(b)	F	S		deg/ rad	1.04
Altitude of mean sea level above reference ellipsoid at runway	DELH_MSL_ ELLIPSOID_RW	(a)	F	S		ft	1.04
Altitude of mean sea level above reference ellipsoid at TACAN station obtained from site lookup for N'th receiver	DH_TACAN_SL(N) FIRST_PASS	(a)	F	S		ft	1.04
Reference altitude evaluated at the MEP	HCO (1)	(b)	Arr	S		ft	1.04
Altitude for terminating calculation of glide slope deviation	H_GSI_SHALLOW	(b)	F	S		ft	1.04
Flag denotating high or low winds at runway	HI_WINDS	(a)	D		ON/OFF		1.04
Baro altitude obtained from the air data SOP	HPC	(a)	F	S		ft	1.04
Earth-fixed to prime RW transformation matrix	M_EFTORW	(a)	M	S			1.04
Transformation matrix from earth-fixed to topodetic coordinates at TACAN site obtained from site lookup for N'th receiver	M_EFTOTD_TACAN_ SL(N)	(a)	M	S			1.04
Indicates setting of display mode switch (entry, TAEM, or land) for left-side HSI	MODE_LEFT	(a)	CHAR				1.04

[a]See ascent area navigation principal function input parameter table.
[b]See ascent area navigation principal function I-load, K-load, and constant tables.

Table 4.7-3. Area Navigation Input Parameters (Cont)

Description	Symbol	Source	Input Type	Precision	Range	Units	Sample Rate
Indicates setting of display mode switch (entry, TAEM, or land) for right-side HSI	MODE_RIGHT	(a)	Char				1.04
MSBLS azimuth commfault/lock-on flag for selected receiver, N = 1,3	MAZM_CMLK(N)	(a)	Char				1.04
MSBLS azimuth for the selected receiver, N = 1,3	MSBAZIMO(N)	(a)	F	S		rad	1.04
MSBLS elevation commfault/lock-on flag for selected receiver, N = 1,3	MELV_CMLK(N)	(a)	D		ON/OFF		1.04
Major Mode 602 flag	MM_CODE_602	(a)	D		ON/OFF		1.04
MSBLS elevation for the selected receiver, N = 1,3	MSBELEVO(N)	(a)	F	S		rad	1.04
MSBLS range commfault/lock-on flag for the selected receiver, N = 1,3	MRNG_CMLK(N)	(a)	D		ON/OFF		1.04
MSBLS range for the selected receiver, N = 1,3	MSBRANGEO(N)	(a)	F	S		ft	1.04
Flag denoting switch from NEP to MEP circle	NEP	(a)	D		OFF/ON		1.04
Vehicle position vector wrt runway reference point (R_LS_EF)	POSITION_WRT_RUNWAY	(a)	V	S		ft	1.04
Angle between mag north and Shuttle X-axis	PSI_HSIMV	(a)	F	S		rad	1.04
Indicates setting of string selection switch (when source in MSBLS or TACAN) on left-side HSI	RCVR_LEFT	(a)	I	S			1.04
Indicates setting of string selection switch (when source in MSBLS or TACAN) on right-side HSI	RCVR_RIGHT	(a)	I	S			1.04
Position vector of the HAC center on the left-side (-Y) of the runway centerline	R_CC_L_PRI	(a)	V	S		ft	1.04
Magnitude of the vector R_CC_L_PRI	R_CC_LMAG_PRI	(a)	F	S		ft	1.04
Position vector of the HAC center on the right side (+Y) of the runway centerline	R_CC_R_PRI	(a)	V	S		ft	1.04
Magnitude of the vector R_CC_R_PRI	R_CC_RMAG_PRI	(a)	F	S		ft	1.04
Radius of the heading alignment	RADIUS_EP	(b)	F	S		ft	1.04
Geodetic radius of mean sea level at TACAN site to which the N'th TACAN receiver is tuned	RD_RAC_SL(N)	(a)	F	S		ft	1.04
Shuttle position vector in earth-fixed coordinates	R_EF	(a)	V	DP		ft	1.04

[a]See ascent area navigation principal function input parameter table.
[b]See ascent area navigation principal function K-load table.

Table 4.7-3. Area Navigation Input Parameters (Cont)

Description	Symbol	Source	Input Type	Precision	Range	Units	Sample Rate
Position vector of runway in earth-fixed coordinates	R_LS_EF	(a)	V	DP		ft	1.04
TACAN station earth-fixed position vector obtained from site lookup for N'th receiver	R_TACAN_EF_SL(N)	(a)	V	DP		ft	1.04
Magnitude of the Shuttle position vector from UPP	R_VEH_MAG_UPP	(a)	F	DP		ft	1.04
Indicates which data source (MSBLS, TACAN, or NAV) switch is on for leftside HSI	SOURCE_LEFT	(a)	CHAR				1.04
Indicates which data source (MSBLS, TACAN, or NAV) switch is on for rightside HSI	SOURCE_RIGHT	(a)	CHAR				1.04
TACAN bearing data obtained from the SOP for each receiver, I = 1,3	TACBEARO(I)	(a)	F	S		rad	1.04
TACAN azimuth comm fault/lock-on flag for the I-th receiver, I = 1,3	TBRG_CMLK(I)	(a)	D		ON/OFF		1.04
Switch indicating (ON) a valid TACAN channel has been selected (site lookup output)	TAC_CHAN_VALID_SL(I)	(a)	D		ON/OFF		1.04
TACAN range comm fault/lock-on flag for the I-th receiver, I = 1,3	TRNG_CMLK(I)	(a)	D		ON/OFF		1.04
TACAN range data obtained from the SOP for each receiver, I = 1,3	TACRANGEO(I)	(a)	F	S		ft	1.04
Vehicle relative velocity vector in earth-fixed coordinates	V_RHO_EF	(a)	V	S		ft/s	1.04
X component of range/azimuth antenna in runway coordinates	X_DMEAZ_RW	(a)	F	S		ft	1.04
X component of elevation antenna--RW coordinates	X_EL_RW	(a)	F	S		ft	1.04
Glide slope intercept point on extended runway centerline for high wind condition	X_GSI_HI_WIND	(b)	F	S		ft	1.04
Glide slope intercept point on extended runway centerline for low wind condition	X_GSI_NOMINAL	(b)	F	S		ft	1.04
X-distance from RW threshold to HAC, used in ENTRY display mode	X_NEP	(b)	F	S		ft	1.04
Runway X-component of WP2	X_WP2	(b)	F	SP		ft	1.04
Y component of range/azimuth antenna in runway coordinates	Y_DMEAZ_RW	(a)	F	S		ft	1.04
Initial L/R HAC indicator-primary runway	YSGNP	(a)	I	S	±1	NA	1.04
Overhead/straight indicator	OVHD	(a)	D	—	ON/OFF	NA	1.04

[a]See ascent area navigation principal function input parameter table.
[b]See ascent area navigation principal function I-load table.

Table 4.7-3. Area Navigation Input Parameters (Cont)

Description	Symbol	Source	Input Type	Precision	Range	Units	Sample Rate
Altitude (AGL) of the minimum energy point	HMEP (1)	(b)	V	S		ft	1.04

[b]See ascent area navigation principal function K-load table.

Table 4.7-4. Area Navigation Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
HSI data validity flag	BRG_FLAG_LEFT	(a)	B		ON/OFF		1.04
HSI data validity flag	BRG_FLAG_RIGHT	(a)	B		ON/OFF		1.04
HSI data validity flag	CDI_FLAG_LEFT	(a)	B		ON/OFF		1.04
HSI data validity flag	CDI_FLAG_RIGHT	(a)	B		ON/OFF		1.04
Course deviation from the extended runway centerline	CDI_LEFT	(a)	F	S		deg	1.04
Course deviation from the extended runway centerline	CDI_RIGHT	(a)	F	S		deg	1.04
HSI data validity flag	GSI_FLAG_LEFT	(a)	B		ON/OFF		1.04
HSI data validity flag	GSI_FLAG_RIGHT	(a)	B		ON/OFF		1.04
Glide slope deviation for primary runway	GSI_LEFT	(a)	F	S		ft	1.04
Glide slope deviation for primary runway	GSI_RIGHT	(a)	F	S		ft	1.04
Heading of relative velocity vector (entry) or of body X-axis (TAEM or A/L)	HEADING_LEFT	(a)	F	S		deg	1.04
Heading of relative velocity vector (entry) or of body X-axis (TAEM or A/L)	HEADING_RIGHT	(a)	F	S		deg	1.04
Primary bearing (to WP1_ENTRY and TAEM, to WP2_LAND)	PRIBEAR_LEFT	(a)	F	S		deg	1.04
Primary bearing (to WP1_ENTRY and TAEM, to WP2_LAND)	PRIBEAR_RIGHT	(a)	F	S		deg	1.04
Primary range to WP2 (via WP1_ ENTRY and TAEM, DIRECT_LAND)	PRIRANGE_LEFT	(a)	F	S		nmi	1.04
Primary range to WP2 (via WP1_ ENTRY and TAEM, DIRECT_LAND)	PRIRANGE_RIGHT	(a)	F	S		nmi	1.04
Bearing from Shuttle to WP1 for secondary RUNWAY_ENTRY, bearing from Shuttle to center of selected HAC for primary RUNWAY_TAEM	SECBEAR_LEFT	(a)	F	S		deg	1.04
Bearing from Shuttle to WP1 for secondary RUNWAY_ENTRY, bearing from Shuttle to center of selected HAC for primary RUNWAY_TAEM	SECBEAR_RIGHT	(a)	F	S		deg	1.04
Secondary range to WP2 via WP1_ ENTRY and DIRECT_LAND, horizontal distance to center of selected HAC for primary RUNWAY_TAEM	SECRANGE_LEFT	(a)	F	S		nmi	1.04
Secondary range to WP2 via WP1_ ENTRY and DIRECT_LAND, horizontal distance to center of selected HAC for primary RUNWAY_TAEM	SECRANGE_RIGHT	(a)	F	S		nmi	1.04

[a]See ascent area navigation principal function output parameter table.

Table 4.7-4. Area Navigation Output Parameters

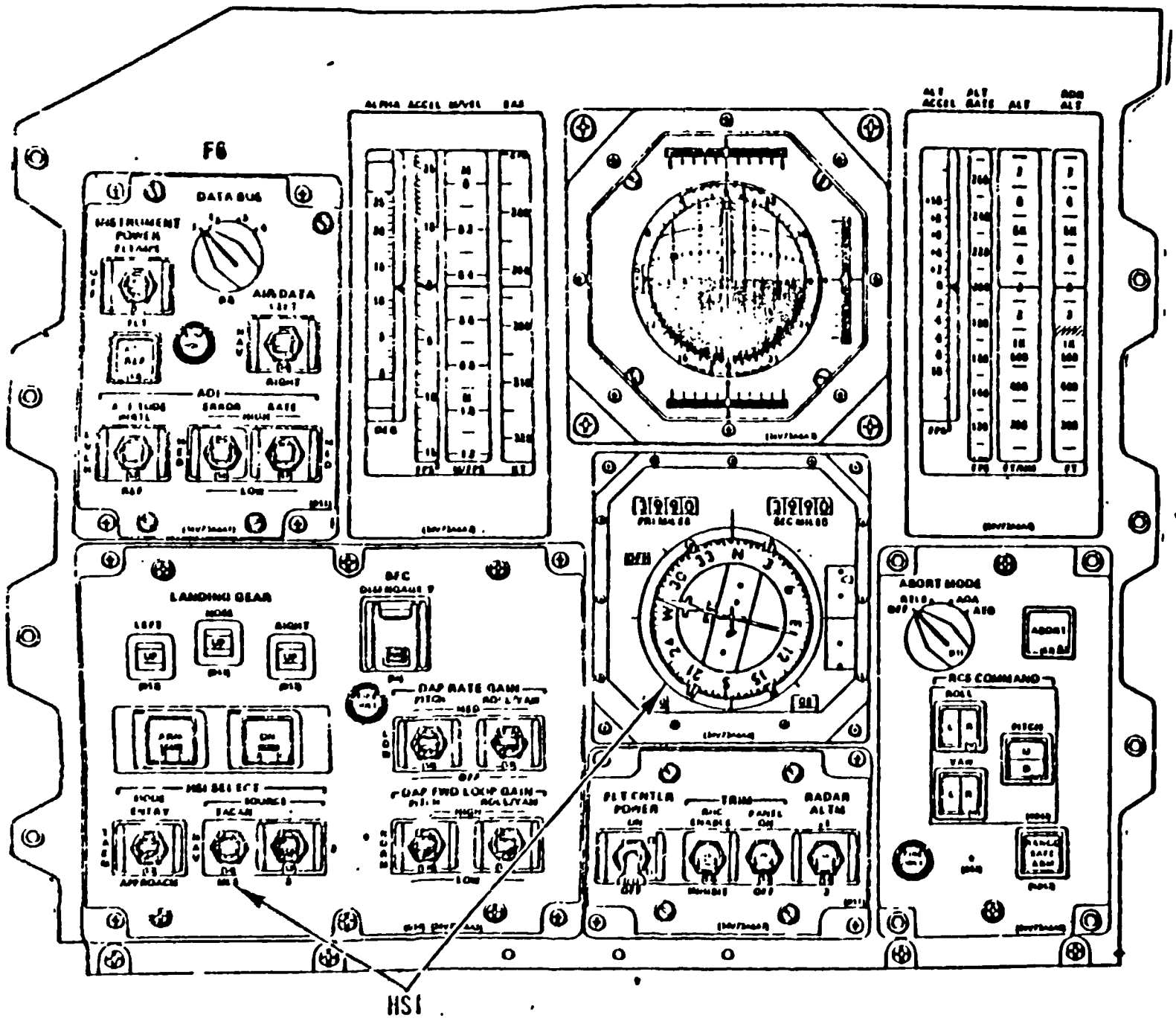
Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
HSI data validity flag	BRG_FLAG_LEFT	(a)	D		ON/OFF		1.04
HSI data validity flag	BRG_FLAG_RIGHT	(a)	D		ON/OFF		1.04
HSI data validity flag	CDI_FLAG_LEFT	(a)	D		ON/OFF		1.04
HSI data validity flag	CDI_FLAG_RIGHT	(a)	D		ON/OFF		1.04
Course deviation from the extended runway centerline	CDI_LEFT	(a)	F	S		deg	1.04
Course deviation from the extended runway centerline	CDI_RIGHT	(a)	F	S		deg	1.04
HSI data validity flag	GSI_FLAG_LEFT	(a)	D		ON/OFF		1.04
HSI data validity flag	GSI_FLAG_RIGHT	(a)	D		ON/OFF		1.04
Glide slope deviation for primary runway	GSI_LEFT	(a)	F	S		ft	1.04
Glide slope deviation for primary runway	GSI_RIGHT	(a)	F	S		ft	1.04
Heading of relative velocity vector (entry) or of body X-axis (TAEM or A/L)	HEADING_LEFT	(a)	F	S		deg	1.04
Heading of relative velocity vector (entry) or of body X-axis (TAEM or A/L)	HEADING_RIGHT	(a)	F	S		deg	1.04
Primary bearing (to WP1_ENTRY and TAEM, to WP2_LAND)	PRIBEAR_LEFT	(a)	F	S		deg	1.04
Primary bearing (to WP1_ENTRY and TAEM, to WP2_LAND)	PRIBEAR_RIGHT	(a)	F	S		deg	1.04
Primary range to WP2 (via WP1_ ENTRY and TAEM, DIRECT_LAND)	PRIRANGE_LEFT	(a)	F	S		nmi	1.04
Primary range to WP2 (via WP1_ ENTRY and TAEM, DIRECT_LAND)	PRIRANGE_RIGHT	(a)	F	S		nmi	1.04
Bearing from Shuttle to WP1 for secondary RUNWAY_ENTRY, bearing from Shuttle to center of selected HAC for primary RUNWAY_TAEM	SECBEAR_LEFT	(a)	F	S		deg	1.04
Bearing from Shuttle to WP1 for secondary RUNWAY ENTRY, bearing from Shuttle to center of selected HAC for primary RUNWAY_TAEM	SECBEAR_RIGHT	(a)	F	S		deg	1
Secondary range to WP2 via WP1_ ENTRY and DIRECT LAND, horizontal distance to center of selected HAC for primary RUNWAY_TAEM	SECRANGE_LEFT	(a)	F	S		nmi	1
Secondary range to WP2 via WP1_ ENTRY and DIRECT LAND, horizontal distance to center of selected HAC for primary RUNWAY TAEM	SECRANGE_RIGHT	(a)	F	S		nmi	1.04

[a]See ascent area navigation principal function output parameter table.

Table 4.7-4. Area Navigation Output Parameters (Cont)

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Heading valid flag for left-side HSI	HDG_FLAG_LEFT	(a)	D		ON/OFF		1.04
Heading valid flag for right-side HSI	HDG_FLAG_RIGHT	(a)	D		ON/OFF		1.04
Current L/R HAC indicator	LHSI_P	(a)	I	S	±1	—	1.04

[a]See ascent area navigation principal function output parameter table.



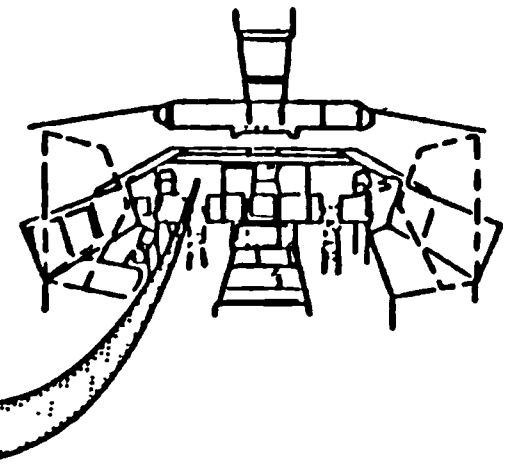


Figure 4.7-1. Left-Hand Forward Flight Station

Space Transportation Systems Division
Rockwell International

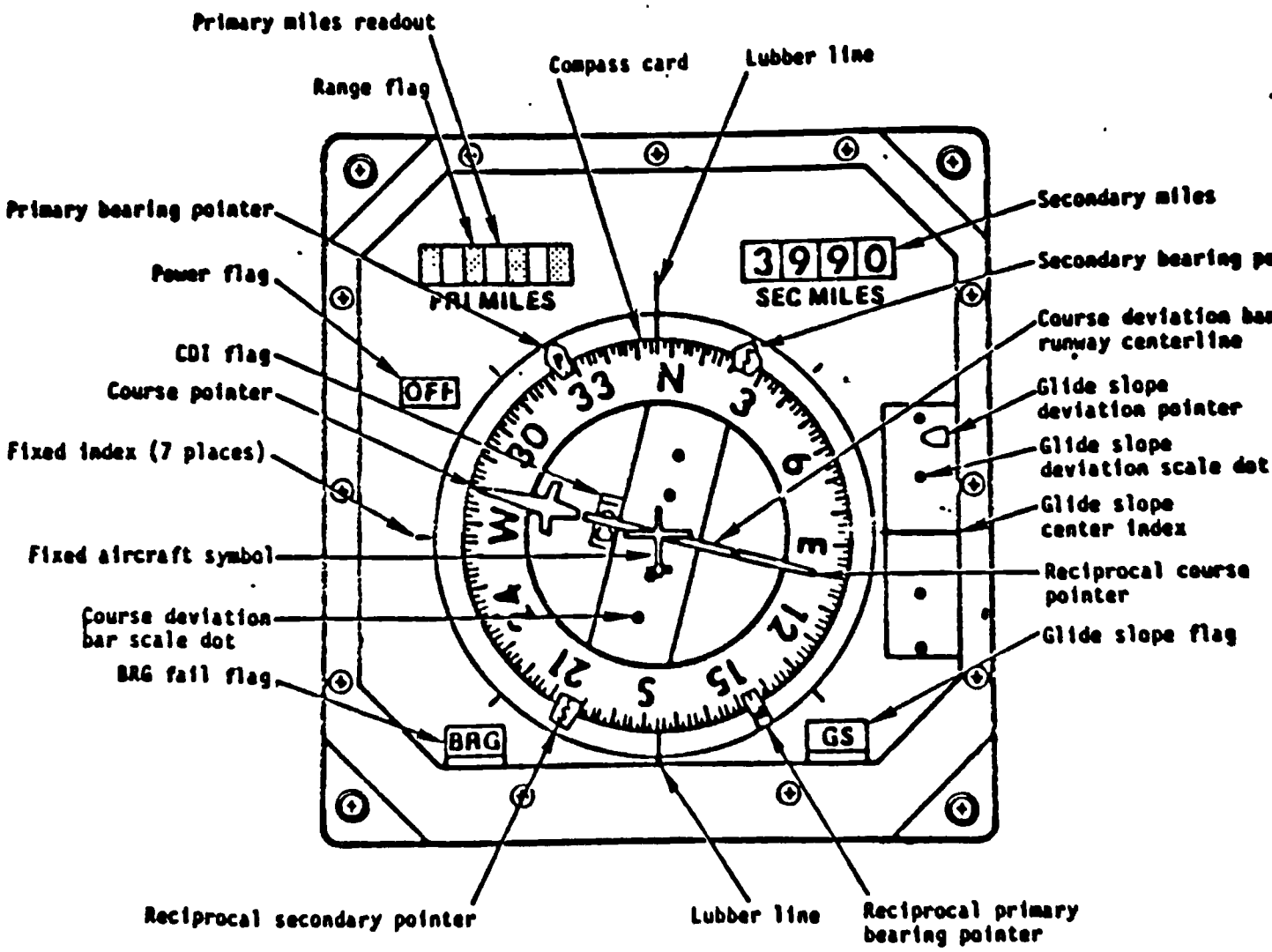


Figure 4.7-2. HSI Display

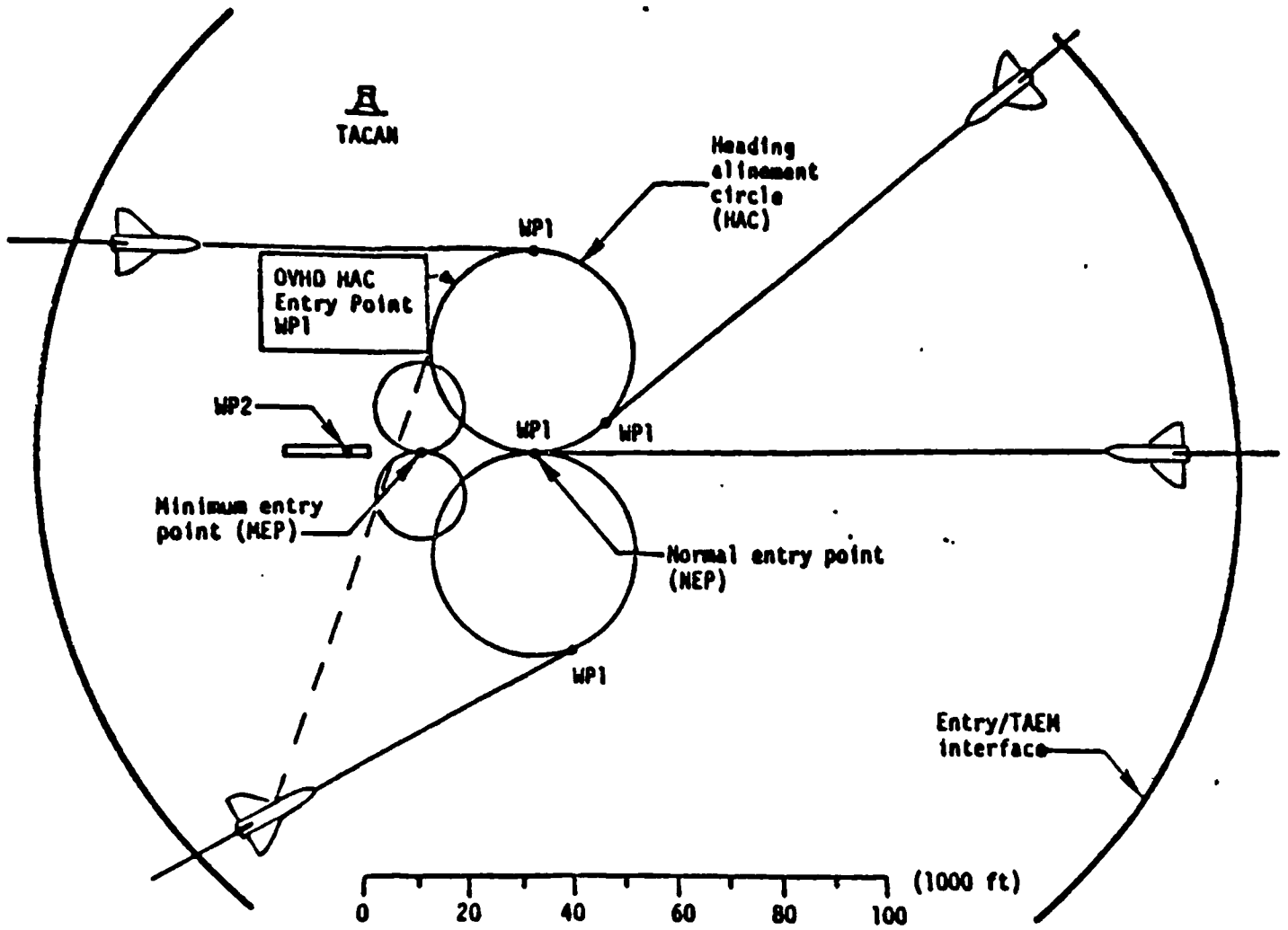


Figure 4.7-3. Flightpath Geometry - Horizontal Plane

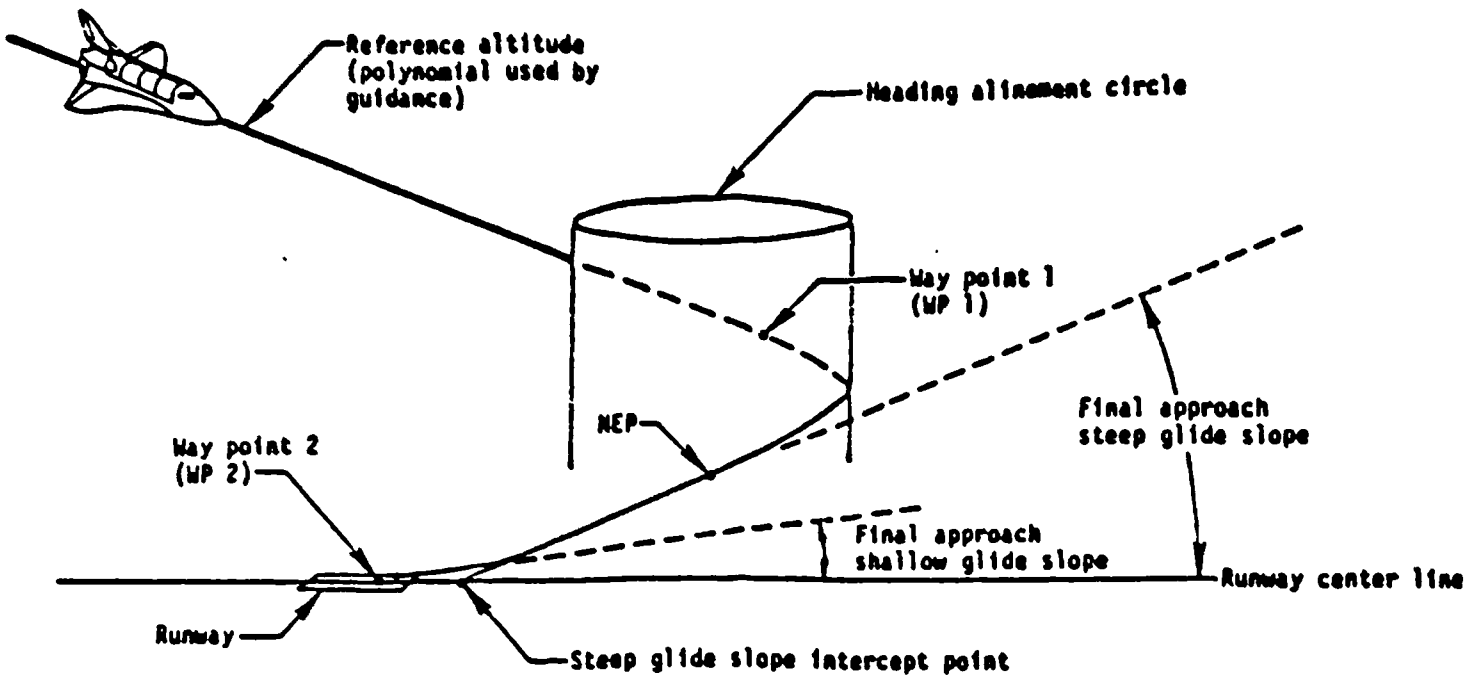


Figure 4.7-4. Flightpath Geometry - Vertical

4.7.1 Ascent Area Navigation Processing (4.237) Principal Function Tables. The ascent area navigation principal function input and output parameters, along with the I-loads, K-loads, constants, and cross-references, are presented in Tables 4.7.1-1 through 4.7.1-5.

The values for the I-loads are contained in the I-loads requirements document (JSC-19350).

Table 4.7.1-1. Ascent Area Navigation Processing (4.237) Input/Output Functional Parameters

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
ADS_MJ	V95X3112X	ADS MACH JUMP FLAG	ADTA SOP		BD	
ALT_DG	V95X3111X	PRESSURE ALTITUDE DATA GOOD FLAG	ADTA SOP		BD	
ALT_RW	V90H1818CB	ALTITUDE OF RW WRT REF ELLIPSOID	ASC SITE LOOKUP	FT		
ALT_TACAN_SL(1)	V90H1846CB	ALTITUDE OF TACAN 1 STATION	ASC SITE LOOKUP	FT		
ALT_TACAN_SL 2)	V90H1847CB	ALTITUDE OF TACAN 2 STATION	ASC SITE LOOKUP	FT		
ALT_TACAN_SL 3)	V90H1848CB	ALTITUDE OF TACAN 3 STATION	ASC SITE LOOKUP	FT		
ALT_WHEELS	V95H0165CA	ALT TO REAR WHEELS/NAV BASE(ENTRY)	RTLS UPP	FT		
ANGLE_CORR_TNTOMAG_RW	V90H1820CB	MAGNETIC VARIATION OF RW	ASC SITE LOOKUP	RAD		
ANGLE_CORR_TNTOMAG_S1	V90H1843CB	MAGNETIC VARIATION AT TACAN 1 SITE	ASC SITE LOOKUP	RAD		
ANGLE_CORR_TNTOMAG_S2	V90H1844CB	MAGNETIC VARIATION AT TACAN 2 SITE	ASC SITE LOOKUP	RAD		
ANGLE_CORR_TNTOMAG_S3	V90H1845CB	MAGNETIC VARIATION AT TACAN 3 SITE	ASC SITE LOOKUP	RAD		
AZIMUTH_RW	V90H1817CB	AZIMUTH OF RW FROM TRUE NORTH	ASC SITE LOOKUP	RAD		
DELH_MSL_ELLIPSOID_RW	V90H1819CB	ALT OF MSL ABOVE REF ELLIP AT RW	ASC SITE LOOKUP	FT		
DH_TACAN_SL(1)	V90H1849CB	ALT OF MSL ABV REF ELLIP AT TAC 1	ASC SITE LOOKUP	FT		
DH_TACAN_SL(2)	V90H1850CB	ALT OF MSL ABV REF ELLIP AT TAC 2	ASC SITE LOOKUP	FT		
DH_TACAN_SL(3)	V90H1851CB	ALT OF MSL ABV REF ELLIP AT TAC 3	ASC SITE LOOKUP	FT		
ENT_PT_SW/NEP	V93X4466X	ENTRY POINT SWITCH CMD	6.21		BD	
FIRST_PASS	V95X0184XC	AREA NAV HAC INIT FLAG	RTLS UPP			
GI_CHANGE	V93X4476X	HEAD WIND HI/LO CMD	6.21		BD	
HPC	V95H3001C	ADS CORRECTED PRESSURE ALTITUDE	ADTA SOP	FT	SPL	
M_EFTORW(1-1)	V90U1805CB	EF TO PRIME RW XFORM MTRX ELE 1-1	ASC SITE LOOKUP			
M_EFTORW(1-2)	V90U1806CB	EF TO PRIME RW XFORM MTRX ELE 1-2	ASC SITE LOOKUP			
M_EFTORW(1-3)	V90U1807CB	EF TO PRIME RW XFORM MTRX ELE 1-3	ASC SITE LOOKUP			
M_EFTORW(2-1)	V90U1808CB	EF TO PRIME RW XFORM MTRX ELE 2-1	ASC SITE LOOKUP			
M_EFTORW(2-2)	V90U1809CB	EF TO PRIME RW XFORM MTRX ELE 2-2	ASC SITE LOOKUP			
M_EFTORW(2-3)	V90U1810CB	EF TO PRIME RW XFORM MTRX ELE 2-3	ASC SITE LOOKUP			
M_EFTORW(3-1)	V90U1811CB	EF TO PRIME RW XFORM MTRX ELE 3-1	ASC SITE LOOKUP			
M_EFTORW(3-2)	V90U1812CB	EF TO PRIME RW XFORM MTRX ELE 3-2	ASC SITE LOOKUP			
M_EFTORW(3-3)	V90U1813CB	EF TO PRIME RW XFORM MTRX ELE 3-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(1-1)	V90U1775CB	EF TO TOPO COORD AT TA SITE 1/1-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(1-2)	V90U1776CB	EF TO TOPO COORD AT TA SITE 1/1-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(1-3)	V90U1777CB	EF TO TOPO COORD AT TA SITE 1/1-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(2-1)	V90U1778CB	EF TO TOPO COORD AT TA SITE 1/2-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(2-2)	V90U1779CB	EF TO TOPO COORD AT TA SITE 1/2-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(2-3)	V90U1780CB	EF TO TOPO COORD AT TA SITE 1/2-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(3-1)	V90U1781CB	EF TO TOPO COORD AT TA SITE 1/3-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(3-2)	V90U1782CB	EF TO TOPO COORD AT TA SITE 1/3-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL1(3-3)	V90U1783CB	EF TO TOPO COORD AT TA SITE 1/3-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(1-1)	V90U1784CB	EF TO TOPO COORD AT TA SITE 2/1-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(1-2)	V90U1785CB	EF TO TOPO COORD AT TA SITE 2/1-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(1-3)	V90U1786CB	EF TO TOPO COORD AT TA SITE 2/1-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(2-1)	V90U1787CB	EF TO TOPO COORD AT TA SITE 2/2-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(2-2)	V90U1788CB	EF TO TOPO COORD AT TA SITE 2/2-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(2-3)	V90U1789CB	EF TO TOPO COORD AT TA SITE 2/2-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(3-1)	V90U1790CB	EF TO TOPO COORD AT TA SITE 2/3-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(3-2)	V90U1791CB	EF TO TOPO COORD AT TA SITE 2/3-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL2(3-3)	V90U1792CB	EF TO TOPO COORD AT TA SITE 2/3-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(1-1)	V90U1793CB	EF TO TOPO COORD AT TA SITE 3/1-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(1-2)	V90U1794CB	EF TO TOPO COORD AT TA SITE 3/1-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(1-3)	V90U1795CB	EF TO TOPO COORD AT TA SITE 3/1-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(2-1)	V90U1796CB	EF TO TOPO COORD AT TA SITE 3/2-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(2-2)	V90U1797CB	EF TO TOPO COORD AT TA SITE 3/2-2	ASC SITE LOOKUP			

CR89805

Space Transportation Systems Division
Rockwell International

Table 4.7.1-1. Ascent Area Navigation Processing (4.237) Input/Output Functional Parameters (Cont)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
M_EFTOTD_TACAN_SL3(2-3)	V90U1798CB	EF TO TOPO COORD AT TA SITE 3/2-3	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(3-1)	V90U1799CB	EF TO TOPO COORD AT TA SITE 3/3-1	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(3-2)	V90U1800CB	EF TO TOPO COORD AT TA SITE 3/3-2	ASC SITE LOOKUP			
M_EFTOTD_TACAN_SL3(3-3)	V90U1801CB	EF TO TOPO COORD AT TA SITE 3/3-3	ASC SITE LOOKUP			
MAZM_CMLK(1)	V95X6058X	MSBLS 1 AZ COMFAULT/LOCKON FLAG	MSBLS SOP			
MAZM_CMLK(2)	V95X6064X	MSBLS 2 AZ COMFAULT/LOCKON FLAG	MSBLS SOP			
MAZM_CMLK(3)	V95X6069X	MSBLS 3 AZ COMFAULT/LOCKON FLAG	MSBLS SOP			
MELV_CMLK(1)	V95X6057X	MSBLS 1 EL COMFAULT/LOCKON FLAG	MSBLS SOP			
MELV_CMLK(2)	V95X6063X	MSBLS 2 EL COMFAULT/LOCKON FLAG	MSBLS SOP			
MELV_CMLK(3)	V95X6068X	MSBLS 3 EL COMFAULT/LOCKON FLAG	MSBLS SOP			
MM_CODE_304/MM_304	V90X8161X	MAJOR MODE 304 FLAG	MSC			
MM_602	V90X8174X	MAJOR MODE 602 FLAG	MSC			
MRNG_CMLK(1)	V95X6056X	MSBLS 1 RANGE COMFAULT/LOCKON FLAG	MSBLS SOP			
MRNG_CMLK(2)	V95X6062X	MSBLS 2 RANGE COMFAULT/LOCKON FLAG	MSBLS SOP			
MRNG_CMLK(3)	V95X6067X	MSBLS 3 RANGE COMFAULT/LOCKON FLAG	MSBLS SOP			
MSBAZIMO(1)	V95H6122C	MSBLS 1 AZIMUTH OUT	MSBLS SOP	RAD		
MSBAZIMO(2)	V95H6222C	MSBLS 2 AZIMUTH OUT	MSBLS SOP	RAD		
MSBAZIMO(3)	V95H6322C	MSBLS 3 AZIMUTH OUT	MSBLS SOP	RAD		
MSBELEVO(1)	V95H6142C	MSBLS 1 ELEVATION OUT	MSBLS SOP	RAD		
MSBELEVO(2)	V95H6242C	MSBLS 2 ELEVATION OUT	MSBLS SOP	RAD		
MSBELEVO(3)	V95H6342C	MSBLS 3 ELEVATION OUT	MSBLS SOP	RAD		
MSBRANGEO(1)	V95H6102C	MSBLS 1 RANGE OUT	MSBLS SOP	FT		
MSBRANGEO(2)	V95H6202C	MSBLS 2 RANGE OUT	MSBLS SOP	FT		
MSBRANGEO(3)	V95H6302C	MSBLS 3 RANGE OUT	MSBLS SOP	FT		
OVHD	V95J0154CC	OVHD/STRT IND	RTLS UPP			
POSN_WRT_RW(VERT)	V95H0300CA	VERTICAL DISTANCE WRT RW	RTLS UPP	FT		
POSN_WRT_RW(1)/X	V95H0220CA	DOWNRANGE DISTANCE WRT RW	RTLS UPP	FT		
POSN_WRT_RW(2)/Y	V95H0221CA	CROSSRANGE DISTANCE WRT RW	RTLS UPP	FT		
PSI_HSIMU	V90H2212C	HEADING RELATIVE TO MAG NORTH	A/E ATT PROC	RAD		
R_CC_L_PRI(1)	V90H1925CB	X-COMP POS VCT HAC LFT SIDE RW	ASC SITE LOOKUP	FT		
R_CC_L_PRI(2)	V90H1926CB	Y-COMP POS VCT HAC LFT SIDE RW	ASC SITE LOOKUP	FT		
R_CC_L_PRI(3)	V90H1927CB	Z-COMP POS VCT HAC LFT SIDE RW	ASC SITE LOOKUP	FT		
R_CC_LMAG_PRI	V90H1931CB	MAG OF POS VCT HAC LFT SIDE RW	ASC SITE LOOKUP	FT		
R_CC_R_PRI(1)	V90H1928CB	X-COMP POS VCT HAC RHT SIDE RW	ASC SITE LOOKUP	FT		
R_CC_R_PRI(2)	V90H1929CB	Y-COMP POS VCT HAC RHT SIDE RW	ASC SITE LOOKUP	FT		
R_CC_R_PRI(2)	V90H1930CB	Z-COMP POS VCT HAC RHT SIDE RW	ASC SITE LOOKUP	FT		
R_CC_RMAG_PRI	V90H1932CB	MAG OF POS VCT HAC RHT SIDE RW	ASC SITE LOOKUP	FT		
R_EF(1)	V95H0155CB	ORBITER X POSITION EF(TOD)	RTLS UPP	FT	DPL	
R_EF(2)	V95H0156CB	ORBITER Y POSITION EF(TOD)	RTLS UPP	FT	DPL	
R_EF(3)	V95H0157CB	ORBITER Z POSITION EF(TOD)	RTLS UPP	FT	DPL	
R_LS_EF(1)	V90H1900CB	X-COMP LDG SITE POS VCT-EF COORD	ASC SITE LOOKUP	FT		
R_LS_EF(2)	V90H1901CB	Y-COMP LDG SITE POS VCT-EF COORD	ASC SITE LOOKUP	FT		
R_LS_EF(3)	V90H1902CB	Z-COMP LDG SITE POS VCT-EF COORD	ASC SITE LOOKUP	FT		
R_TACAN_EFSL1(1)	V90H1834CB	X-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP	FT		
R_TACAN_EFSL1(2)	V90H1835CB	Y-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP	FT		
R_TACAN_EFSL1(3)	V90H1836CB	Z-COMP EF POS VECTOR OF TACAN 1	ASC SITE LOOKUP	FT		
R_TACAN_EFSL2(1)	V90H1837CB	X-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP	FT		
R_TACAN_EFSL2(2)	V90H1838CB	Y-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP	FT		
R_TACAN_EFSL2(3)	V90H1839CB	Z-COMP EF POS VECTOR OF TACAN 2	ASC SITE LOOKUP	FT		
R_TACAN_EFSL3(1)	V90H1840CB	X-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP	FT		
R_TACAN_EFSL3(2)	V90H1841CB	Y-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP	FT		
R_TACAN_EFSL3(3)	V90H1842CB	Z-COMP EF POS VECTOR OF TACAN 3	ASC SITE LOOKUP	FT		
R_VEH_MAG_UPP	V95H0167CA	MAG SHUTTLE POS VECTOR	RTLS UPP	FT		

CR89599C

Space Transportation Systems Division
Rockwell International

Table 4.7.1-1. Ascent Area Navigation Processing (4.237) Input/Output Functional Parameters (Cont)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	PREC
RCVR_LEFT	V96J2105C	LH HSI RECEIVER SELECT	GN&C SW RM			
RCVR_RIGHT	V96J2205C	RH HSI RECEIVER SELECT	GN&C SW RM			
RD_TAC_SL(1)	V90H1861CB	GEODETIC RADIUS AT TACAN SITE 1	ASC SITE LOOKUP	FT		
RD_TAC_SL(2)	V90H1862CB	GEODETIC RADIUS AT TACAN SITE 2	ASC SITE LOOKUP	FT		
RD_TAC_SL(3)	V90H1863CB	GEODETIC RADIUS AT TACAN SITE 3	ASC SITE LOOKUP	FT		
SOURCE_LEFT	V96X2111X	LH HSI SOURCE SELECT	GN&C SW RM			
SOURCE_RIGHT	V96X2211X	RH HSI SOURCE SELECT	GN&C SW RM			
T_HPC	V95W3400C	ADS CORRECTED PRESS ALT TIME TAG	ADTA SOP	S	DPL	
TACAN_CHAN_VALID_SL1	V90X1858XB	TACAN CHANNEL VALIDITY FLAG(TAC 1)	ASC SITE LOOKUP			
TACAN_CHAN_VALID_SL2	V90X1859XB	TACAN CHANNEL VALIDITY FLAG(TAC 2)	ASC SITE LOOKUP			
TACAN_CHAN_VALID_SL3	V90X1860XB	TACAN CHANNEL VALIDITY FLAG(TAC 3)	ASC SITE LOOKUP			
TACBEARO(1)	V95H5122CA	TACAN NO 1 BEARING OUT	TACAN SOP	RAD		
TACBEARO(2)	V95H5222CA	TACAN NO 2 BEARING OUT	TACAN SOP	RAD		
TACBEARO(3)	V95H5322CA	TACAN NO 3 BEARING OUT	TACAN SOP	RAD		
TACRANGEO(1)	V95H5102CA	TACAN NO 1 RANGE OUT	TACAN SOP	FT		
TACRANGEO(2)	V95H5202CA	TACAN NO 2 RANGE OUT	TACAN SOP	FT		
TACRANGEO(3)	V95H5302CA	TACAN NO 3 RANGE OUT	TACAN SOP	FT		
TBRG_CMLK 1)	V95X5141XA	TACAN 1 BEAR COMFAULT/LOCKON FLAG	TACAN SOP			
TBRG_CMLK 2)	V95X5241XA	TACAN 2 BEAR COMFAULT/LOCKON FLAG	TACAN SOP			
TBRG_CMLK 3)	V95X5341XA	TACAN 3 BEAR COMFAULT/LOCKON FLAG	TACAN SOP			
TRNG_CMLK 1)	V95X5140XA	TACAN 1 RANGE COMFAULT/LOCKON FLAG	TACAN SOP			
TRNG_CMLK 2	V95X5240XA	TACAN 2 RANGE COMFAULT/LOCKON FLAG	TACAN SOP			
TRNG_CMLK 3	V95X5340XA	TACAN 3 RANGE COMFAULT/LOCKON FLAG	TACAN SOP			
V_RHO_EF 1	V95L3884CB	X VELOCITY VECTOR EF(TOD)	RTLS UPP	FT/S		
V_RHO_EF 2	V95L3885CB	Y VELOCITY VECTOR EF(TOD)	RTLS UPP	FT/S		
V_RHO_EF 3	V95L3886CB	Z VELOCITY VECTOR EF(TOD)	RTLS UPP	FT/S		
X_DMEAZ_RW	V90H1815CB	X-COMP RNG/AZ ANTENNA IN RW COORD	ASC SITE LOOKUP	FT		
X_E_RW	V90H1910CB	X-COMP OF ELEV ANTENNA IN RW COORD	ASC SITE LOOKUP	FT		
Y_DMEAZ_RW	V90H1816CB	Y-COMP RNG/AZ ANTENNA IN RW COORD	ASC SITE LOOKUP	FT		
[illegible]	V90H2294CA	RH ADI SEL EULER ANG YAW COSINE	A/E ATT PROC			
[illegible]	V95J0153CC	R/L CONE IND PRI RW	RTLS UPP			
	V96X2101X	LH HSI MODE SELECT	GN&C SW RM			
	V96X2201X	RH HSI MODE SELECT	GN&C SW RM			

Space Transportation Systems Division
Rockwell International

Table 4.7.1-1. Ascent Area Navigation Processing (4.237) Input/Output Functional Parameters (Cont)

DBFN: D3B008-D PN: VP707100037P00L JULY 17, 1989 OI8B REV00 PAGE 234
OUTPUT FUNCTIONAL PARAMETERS FROM ASCENT AREA NAVIGATION PROCESSING ASC AREA NAV 04.237 BOOK: 5

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
BRG_FLAG LEFT	V90X0970XB	LH BEARING DATA - VALID FLAG	HSI PROC			
BRG_FLAG RIGHT	V90X0971XB	RH BEARING DATA - VALID FLAG	HSI PROC			
CDI_FLAG LEFT	V90X0966XB	LH COURSE DEVIATION - VALID FLAG	HSI PROC			
CDI_FLAG RIGHT	V90X0967XB	RH COURSE DEVIATION - VALID FLAG	HSI PROC			
CDI LEFT	V90H0958CB	LH COURSE DEVIATION	HSI PROC	DEG		
CDI RIGHT	V90H0959CB	RH COURSE DEVIATION	HSI PROC	DEG		
GSI_FLAG LEFT	V90X09[illegible]2XB	LH GLIDESLOPE DEV DATA VALID FLAG	HSI PROC			
GSI_FLAG RIGHT	V90X09[illegible]3XB	RH GLIDESLOPE DEV DATA VALID FLAG	HSI PROC			
GSI LEFT	V90H0960[illegible]B	LH GLIDESLOPE DEVIATION	HSI PROC	FT		
GSI RIGHT	V90H0961[illegible]B	RH GLIDESLOPE DEVIATION	HSI PROC	FT		
HDG_FLAG LEFT	V90X0968XB	LH HEADING DATA - VALID FLAG	HSI PROC			
HDG_FLAG RIGHT	V90X0969XB	RH HEADING DATA - VALID FLAG	HSI PROC			
HEAD NOTE	V90H0[illegible]8CB	LH MAG HEADING OF RE VE VECTOR	HSI PROC	DEG		
HEAD NOTE RIGHT	V90H0[illegible]CB	RH MAG HEADING OF RE VE VECTOR	HSI PROC	DEG		
[illegible]	V90[illegible]CB	HSI [illegible] INDICATOR PRI	6 21			
PRI BEAR LEFT	V90H0[illegible]CB	LH PRIMARY BEARING	HSI PROC	DEG		
PRI BEAR RIGHT	V90H0[illegible]CB	RH PRIMARY BEARING	HSI PROC	DEG		
PRI RANGE LEFT	V90H0[illegible]CB	LH PRIMARY RANGE	HSI PROC	NM		
PRI RANGE RIGHT	V90H0[illegible]CB	RH PRIMARY RANGE	HSI PROC	NM		
SEC BEAR LEFT	V90H0[illegible]CB	LH SECONDARY BEARING	HSI PROC	DEG		
SEC BEAR RIGHT	V90H0[illegible]CB	RH SECONDARY BEARING	HSI PROC	DEG		
SEC RANGE LEFT	V90H0[illegible]CB	LH SECONDARY RANGE	HSI PROC	NM		
SEC RANGE RIGHT	V90H0[illegible]CB	RH SECONDARY RANGE	HSI PROC	NM		

Space Transportation Systems Division

Rockwell International

Table 4.7.1-2. Ascent Area Navigation Processing (4.237) I-Loads

OI8B MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	B	S	PR	FCTN	CAT
CUBC1(1,1)	V97U0087C	FT	F	S	M	C	G4.204 G4.237		ZFU2
CUBC1(1,2)	V97U0088C	FT	F	S	M	C	G4.204 G4.237		GT12
CUBC2(1,1)	V97U0091C	ND	F	S	M	C	G4.204 G4.237		XS31
CUBC2(1,2)	V97U0092C	ND	F	S	M	C	G4.204 G4.237		GT12
CUBC3(1,1)	V97U0095C	FT##-1	F	S	M	C	G4.204 G4.237		GT12
CUBC3(1,2)	V97U0096C	FT##-1	F	S	M	C	G4.204 G4.237		GT12
CUBC4(1,1)	V97U0099C	FT##-2	F	S	M	C	G4.204 G4.237		GT12
CUBC4(1,2)	V97U0100C	FT##-2	F	S	M	C	G4.204 G4.237		GT12
CUBRC(1)	V97U0107C	FT	F	S	M	C	G4.204 G4.237		GT12
HFTC(1)	V97U0291C	FT	F	S	D	C	G4.9 G4.204 G4.220 G4.237		ZFU2 ZFU2
HMEP(1)	V96U8636C	FT	F	S	D	C	G4.9 G4.204 G4.220 G4.237		ZFU2 ZFU2
RADIUS_EP	V99U6873C	FT	F	S	D	X	G4.220 G4.237		ZFV2
X_AIM_PT	V97U8445C	FT	F	S	M	C	G4.154 G5.7 G4.10 G4.234 G4.220 G4.237 G4.2		GL13 GL33
X_EP	V98U9427C	FT	F	S	D	C	G4.220 G4.237		XS80 XS80

DBFN:0464 DATE:07/29/88

STS 83 0001R
PCN 2 OI 8R
November 30, 1988

Space Transportation Systems Division
Rockwell International

Table 4.7.1-2. Ascent Area Navigation Processing (4.237) I-Loads (Cont)

DIDBB MISSIONS DBFN 0431
G4.2.7 - DDD5 - ASCENT AREA NAVIGATION PROCESSING
ACTIVE MEMORY CONFIGURATIONS 01

PFS ILOADS UPDATE B/L
TABLE
- 4.7.1-2

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR FCTN	CAT
[illegible]	V97U0456C	FT	F	S	M	X	G4.9 G4.204 G4.220 G4.237	XS31
[illegible]	V97U0457C	FT	F	S	M	X	G4.9 G4.204 G4.220 G4.237	XS31

Space Transportation Systems Division
Rockwell International

Table 4.7.1-3. Ascent Area Navigation (G4.237) K-Loads Ascent Area Navigation Processing

OI88 MISSIONS

FSSR NAME / DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT	PR	S	PR	FCTN	LAST CR EQTN MSID
M_GSI_SHALLOW	V97U9022C	+1.5000	E+03 FT	F	S	C	G4.220 G4.237		59960

DBFN:0534 DATE:07/14/88

Table 4.7.1-4. Ascent Area Navigation Processing (4.237) Constants

NROKRMM.FSSR2.DATA(X09)BOOK5
PFS CONSTANTS UPDATE B/L

FSSR NAME DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
DEG_PER_RAD RADIANS TO DEGREES CONVERSION FACTOR	V97U0112C		57.2957795131	DEG/RAD	F	S				
EARTH_RATE EARTH'S ROTATIONAL RATE	V97U4379C		.729211514646 0000 E-05	RAD/SEC	F	D				
ELLIPT EARTH'S ELLIPTICITY CONSTANT	V97U5332C		.335232980000 0000 E-02	ND	F	D				
NAUTMI_PER_FT FEET TO NAUTICAL MILES CONVERSION FACTOR	V97U5423C		.16457884 E-03	NMI/FT	F	S				
PI RATIO CIRCUMFERENCE TO DIAMETER	V98U8725C		3.1415926535897	ND	F	D				

STS 83-0005B
PCN-2 OI-8B

Space Transportation Systems Division
Rockwell International

Table 4.7.1-5. Ascent Area Navigation (4.237)
Cross-Reference

FSSR Name	Source Name
C0	CUBC1
C1	CUBC2
C2	CUBC3
C3	CUBC4
HC0	HFTC
M_EFTOTD_TACAN_SL(1)	M_EFTOTD_TACAN_SL1
M_EFTOTD_TACAN_SL(2)	M_EFTOTD_TACAN_SL2
M_EFTOTD_TACAN_SL(3)	M_EFTOTD_TACAN_SL3
R_TACAN_EF_SL(1)	R_TACAN_EFSL1
R_TACAN_EF_SL(2)	R_TACAN_EFSL2
R_TACAN_EF_SL(3)	R_TACAN_EFSL3
TAC_CHAN_VALID_SL	TACAN_CHAN_VALID_SL
X_GSI_HI_WINDS	XA(2)
X_GSI_NOMINAL	XA(1)
X_WP2	X_AIM_PT

4.8 SPECIALIST FUNCTIONS NAVIGATION SUPPORT FORMULATIONS

This section describes noncyclic navigation processing and data transfer required for the navigation system to respond to crew controls and data entered at the display keyboard, via a specialist function, and to provide the software support associated with that specialist function. Output from these formulations is not uniquely generated for the navigation system. Specialist functions navigation support formulations consist of the formulations required for keyboard entry of a delta state update.

4.8.1 Keyboard Delta State Update

The capability for keyboard entry of a delta state update shall be provided via the horizontal situation display (HSD) specialist function.

A. Detailed Requirements. The HSD keyboard support software shall interpret the keyboard entries and set the appropriate elements of the delta vectors needed by the cyclic navigation functions to the input values. This software shall also set flag, DO_DELTA_UPDATE, indicating to the navigation that a command to perform the delta state update has been entered via the keyboard. The navigation function will return this flag to the "OFF" position to preclude multiple updates.

B. Interface Requirements. Input and output parameters for this subformation are shown in Tables 4.8.1-1 and 4.8.1-2, respectively.

C. Processing Requirements. The keyboard delta state update data and execution command shall be provided only via keyboard entry.

D. Constraints. It is the responsibility of the crew to input the data (delta vectors) before commanding that a delta state update be performed. No method for testing the values of input data for errors is provided.

E. Supplemental Information. An example implementation of these requirements is shown in Section 5.5, ASCENT_KEYBOARD_PROCESSOR.

Table 4.8.1-1. Keyboard Delta State Update Input Parameters

Description	Symbol	Input Source	Type	Precision	Range	Units	Sample Rate
Keyboard entry for each component of DR_RW	DR_RW	Keyboard	V	S		ft	As needed
Keyboard entry for each component of DV_RW	DV_RW	Keyboard	V	S		ft/sec	As needed
Keyboard entry to initiate delta update processing	DO_DELTA_UPDATE	Keyboard	D		ON/OFF		As needed

Table 4.8.1-2. Keyboard Delta State Update Output Parameters

Description	Symbol	Output Destination	Type	Precision	Range	Units	Comp Rate
Position delta vector for delta state update	DR_RW	ASCENT NAV, RTLS NAV	V	S		ft	As needed
Velocity delta vector for delta state update	DV_RW	ASCENT NAV, RTLS NAV	V	S		ft/sec	As needed
Command to perform delta state update	DO_DELTA_UPDATE	ASCENT NAV, RTLS NAV	D	—	ON/OFF		As needed

4.9 DOWNLIST REQUIREMENTS

Downlist requirements for the ascent/RTLS operations computer load are discussed in the Computer Program Development Specification, Volume I, Book 4, (SS-P-0002-140), Downlist/Uplink Software Requirements.

4.9 DOWNLIST REQUIREMENTS

Downlist requirements for the ascent/RTLS operations computer load are discussed in the Computer Program Development Specification, Volume I, Book 4, (SS-P-0002-140), Downlist/Uplink Software Requirements.

4.10 UPLINK REQUIREMENTS

This section is included to discuss the navigation-related uplink capabilities, data, and any special processing requirements needed to enable proper action by the appropriate navigation function. This discussion is not intended to supplant the requirements imposed by the UPLINK/DOWNLIST CPDS (SS-P-0002-140) but rather to clarify the action necessary to provide the proper interfaces between the navigation function and other onboard software which interprets and decodes the uplinked data for applications processing. The term special processing requirement is used to identify computation, flag settings, or other actions performed by onboard software external to the navigation functions to provide or establish values for inputs needed by the navigation function.

This discussion is limited to the formatted uplink capabilities defined in the UPLINK/DOWNLIST CPDS. The formated uplink capabilities are:

1. DELTA STATE VECTOR UPDATE

2. ORBITER STATE VECTOR UPDATE

4.10.1 Delta State Vector Update

When a delta state vector update is received via command uplink (recognized by OP_CODE = 0100000) the following computations must be performed by the uplink processing software external to the navigation function for proper performance of the update to occur. The delta vectors DR_RW_UP and DV_RW_UP must be set to the uplinked values and the flag DO_DELTA_UPDATE_UP must be set to the ON position. The setting of the flag must follow the setting of DR_RW_UP and DV_RW_UP to the uplinked values. In addition, OP_CODE must be set to zero (OP_CODE = 0000000) to prevent repeated acquisition of the uplinked data.

Upon sensing DO_DELTA_UPDATE_UP to be in the ON position, the navigation function will perform the update to the navigation state vector and return the flag DO_DELTA_UPDATE_UP to the OFF position which will automatically inhibit multiple processing of the same uplinked data. The performance of the delta state update by the navigation function is described in Sections 4.2.5, 4.3.1.1, 4.3.1.3, 4.3.2.1, and 4.3.2.4.2.

An example of these special processing requirements is presented in the form of a flow chart (ASCENT_UPLINK_PROCESSING) in Section 5.5.

4.10.2 Orbiter State Vector Update

When an orbiter state vector update is received via command uplink (recognized by OP_CODE = 0001001) the following actions must be taken by the uplink processing software external to the navigation function. The vectors R_GND and V_GND and the time tag T_GND must be set to the uplinked values. The OP_CODE must be set to zero (OP_CODE = 0000000) to prevent repeated acquisition of the uplinked data. Following the setting of R_GND, V_GND, and T_GND to the uplinked values, execution of the ascent state vector prediction task (Section 4.3.1.4) shall be initialized.

The completion of the orbiter state vector update will then be performed by the navigation function as described in Sections 4.3.1.1 and 4.3.1.4.

An example of these special processing requirements is presented in the form of a flow chart (ASCENT_UPLINK_PROCESSING) in Section 5.5.

Table 4.7.1-4. Ascent Area Navigation Processing (4.237) Constants

[illegible] FSSR2 DATA X89 BOOKS
PFS CONSTANTS UPDATE 8/L

FSSR NAME DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
DEG PER RAD RADIANS TO DEGREES CONVERSION FACTOR	V97U0112C		57.2957795131	DEG/RAD	F	S				
EARTH RATE EARTH S ROTATIONAL RATE	V97U4379C		.729211514646 0000 E-04	RAD/SEC	F	D				
ELLIPT EARTH S ELLIPTICITY CONSTANT	V97U5332C		.335232980000 0000 E-02	ND	F	D				
NAUTMI PER FT FEET TO NAUTICAL MILES CONVERSION FACTOR	V97U5423C		.16457884 E-03	NMI/FT	F	S				
PI RATIO CIRCUMFERENCE TO DIAMETER	V98U8725C		3.1415926535897	ND	F	D				

CR89596C

This page left intentionally blank.

5.0 SUPPLEMENTAL MATERIAL

5.0 SUPPLEMENTAL MATERIAL

The material in this section is provided for information. It is divided by major functions as follows:

Section 5.1 and 5.2	Basic Ascent/RTLS Navigation
Section 5.3	Coordinate System
Section 5.4	Area Navigation
Section 5.5	Specialist Functions
Section 5.6	User Parameter Processing

5.1 NAVIGATION SEQUENCER PRINCIPAL FUNCTIONS AND NAVIGATION PRINCIPAL FUNCTIONS VARIABLES NAMES AND DESCRIPTIONS

Provided in Table 5.1-1 is a list of the total navigation variables for Ascent/RTLS excluding user processing and specialist functions. Listed below are definitions which will aid in interpreting Table 5.1-1. Note that this variable list is directly correlated to the flow charts in Section 5.2.

DEFINITIONS

Code used for variable data type

F: floating point scalar

S: scalar

V: vector

M: square matrix

INT: integer

BIT: bit

B(M): M digit bit string

CHAR: character

STR: structure

ARR: array

Coordinate frame code and definition

Body: (structural)
- x: parallel to the longitudinal axis (positive aft)
- y: completes right-hand system
- z: perpendicular to the x-axis, positive upward

EF: Earth-fixed coordinate system

M50: Mean of 50 reference coordinate system

RW: (runway coordinates)
- x: down runway centerline in direction of landing
- y: completes right-hand system
- z: down, normal to ellipsoid

SCAN: (MLS scanner coordinates)	x:	scanner boresight axis
	y:	completes right-hand system
	z:	up, normal to ellipsoid
TD: (topodetic coordinates)	x:	north
	y:	east
	z:	down, normal to ellipsoid
UVW	Quasi-inertial, right-handed Cartesian coordinate system	

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
A	ARR	0	--	Array for temporary storage of Legendre polynomials Pine's formulation
ACC_SENSED	S	0	--	Magnitude of non-gravitational acceleration computed by navigation
ACC_DRAG	S	0	--	Vehicle c.g. drag acceleration
ACC_DRAG_MIN	S	Pad	--	Minimum acceleration magnitude required for processing drag data
ACCEL	V	0	M50	Modeled acceleration vector
ACC_PROP_MIN	S	0	--	Minimum magnitude of non-gravitational acceleration required for employment of data in state propagation
ADS_MJ	BIT	Off	--	Flag indicating (ON) that the orbiter is in the Mach jump region
ACC_PROP_MIN_REF	S	Pad	--	Reference value for initializing ACC_PROP_MIN
ALP	S	0	--	Angle of attack for computing drag coefficient (expressed in radians)
ALPHA	S	0	--	Angle of attack used in state propagation (radians)
ALPHAIN	S	0	--	Snapped copy of angle of attack (degrees)
ALT	S	0	--	Current orbiter altitude above reference ellipsoid
ALT_NAV_EVLT	V	Pad	--	Altitude regions for nav event lamp processing
ALT_BARO_CUTOFF*	S	I-load	--	Baro processing cutoff altitude

*Initial I-Load value is the processing cutoff altitude if MSBLS Data Processing is terminated at high altitude.

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
ALT_BARO_CUTOFF_ HIGH	S	I-load	—	Baro processing cutoff altitude if MSBLS data processed at low vehicle altitudes
ALT_RW	S	0	—	Altitude of runway reference point above reference ellipsoid
ALT_WHEELS	S	0	—	Altitude of Orbiter c.g. (entry) or rear wheels (TAEM A/L) above the runway altitude
ALT_ZONE_CHANGE	S	Pad	—	Altitude where model for atmospheric density is changed
ANGLE_CORR_ TNTOMAG	S	0	—	Copy of ANGLE_CORR_TNTOMAG_SL for navigation processing
ANGLE_CORR TNTOMAG_SL	S	Pad	—	Variation of magnetic north from true north at TACAN site obtained from site lookup
ASCENT_INIT_ COMPLETE	BIT	Off	—	Signal to MSC indicating completion of ascent nav initialization
A _SENSED	V	0	M50	Sensed acceleration for use by the UPP propagator
AUXILIARY	S	0	—	Intermediate variable in the Pine's formulation
B	V(6)	0	—	Measurement first partials with respect to filter state
BARO_AIF	CHAR	Auto	—	Auto-inhibit-force switch for barometric altimeter sensor selection
BARO_AIF_RCVD	CHAR	Auto	—	Copy of baro AIF to be used by HSD
BARO_DATA_GOOD	BIT	Off	—	Copy of current data-good discrete reserved for measurement processing
BARO_EDIT_ OVERRIDE	BIT	Off	—	Switch used to force incorporation of barometric data regardless of residual edit test

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
BARO_MARK_NUM	INT	0	--	Counter indicating the number of times that barometric measurement was selected for filter processing
BARO_STAT	BIT	Off	--	Flag indicating stat-flag setting for barometric measurements
BASE_DEN	V(4)	Pad	--	Vector of base densities for each layer to model drag
BETA	S	0	--	Sideslip angle used in ACCEL function
BETAIN	S	0	--	Copy of sideslip angle snapped (degree)
BIAS_AZMLS	S	Pad	--	MLS azimuth antenna measurement bias
BIAS_BARO	S	Pad	--	Barometric altimeter measurement bias
BIAS_DRAG	S	0	--	Drag measurement bias
BIAS_DRAG_ LAYER	V(4)	Pad	--	Vector of deterministic drag biases for each layer
BIAS_ELMLS	S	Pad	--	MLS elevation antenna measurement bias
BIAS_MLSRANGE	S	Pad	--	MLS range antenna measurement bias
BT_E_B	S	0	--	Variable used to store the calculation of B*E*B TRANSPOSE
C	V(9)	Pad	--	Tesseral harmonic coefficients in gravity model
CD	S	--	--	Shuttle's drag coefficient
CDA	S	Pad	--	Constant used to model drag coefficient (additional corrective term)
CDF	S	Pad	--	Constant used to model drag coefficient (frontal area)

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
CDN	S	Pad	--	Constant used to model drag coefficient (top area correction)
C_DRAG	S	0	--	Drag coefficient
C_DRAG_ONE	S	Pad	--	Polynomial term for computing drag coefficient as function of angle of attack
C_DRAG_TWO	S	Pad	--	Polynomial term for computing drag coefficient as function of angle of attack
C_DRAG_ZERO	S	Pad	--	Polynomial term for computing drag coefficient as function of angle of attack
CDS	S	Pad	--	Constant used to model drag coefficient (side area correction)
COLUMN	INT	0	--	Local variable subscript used by MEAS_PROCESSING_STATISTICS_RTLS
COR	V(7)		UVW	Generalized correlation coefficients
CORR_COEFF_RTLS	V(7)	Pad	UVW	Correlation coefficients to initialize covariance matrix for RTLS
CORR_COEFF_ UPDATE	V(7)	Pad	UVW	Correlation coefficients to initialize covariance matrix for manual update
D	V	0	M50	Drag acceleration vector
DELH_MSL_ ELLIPSOID_RW	S	Pad	--	Altitude of mean sea level above reference ellipsoid at runway
DELQ	S	0	--	General term for measurement residual
DEL_TIME_STEP	S	Pad	--	Step size for prediction whole vector update
DENSE	V(6)	Pad	--	Coefficients used to model atmospheric density in ACCEL

CR89596C

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
DELCD	S	0	—	Additive CD factor which accounts for effects of angle of attack and altitude variations
DENSITY_LIMIT	V(4)	Pad	—	Altitudes defining drag atmosphere model layers
DIFCD1	S	Pad	—	Constant used in expression for computing DIFF_CD
DIFCD2	S	Pad	—	Constant used in expression for computing DIFF_CD
DIFCD3	S	Pad	—	Constant used in expression for computing DIFF_CD
DIFCD4	S	Pad	—	Constant used in expression for computing DIFF_CD
DIFF_CD	S	0	—	Difference between the coefficients of drag at 600,000 ft and 300,000 ft as a function of angle of attack
DISP_DELQ	V(7)	0	—	Display measurement residual for Ith sensor measurement
DISP_EDIT	V(7)	Blank	—	Display edit history indicator for Ith sensor measurement
DISP_SIG	V(7)	0	—	Display residual ratio Ith sensor measurement
DNM	S	0	—	Variable used in Pine's gravity model formulation
DNSA	S	0	—	Variable used in density calculations
DNSB	S	0	—	Variable used in density calculations
DNSC	S	0	—	Variable used in density calculations
DO_BARO_NAV	BIT	Off	—	Flag indicating (ON) that barometric altimeter data are to be processed

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
DO_DRAG_NAV	BIT	Off	--	Flag indicating (ON) that drag altitude data are to be processed
DO_DELTA_ UPDATE	BIT	Off	--	Flag indicating (ON) that a delta state update is to be performed
DO_DELTA_ UPDATE_UP	BIT	Off	--	Flag indicating (ON) that a delta state update has been received via command uplink
DO_MLS_NAV	BIT	Off	--	Flag indicating (ON) that MLS data are to be processed
DO_TACAN_NAV	BIT	Off	--	Flag indicating (ON) that TACAN data are to be processed
DR	V	0	M50	Ground computed position deviation to update onboard state vector (rotated to mean of 1950 coords)
DRAG_AIF	CHAR	Auto	--	Auto-inhibit-force switch used in drag data selection
DRAG_AIF_RCVD	CHAR	Auto	--	Copy of drag AIF to be used by HSD
DRAG_CONST	S	0	--	Drag constant equal to the vehicle reference area divided by twice the vehicle mass
DRAG_CONST_RTLS	S	Pad	--	Drag constant - Post ET SEP during RTLS
DRAG_EDIT_ OVERRIDE	BIT	Off	--	Flag indicating (ON) that the residual edit test on drag data is overridden
DRAG_MARK_NUM	INT	0	--	Counter indicating the number of times that drag measurement was selected for filter processing
DRAG_PARAM	S	0	--	Local variable used in drag navigation
DRAG_STAT	BIT	Off	--	Flag indicating stat-flag setting to be used for drag data

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
DR_RW	V	0	RW	Ground computed position deviations to update onboard state vector
DR_RW_UP	V	0	RW	Ground computed position deviations to update onboard state vector - received via command uplink
DT_ASCENT_NAV	S	Pad	—	Sequencing time interval for ascent navigation
DT_FILT	S	0	—	Interval over which to propagate the state vector(s) and covariance matrix
DT_GRTLS_NAV_ HIGH	S	Pad	—	High-rate sequencing time interval for RTLS navigation
DT_GRTLS_NAV_ LOW	S	Pad	—	Low-rate sequencing time interval for RTLS navigation
DT_INTERP	S	0	—	State vector interpolation time interval
DT_MAX	S	0	—	Maximum time step for ascent precise predictor
DT_RTLS_ SECOND STAGE	S	Pad	—	Sequencing time interval for ascent nav during RTLS second stage
DV_FILT	V	0	M50	Difference between accumulated sensed IMU readings on present cycle and previous cycle
DV_RW	V	0	RW	Ground computed velocity deviations to update onboard state vector
DV_RW_UP	V	0	RW	Ground computed velocity deviations to update onboard state vector received via command uplink
E	M	0	M50	Filter covariance matrix
EARTH_MU	S	Pad	—	Gravitational constant of earth
EARTH_POLE	V	Pad	M50	Unit vector in direction of earth's axis of rotation

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
EARTH_RADIUS_ EQUATOR	S	Pad	—	Earth equatorial radius
EARTH_RADIUS_ GRAV	S	Pad	—	Earth radius used for gravity oblateness calculations
EARTH_RATE	S	Pad	—	Earth rotation rate
EB_COPY	V	0	M50	Variable used to reserve the product of the covariance matrix and the partials vector B
EDIT_ARRAY	ARR	0	—	Array of one edit flags display processing
EDIT_FLAG	BIT	Off	—	General variable for edit flags
ELLIPT	S	Pad	—	Earth ellipticity constant
E_TEMP	M	0	—	Temporary matrix for covariance initialization
EPS_TAG	S	Pad	—	Criterion for difference between measurement time and state time, above which the filter state will be extrapolated for residual calculations
EVENT 14	BIT	Off	—	MSC event (T_L - 8 sec)
EVENT_A30	BIT	Off	—	Crew pro to major mode from MM 102
EVENT_A31	BIT	Off	—	Crew pro to major mode 601 from MM 103
EVENT_A39	BIT	Off	—	RTLS entry major mode transition (602)
EVENT_43A	BIT	Off	—	MSC event (terminate MPS dump and stow SSME's)
EVENT_45	BIT	Off	—	MSC event: OMS-2 TIG-15 sec
EVENT_47B	BIT	Off	—	MSC event indicating RCS backup translation burn

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
EVENT_48B	BIT	Off	--	MSC event (OMS engine purge complete)
EVENT_60	BIT	Off	--	MSC event (terminate OPS-1 to OPS-2)
EVENT_50	BIT	Off	--	MSC event (terminate OPS-1 to OPS-3)
NAV_EDIT_IND	BIT	Off	--	Nav edit flag
EXP_SHAPE_ FACTOR	S	Pad	--	Exponential shaping factor for drag coefficient model
FIFTY	M	0	--	General transformation matrix from EF to M50 coordinates
FILT_UPDATE	BIT	Off	--	Switch indicating (ON) that current measurement processing is complete for UPP propagator reset
F1	S	0	--	Auxiliary variable in Pine's gravity model formulation
F2	S	0	--	Auxiliary variable in Pine's gravity model formulation
F3	S	0	--	Auxiliary variable in Pine's gravity model formulation
F4	S	0	--	Auxiliary variable in Pine's gravity model formulation
G	V	0	M50	Gravity acceleration
G_FINAL	V	0	M50	Modeled acceleration vector at end of prediction
GMD	S	0	--	General term indicating degree of modeled acceleration
GM_DEG	S	0	--	Integer indicating degree of modeled acceleration
GMD_PRED	INT	0	--	Degree of gravity model for predictor
GMO	S	0	--	General term indicating order of modeled acceleration

CR89947A

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
GMO_PRED	INT	0	—	Order of gravity model for predictor
GM_ORD	S	0	—	Integer indicating order of modeled acceleration
G_OLD	V	0	M50	Gravity acceleration at start of Shuttle state integration interval
GRAV_GRAD_NEW	M	0	M50	Gravity gradient at end of transition matrix integration interval
GRAV_GRAD_OLD	M	0	M50	Gravity gradient at start of transition matrix integration interval
G_RESET	V	0	M50	Total vehicle acceleration vector stored for reset of the user parameters staff propagator
H_DRAG_LOW	S	Pad	—	Altitude below which the drag data are not processed
H_INHIB	BIT	Off	—	Flag used to indicate (ON) that attitude data have been deselected because of altitude or acceleration constraints
H_S	S	0	—	Atmospheric scale height for density calculation
I	INT	1	—	Integer-subscript or iteration counter
ID_MATRIX_3x3	M	Pad	—	Identity matrix (3x3)
IN_CONE_FLAG	BIT	Off	—	Flag used to indicate that cone of confusion condition exists for TACAN bearing data
I_Z	V	0	M50	Unit vector along TACAN, MLS azimuth, or elevation scanner coordinate Z-axis
I_Z_CROSS_RELR	V	0	—	Temporary vector in ANGLE_PARTIALS

CR89947A

CR89596C

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
J	INT	1	--	Integer - subscript or iteration counter
K	INT	1	--	Integer used in Pine's formulation
K_EDIT_BARO	S	Pad	--	Scale factor on filter mean square residual used in residual edit test for baro measurement
K_EDIT_DRAG	S	Pad	--	Scale factor of filter mean square residual used in residual edit test for drag measurement
K_EDIT_MLSAZ	S	Pad	--	Scale factor on filter mean square residual used in residual edit test for MSBLS azimuth measurement
K_EDIT_MLSEL	S	Pad	--	Scale factor on filter mean square residual used in residual edit test for MSBLS elevation measurement
K_EDIT_MLSR	S	Pad	--	Scale factor on filter mean square residual used in residual edit test for MSBLS range measurement
K_EDIT_TACBR	S	Pad	--	Scale factor on filter mean square residual used in residual edit test for TACAN bearing measurement
K_EDIT_TACR	S	Pad	--	Scale factor on filter mean square residual used in residual edit test for TACAN range measurement
K_MAX	S	Pad	--	Maximum number of edits allowed a measurement before display of edit warning
KN1	S	Pad	--	Constant used in expression for computing logarithm of Knudsen number for altitudes less than 400,000 ft
KN2	S	Pad	--	Constant used in expression for computing logarithm of Knudsen number for altitudes less than 400,000 ft

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
KN3	S	Pad	--	Constant used in expression for computing logarithm of Knudsen number for altitudes less than 400,000 ft
KN4	S	Pad	--	Constant used in expression for computing logarithm of Knudsen number for altitudes between 400,000 and 600,000 ft
KN5	S	Pad	--	Constant used in expression for computing logarithm of Knudsen number for altitudes between 400,000 and 600,000 ft
KN6	S	Pad	--	Constant used in expression for computing logarithm of Knudsen number for altitudes between 400,000 and 600,000 ft
K_RES_EDIT	S	Pad	--	Scale factor on filter mean square residual used in residual edit test
K_UND_WGT	S	Pad	--	Scale factor used in measurement under weighting equation
L	INT	1	--	Integer used in Pine's gravity formulation
LAYER	INT	0	--	Integer index used in the drag layer model in drag navigation
LOG_10_KN	S	0	--	Logarithm of Knudsen number
M	M	0	--	General transformation matrix
MANUAL_EDIT_ OVERRIDE	BIT	Off	--	Flag indicating (ON) that the filter's residual edit test is to be overridden
MAX_TIME_TOL	S	Pad	--	Maximum time difference between the onboard state time tag and an uplinked whole vector time tag for which the update will be accepted

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
M_EFTOM50	M	0	—	Earth fixed to M50 coordinate transformation matrix
M_EFTORAD_EL	M	0	—	Transformation matrix from earth-fixed to MSBLS elevation radar coordinates
M_EFTORAD_R_AZ	M	0	—	Transformation matrix from earth-fixed to AZ/range MSBLS radar coordinate frame
M_EFTORW	M	0	—	Earth-fixed to runway coordinate transformation for selected runway
M_EFTOTD_TACAN	M	0	—	Copy of M_EFTOTD_TACAN_SL from site lookup
M_EFTOTD_TACAN_SL	M	Pad	—	Transformation matrix from earth-fixed to topodetic coordinates at TACAN site obtained from site lookup
MSL_AVAIL	BIT		—	Flag indicating (ON) the availability of MSBLS transmitters at the currently selected runway
MLS_COV_INIT	BIT	Off	—	Switch to initialize portions of the covariance matrix to zero when MSBLS is first acquired
MLS_MARK_NUM	INT	0	—	Counter indicating the number of times that MSBLS measurement was selected for filter processing
MLS_R_AZ_GOOD	BIT	Off	—	Switch that indicates when a good set of MLS range and azimuth data has been obtained
MLSANT_ANG	S	Pad	—	Angle between navigation base-to-MLS antenna vector and positive vehicle X_ body axis
MLSANT_NB_DIST	S	Pad	—	Distance from navigation base-to-MLS antenna

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
MLSAZ_DATA_GOOD	BIT	Off	—	Copy of current data-good discrete reserved for measurement processing
MLSEL_DATA_GOOD	BIT	Off	—	Copy of current data-good discrete reserved for measurement processing
MLS_PHASE	BIT	Off	—	Flag indicating (ON) that high-rate navigation has been initiated
MLSRANGE_DATA_GOOD	BIT	Off	—	Copy of current data-good discrete reserved for measurement processing
MM_CODE	INT	0	—	Major mode number (set by MSC for use by navigation)
M_M50_TO_SCANNER	M	0	—	Transformation matrix from M50 to MLS scanner coordinates
M_M50T0TD	M	0	—	Transformation matrix M50 to topodetic coordinates
MSBLS_EL_ANGLE_CUTOFF	S	Pad	—	Angle below which MSBLS elevation data not used to update state vector
MSBLS_EL_INHIBIT	BIT	OFF	—	Flag indicating (ON) that MSBLS elevation data updates to the state vector have been terminated
MS_DELQ	S	0	—	Filter estimated mean squared measurement residual
MS_POS_UND_WGT	S	Pad	—	Value of filter mean squared position error below which no measurement underweighting is used
M_TEMP	M	0	—	Transformation matrix
N	INT	1	—	General indexing integer
N1	INT	1	—	General indexing integer
NAUTMI_PER_FT		Pad	—	Nautical miles per foot .
NAVBASE_ALT_ZERO	S	Pad	—	Altitude of vehicle nav base at reference point on pad

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
NAVBASE_LAT_ ZERO	S	Pad	—	Longitude of vehicle nav base at reference point on pad
NAVBASE_LONG_ ZERO	S	Pad	—	Longitude of vehicle nav base at reference point on pad
NAV_ALT_FLAG	BIT	Off	—	Nav edit altitude crew alert
NAV_TAC_FLAG	BIT	Off	—	Nav edit TACAN crew alert
NAV_MLS_FLAG	BIT	Off	—	Nav edit MSBLS crew alert
NOISE	S	0	—	State process noise added to velocity diagonals of filter covariance matrix
NOISE_R	S	0	—	State process noise added to position diagonals of filter covariance matrix
NOISE_RV	S	0	—	State process noise added to off diagonals of position-velocity sub-matrix of filter covariance matrix
N_SEQ_ALT	INT	0	—	Sequential counter, nav altitude
N_SEQ_TAC	INT	1	—	Sequential counter, nav TACAN
N_SEQ_MLS	INT	0	—	Sequential counter, nav MSBLS
N_SEQ_MAX	INT	Pad	—	Number of sequential failures of the nav event lamp test criteria allowed before activating the event lamp
OMEGA	V	0	—	Kalman filter gain vector
ONE_BRG_LOCK	BIT	Off	—	TACAN RM one LRU bearing lockon requirement flag
ONE_RANGE_LOCK	BIT	Off	—	TACAN RM one LRU range lockon requirement flag
PHI	M	0	—	Transition matrix for covariance propagation
PI	S	Pad	—	The constant PI
PITCH_M	S	0	—	Copy of pitch-store reserved for MLS elevation processing

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
R_ELMLS	V	0	M50	Position vector of MLS elevation scanner in M50 coordinates
R_ELMLS_EF	V	0	EF	Earth-fixed MLS elevation scanner position vector
REL_R	V	0	M50	Vector from sensor ground station to vehicle
RESID_TEST	S	0	—	General resid test variable
R_FILT	V	0	M50	Filter current Shuttle position vector in M50 coordinates
R_FILT_INIT	V	0	M50	Shuttle position vector for OPS 2, 3, or 8 initialization
R_FINAL	V	0	M50	Final position vector from ASC_PRECISE_PREDICTOR (WHOLE VECTOR_UPDATE)
R_GND	V	0	M50	Uplinked Shuttle M50 position vector
RHO	S	0	—	General range variable also, atmospheric density
RHO_ZERO	S	—	—	Copy of BASE_DEN for the selected layer
R_INIT	V	0	M50	Initial position vector for prediction
R_INV	S	0	—	Inverse of the magnitude of the position vector
R_LAUNCH_EF	V	0	EF	Initial navigation base position vector in earth-fixed coordinates
RNG	S	—	—	Range from the TACAN station to the vehicle
RNG_VAR_BEARING_STEP	S	Pad	—	Range criterion used to select TACAN bearing variance

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
RNG_VAR_RNG_ STEP	S	Pad	—	Range criterion used to select TACAN range variance
RO_N	S	0	—	Variable used in gravity model
RO_ZERO	S	0	—	Variable used in gravity model
R_RESET	V	0	M50	Vehicle position vector after all navigation updates reserved for reset of guidance integrator position vector
R_RESID	V	0	M50	Vehicle position vector used in measurement residual calculation after interpolation to time of measurement
R_RHO	S	0	—	Magnitude of general position vector, R
R_RMLS_EF	V	0	EF	Earth-fixed position vector of MLS range scanner
R_SCANNER	V	0	M50	General M50 position vector used in range residual calculations
R_SENSOR	V	0	M50	Sensor ground station position vector
R_TACAN_EF	V	—	EF	Copy of R_TACAN_EF_SL for TACAN station used by navigation filter
R_TACAN_ EF_SL	V	—	EF	TACAN station earth-fixed position vector obtained from site lookup
R_TO_NAV	V		M50	Uplinked whole vector predicted to current time
RV_MAG	S	0	—	Orbiter relative velocity magnitude
RV_MAX	S	Pad	—	Maximum relative velocity magnitude for baro processing
S	V	Pad	—	Tesseral harmonic coefficients in gravity model

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
Q	S	0	--	Measurement estimate
Q_AZMLS	S	Pad	--	MSBLS azimuth sensor measurement
Q_BARO	S	0	--	Barometric altimeter sensor measurement
Q_DRAG	S	0	--	Pseudodrag altitude generated sensor measurement
Q_ELMLS	S	Pad	--	MSBLS elevation sensor measurement
Q_RANGE	S	Pad	--	MSBLS range sensor measurement
Q_TAC_BRG	S	0	--	TACAN bearing sensor measurement
Q_TAC_R	S	0	--	TACAN range sensor measurement
R	V	0	M50	General Shuttle position vector
RAD_PER_DEG	S	Pad	--	Conversion constant in degrees to radians
R_AZ_COUNT	INT	0	--	Running count of number of consecutive MLS azimuth and range measurements, failing data-good test
R_AZ_COUNT_MAX	S	Pad	--	Prescribed number of consecutive MLS azimuth measurement data-good 'fails' to force inhibit of MLS processing and allow TACAN processing
R_AZMLS	V	0	M50	Position vector of MLS azimuth scanner in M50 coordinates
R_AZMLS_EF	V	0	EF	Earth-fixed MLS azimuth scanner position vector
R_COV_LAST	V	0	M50	Updated vehicle position vector associated with current covariance matrix
R_EF	V	0	EF	General position vector in earth-fixed coordinates

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
SA	S	0	--	Sine of alpha
SB	S	0	--	Sine of beta
SCALE_HT	V	I-load	--	Array of scale heights for each layer of the drag model
SEA_LEVEL_ DENSITY	S	K-load	--	Sea level atmosphere density
SEL_LRU_ID	INT	0	--	Integer indicating which TACAN LRU (1, 2, or 3) is selected by RM for use by navigation filter for TACAN data processing
SENSOR_DELQ	V	0	--	Vector of measurement residuals for display purposes
SENSOR_EDIT	V	Off	--	Edit indicator for measurement types
SENSOR_RESID_ TEST	V	0	--	Vector of residual edit test values for measurements to be used for display
SIG	V	0	--	General term for square root of diagonal elements of covariance matrix
SIG_DIAG_ UPDATE	V	K-load	UVW	Square root of diagonal elements for manual update covariance initialization
SIG_DIAG_ UVW_RTLS	V	K-load	UVW	Square root of diagonal elements for OPS 6 covariance matrix initialization
S2B	S	0	--	Sine of double the sideslip angle
STAT_FLAG	BIT	Off	--	Switch indicating (ON) that only filter statistics are to be generated for display with no incorporation of measurements into the filter state

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
STATE_VECTOR_ UPDATE	BIT	Off	--	Flag indicating (ON) that a whole vector update has been predicted to current time and is ready for incorporation by navigation
SUM	V	0	--	Accumulated sum of post-residual edits
SV_TIME_TAG_ DIFF	S	Pad	--	Maximum difference between the current filter state time tag and a state vector update time tag for which the prediction is considered to be complete
T	S	0	--	Time tag for Shuttle state vector
TAC_AIF_RCVD	CHAR	Auto	--	Copy of TACAN_AIF to be used by HSD
TACAN_AIF	CHAR	Auto	--	AUTO_INHIBIT_FORCE switch for TACAN sensor selection
TACAN_BRG_ CONVERG_TEST	S	Pad	--	Expected bearing variance criterion to turn on TACAN RM bearing one-lock flag
TACAN_CHAN_ VALID	BIT	Off	--	Copy of TACAN_CHAN_VALID_SL for TACAN station used by navigation filter
TACAN_EDIT_ OVERRIDE	BIT	Off	--	Switch used to override TACAN residual edit test
TACAN_ ID(I)	S	--	--	ID of the TACAN station to be used by filter for LRU I, I = 1, 3
TACAN_ID_LAST	INT	0	--	Previous value of TACAN_ID_FILTER
TACAN_MARK_NUM	INT	0	--	Counter indicating the number of times that TACAN measurement was selected for filter processing
TACAN_RNG_ CONVERG_TEST	S	Pad	--	Expected range variance criterion to turn on TACAN RM range one-lock flag
TACAN_STAT	BIT	Off	--	Flag indicating TACAN data processed only for statistical display

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
TAC_BRG_DATA_GOOD	BIT	Off	--	Copy of current data-good discrete reserved for measurement processing
TAC_CHAN_VALID_SL	BIT	Off	--	TACAN channel validity flag obtained from site lookup
TAC_RNG_DATA_GOOD	BIT	Off	--	Copy of current data-good discrete reserved for measurement processing
T_BARO	S	0	--	Time tag associated with barometric measurement
T_CURRENT_FILT	S	0	--	MTU or clock time when IMU was read
T_EF_AZMLS	S	0	--	Time tag of current MSBLS azimuth measurement
T_EF_ELMLS	S	0	--	Time tag of current MSBLS elevation measurement
T_EF_RMLS	S	0	--	Time tag of current MSBLS range measurement
TEMP_RCS_FLAG	BIT	Off	--	Internal flag used by the ASCENT_NAV_SEQ
T_FILT_INIT	S	OPS 2	--	Time of current filter state vector and covariance matrix for OPS reconfiguration
T_FINAL	S	0	--	Time at which state is desired - for predictor
T_GND	S	0	--	Time tag of uplinked state vector
THETAIN	S	0	--	Snapped pitch angle (degrees)
TIME_BIAS_BARO	S	Pad	--	Pad-loaded bias used to correct barometric time tag
TIME_BIAS_MLS	S	Pad	--	Pad-loaded bias used to correct MSBLS time tags
TIME_BIAS_TACAN	S	Pad	--	Pad-loaded bias used to correct TACAN time tag

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
T_IMU_LAST	S	0	--	Old value of IMU data time tag
T_INIT	S	0	--	Time tag of state vector at beginning of prediction
T_L	S	Pad	--	Time of liftoff general time tag
T_LAST_FILT	S	0	--	Time of the filter state vector
T_RESET	S	0	--	Time associated with reserved reset state
T_SENSORS	S	0	--	General time tag of sensor data
T_TACAN	S	--	--	Time at which TACAN was read
T_TO_NAV	S	0	--	Time tag of uplinked-predicted update vectors
UR	V	0	M50	Unit vector of R position vector
USE_IMU_DATA	BIT	Off	--	Flag indicating whether IMU data are to be used for propagation
V	V		M50	General Shuttle velocity vector in M50 coordinates
VAR	S	Pad	--	General sensor variance
VAR_ACC_QUANT	S	Pad	--	Accelerometer quantization error variance
VAR_AZMLS	S	Pad	--	MSBLS azimuth measurement instrument variance
VAR_DRAG	S	Pad	--	Drag altitude measurement error variance
VAR_ELMLS	S	Pad	--	MSBLS elevation instrument variance
VAR_H1	S	Pad	--	Barometric altimeter instrument variance constant
VAR_H2	S	Pad	--	Barometric altimeter instrument variance constant

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
VAR_RMLS	S	Pad	--	MSBLS range measurement instrument variance
VAR_TAC_BRG_ HIGH	S	Pad	--	TACAN bearing instrument variance at high range
VAR_TAC_BRG_LOW	S	Pad	--	TACAN bearing instrument variance low range
VAR_TAC_R_HIGH	S	Pad	--	TACAN range instrument variance at high range
VAR_TAC_R_LOW	S	Pad	--	TACAN range instrument variance at low range
VAR_UNMOD_ACC_ DT	S	0	--	Variance of unmodeled acceleration times scale time
V_CURRENT_ FILT	V	0	M50	Snap of IMU raw velocity counts reserved for measurement processing
V_FILT	V	0	M50	Shuttle current velocity vector
V_FILT_INIT	V	OPS 3	M50	Shuttle velocity vector for OPS reconfiguration
V_FINAL	V	0	M50	Velocity at end of prediction
V_GND	V	0	M50	Uplinked M50 velocity vector
V_IMU_LAST	V	0	M50	Previous snapped IMU velocity
V_INIT	V	0	M50	Velocity vector at beginning of prediction
V_IMU_RESET	V	0	M50	Copy of V_LAST_FILT reserved is velocity count at start of extrapolation interval when guidance integrator is reset
V_LAST_FILT	V	0	M50	Previously read selected accumulated IMU velocity
V_R	V	0	M50	Vehicle relative velocity vector

Table 5.1-1. Variable List - Basic Ascent/RTLS Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
V_RESET	V	0	M50	Vehicle velocity vector after all navigation updates reserved for reset of guidance integrator velocity vector
V_RHO	V	0	M50	Vehicle relative velocity vector
V_TO_NAV	V	0	M50	Uplinked-predicted orbiter state vector
ZETA_IMAG	V	0	--	Complex vector to account for effect of the tesseral harmonics (imaginary portion)
ZETA_REAL	V	0	--	Complex vector to account for effect of the tesseral harmonics (real portion)
ZONAL	V	Pad	--	Zonal harmonic coefficients

5.2 NAVIGATION SEQUENCER PRINCIPAL FUNCTION AND NAVIGATION PRINCIPAL FUNCTION FLOW CHARTS

The material provided in this section is suggested flow charts (Figures 5.2-1 through 5.2-33) for the Navigation Sequencer principal function and basic navigation principal function. Excluded is Area Navigation and User Parameter Processor. Note that these flow charts directly correlate to the variable list in Section 5.1.

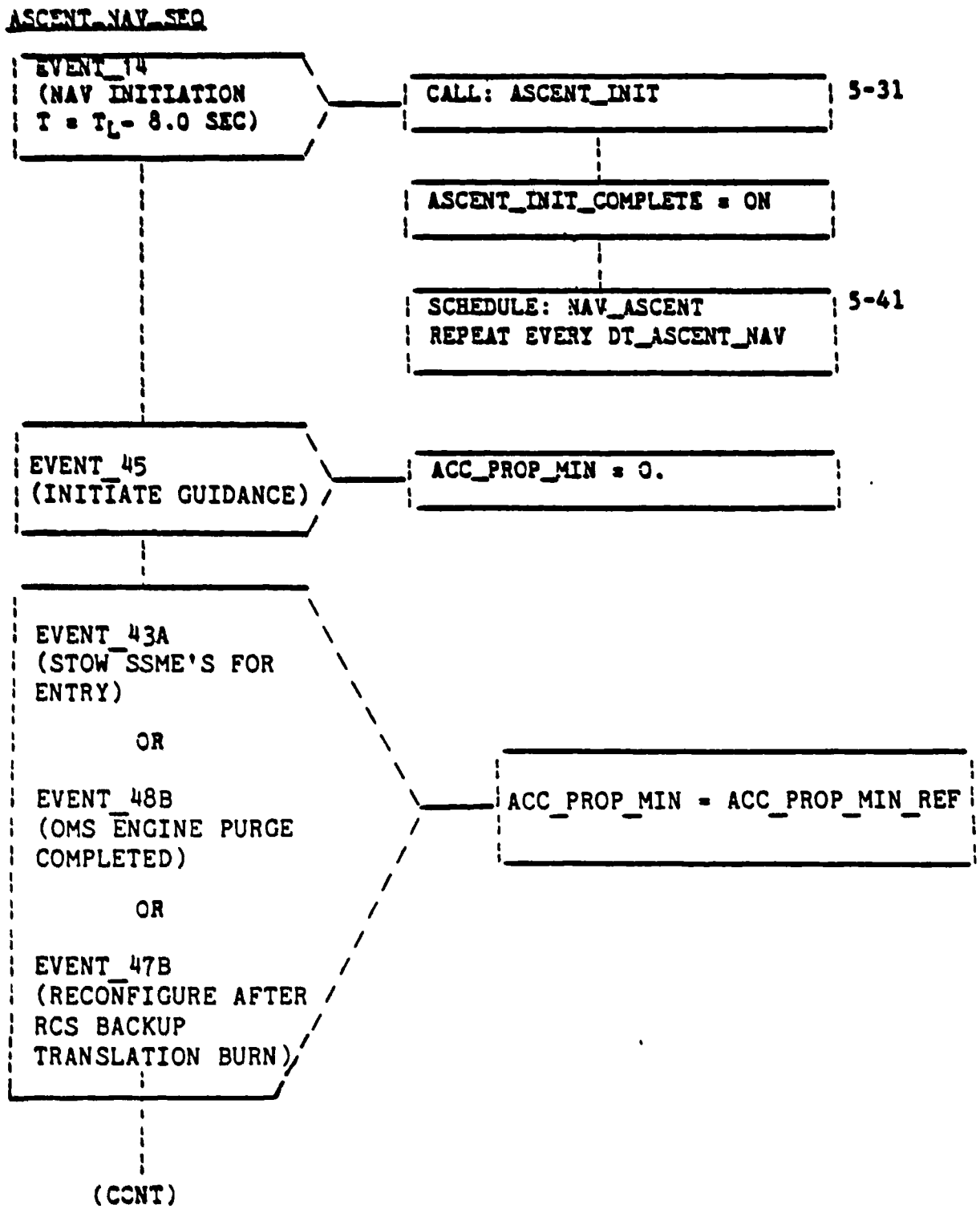
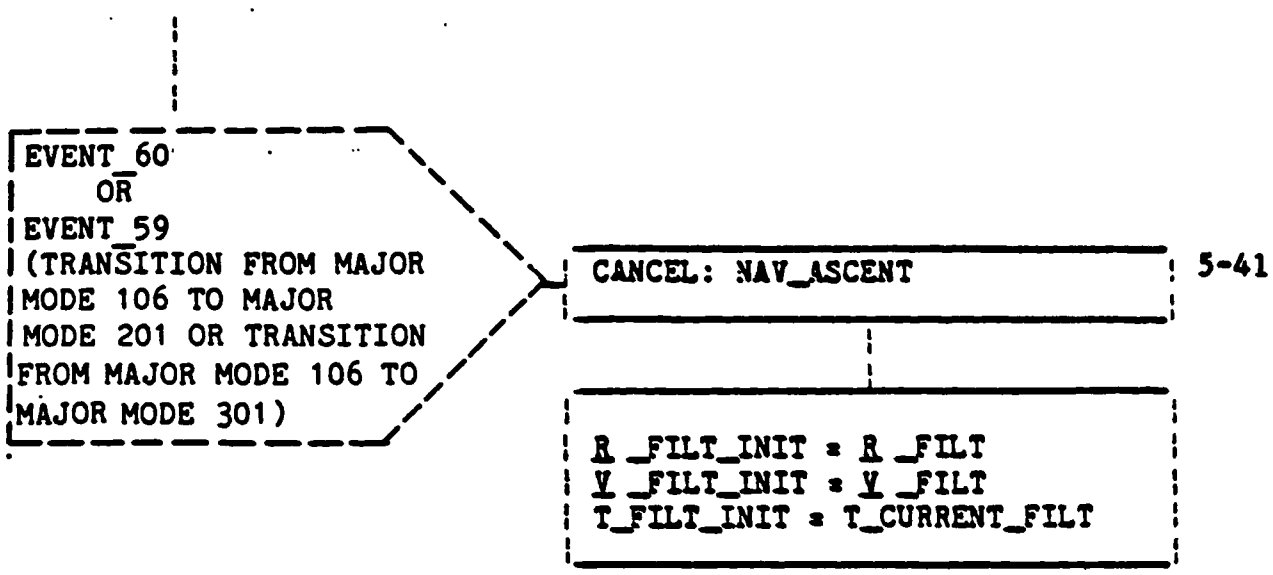


Figure 5.2-1. ASCENT_NAV_SEQ

ASCENT_NAV_SEQ (CONTINUED)



Δ SAVED PARAMETERS IN PROTECTED MEMORY LOCATION FOR USE BY OPS-2, OR OPS-3 NAVIGATION SEQUENCER PRINCIPAL FUNCTION.

o UNDER NORMAL CONDITIONS THIS SEQUENCER IS TERMINATED BY COMPUTER MEMORY RECONFIGURATION TO THE ONORBIT COMPUTER LOAD (OPS-2)

o IN THE EVENT OF AN RTLS ABORT, THE ASCENT/RTLS NAV SEQUENCER WILL TAKE CONTROL FROM THIS SEQUENCER.

o IN THE EVENT OF AN AOA ABORT THIS SEQUENCER IS TERMINATED BY COMPUTER MEMORY RECONFIGURATION TO THE ENTRY THROUGH LANDING MEMORY LOAD (OPS-3).

Figure 5.2-1. ASCENT_NAV_SEQ (Cont)

ASCENT_INIT

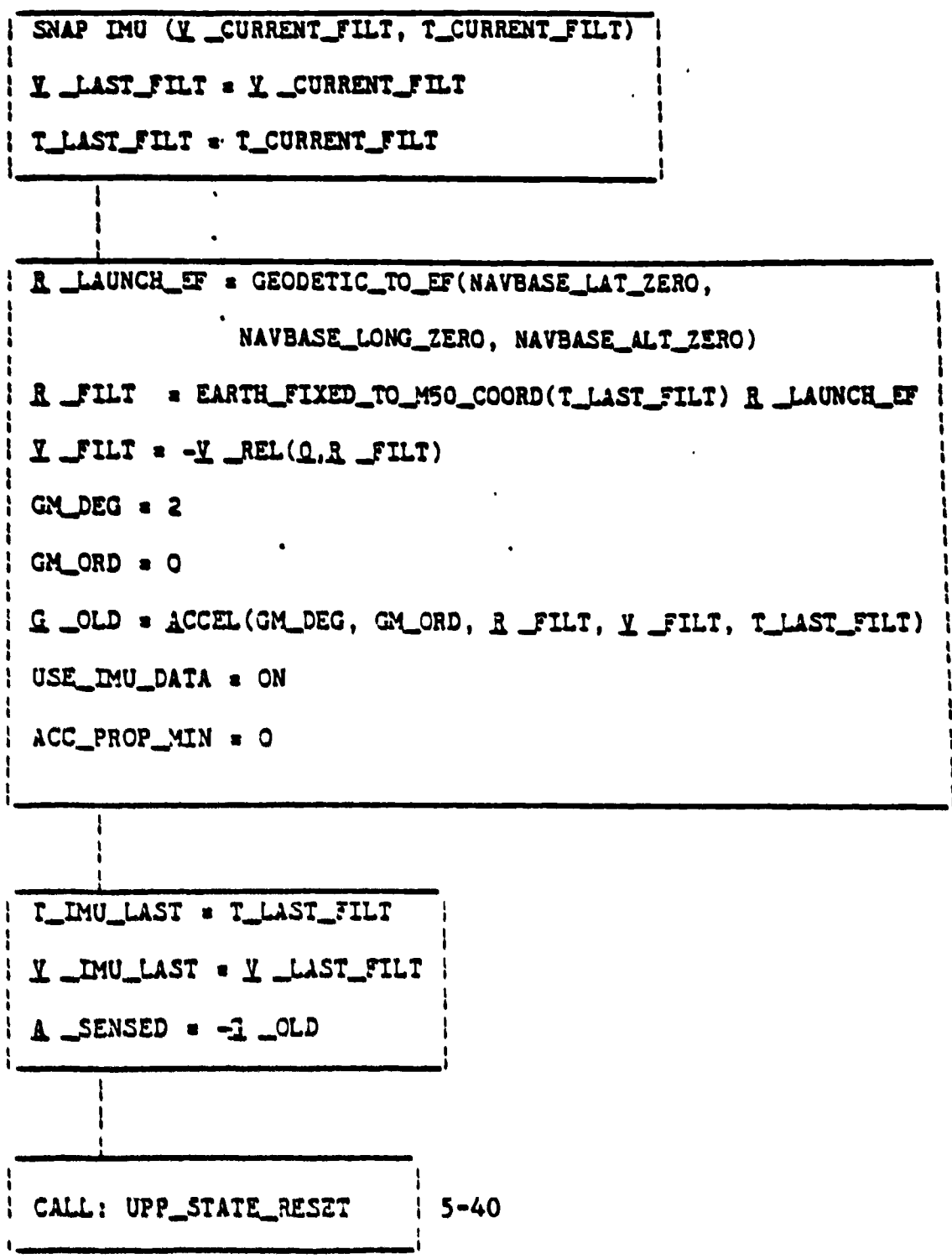


Figure 5.2-2. ASCENT_INIT

V_REL(FUNCTION)

V_REL (V, R) = V -EARTH_RATE (EARTH_POLE x R)

Figure 5.2-3. V_REL (FUNCTION)

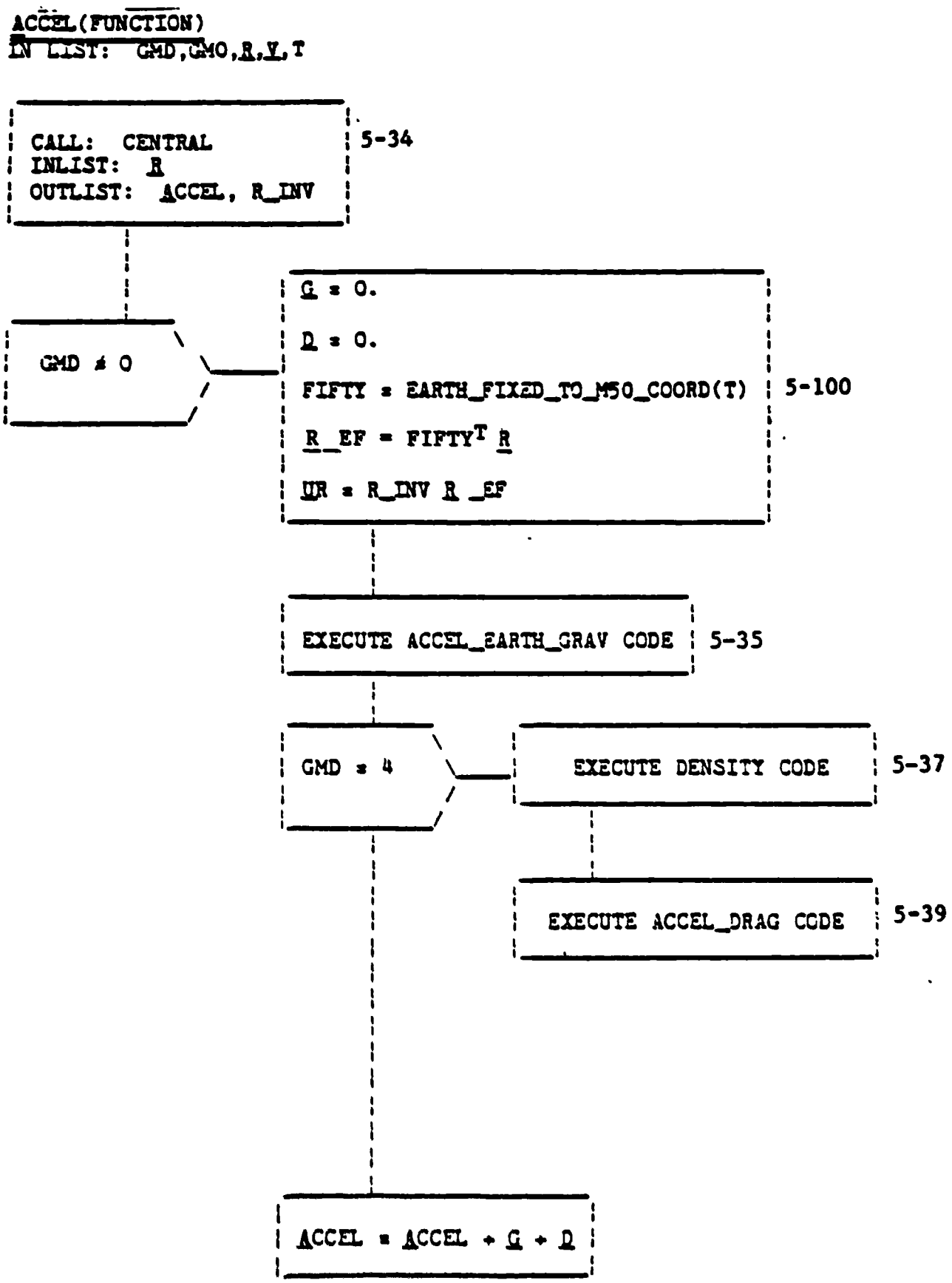


Figure 5.2-4. ACCEL (FUNCTION)

CENTRAL

INLIST: R
OUTLIST: ACCEL, R_INV

```
R_INV = 1./|R|

ACCEL = -EARTH_MU R_INV^3 R
```

Figure 5.2-5. CENTRAL

ACCEL_EARTH_GRAV CODE

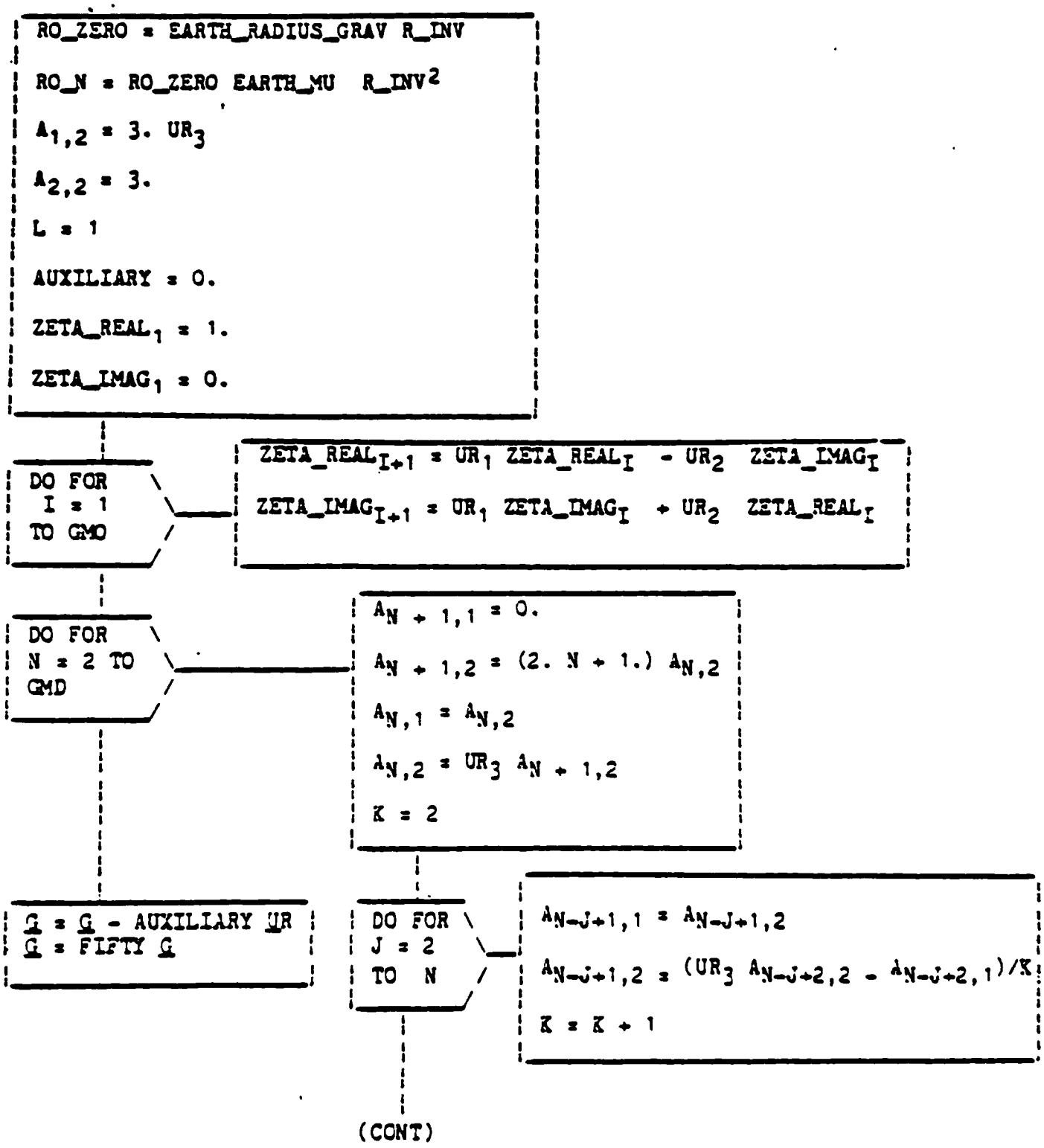


Figure 5.2.6. ACCEL_EARTH_GRAV CODE

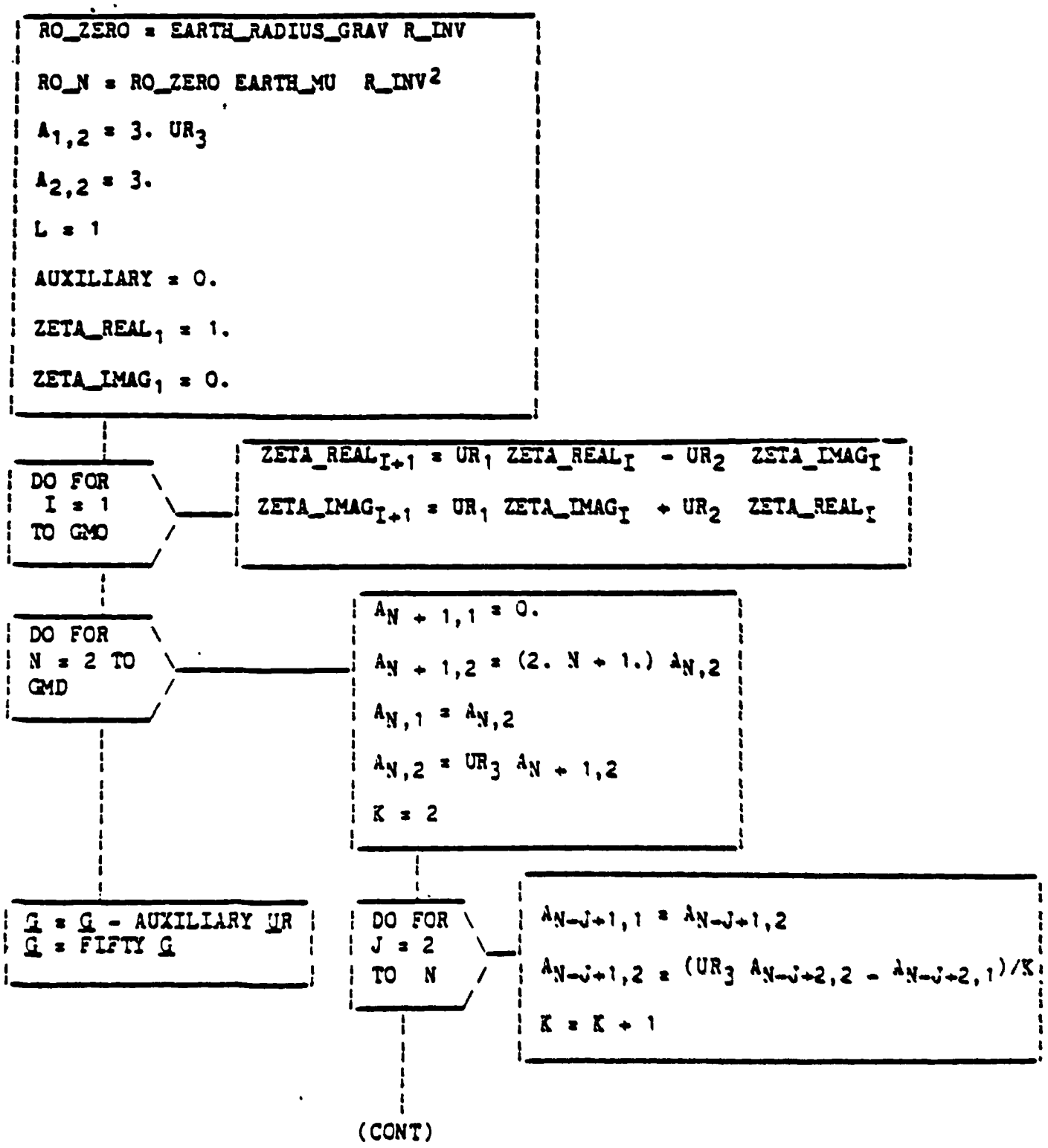


Figure 5.2.6. ACCEL_EARTH_GRAV CODE

ACCEL_EARTH_GRAV CODE (CONT)

F1 = 0.

F2 = 0.

F3 = $-A_{1,1}$ ZONAL$_N$

F4 = $-A_{1,2}$ ZONAL$_N$

N $\leq$ GMO

DO FOR N1 = 1 TO N

F1 = F1 + N1 $A_{N1,1}$(C_LZETA_REAL$_{N1}$ + S_LZETA_IMAG$_{N1}$)

F2 = F2 + N1 $A_{N1,1}$(S_LZETA_REAL$_{N1}$ - C_LZETA_IMAG$_{N1}$)

DNM = C_LZETA_REAL$_{N1+1}$ + S_L ZETA_IMAG$_{N1+1}$

F3 = F3 + DNM $A_{N1+1,1}$

F4 = F4 + DNM $A_{N1+1,2}$

L = L + 1

RC_N = RC_N RC_ZERO

G_1 = G_1 + RC_N F1

G_2 = G_2 + RC_N F2

G_3 = G_3 + RC_N F3

AUXILIARY = AUXILIARY + RC_N F4

Figure 5.2-6. ACCEL_EARTH_GRAV CODE (Cont)

DENSITY CODE

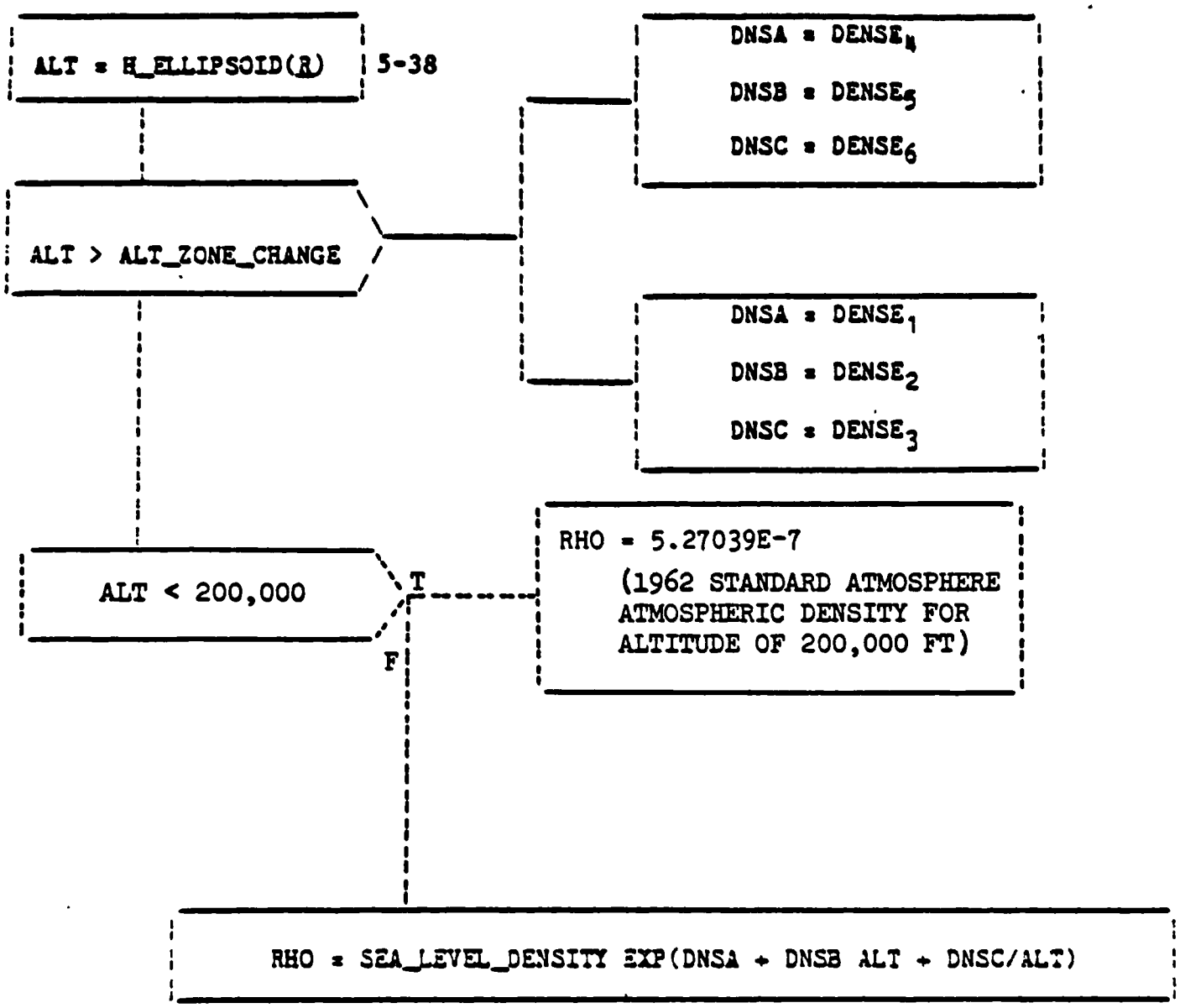


Figure 5.2-7. DENSITY CODE

H_ELLIPSOID (FUNCTION)

$$H\_ELLIPSOID(R) = |R| - \frac{(1-ELLIPT)\ EARTH\_RADIUS\_EQUATOR}{\sqrt{1 + ((1-ELLIPT)^2-1)(1-(UNIT(R)\cdot EARTH\_POLE)^2)}}$$

Figure 5.2-8. H_ELLIPSOID (FUNCTION)

ACCEL_DRAG CODE

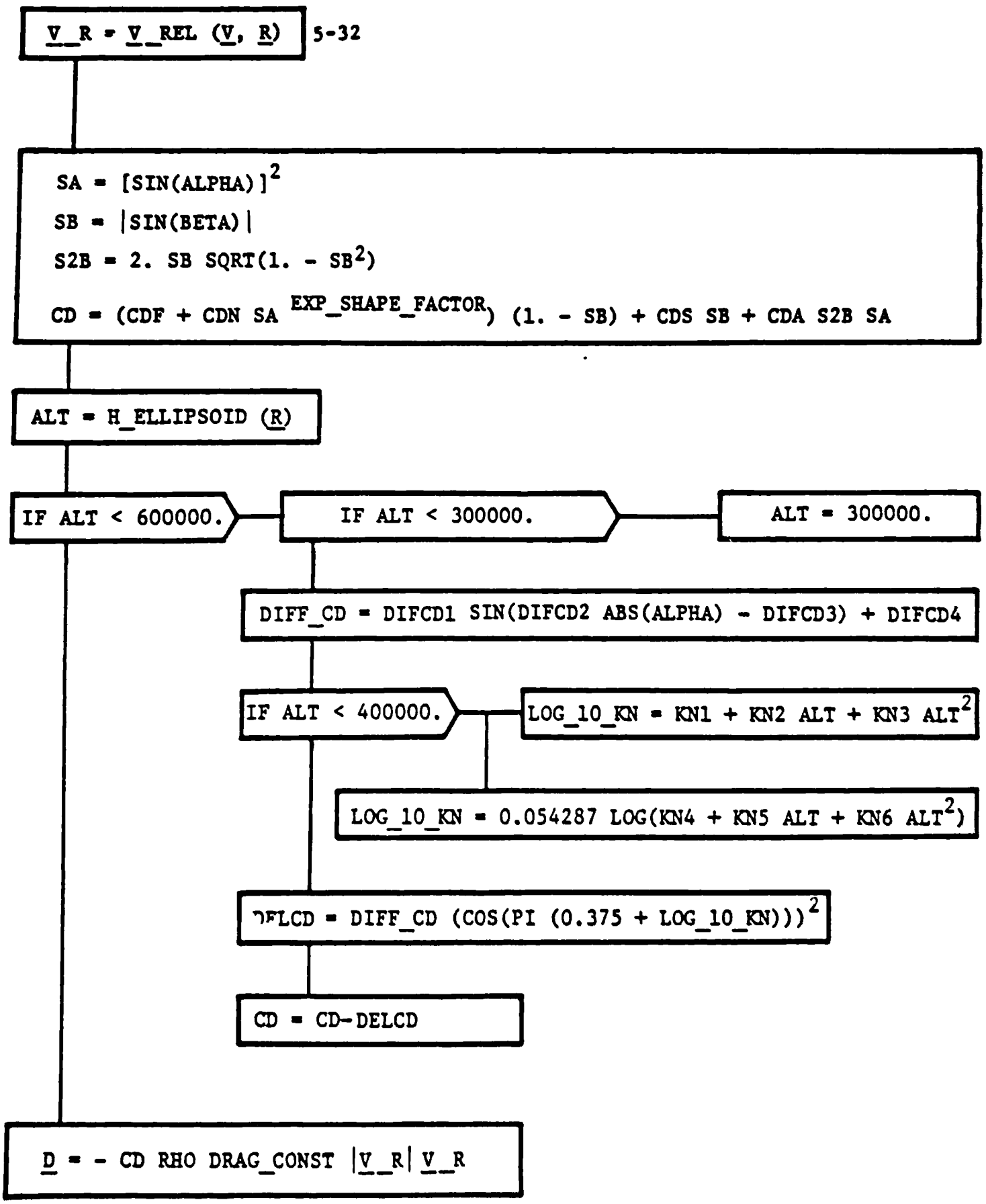


Figure 5.2-9. ACCEL_DRAG CODE

UPP_STATE_RESET

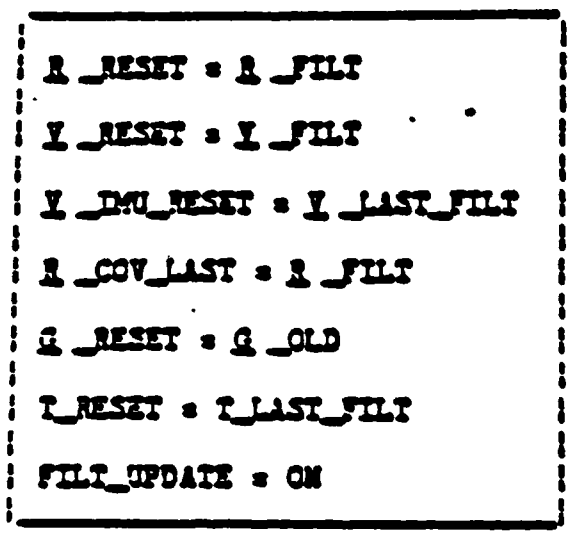


Figure 5.2-10. UPP_STATE_RESET

NAV_ASCENT

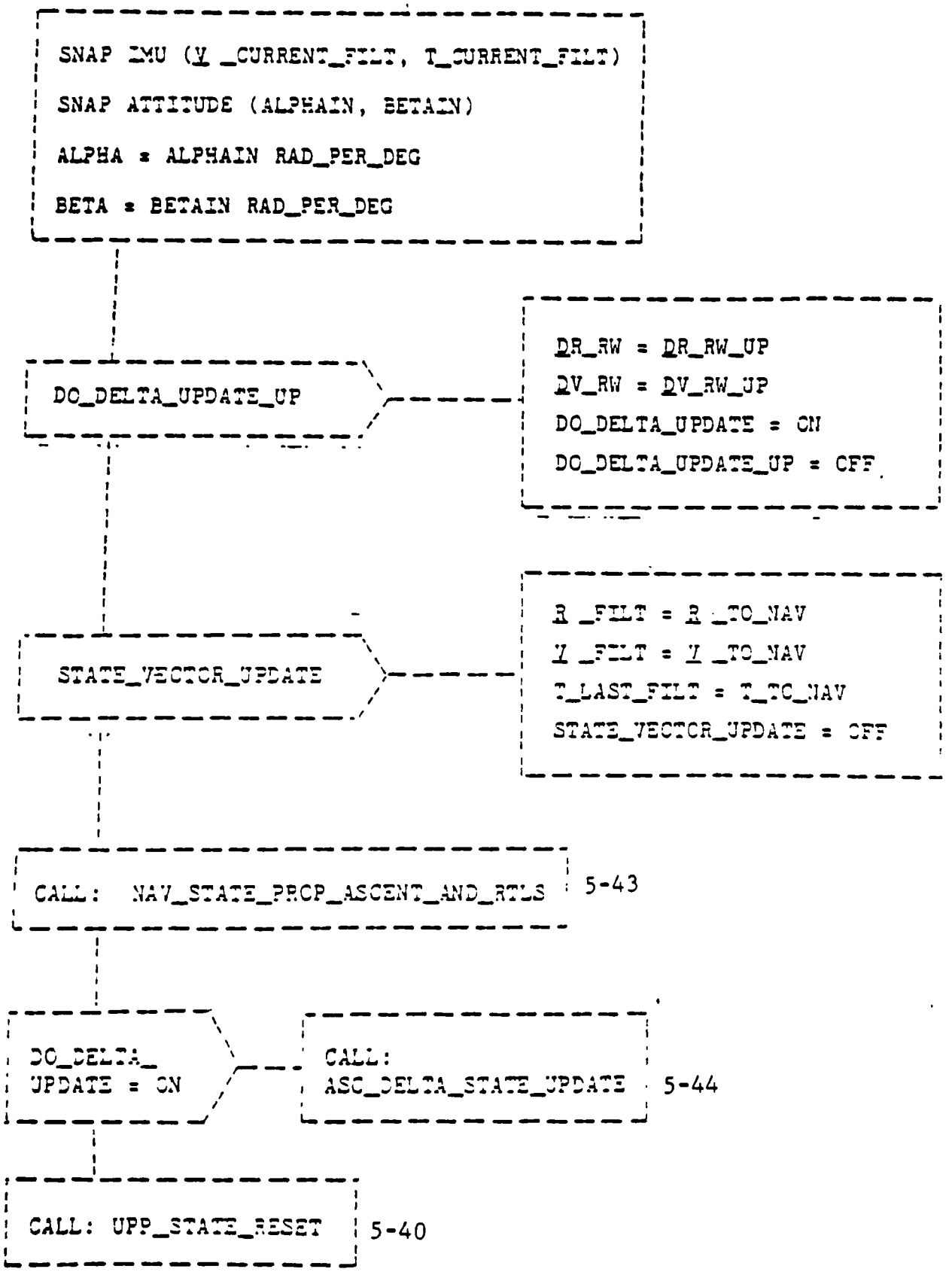


Figure 5.2-11. NAV_ASCENT

STATE_VECTOR_PRED_TASK_ASC

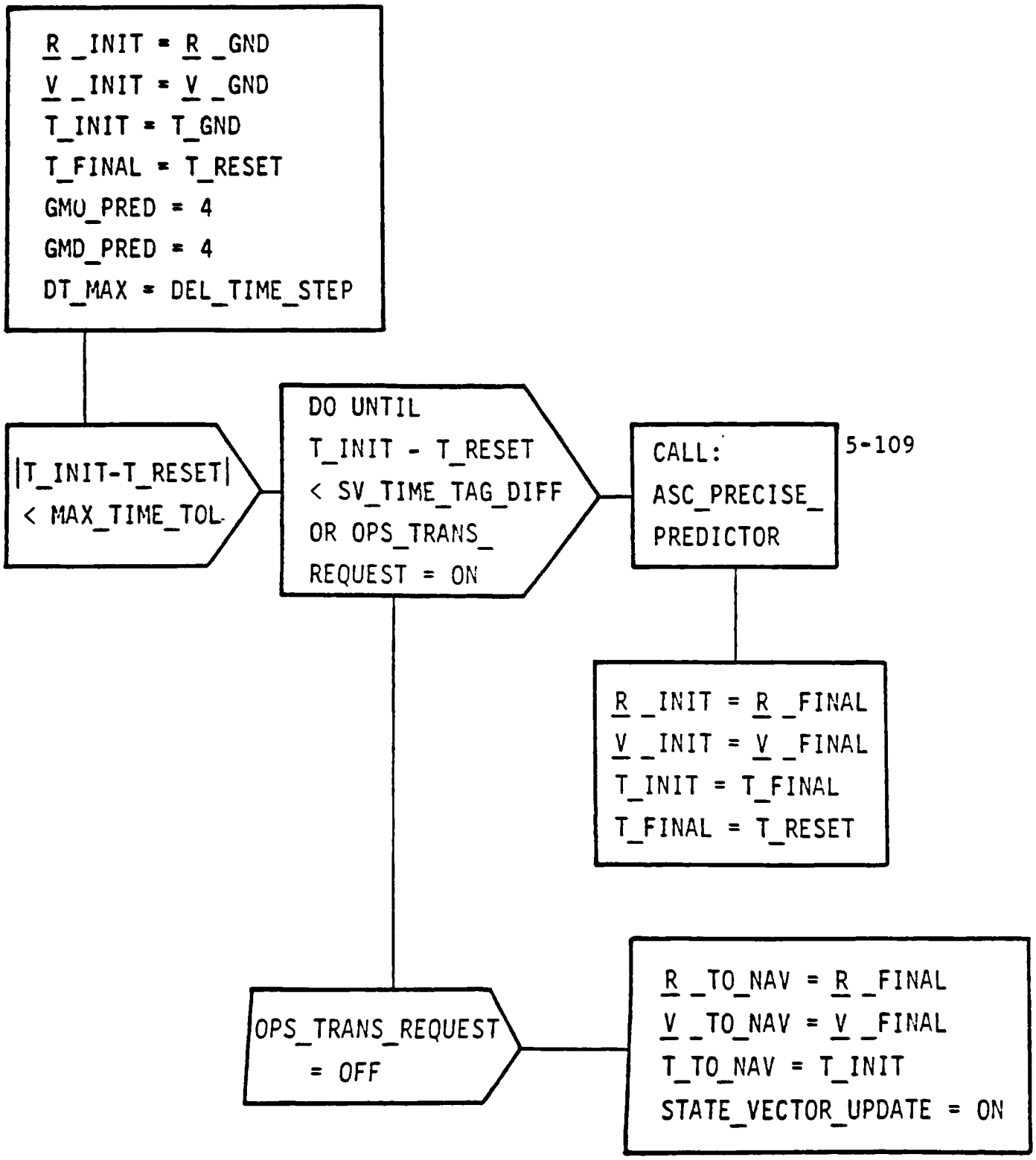


Figure 5.2-12. STATE_VECTOR_PRED_TASK_ASC

NAV_STATE_PROP_ASCENT_AND_RTLS

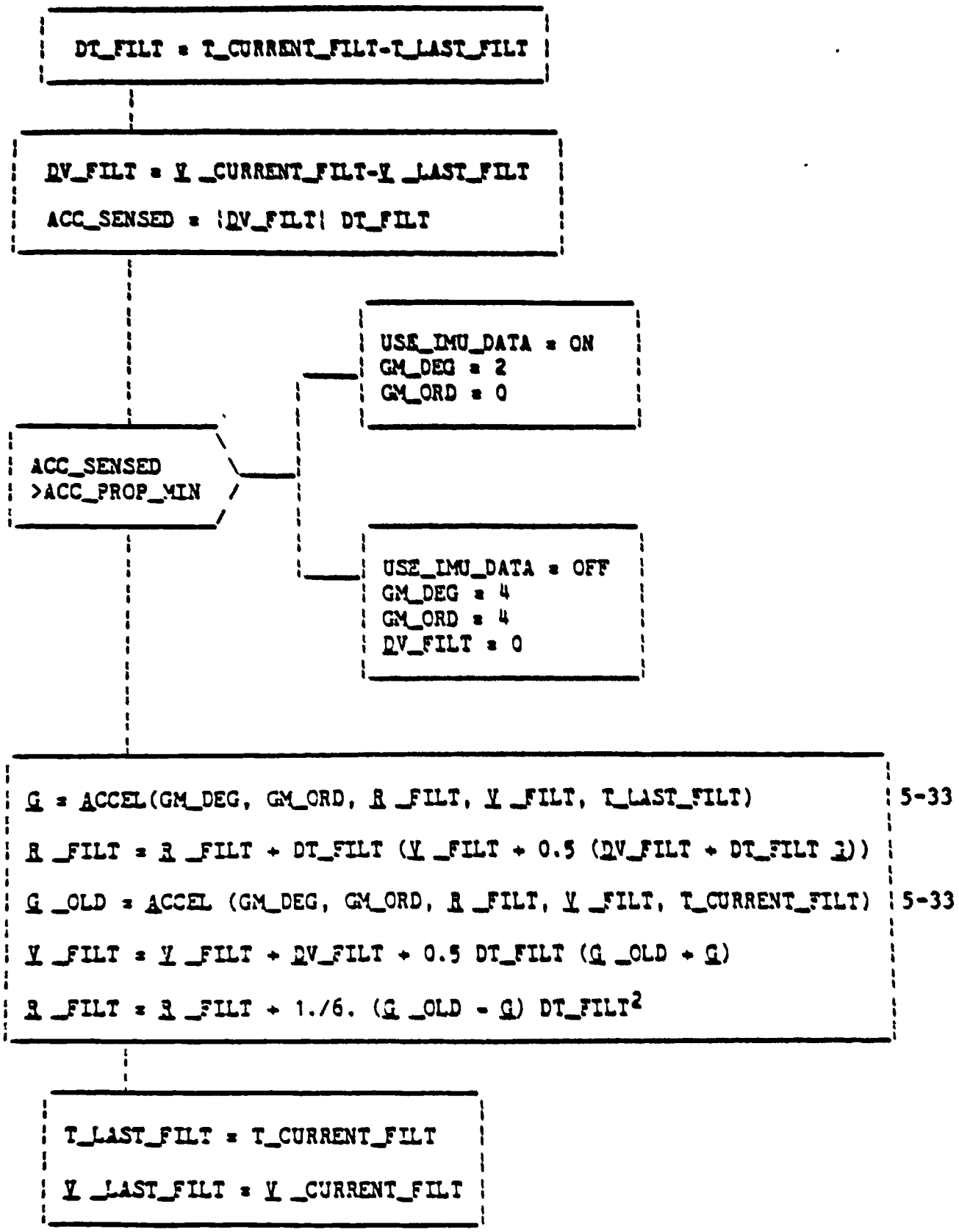


Figure 5.2-13. NAV_STATE PROP ASCENT AND RTLS

ASC_DELTA_STATE_UPDATE

```
M_TEMP = EARTH_FIXED_TO_M50_COORD(T_CURRENT_FILT) M_EFTORW^T        5-100
DR = M_TEMP DR_RW
R_FILT = R_FILT + DR
V_FILT = V_FILT + M_TEMP DV_RW + EARTH_RATE (EARTH_POLE X DR)
```

```
DR_RW = 0.
DV_RW = 0.
DO_DELTA_UPDATE = OFF
```

Figure 5.2-14. ASC_DELTA_STATE_UPDATE

ASCENT_RTLS_NAV_SEQUENCER

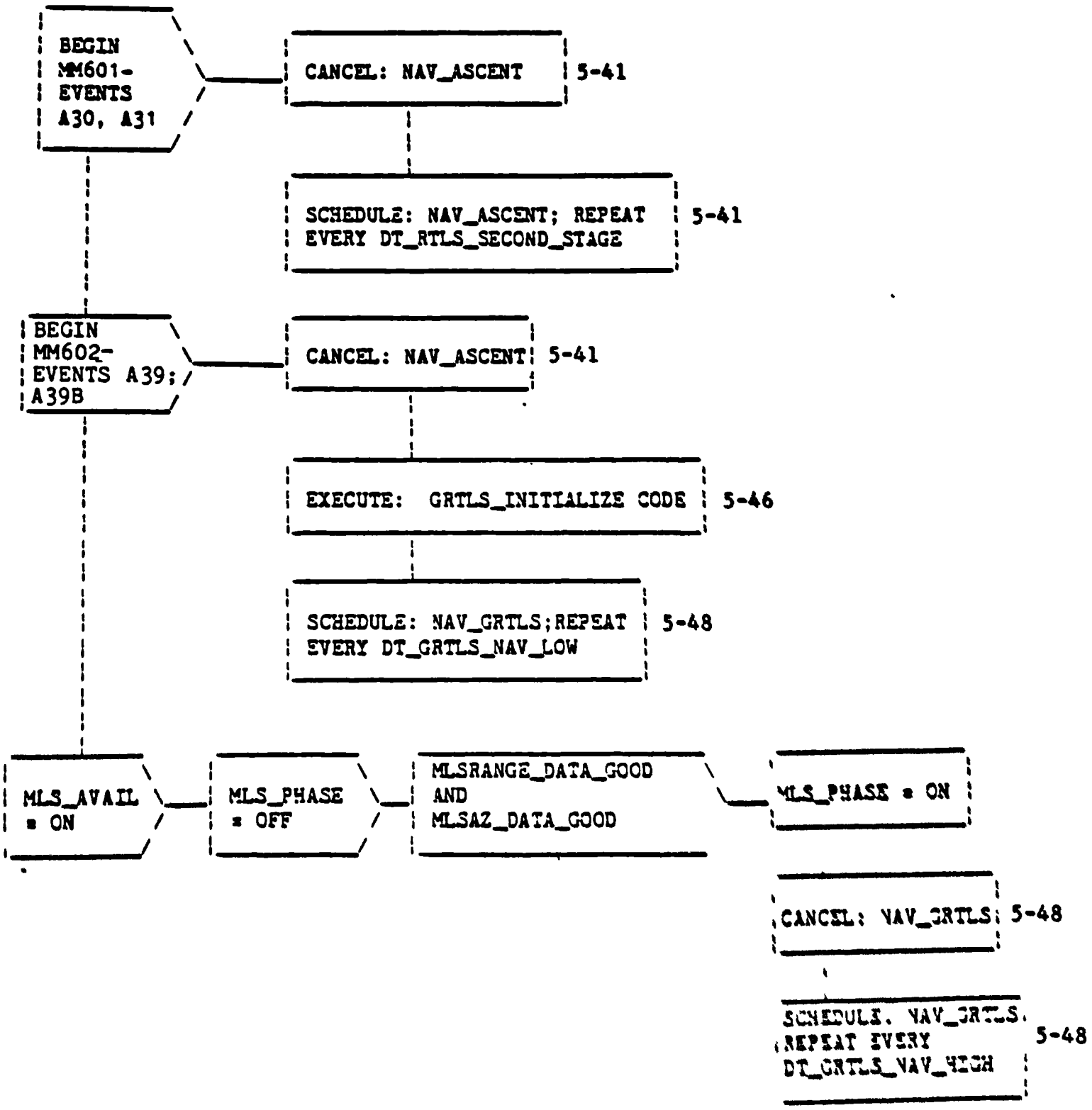


Figure 5.2-15. ASCENT_RTLS_NAV_SEQUENCER

GRTLS_INITIALIZE_CODE

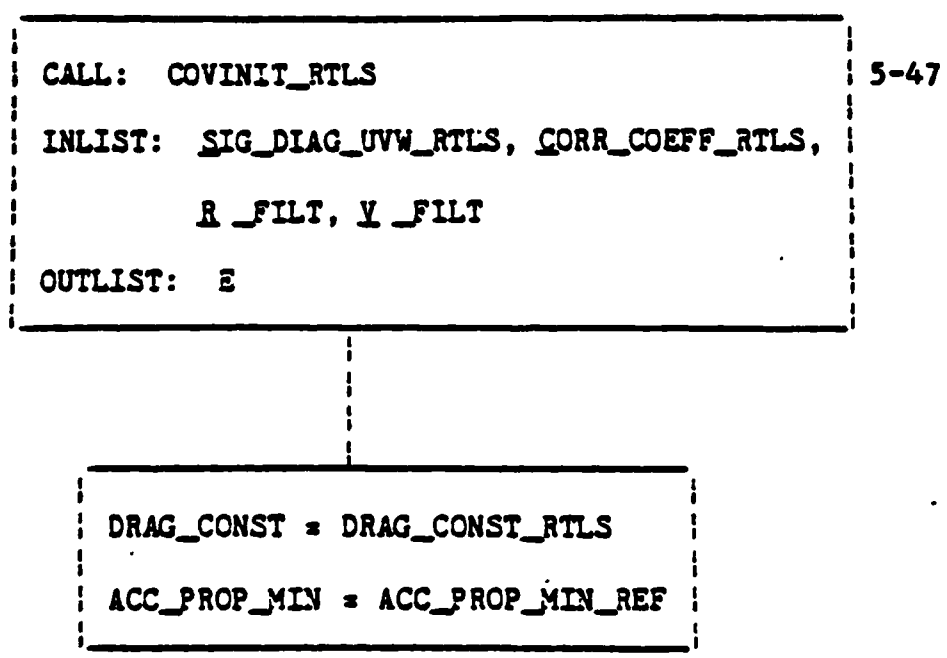


Figure 5.2-16. GRTLS_INITIALIZE_CODE

COVINIT_RTLS

IN LIST: SIG, COR, R, V

OUT LIST: E_TEMP

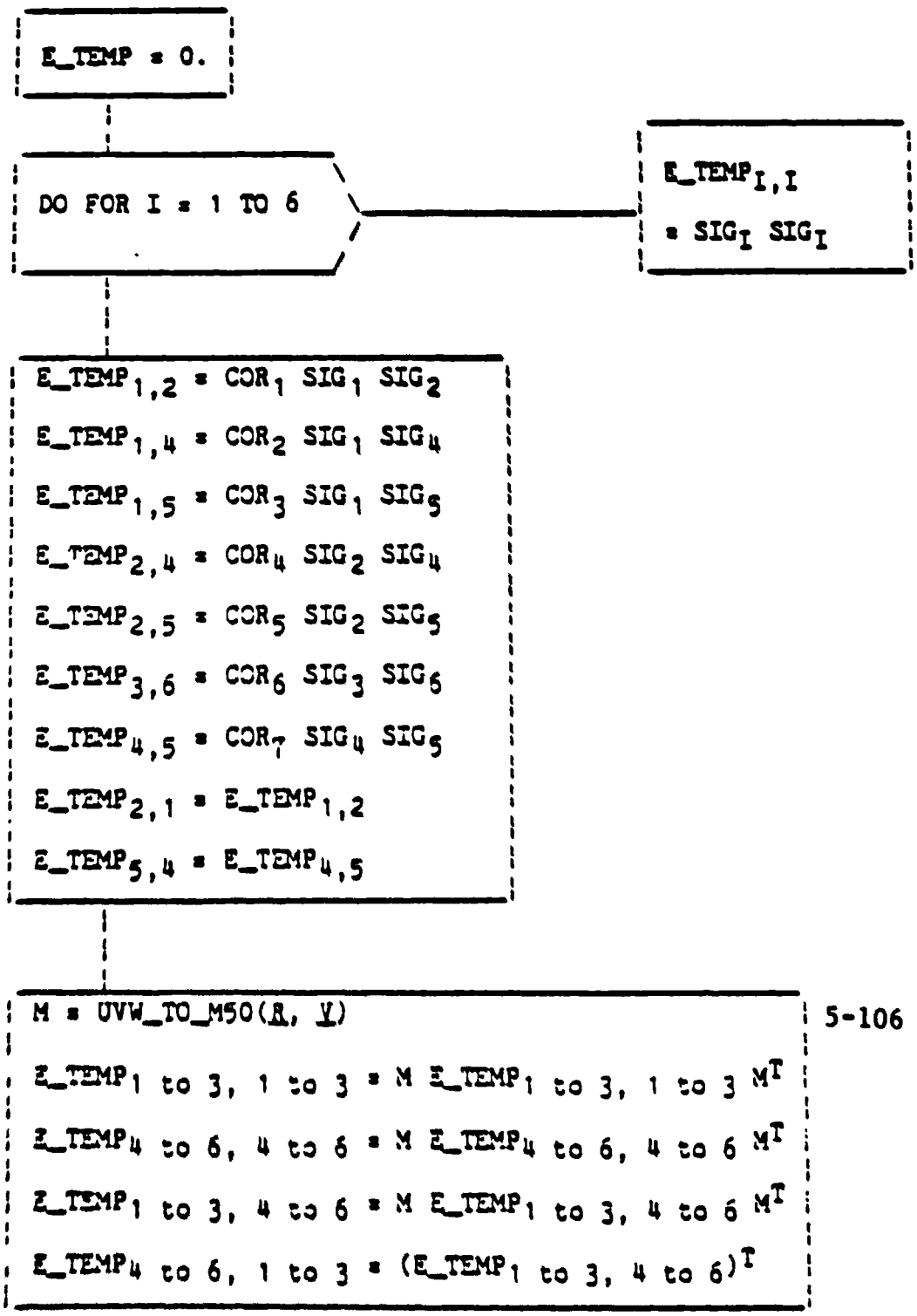


Figure 5.2-17. COVINIT_RTLS

NAV_GRTLS

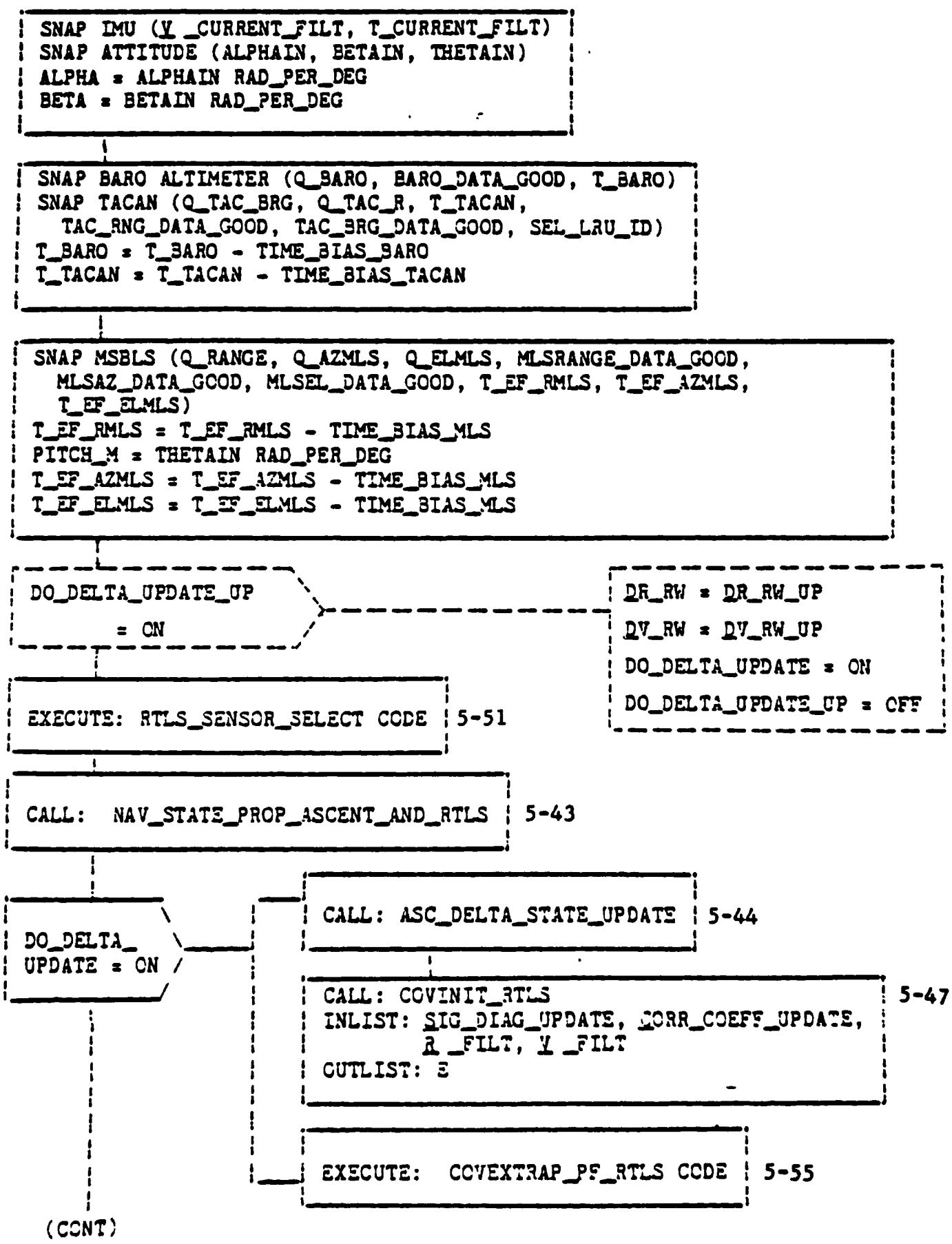


Figure 5.2-18. NAV_GRTLS

NAV_GRTLS (CONTINUED)

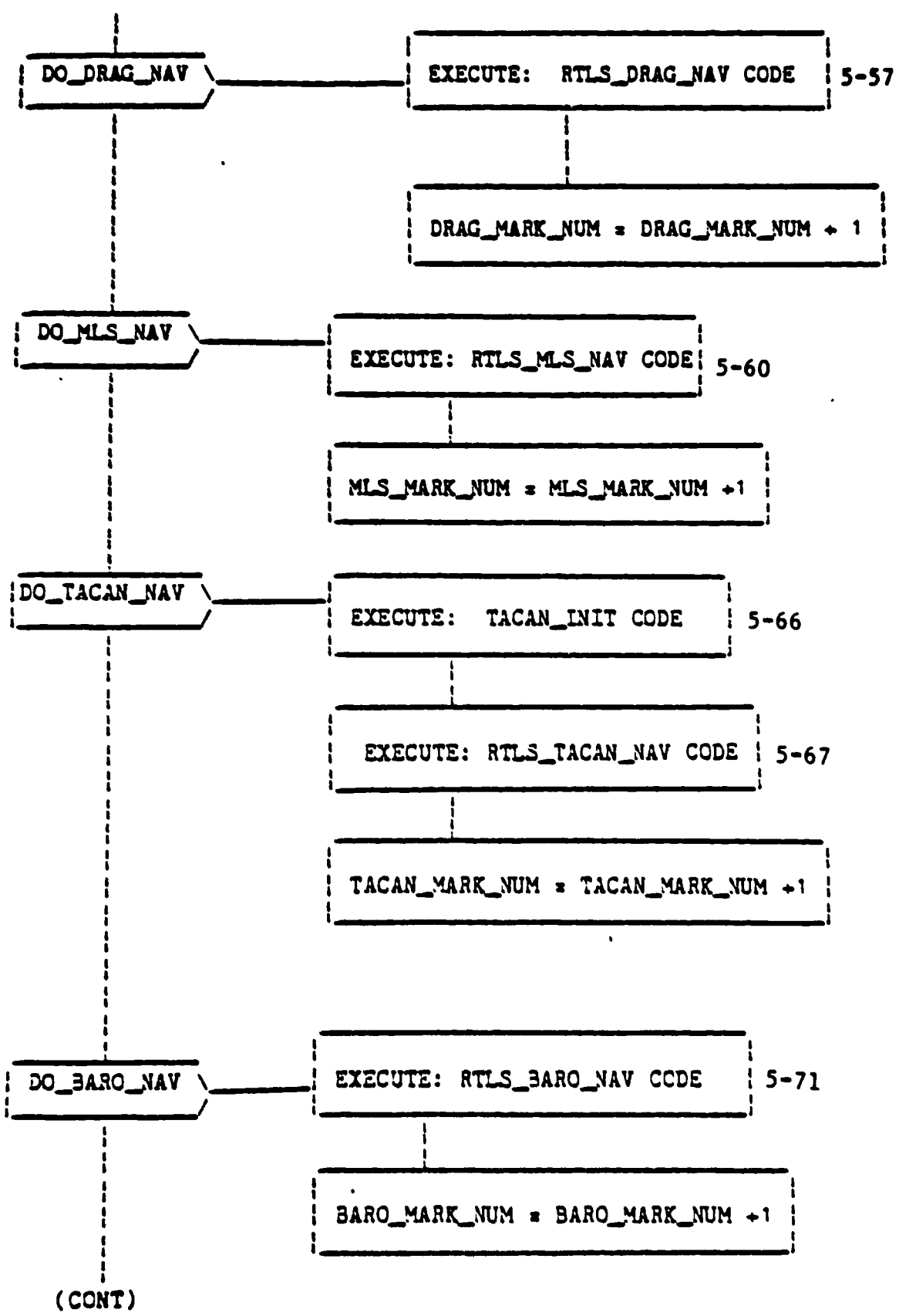


Figure 5.2-18. NAV_GRTLS (Cont)

NAV_GRTLS (CONTINUED)

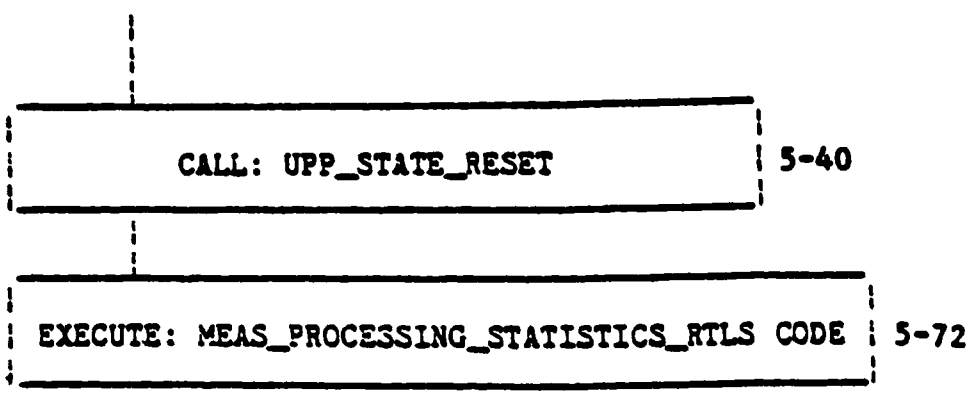


Figure 5.2-18. NAV_GRTLS (Cont)

RTLS_SENSOR_SELECT CODE

DO_BARO_NAV = OFF
DO_TACAN_NAV = OFF
DO_MLS_NAV = OFF
BARO_EDIT_OVERRIDE = OFF
TACAN_EDIT_OVERRIDE = OFF
DRAG_EDIT_OVERRIDE = OFF
DRAG_STAT = OFF

BARO_STAT = OFF,
TACAN_STAT = OFF
SENSOR_EDIT = OFF
DO_DRAG_NAV = OFF
TAC_AIF_RCVD = TACAN_AII
H_INHIB = OFF
BARO_AIF_RCVD = BARO_AIF
DRAG_AIF_RCVD = DRAG_AIF

MLS_AVAIL = ON

MLSRANGE_DATA_GOOD AND MLSAZ_DATA_GOOD

R_AZ_COUNT = 0
MLS_R_AZ_GOOD = ON

ALT_WHEELS < ALT_BARO_CUTOFF_HIGH

ALT_BARO_ CUTOFF = ALT_BARO_ CUTOFF_HIGH

R_AZ_COUNT = R_AZ_COUNT + 1

R_AZ_COUNT > R_AZ_COUNT_MAX

MLS_R_AZ_GOOD = OFF
MLS_COV_INIT = OFF

(CONT)

Figure 5.2-19. RTLS_SENSOR_SELECT CODE

RTLS_SENSOR_SELECT CODE (CONTINUED)

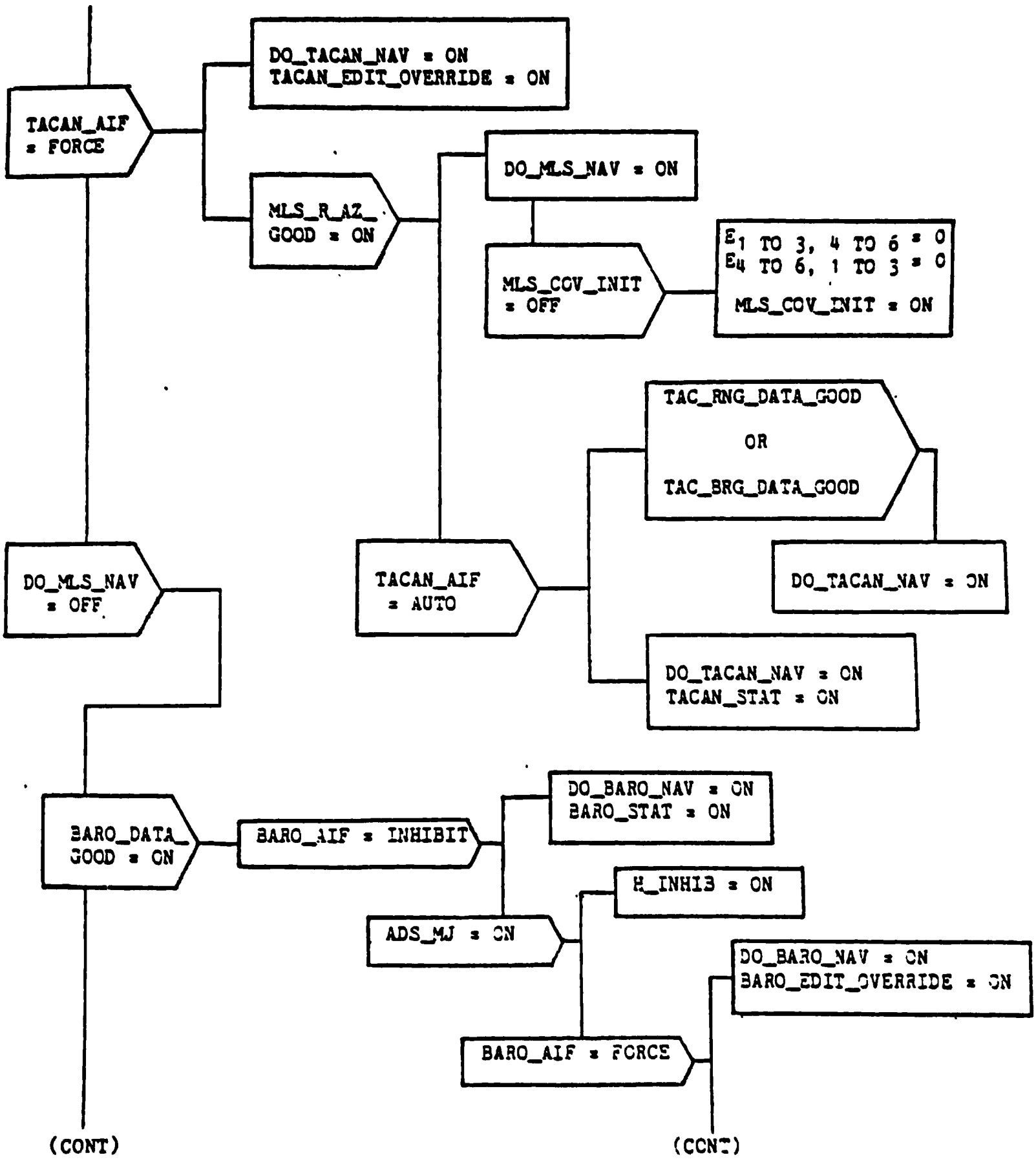


Figure 5.2-19. RTLS_SENSOR_SELECT CODE (Cont)

RTLS_SENSOR_SELECT CODE (CONT)

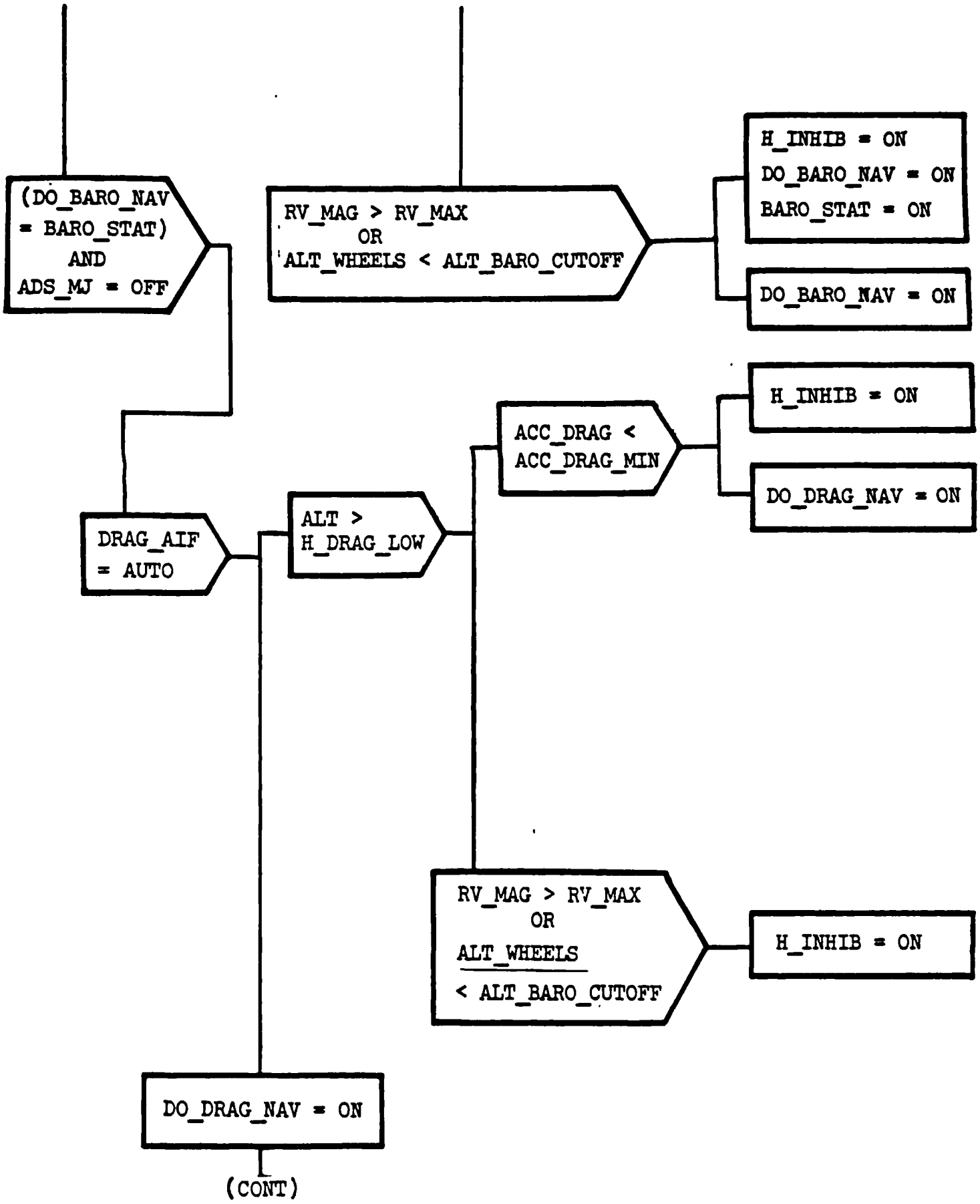


Figure 5.2-19. RTLS_SENSOR_SELECT CODE (Cont)

RTLS_SENSOR_SELECT_CODE (CONTINUED)

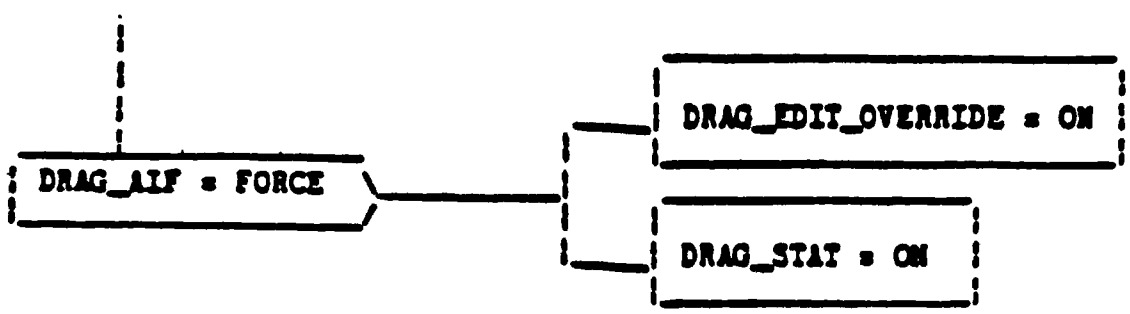


Figure 5.2-19. RTLS_SENSOR_SELECT CODE (Cont)

COVEXTRAP_PF_RTLS

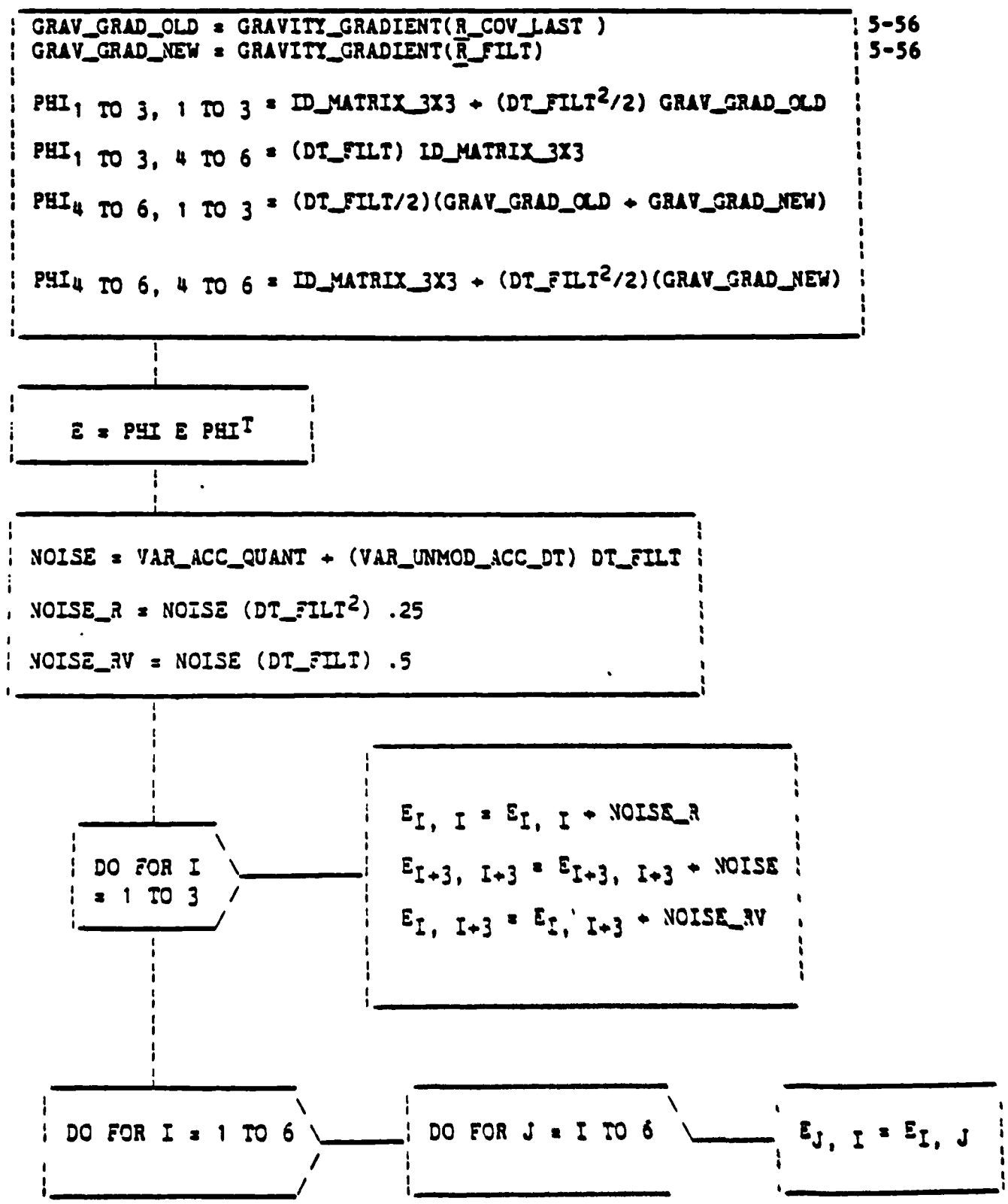


Figure 5.2-20. COVEXTRAP PF RTLS

GRAVITY_GRADIENT (FUNCTION)

GRAVITY_GRADIENT(R) = (EARTH_MU/|R|^5)(3 R R^T - |R|^2 ID_MATRIX_3X3)

Figure 5.2-21. GRAVITY_GRADIENT (FUNCTION)

RTLS_DRAG_NAV_CODE

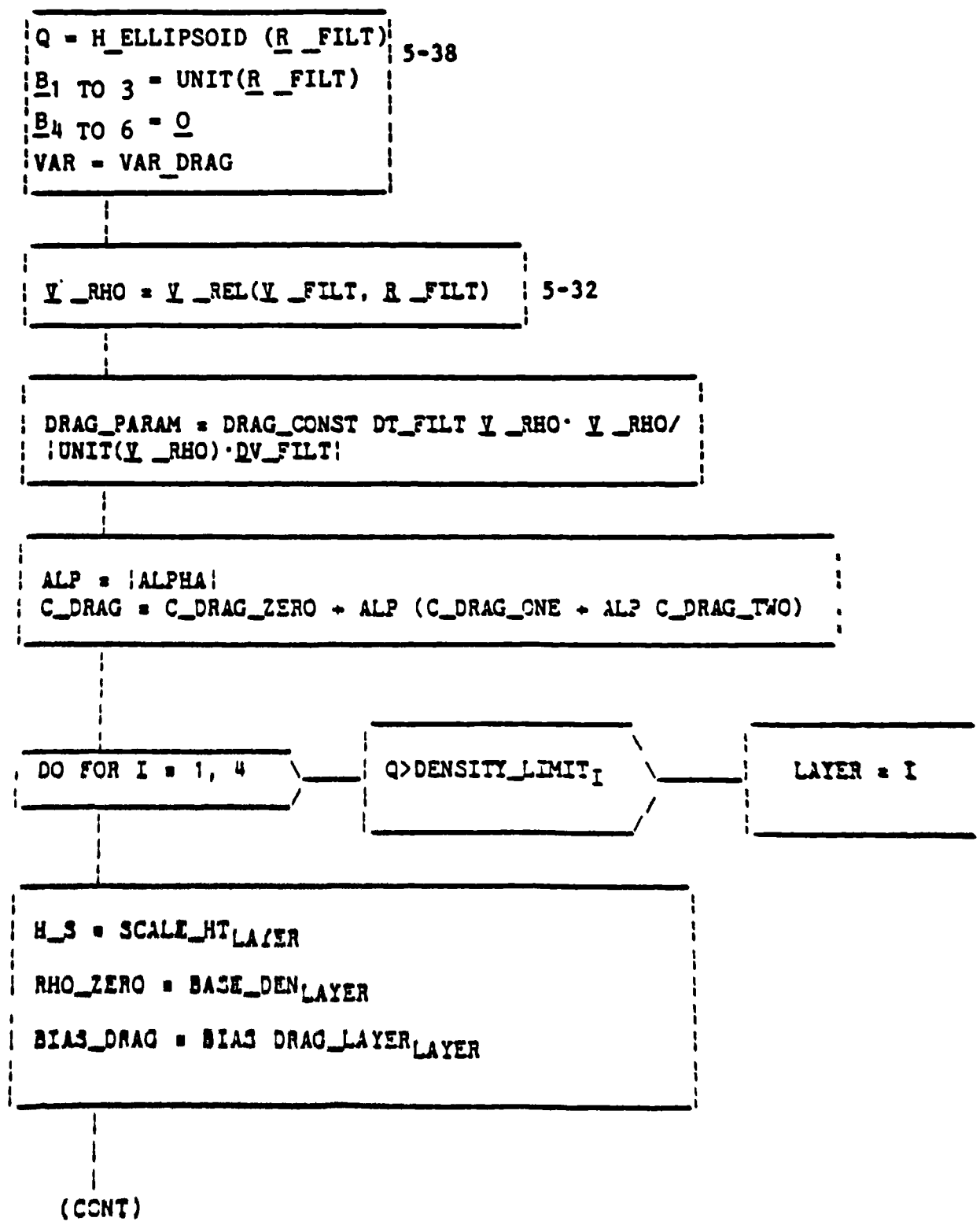


Figure 5.2-22. RTLS_DRAG_NAV CODE

RTLS_DRAG_NAV CODE (CONTINUED)

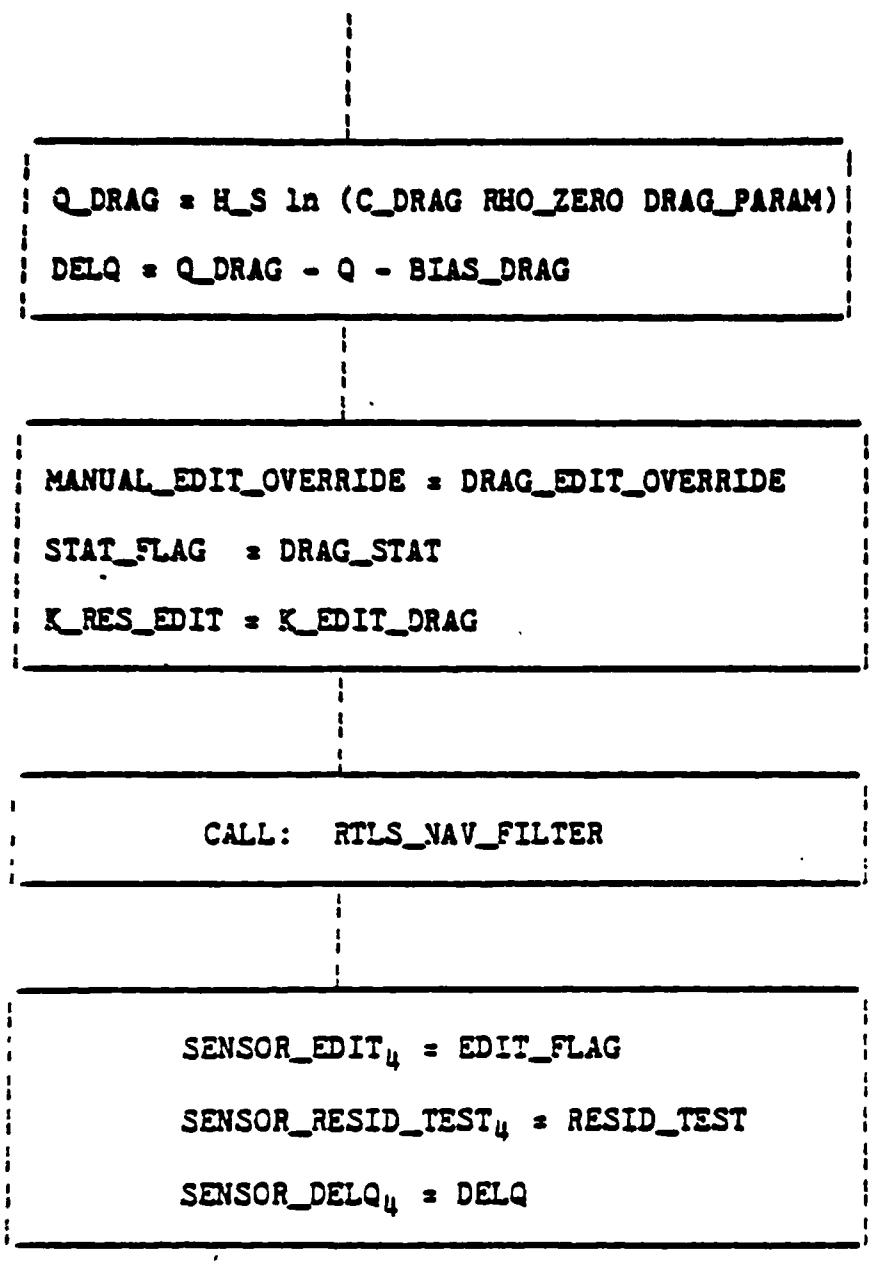


Figure 5.2-22. RTLS_DRAG_NAV CODE (Cont)

RTLS_NAV_FILTER

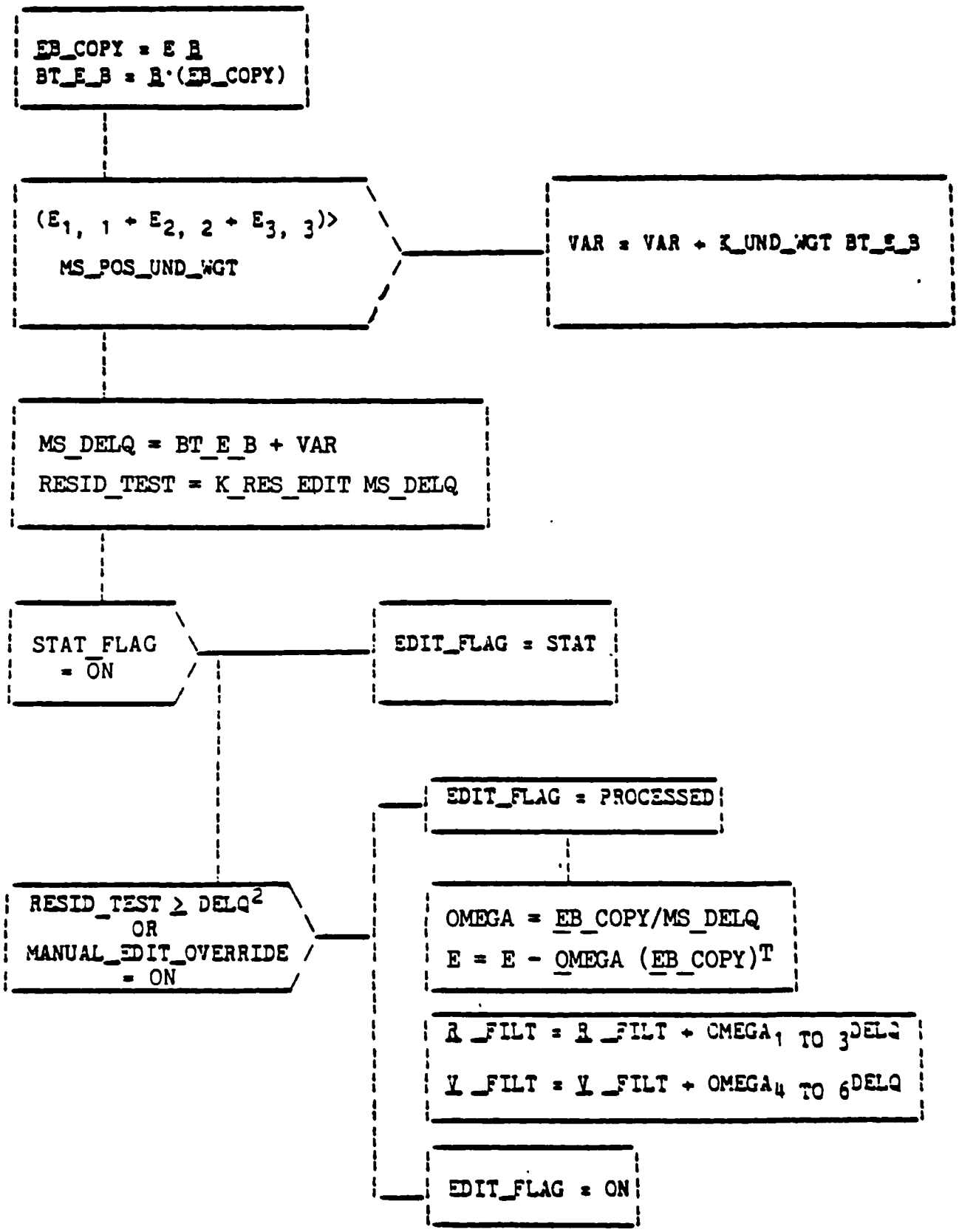


Figure 5.2-23. RTLS_NAV_FILTER

RTLS_MLS_NAV_CODE

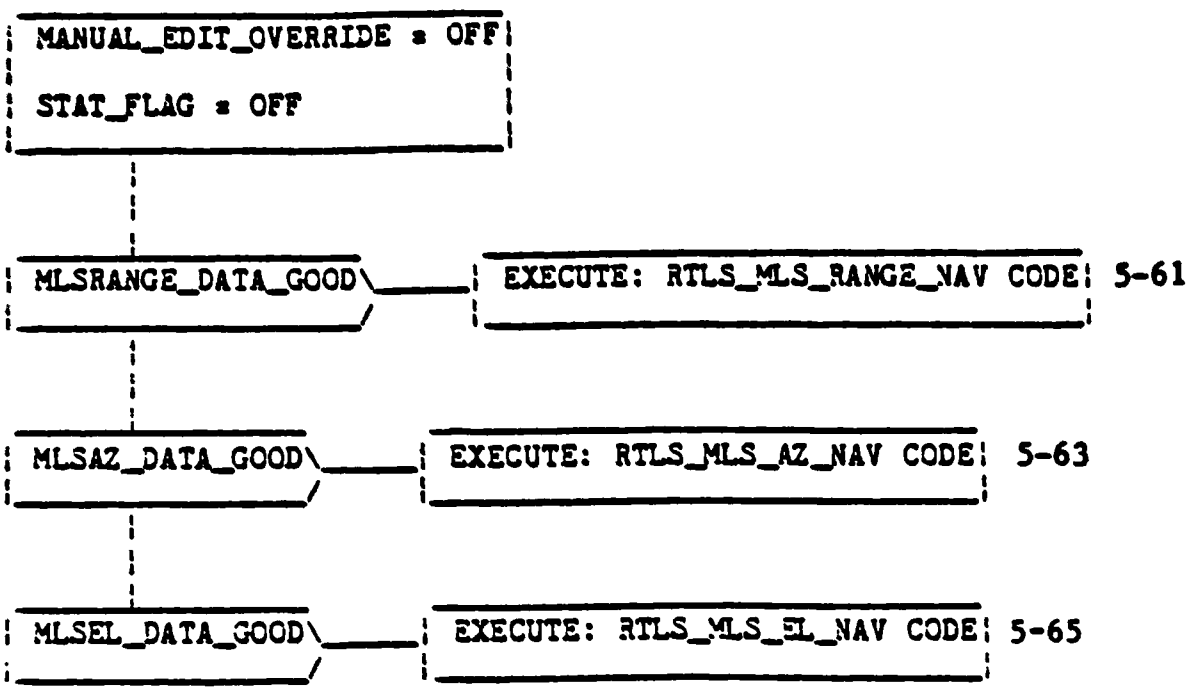


Figure 5.2-24. RTLS_MLS_NAV CODE

RTLS_MLS_RANGE_NAV CODE

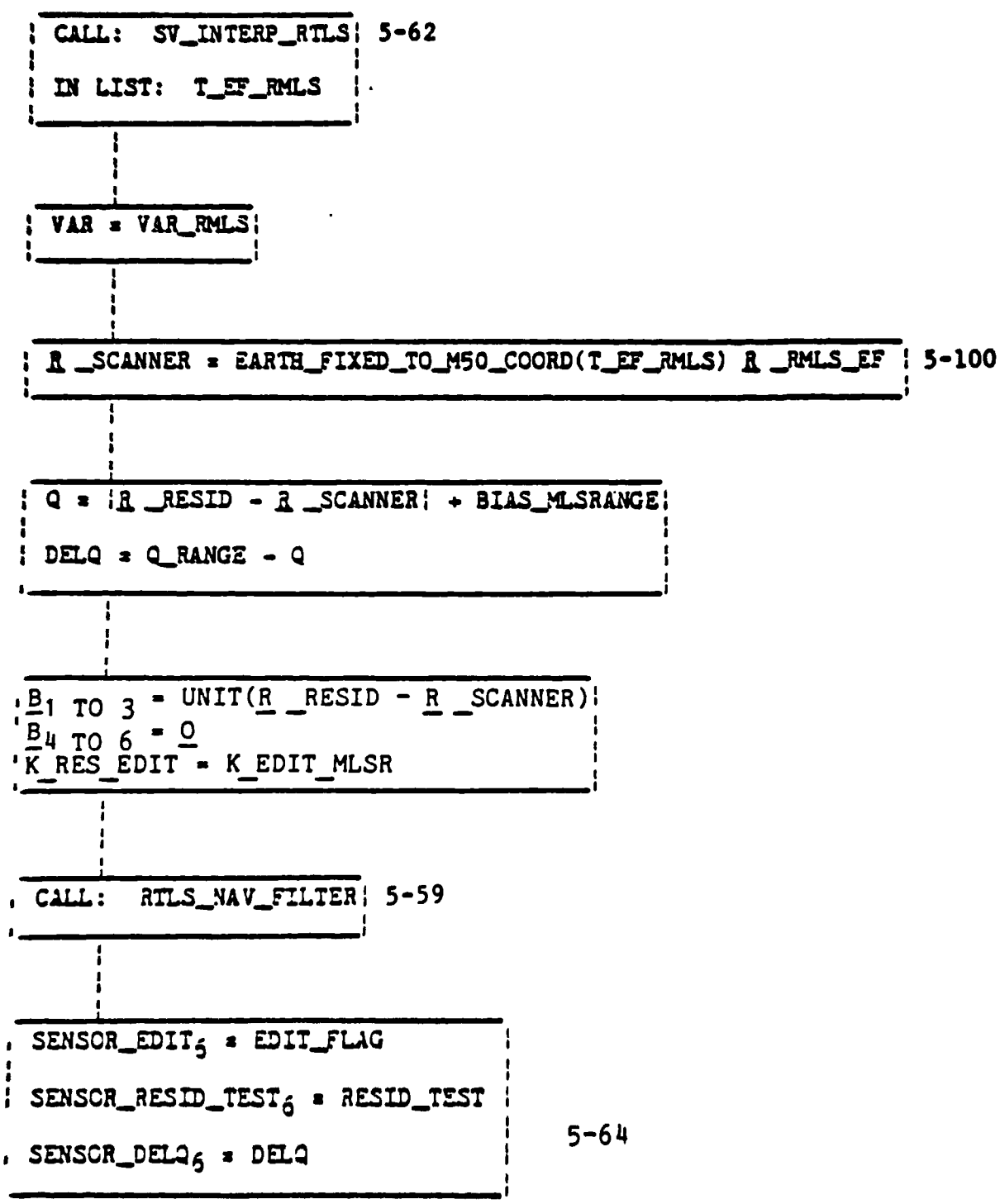


Figure 5.2-25. RTLS_MLS_RANGE_NAV CODE

SV_INTERP_RTLS

IN LIST: T_SENSORS

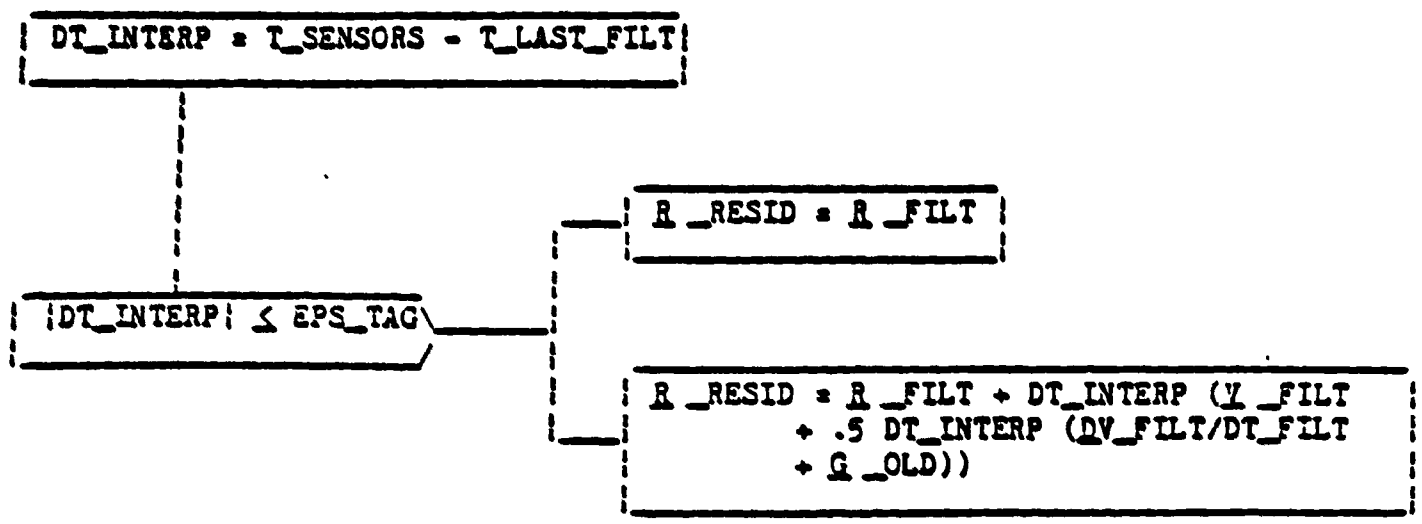


Figure 5.2-26. SV_INTERP_RTLS

RTLS_MLS_AZ_NAV_CODE

CALL: SV_INTERP_RTLS 5-62

IN LIST: T_EF_AZMLS

. M_EFTOM50 = EARTH_FIXED_TO_M50_COORD(T_EF_AZMLS) 5-100

. R_AZMLS = M_EFTOM50 R_AZMLS_EF

. VAR = VAR_AZMLS

M_M50_TO_SCANNER = M_EFTORAD_R_AZ $M_{EFTOM50}^{T}$

R = M_M50_TO_SCANNER (R_RESID - R_AZMLS)

Q = ARCTAN(R_2/R_1) + BIAS_AZMLS

DELQ = Q_AZMLS - Q

CALL: ANGLE_PARTIALS 5-64

IN LIST: R_AZMLS, $M\_M50\_TO\_SCANNER_{3,\ 1\ TO\ 3}$

R_RES_EDIT = R_EDIT_MLSAZ

CALL RTLS_NAV_FILTER 5-59

AZMLSR_EDIT$_S$ = EDIT_FLAG

SENSOR_RESID_TEST$_S$ = RESID_TEST

SENSOR_DELQ$_S$ = DELQ

Figure 5.2 2 RTLS MLS AZ NAV CODE

ANGLE_PARTIALS

IN LIST: R_SENSOR, I_Z

REL_R = R_RESID - R_SENSOR

IZ_CROSS_RELR = I_Z x REL_R

$B_{1 \text{ TO } 3}$ = IZ_CROSS_RELR/|IZ_CROSS_RELR|^2

$B_{4 \text{ TO } 6} = 0$

Figure 5.2-28. ANGLE_PARTIALS

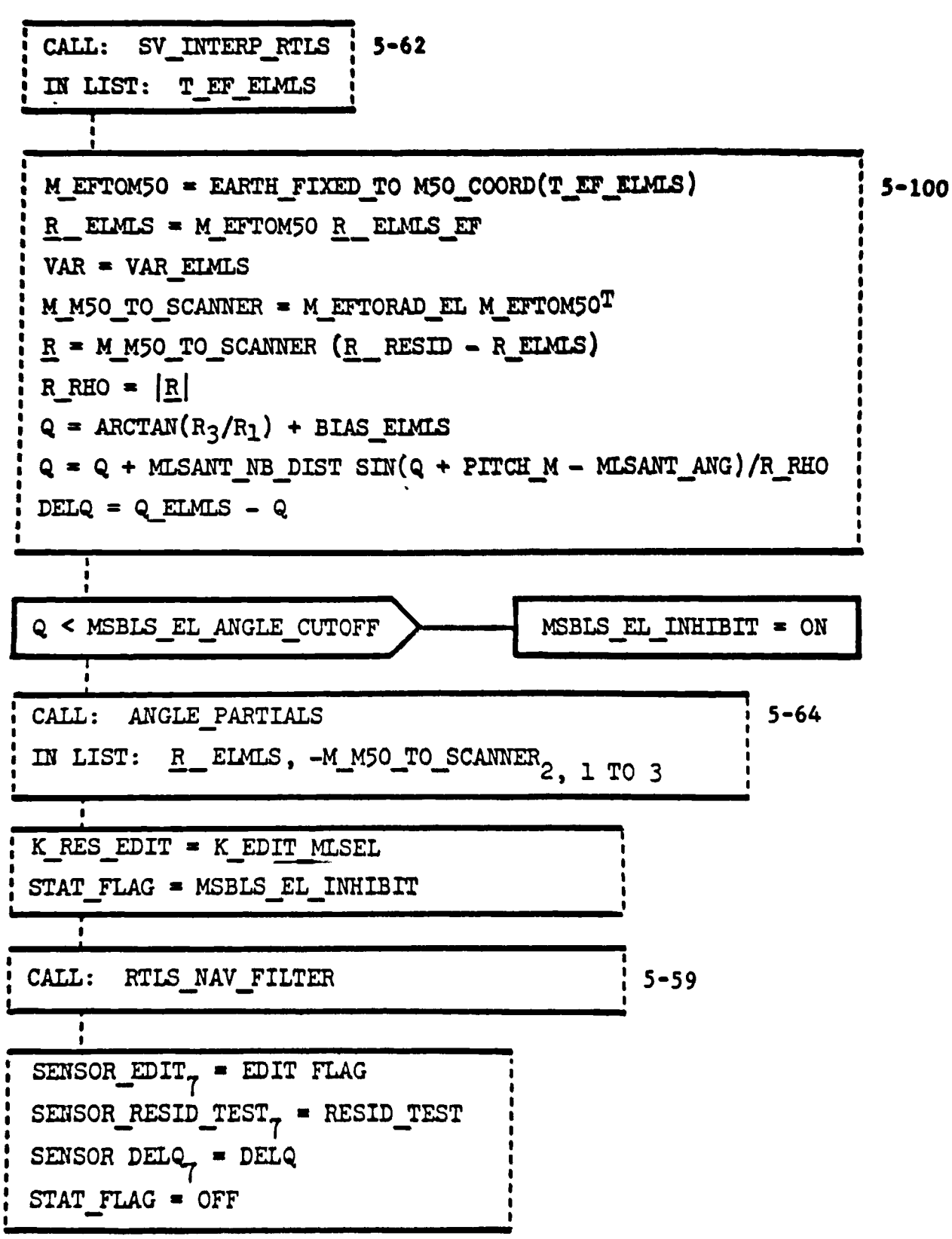


Figure 5.2-29. RTLS_MLS_EL_NAV CODE

TACAN_INIT CODE

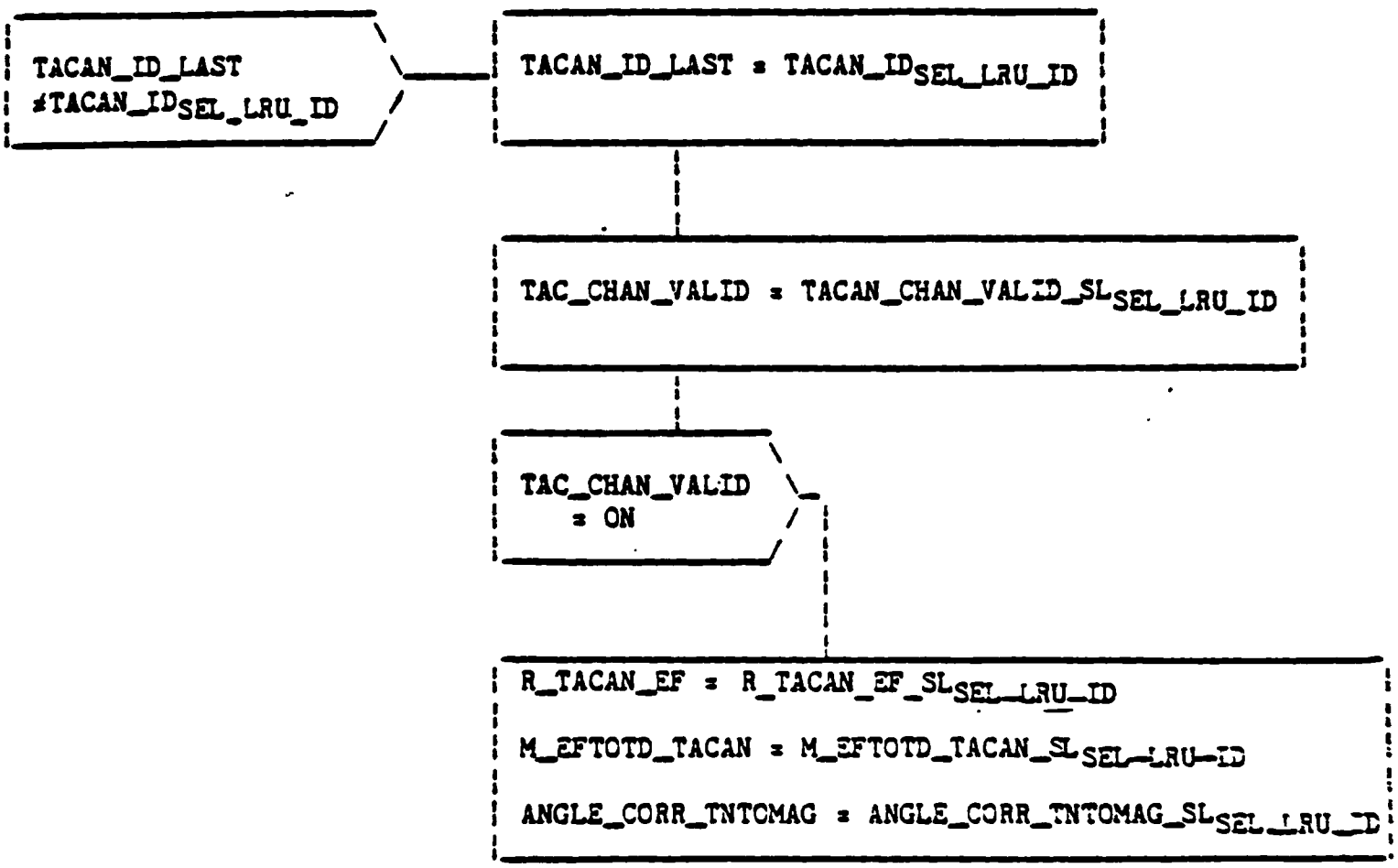


Figure 5.2-30. TACAN_INIT CODE

RTLS_TACAN_NAV_CODE

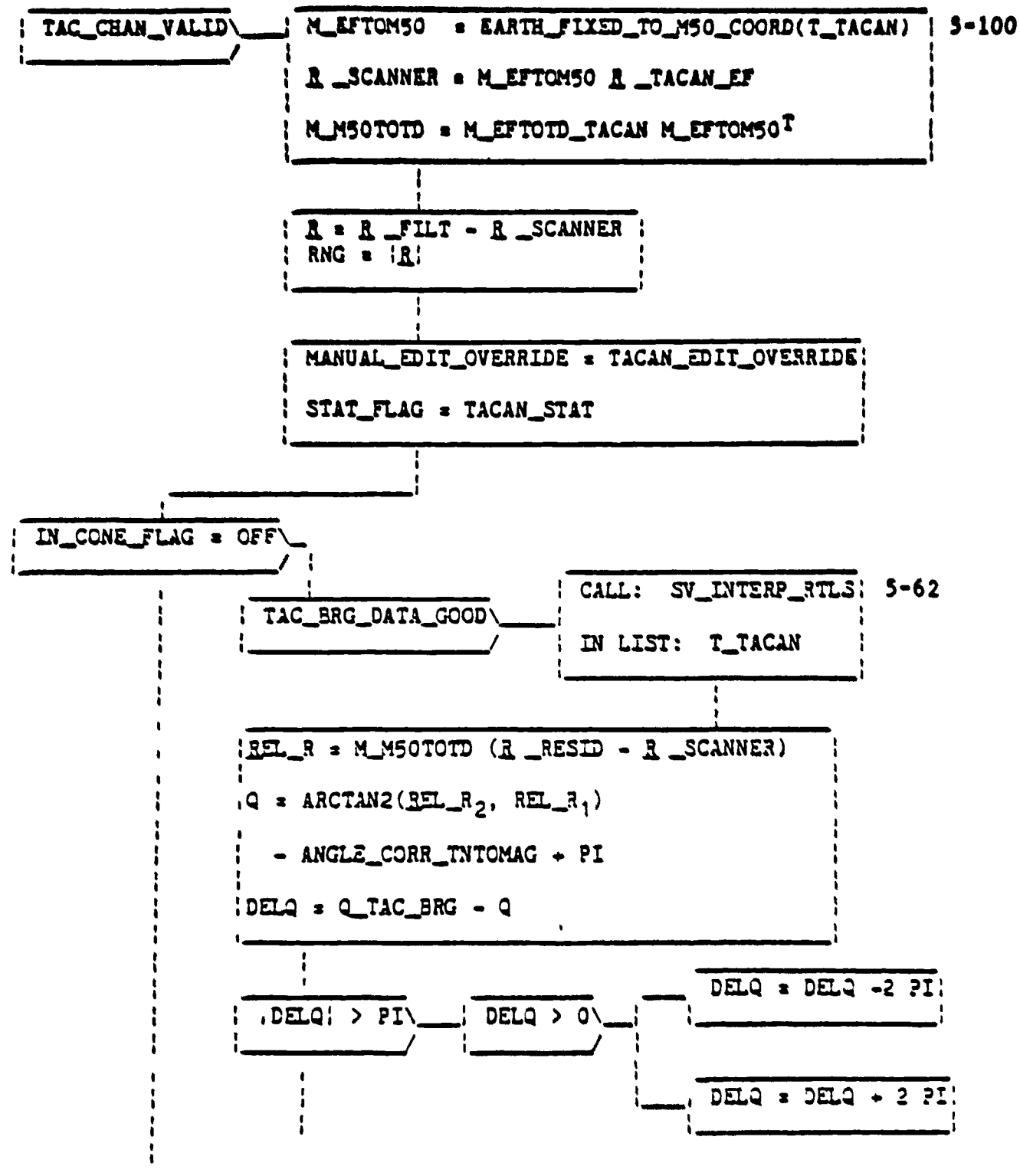


Figure 5.2-31. RTLS TACAN NAV CODE

RTLS_TACAN_NAV_CODE (CONTINUED)

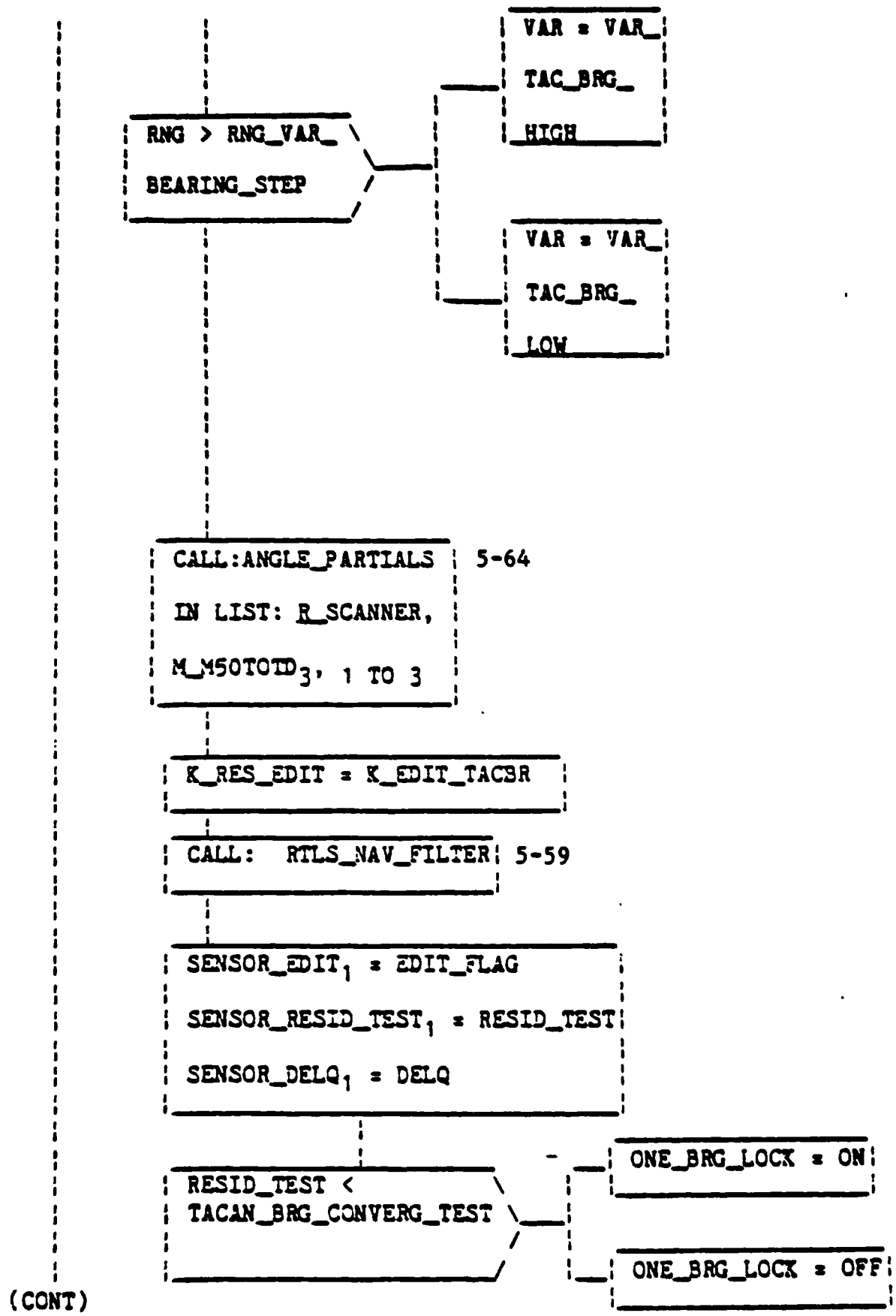


Figure 5.2-31. RTLS_TACAN_NAV CODE (Cont)

RTLS_TACAN_NAV_CODE (CONTINUED)

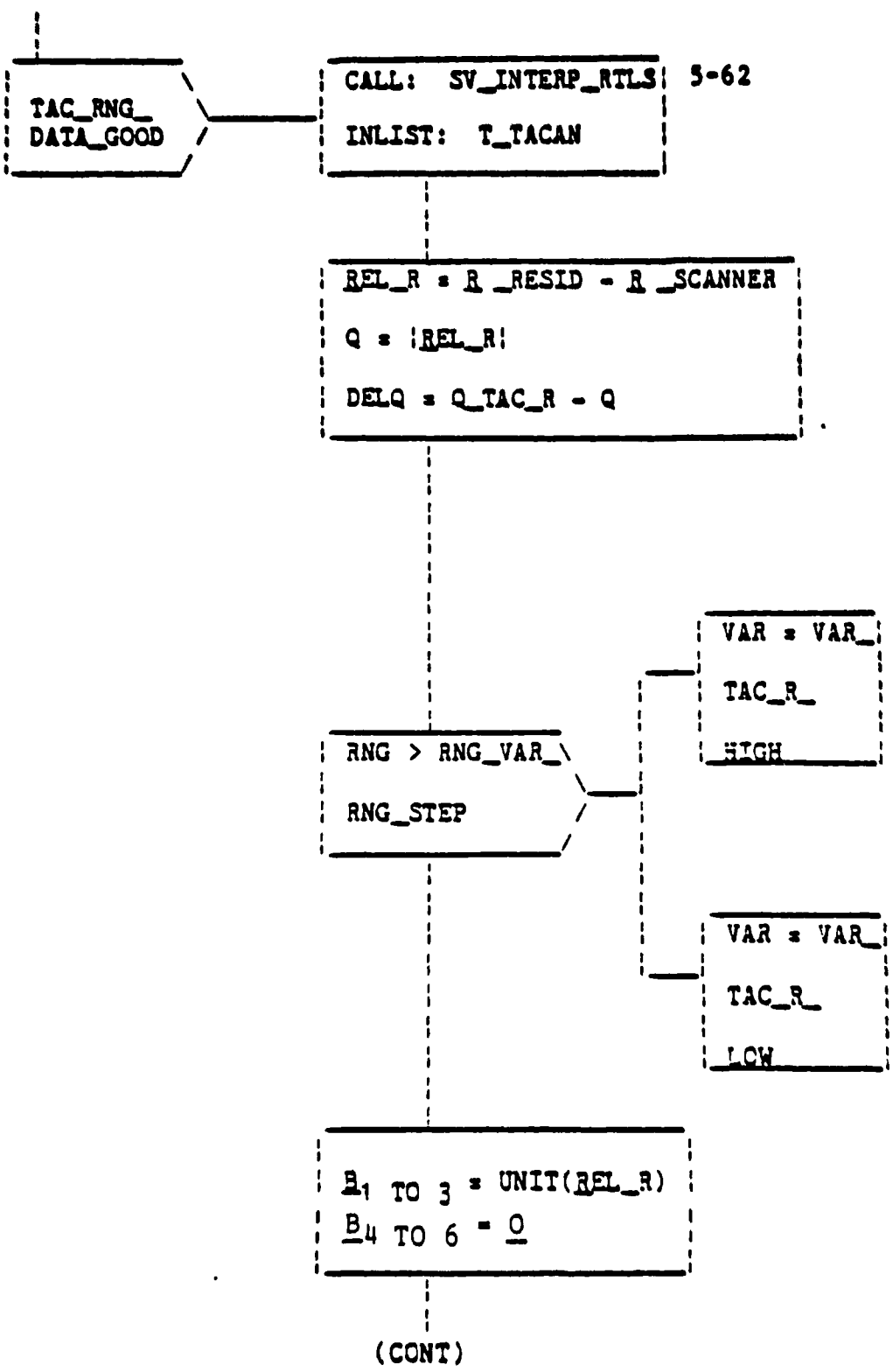


Figure 5.2-31. RTLS_TACAN_NAV CODE (Cont)

RTLS_TACAN_NAV_CODE (CONTINUED)

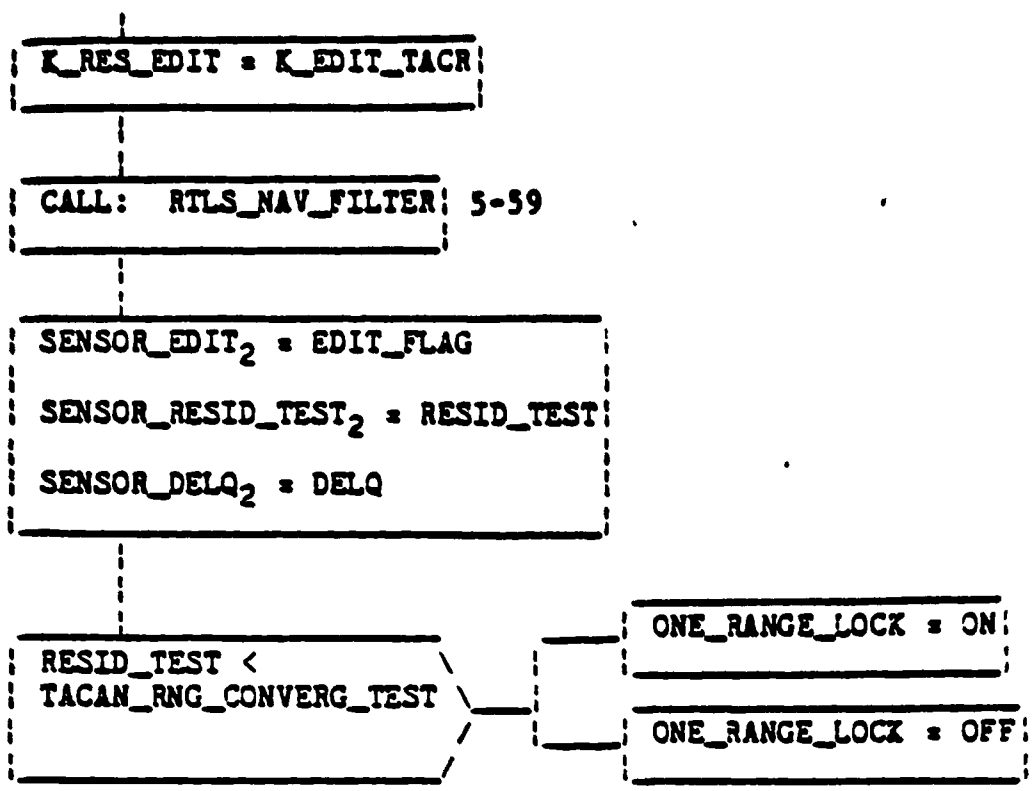


Figure 5.2-31. RTLS_TACAN_NAV CODE (Cont)

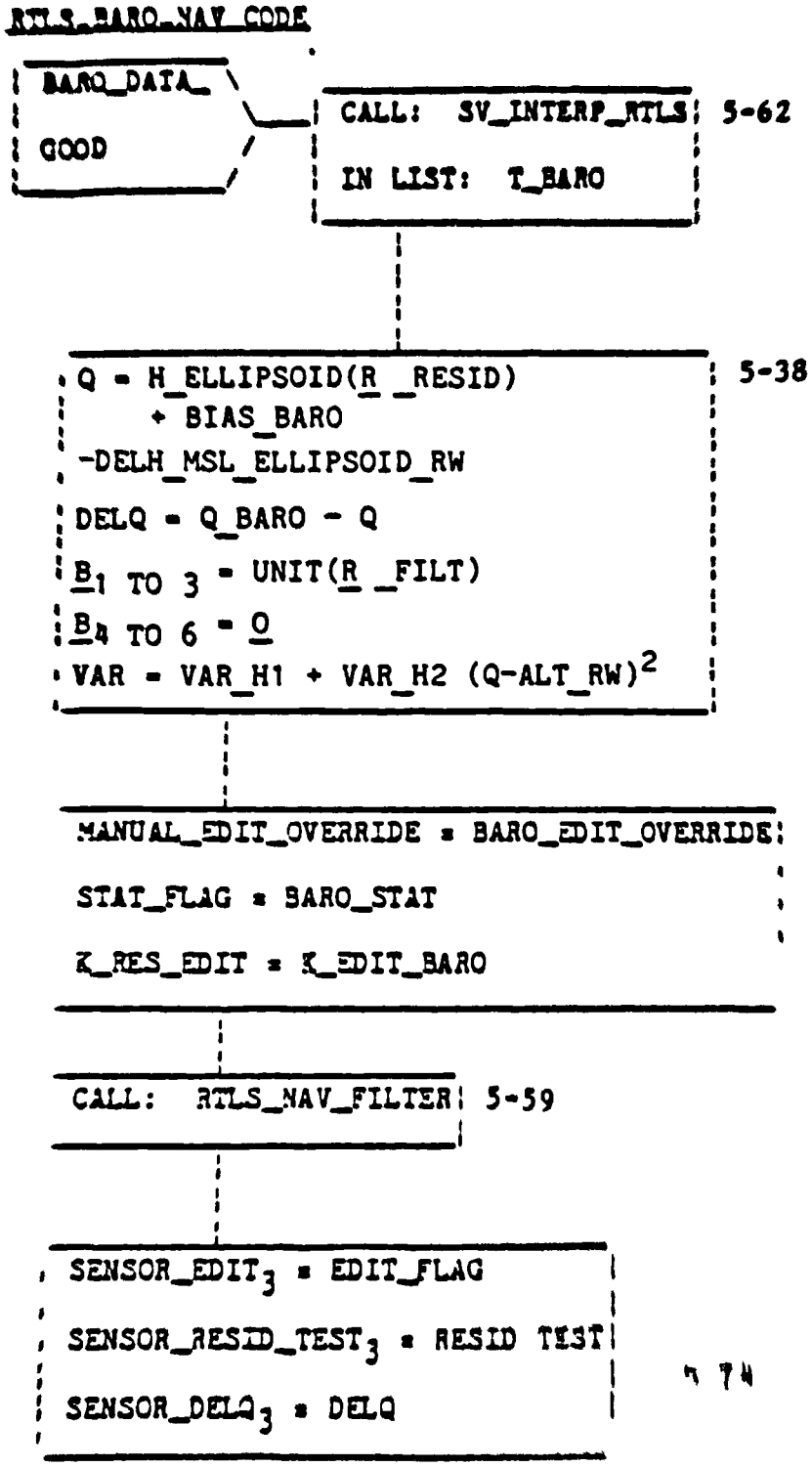
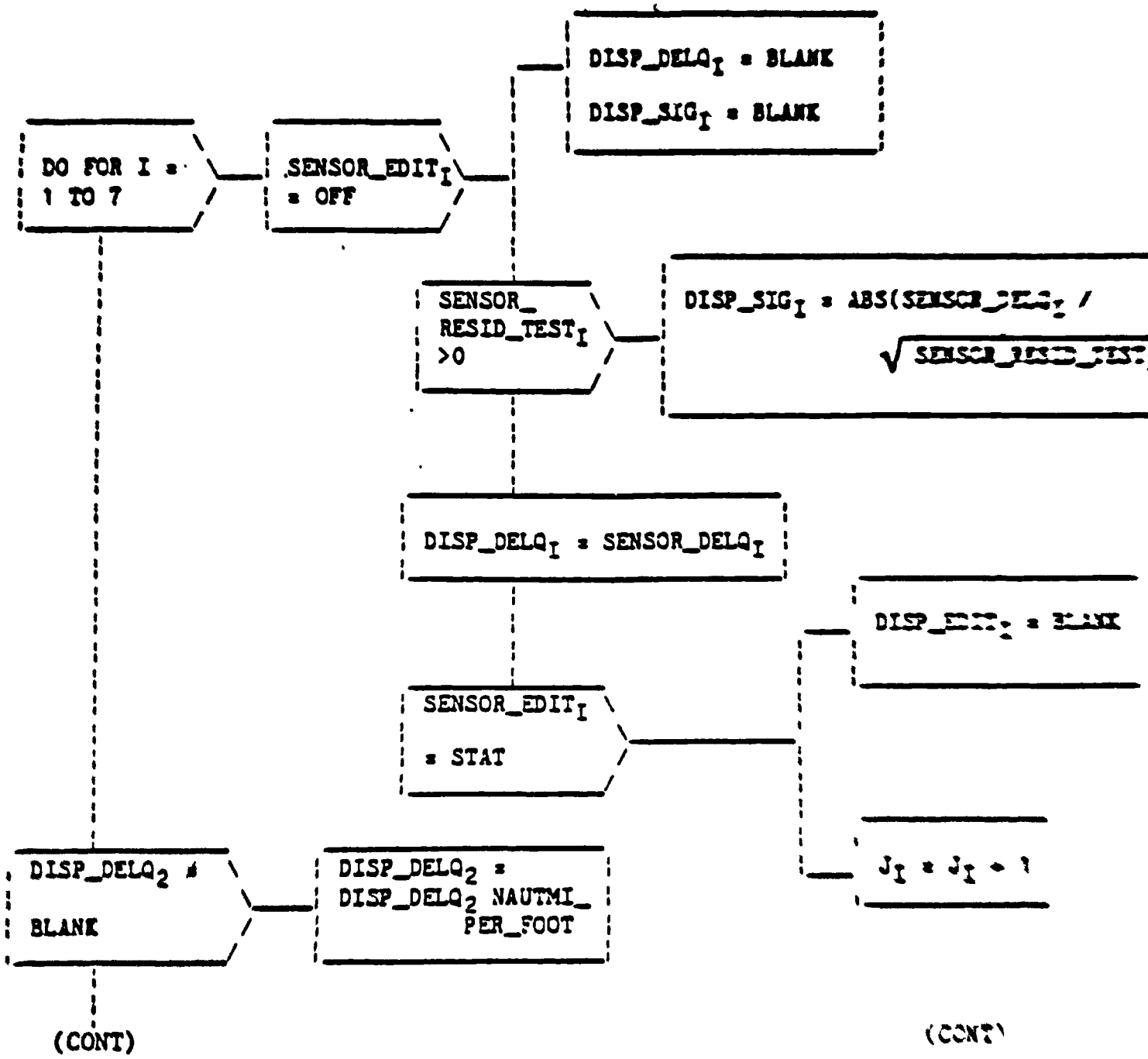


Figure 5 2 12 RTLS BARO NAV CODE

MEAS_PROCESSING_STATISTICS_RTLS_CODE



NOTE: THE CORRESPONDENCE BETWEEN THE INDEX I AND THE MEASUREMENT TYPE IS AS FOLLOWS: 1 = TACAN BEARING, 2 = TACAN RANGE, 3 = BARO ALTITUDE, 4 = DRAG ALTITUDE, 5 = MLS AZIMUTH, 6 = MLS RANGE, 7 = MLS ELEVATION. THE ARRAYS SENSOR_DELQ AND SENSOR_RESID_TEST AND SENSOR_EDIT ARE DIMENSIONED SEVEN

Figure 5.2 33. MEAS PROCESSING_STATISTICS_RTLS CODE

MEAS_PROCESSING_STATISTICS_RTLS_CODE (CONT)

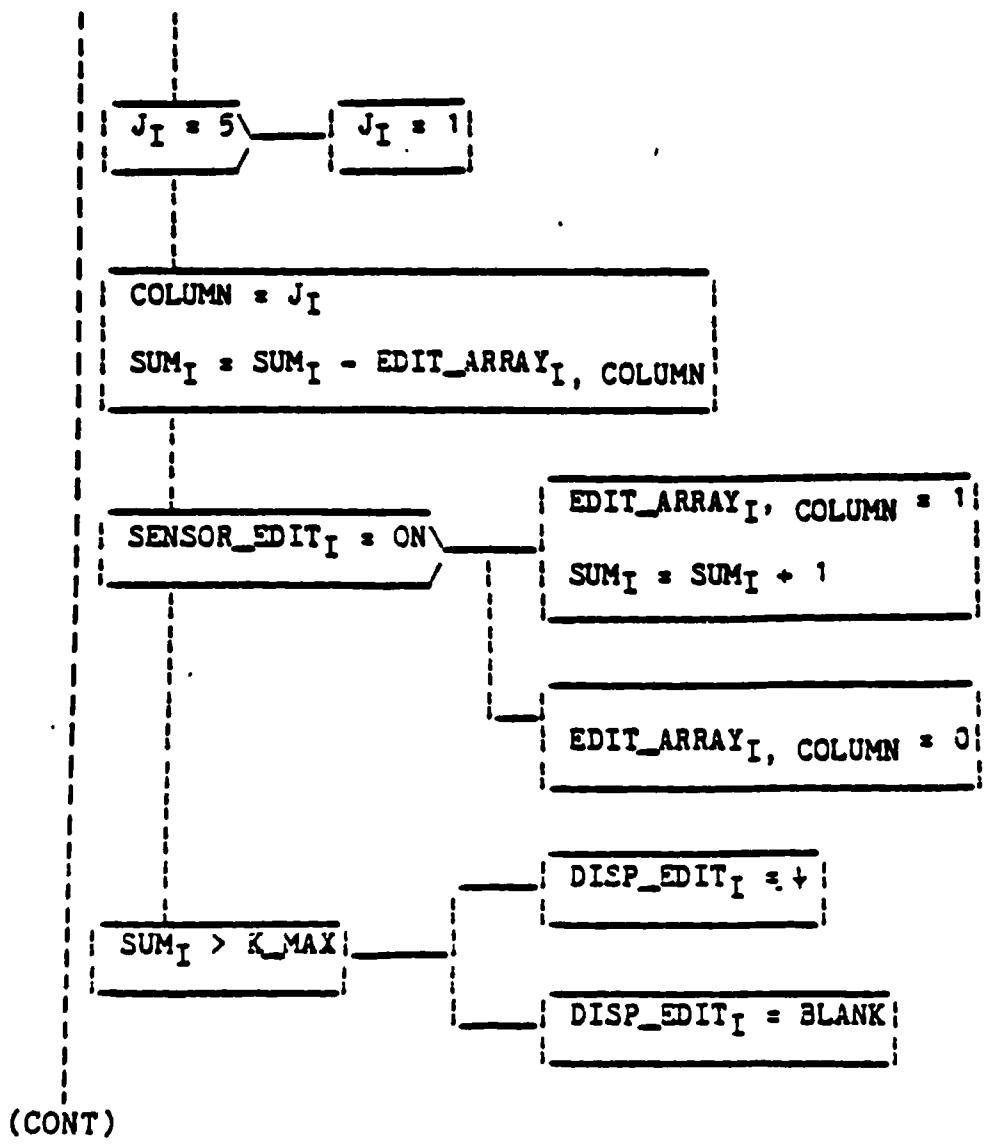


Figure 5.2-33. MEAS_PROCESSING_STATISTICS_RTLS CODE (Cont)

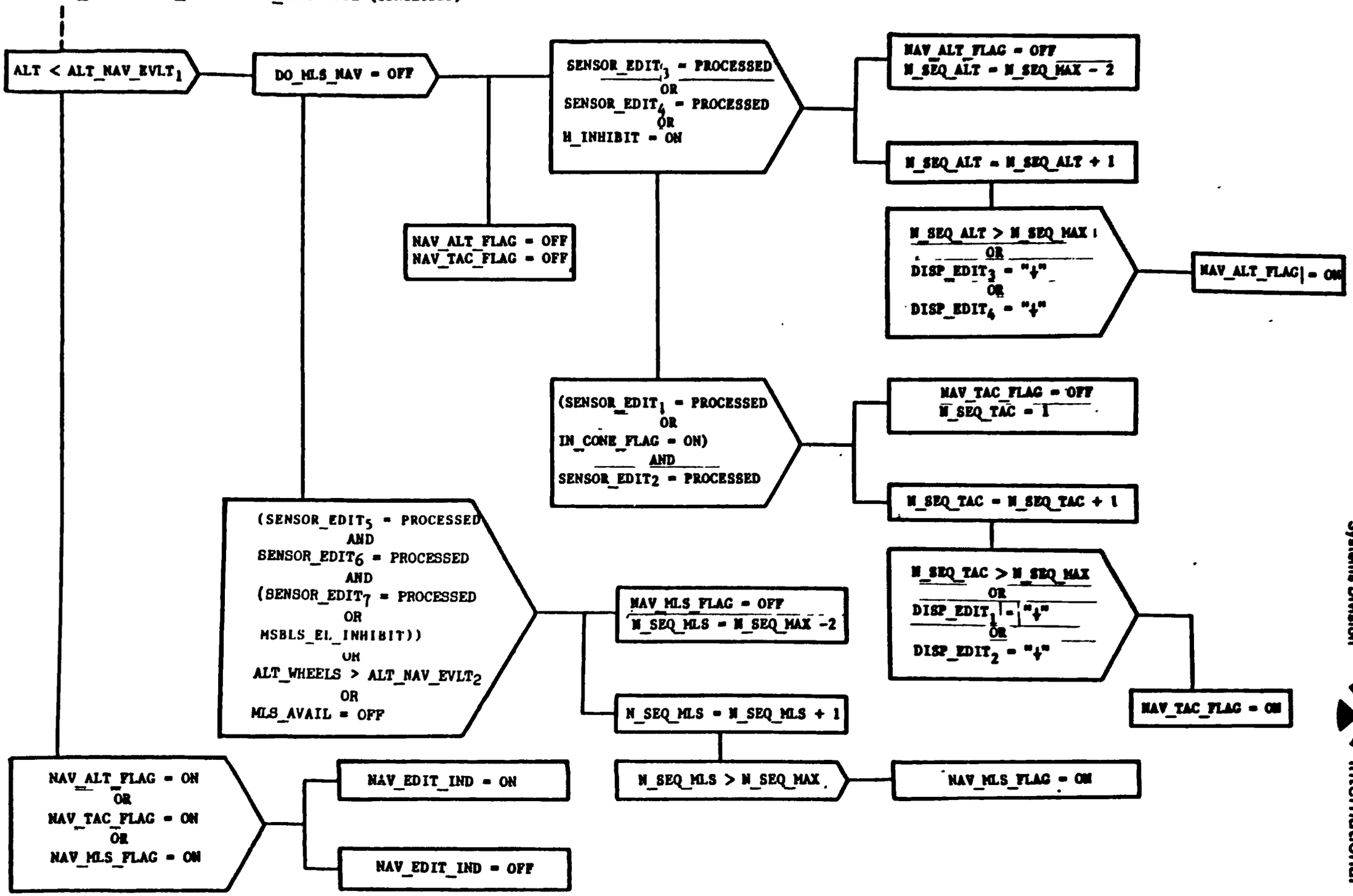
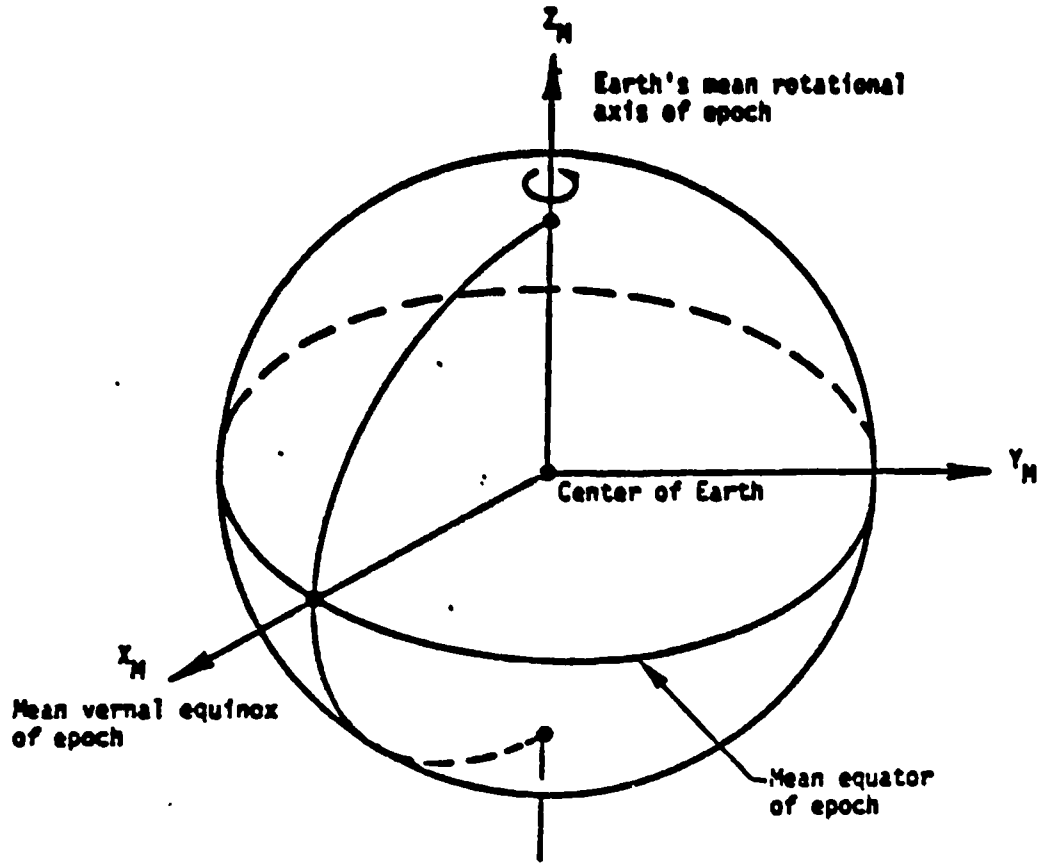


Figure 5.2-33. MEAS_PROCESSING_STATISTICS_RTLS CODE (Cont)

5.3 GENERAL REQUIREMENTS PRINCIPAL FUNCTIONS AND COORDINATE TRANSFORMATION FLOW CHARTS, VARIABLE NAMES, AND DESCRIPTIONS

The supplemental material provided in this section includes (1) definition/explanations of the various coordinate systems used in the navigation requirements (Figures 5.3-1 through 5.3-13) and (2) the transformation and general operations functional flow charts (Figures 5.3-14 through 5.3-26). The variable list for the flow charts is provided in Table 5.3-1.



NAME: Aries mean of 1950, Cartesian, coordinate system

ORIGIN: The center of the Earth

ORIENTATION: The epoch is the beginning of Besselian Year 1950 or Julian ephemeris date 2433282.423357.

The X_M-Y_M plane is the mean Earth's equator of epoch.

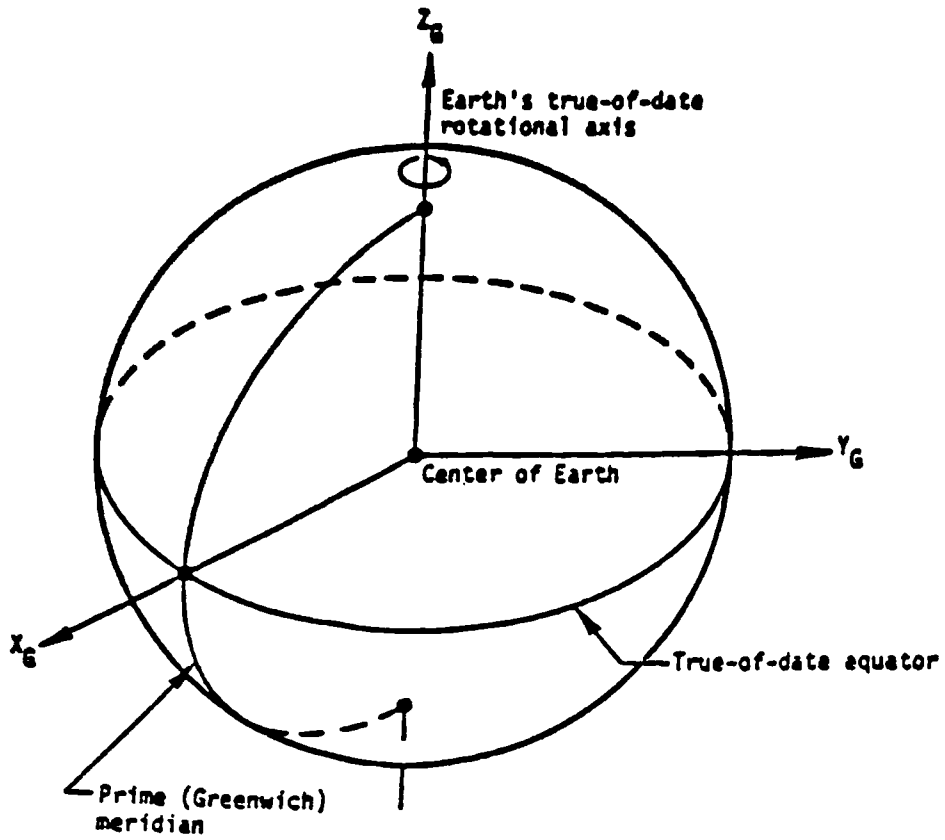
The X_M axis is directed toward the mean vernal equinox of epoch.

The Z_M axis is directed along the Earth's mean rotational axis of epoch and is positive north.

The Y_M axis completes a right-handed system.

CHARACTERISTICS: Inertial, right-handed Cartesian system

Figure 5.3-1. Aries Mean of 1950, Cartesian



NAME: Earth-fixed (Greenwich true of date) coordinate system

ORIGIN: The center of the Earth

ORIENTATION: The X_G-Y_G plane is the Earth's true of date equator.

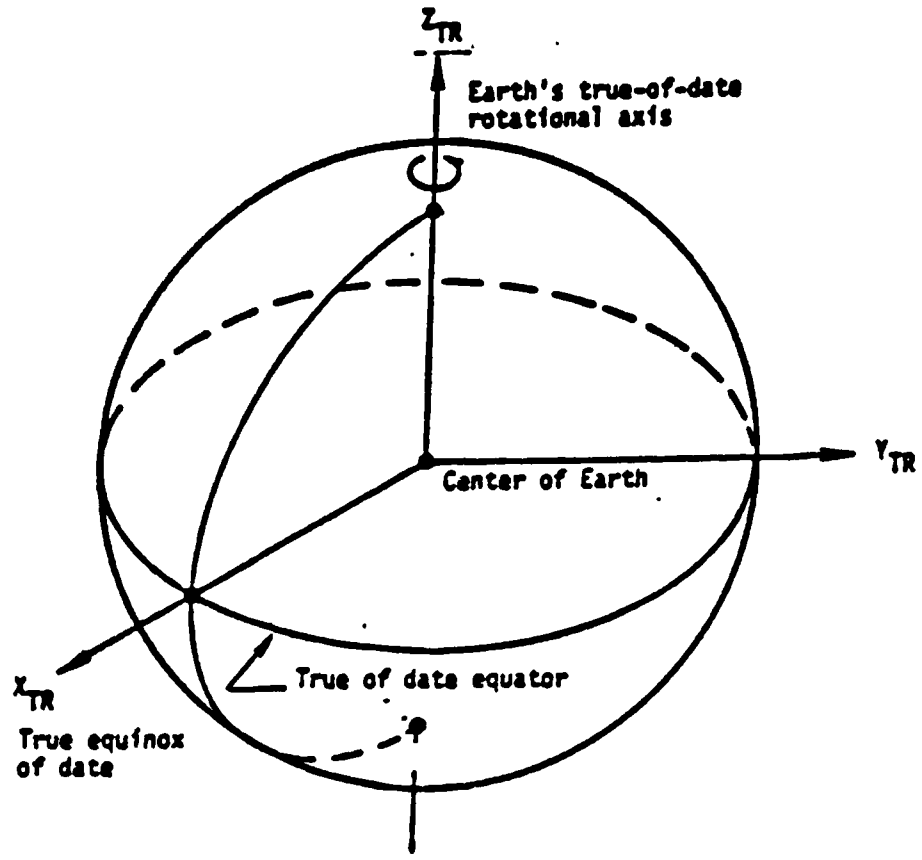
The Z_G axis is directed along the Earth's true of date rotational axis and is positive north.

The $+X_G$ axis is directed toward the prime meridian.

The Y_G axis completes a right-handed system.

CHARACTERISTICS: Rotating, right-handed Cartesian. Velocity vectors expressed in this system are relative to a rotating reference frame fixed to the Earth, whose rotation rates are expressed relative to the Aries mean of 1950 system.

Figure 5.3-2. Earth-Fixed Greenwich True of Date



NAME: Aries true of date, Cartesian, coordinate system

ORIGIN: The center of the Earth

ORIENTATION: The epoch is the current time of interest.

The X_{TR}-Y_{TR} plane is the Earth's true equator of epoch.

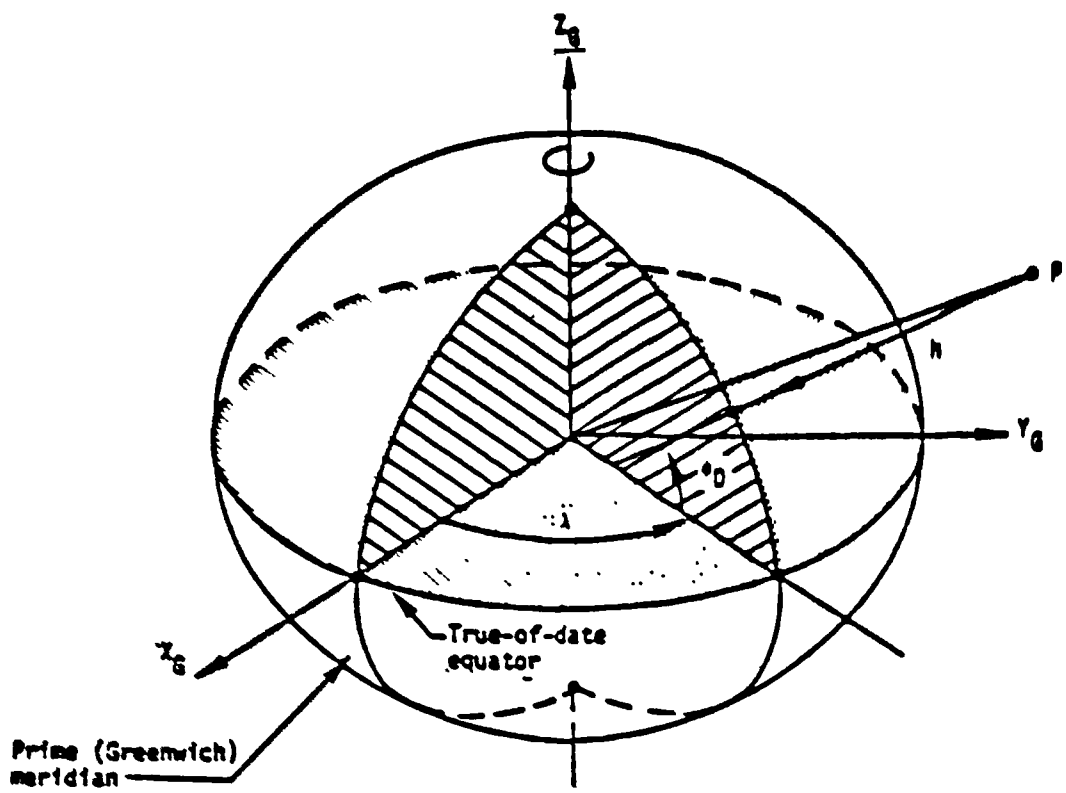
The X_{TR} axis is directed toward the true vernal equinox of epoch.

The Z_{TR} axis is directed along the Earth's true rotational axis of epoch and is positive north.

The Y_{TR} axis completes the right-handed system.

CHARACTERISTICS: Quasi-inertial, right-handed Cartesian

Figure 5.3-3. Aries True of Date, Cartesian



NAME: Geodetic parameters

ORIGIN: This system consists of a set of parameters rather than a coordinate system; therefore, no origin is specified.

ORIENTATION: This system of parameters is based on an ellipsoidal model of the Earth (the Fisher ellipse of 1960). For any point of interest we define a line known as the geodetic local vertical which is perpendicular to the ellipsoid and which contains the point of interest.

h, geodetic altitude, is the distance from the point of interest to the reference ellipsoid, measured along the geodetic local vertical, and is positive for points outside the ellipsoid.

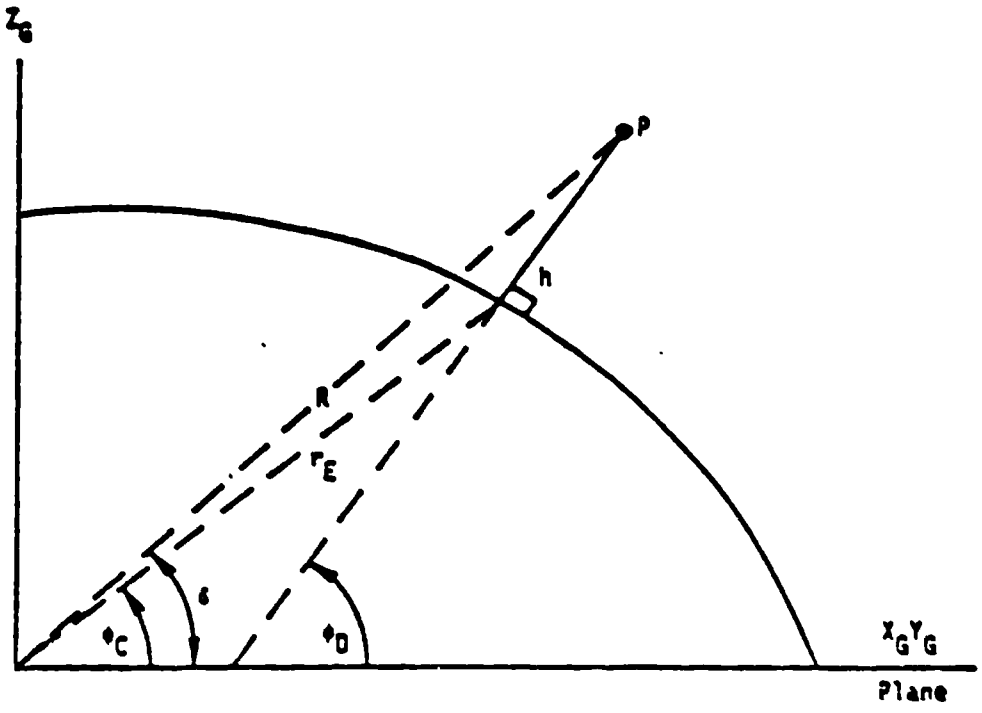
λ is the longitude measured in the plane of the Earth's true equator from the Prime (Greenwich) Meridian to the local meridian, measured positive eastward.

ϕ_D is the geodetic latitude, measured in the plane of the local meridian from the Earth's true equator to the geodetic local vertical, measured positive north from the equator.

NOTE: A detailed explanation of declination, geodetic latitude, and geocentric latitude is provided in Part B of this figure.

CHARACTERISTICS: Rotating polar coordinate parameters. Only position vectors are expressed in this coordinate system. Velocity vectors should be expressed in the Aries mean of 1950 or the Aries true of data polar for inertial or quasi-inertial representations, respectively.

Figure 5.3-4. Basic Definitions--Geodetic Parameters



NAME: Geodetic parameters

DEFINITIONS: h is the altitude of point P. Measured perpendicular from the surface of the referenced ellipsoid.

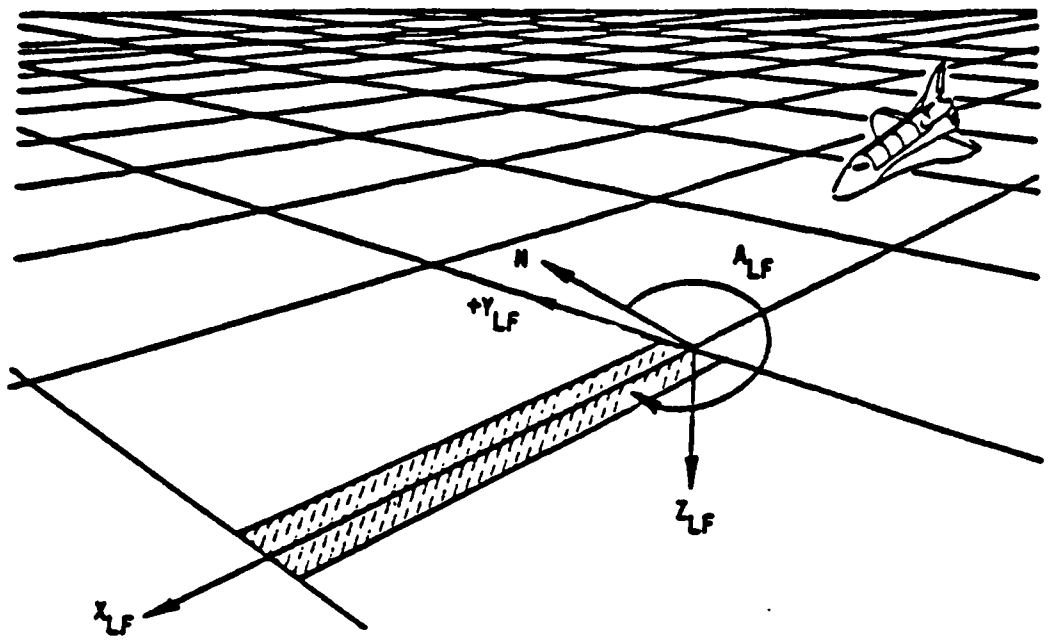
ϕ_D is the geodetic latitude of point P.

ϕ_C is the geocentric latitude of point P.

δ is the angle between radius vector and equatorial plane (declination).

λ is the longitude of point P. Angle (+ east) between plane of the figure and the plane formed by the Greenwich meridian.

Figure 5.3-5. Detailed Explanation--Geodetic Parameters



NAME: Runway coordinate system

ORIGIN: Runway center at approach threshold

ORIENTATION AND DEFINITIONS: Z_{LF} axis is normal to the ellipsoid model through the runway centerline at the approach threshold and positive toward the center of the Earth.

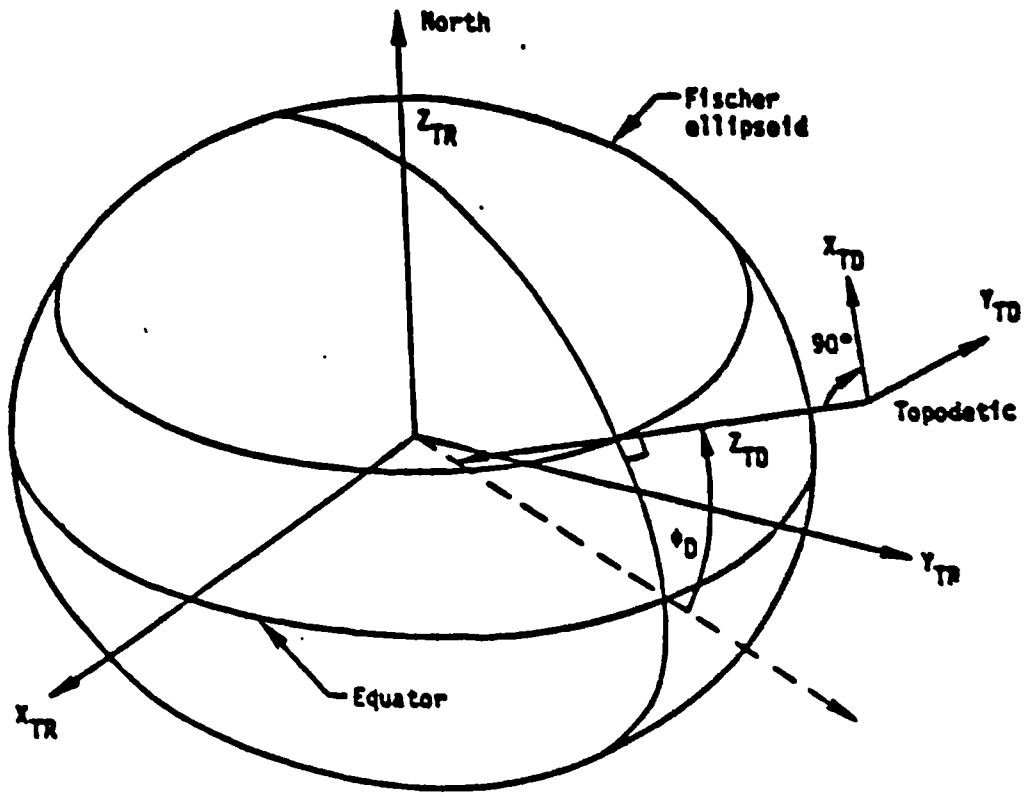
X_{LF} axis is perpendicular to the Z_{LF} axis and lies in a plane containing the Z_{LF} axis and the runway centerline (positive in the direction of landing).

Y_{LF} axis completes the right-handed system.

A_{LF} is the runway azimuth measured in the $X_{LF}Y_{LF}$ plane from true north to the $+X_{LF}$ axis (positive clockwise).

CHARACTERISTICS: Rotating, Earth-referenced

Figure 5.3-6. Runway Coordinate System



NAME: Topodetic coordinate system—

ORIGIN: Orbiter center of mass*

ORIENTATION: Z_{TD} is normal to a geodetic local tangent plane and is positive toward the Earth's center.

X_{TD} is perpendicular to Z_{TD} axis and is positive northward along the meridian plane containing the Orbiter.

Y_{TD} completes the right-handed orthogonal system

CHARACTERISTICS: Rotating, right-handed Cartesian system. Velocity vectors are expressible in this system for the Orbiter, given relative velocity V_{TD} in this system.

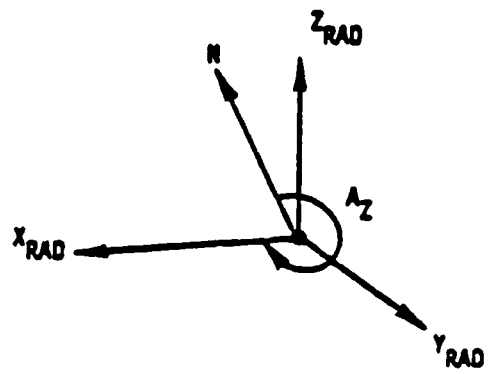
$$\gamma_{TD} = \sin^{-1}\left(\frac{-\dot{z}_{TD}}{V_{TD}}\right)$$

$$\psi_{TD} = \tan^{-1}\left(\frac{\dot{Y}_{TD}}{\dot{X}_{TD}}\right)$$

ϕ_D = geodetic latitude

*A similar system may be defined for any point of interest

Figure 5.3-7. Topodetic Coordinate System



NAME: MSBLS radar coordinate system

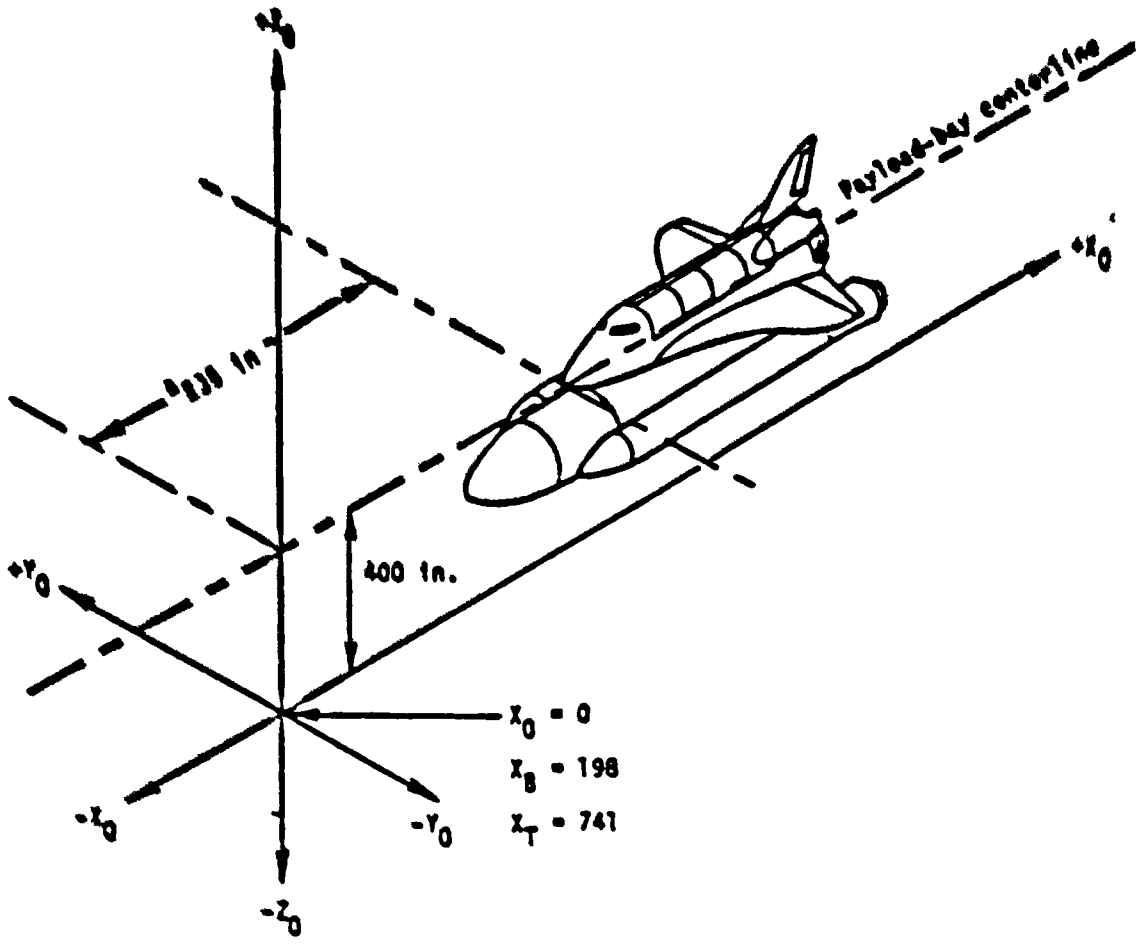
ORIGIN: MSBLS radar position

ORIENTATION AND DEFINITIONS: Z_{RAD} is normal to the ellipsoidal model, positive away from the center of the Earth

X_{RAD} is the local horizontal plane of the radar in the boresight direction of the radar antenna. The angle A_Z is measured positively clockwise from true north to X_{RAD}

CHARACTERISTICS: Rotating, Earth-referenced

Figure 5.3-8. MSBLS Radar Coordinate System



NAME. Body coordinate system (structural)

ORIGIN: In the Orbiter plane of symmetry, 400 inches below the centerline of the payload bay and at Orbiter X-station = 0

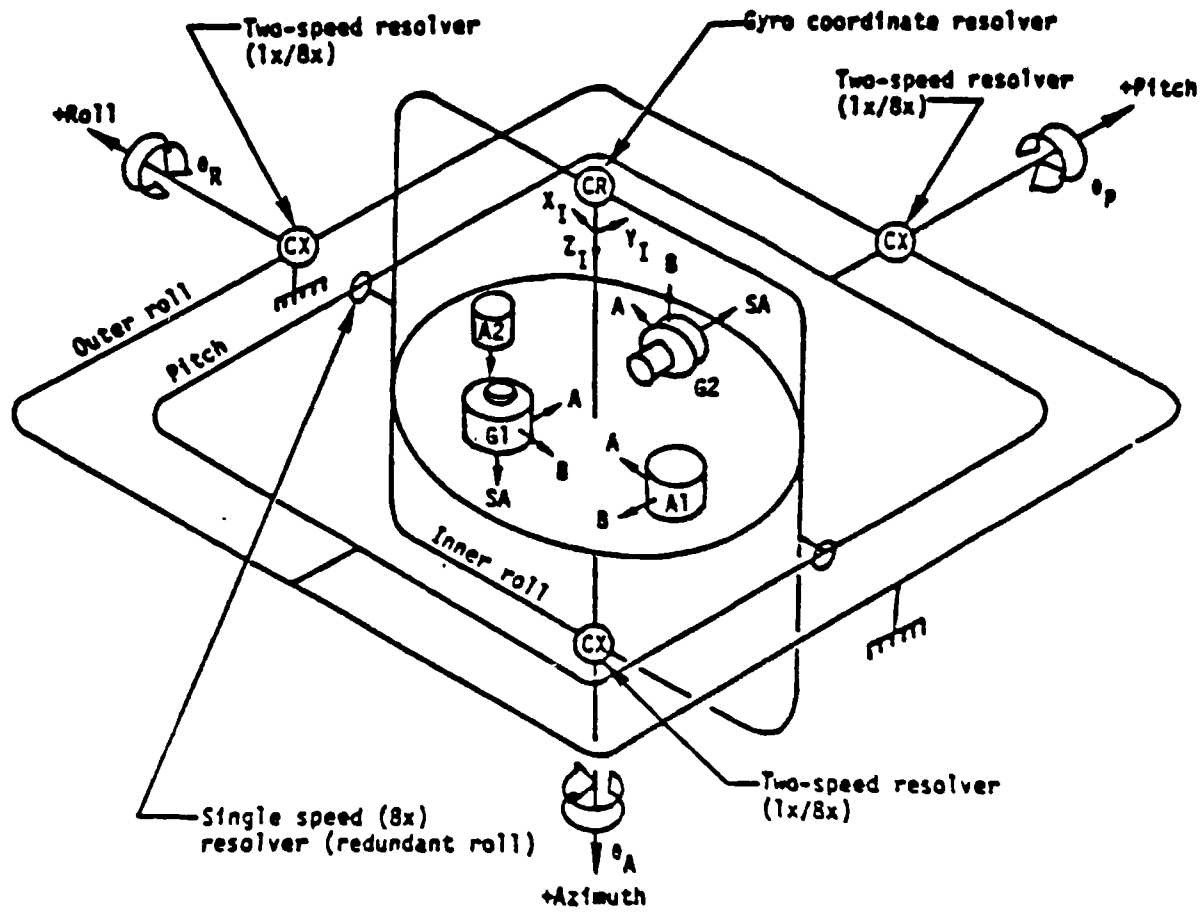
ORIENTATION. The X_0 axis is in the vehicle plane of symmetry, parallel to and 400 inches below the payload bay centerline. Positive sense is from the nose of the vehicle toward the tail.

The Z_0 axis is in the vehicle plane of symmetry, perpendicular to the X_0 axis. Positive upward in landing attitude.

The Y_0 axis completes a right handed system.

CHARACTERISTICS: Rotating, right-handed Cartesian

Figure 5.3-9. Body Coordinate System (Structural)



NAME: Stable member (IMU)

ORIGIN: The intersection of the innermost gimbal axis and the measurement plane of the XY two axis accelerometer

ORIENTATION: The Z_I axis is coincident with the innermost gimbal axis.

The X_I axis is determined by the projection of the X accelerometer input axis (IA) onto a plane orthogonal to Z_I. Y_I completes a right-handed triad.

In a perfect IMU, with all misalignments zero, these relationships hold:

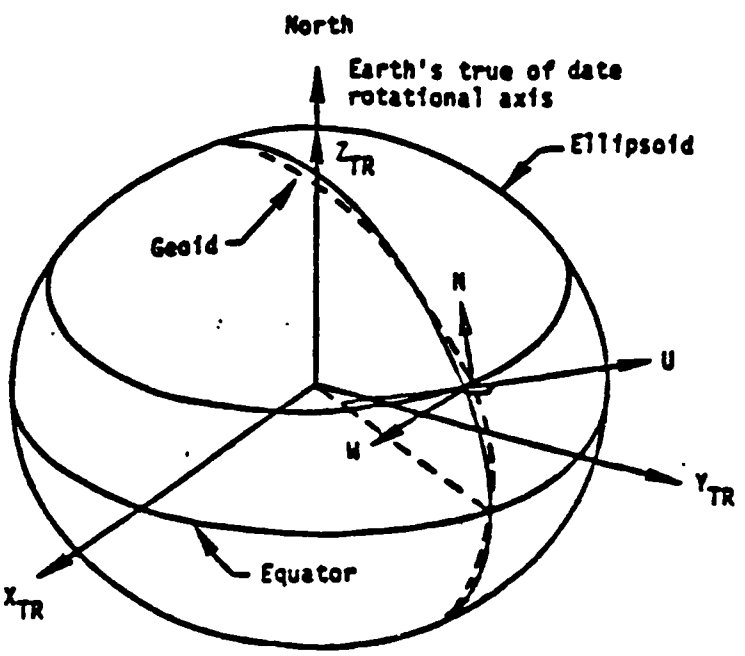
The X accelerometer and X gyro IAs are parallel to the X_I axis.

The Y accelerometer and Y gyro IAs are parallel to the Y_I axis.

The Z accelerometer and Z gyro IAs are parallel to the Z_I axis.

Figure 5.3-10. Stable Member (IMU)

78M54:C



NAME: NWU geographic coordinate system

ORIGIN: Point of interest

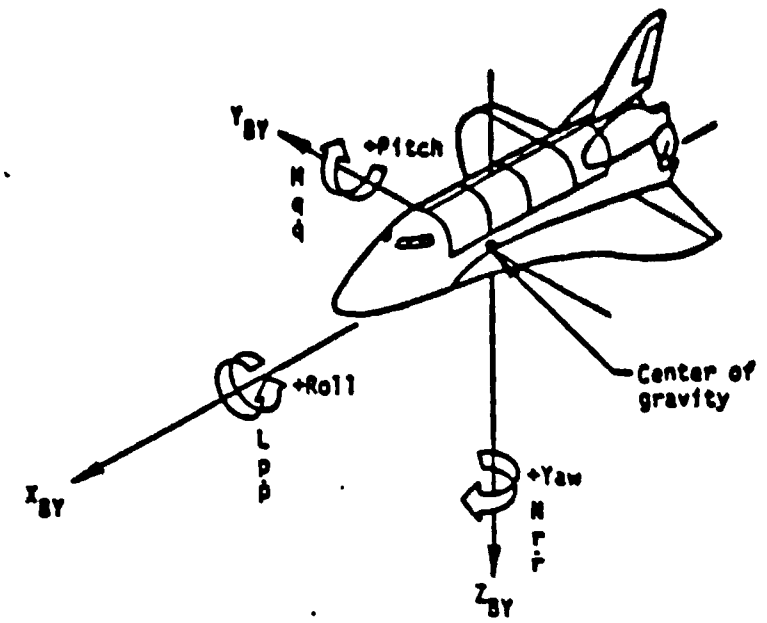
ORIENTATION: U is positive up along the Earth's astronomic or plumb-bob vertical.

W is positive along the cross product of U and the Earth's spin axis.

N completes the right-handed orthogonal system. (N = W x U)

CHARACTERISTICS: Rotating, right-handed, Earth-referenced coordinate system

Figure 5.3-11. NWU Geographic Coordinate System



NAME: Body axis coordinate system

ORIGIN: Center of mass

ORIENTATION: X_{BY} axis is parallel to the Orbiter structural body X_O axis; positive toward the nose.

Z_{BY} axis is parallel to the Orbiter plane of symmetry and is perpendicular to X_{BY}, positive down with respect to the Orbiter fuselage.

Y_{BY} axis completes the right-handed orthogonal system.

CHARACTERISTICS: Rotating, right-handed, Cartesian system

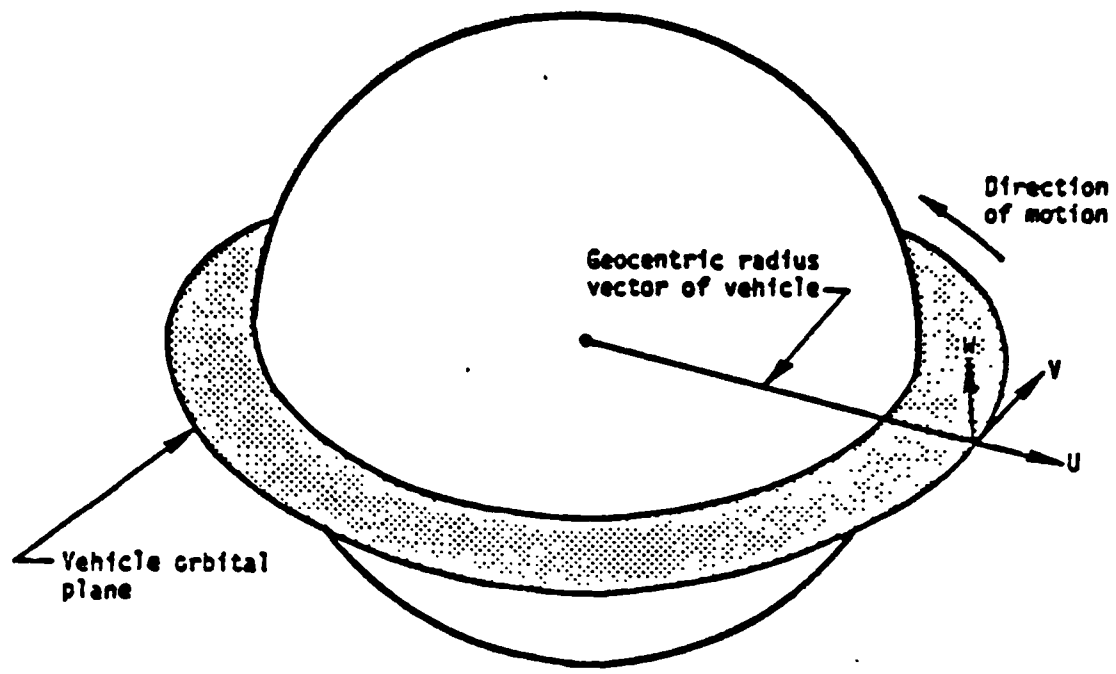
L, M, N: Moments about X_{BY}, Y_{BY}, and Z_{BY} axes, respectively

p, q, r: Body rates about X_{BY}, Y_{BY}, and Z_{BY} axes, respectively

$\dot{p}$, $\dot{q}$, $\dot{r}$: Angular body acceleration about X_{BY}, Y_{BY}, and Z_{BY} axes, respectively

The Euler sequence that is commonly associated with this system is a yaw, pitch, roll sequence, where ψ = yaw, θ = pitch, and ϕ = roll or bank. This attitude sequence is yaw, pitch, and roll around the Z_{BY}, Y_{BY}, and X_{BY} axes, respectively

Figure 5.3-12. Body Axis



NAME: UVW coordinate system

ORIGIN: Point of interest

ORIENTATION: The U-V plane is the instantaneous orbit plane at epoch.

The U axis lies along the geocentric radius vector to the vehicle and is positive radially outward.

The W axis lies along the instantaneous orbital angular momentum vector at epoch and is positive in the direction of the angular momentum vector.

The V axis completes a right-handed system. (V = W x U).

CHARACTERISTICS: Quasi-inertial, right-handed Cartesian coordinate system. This system is quasi-inertial in the sense that it is treated as an inertial coordinate system, but it is redefined at each point of interest.

Figure 5.3-13._ UVW Coordinate System

Table 5.3-1. Variable List - General Requirements Principal Functions and Coordinate Transformations

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
A	M	0	--	Transformation matrix body to M50
ALPHA	S	0	--	Angle of attack used in state prediction (radians)
ALPHAIN	S	0	--	Snapped copy of angle of attack (degrees)
ALT	S	0	--	Current orbiter altitude above reference ellipsoid (EF_TO_GEODETIC, GEODETIC_TO_EF)
ALT_ABOVE_ ELLIPSOID_ MAXI(I)	V(10)	I-load	--	Altitude of the TACAN station above the reference ellipse
ALT_MLSEL ALT_MLSEL(K)	S V(4)	0 I-load	--	Altitude above reference ellipsoid of MSBLS elevation scanner
ALT_MLS_R_AZ ALT_MLS_R_AZ(K)	S V(4)	0 I-load	--	Altitude of MSBLS range/azimuth scanner above reference ellipsoid
ALT_RW	S	0	--	Altitude above reference ellipsoid of runway reference point
ALT_TACAN_ SL(I)	V	0	--	Altitude of TACAN station (each LRU) output from site lookup, I=1, 3
ANGLE_CORR_ TNTOMAG_RW	S		TD	Angle of magnetic variation from true north at selected runway
ANGLE_CORR_ TNTOMAG_SL(I)	V	0	TD	Variation of magnetic north from true north at TACAN site (each LRU) output from site lookup, I=1, 3
A_0	S	0	--	Local parameter in EF_TO_GEODETIC
AREA_SEL	INT	1	--	Selected area
AUTO_CHANNEL_ ID	INT	0	--	Channel/mode identifier for automatically selected Tacan station

CR89596C

Table 5.3-1. Variable List - General Requirements Principal Functions and Coordinate Transformations (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
AZ	S	0	TD	Bearing from true north; EF_TO RUNWAY, EF_TO_SCANNER
AZIMUTH_RW	S	0	TD	Bearing from true north of runway coordinate system +X axis
BETA	S	0	--	SIDESLIP angle used in state prediction (radians)
BETAIN	S	0	--	Snapped copy of sideslip angle (degrees)
BIAS_MLSRANGE BIAS_MLSRANGE(K)	S V(4)	0 I-load	--	MSBLS range measurement bias
BIAS_AZMLS BIAS_AZMLS(K)	S V(4)	0 I-load	-- --	MSBLS azimuth measurement bias
BIAS_ELMLS BIAS_ELMLS(K)	S V(4)	0 I-load	--	MSBLS elevation measurement bias
CAZ	S	0	--	Cosine of AZ
CLAT	S	0	--	Cosine of LAT_GEOD; EF_TO_TOPDET, GEODETIC_TO_EF
CLON	S	0	--	Cosine of LON; EF_TO_TOPDET
COS_P	S	0	--	Cosine of geocentric elevation angle
DEL	S	0	--	Delta value for radius calculations
DEL_LAT	S	0	--	Correction angle for latitude
DELH_MSL_ ELLIPSOID_RW	S S	0 0	--	Altitude of mean sea level above reference ellipsoid at runway
DH_TACAN_SL (I)	V	0	--	Altitude of mean sea level above reference ellipsoid at TACAN station (each LRU) output from site lookup, I=1, 3

CR89596C

Table 5.3-1. Variable List - General Requirements Principal Functions and Coordinate Transformations (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description	
DT_MAX	F		--	A/E precise predictor step size (maximum allowable)	CR89596C
DUM	S	0	--	Dummy variable (EF_TO_GEODETIC, GEODETIC_TO_EF)	
DUM1	S	0	--	Dummy variable (GEODETIC_TO_EF)	
EARTH_RADIUS_ EQUATOR	S	Constant	--	Earth equatorial radius	CR89596C
EARTH_RATE	S	Constant	--	Earth rotation rate	
ELLIPT	S	Constant	--	Earth ellipticity constant	
EL_SCANNER_ BEARING	S	0	--	Bearing from true north of MLS elevation scanner boresight axis	
EL_SCANNER_ BEARING(K)	V(4)	I-load	--		CR89596C
FIRST_PASS	BIT	ON	--	First pass flag used in ascent site lookup init	
FLATCON			--	The eccentricity squared of the ellipsoid	
G _FINAL	V		M50	Total M50 vehicle acceleration vector at end of prediction interval (at T_FINAL)	
GMD_PRED	INT		--	Flag indicating degree of Earth potential model (for prediction)	CR89596C
GMO_PRED	INT		--	Flag indicating order of Earth potential model (for prediction)	
G _PREVIOUS	V	--	M50	Local variable (A E precise predictor) total acceleration vector	
I	INT	1	--	Integer-subscript or iteration counter	

Table 5.3-1. Variable List - General Requirements Principal Functions and Coordinate Transformations (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
J	INT	0	—	Local selected runway MSBLS pointer
K	INT	0	—	Local site table index parameter
L	INT	0	—	Local site table index parameter
LAM	S	0	—	Earth rotation angle from epoch
LAT_GEOD	S	0	—	Geodetic latitude of point EF_TO_TOPDET, EF_TO_RUNWAY, EF_TO_SCANNER, EF_TO_GEODETIC, GEODETIC_TO_EF
LATITUDE_GEODETIC_MAXI(I)	V(10)	I-load	—	Geodetic latitude of the TACAN station
LAT_MLSEL LAT_MLSEL(K)	S V(4)	0 I-load	—	Geodetic latitude of the MSBLS elevation antenna
LAT_MLS_R_AZ LAT_MLS_R_AZ(K)	S V(4)	0 I-load	—	Geodetic latitude of MSBLS range/azimuth scanner site
LAT_TACAN_SL(I)	V	0	—	Geodetic latitude of TACAN site (each LRU) output from site lookup, I=1, 3
LENGTH_RW	INT		—	Runway length
LON	S	0	—	Geodetic longitude of a point EF_TO_TOPDET, EF_TO_RUNWAY, EF_TO_SCANNER, EF_TO_GEODETIC, GEODETIC_TO_EF
LONGITUDE_EAST_MAXI(I)	V(10)	I-load	—	Longitude of the TACAN station
LONG_MLSEL LONG_MLSEL(K)	S V(4)	0 I-load	—	Geodetic longitude of the MSBLS elevation antenna
LONG_MLS_R_AZ LONG_MLS_R_AZ(K)	S V(4)	0 I-load	—	Longitude of MSBLS range/azimuth scanner site
LONG_TACAN_SL(I)	V	0	—	Longitude of TACAN site (each LRU) output from site lookup, I=1, 3

CR89596C

CR89596C

Table 5.3-1. Variable List - General Requirements Principal Functions and Coordinate Transformations (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
LRU_ID	INT	0	--	Index (1 to 3) input to TACAN site lookup when LRU is tuned to a ground station. Identifies which of three sets of output parameters is to be changed
M, matrix, mat	M	0	--	General transformation matrices
MAGNETIC_ VARIATION_ MAXI(I)	V(10)	I-load	--	Angle between true north and magnetic north at the TACAN station
M_EFTORAD_EL	M	0	--	Transformation matrix from Earth-fixed to MSBLS elevation radar coordinates
M_EFTORAD_R_AZ	M	0	--	Transformation matrix from Earth-fixed to AZ/range MSBLS radar coordinate frame
M_EFTORW	M	I-load	--	Earth-fixed to prime RW transformation matrix
M_EFTOTD_ TACAN_SL(I)	M	0	--	Transformation matrix from Earth-fixed to topodetic coordinates at TACAN site (each LRU) output from site lookup, I=1, 3
M_M50TOEF_AT_ EPOCH	M	I-load	--	Transformation matrix from M50 to Earth-fixed at T-epoch
MLS_AVAIL	BIT	OFF	--	Flag indicating (ON) the availability of MSBLS at currently selected runway
MSL_ABOVE_ ELLIPSOID_ MAXI(I)	V(10)	I-load	--	The difference in an altitude above the reference ellipse and that alti tude above mean sea level or geoid
NEW_AREA	BIT	OFF	--	New landing area request flag
NEW_STATION_ID	I	0	--	Current TACAN channel/mode identifier

CR89596C CR89596C CR89596C CR89596C CR89596C

Table 5.3-1. Variable List - General Requirements Principal Functions and Coordinate Transformations (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
NUMBER_STEPS	INT	--	--	Number of times DT_MAX fits into total prediction interval (T_INIT to T_FINAL) local variable
PHI	S	0	--	Geocentric elevation angle to the vehicle
PI	S	Constant	--	The constant PI
PRIME_RUNWAY_INDEX	INT	1	--	Indicator of which landing site choice is desired as prime
PRI_SEL	BIT	OFF	--	Primary runway select command
P2, P3, P4, P5, P6	S	0	--	Local variables used in QUAT_TO_MAT
Q	V(4)	0	M50	General variable for Q_M50_BODY
Q_FIFTY_BODY	V(4)	0	M50	Quaternion representing the orientation of the Orbiter body with respect to M50 coordinates
R	S	0	--	Radius magnitude of vehicle (geocentric)
RAD_P	S	0	--	Radius of earth at geocentric elevation angle, phi
RAD_PER_DEG	S	Constant	--	Radians per degree
R_AZMLS_EF	V	0	EF	Earth fixed MLS azimuth scanner position vector
R AZ SCANNER_BEARING	S	0	--	Bearing from true north of MSBLS range azimuth scanner site
R AZ SCANNER_BEARING(K)	V(4)		--	
R CC LMAG_PRI	S	0	--	Magnitude of R_CC_L_PRI

CR89596C
CR89596C
CR89596C

Table 3.3.1 Variable List - General Requirements Princ pl
Functions and Coordinate Transformations (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Descript on
R_CC_L_PRI	V	0	EF	Position vector of HAC center on the left side of the primary runway centerline in EF coordinates
R_CC_L_SEC	V	0	EF	Position vector of HAC center on the left side of the secondary runway centerline in EF coordinates
R_CC_RMAG_PRI	S	0	—	Magnitude of R_CC_R_PRI
R_CC_R_PRI	V		EF	Position vector of HAC center on the right side of the primary runway centerline in EF coordinates
RD_TAC_MSL_SL(I)	V	0	—	Geodetic radius of mean sea level at TACAN site to which the I-th receiver is tuned
R_EF_EQUAT	S	0	—	Projection of vehicle position vector in equatorial plane EF_TO_GEODETIC GEODETIC_TO_EF
R_ELMLS_EF	V	I-load	EF	Earth-fixed MSL elevation scanner position vector
R_FINAL	V	—	M50	Orbiter position vector at end of prediction interval (T FINAL
R_HAC_RW_L	V	I-load	RW	Position vector of HAC center for the left side of the runway
R_HAC_RW_R	V	I-load	RW	Position vector of HAC center for the right side of the runway centerline
R_INIT	V	0	M50	Position vector at beginning of prediction
R_INV	S	0	—	Temporary parameter in A[illegible] PREDICTOR
R_LS_EF	V	I-load	EF	Position vector of runway in Earth fixed coordinates
R	V		M50	Input position va[illegible]

Table 5.3-1. Variable List - General Requirements Principal Functions and Coordinate Transformations (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
R_RMLS_EF	V	I-load	EF	Earth-fixed position vector of MLS range scanner
R_TACAN_EF_SL(I)	V	0	EF	Earth-fixed position vector of TACAN station (each LRU) output from site lookup, I=1, 3
R_TAC_EF	V	0	EF	Position vector of TACAN site in Earth-fixed coordinates
RW_ID_UPP	INT	0	--	Local runway index parameter; also FIRST PASS FLAG
R_XY	F	0	--	Sum of the squares of R_EF, and R_EF_2
RUNWAY_NAME(L)	V(10)	I-load	--	Name of selected landing site
RUNWAY_ALT(L)	V(10)	I-load	--	Geodetic altitude of the selected landing site
RW_AZIMUTH(L)	V(10)	I-load	--	Azimuth to true north of the selected landing site
RW_DELH(L)	V(10)	I-load	--	Delta height from ellipsoid to MSL for the selected landing site
RW_LAT(L)	V(10)	I-load	--	Geodetic latitude of the selected landing site
RW_LON(L)	V(10)	I-load	--	Longitude of the selected landing site
RW_LENGTH(L)	V(10)	I-load	--	Runway length for selected landing site
RW_MAG_VAR(L)	V(10)	I-load	--	Magnetic variation for the selected landing site
RW_MSBLS_INDEX(L)	V(10)	I-load	--	Runway MSBLS printer index

Table 5.3-1. Variable List - General Requirements Principal Functions and Coordinate Transformations (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
RW_NAME	INT	1	--	Current landing site designation for display symbol positioning
RW_NAME_PSL	CHAR	--	--	Primary runway name for the selected area and used for display
RW_NAME_SSL	CHAR	--	--	Secondary runway name for the selected area used for display
RW_SELECT	BIT	ON	--	Runway selection indicator
SAZ	S	0	--	Sine of AZ
SEC_SEL	BIT	OFF	--	Secondary runway select command
SIN_P	S	0	--	Sine of geocentric elevation angle
SLAT	S	0	--	Sine of LAT_GEOD EF_TO_TOPDET, GEODETIC_TO_EF
SLON	S	0	--	Sine of longitude
STEP_SIZE	F	--	--	Actual predictor step size (constrained to be ≤ DT_MAX)
T	F	--	--	Local time variable in A/E precise predictor
T	S	0	--	General time variable
TACAN_ID(I)	V	0	--	ID of TACAN channel to which the I-th LRU is tuned, I=1, 3
TACAN_ID_MAXI(I)	V(10)	I-load	--	A three-digit channel/mode designation, unique for each TACAN station
TAC_ID	V	I-load	--	A three-digit channel/mode designation, unique for each TACAN station
TAC_CHANGE	BIT	OFF	--	Primary/Secondary TACAN Select Command

CR89947A CR89596C

Table 5.3-1. Variable List - General Requirements Principal Functions and Coordinate Transformations (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
TAC_CHAN_OLD(I)	V	0	--	Previous value of Channel/Mode indicator for each TACAN LRU (I = 1, 3)
TAC_CHAN VALID_SL(I)	BIT	Off	--	Switch indicating (ON) a valid TACAN channel has been selected (site lookup output) for the I-th receiver, I=1, 3
TAC_SEL	INT	0	--	Selected TACAN index
TEMP	S	0	--	Temporary variable used by QUAT_TO_ MAT
T_EPOCH	S	I-load	--	Time tag for M_M50TOEF_AT_EPOCH, Greenwich hour angle, and Earth-pole
T_FINAL	F	--	--	Final desired prediction time (associated with R_FINAL and V_FINAL)
TIME	S	0	--	General time variable
T_INIT	F	--	--	Time of initial state vector (R_INIT, V_INIT) from which the A/E precise predictor is called
U	V	0	M50	Unit vector in the direction of the orbiter's M50 position vector
V	V	0	M50	Input velocity vector (UVW_TO_M50)
V_FINAL	V	--	M50	Orbiter velocity vector at end of prediction interval (T_FINAL)
V_INIT	V	0	M50	Velocity vector at beginning of prediction
W	V	0	M50	Unit vector in direction of orbiter's angular momentum vector

CR89596C

CR89596C

Table 5.3-1. Variable List - General Requirements Principal Functions and Coordinate Transformations (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
X_DMEAZ_RW X_DMEAZ_RW(K)	S V(4)	0 I-load	RW	X-component of MSBLS range/azimuth scanner in runway coordinates
X_EL_RW X_EL_RW(K)	S V(4)	0 I-load	RW	X-component of MSBLS elevation scanner in runway coordinates
Y_DMEAZ_RW Y_DMEAZ_RW(K)	S V(4)	0 I-load	RW	Y-component of MSBLS range/azimuth scanner in runway coordinates
Z	V	0	M50	W X U

EARTH_FIXED_TO_M50_COORD(TIME) = M_M50TOEF_AT_EPOCH^{T} (M)

where: M_M50TOEF_AT_EPOCH is the transformation from mean 50 to EARTH fixed coordinates at time = T_EPOCH. This matrix, T_EPOCH, and EARTH_RATE, are pad loads for ascent.

M is computed within the function (EARTH_FIXED_TO_M50_COORD) as

LAM = EARTH_RATE (TIME - T_EPOCH)

$$M = \begin{pmatrix} \cos(LAM) & -\sin(LAM) & 0 \\ \sin(LAM) & \cos(LAM) & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Figure 5.3-14. EARTH_FIXED_TO_M50_COORD (FUNCTION)

EARTH_FIXED_TO_M50_COORD(TIME) = M_M50TOEF_AT_EPOCH^{T} (M)

where: M_M50TOEF_AT_EPOCH is the transformation from mean 50 to EARTH fixed coordinates at time = T_EPOCH. This matrix, T_EPOCH, and EARTH_RATE, are pad loads for ascent.

M is computed within the function (EARTH_FIXED_TO_M50_COORD) as

LAM = EARTH_RATE (TIME - T_EPOCH)

$$M = \begin{pmatrix} \cos(LAM) & -\sin(LAM) & 0 \\ \sin(LAM) & \cos(LAM) & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Figure 5.3-14. EARTH_FIXED_TO_M50_COORD (FUNCTION)

EF_TO_TOPDET(LAT_GEOD, LON) = M

where: M is calculated within the function as

CLON = cos(LON), SLON = sin(LON)

CLAT = cos(LAT_GEOD), SLAT = sin(LAT_GEOD)

$$M = \begin{pmatrix} -SLAT\ CLON & -SLAT\ SLON & CLAT \\ -SLON & CLON & 0 \\ -CLAT\ CLON & -CLAT\ SLON & -SLAT \end{pmatrix}$$

Figure 5.3-15. EF TO_TOPDET (FUNCTION)

EF_TO_RUNWAY(LAT_GEOD, LON, AZ) = (M) EF_TO_TOPDET(LAT_GEOD, LON) 5-101

where: M is calculated within the function as

CAZ = cos (AZ), SAZ = sin (AZ)

$$M = \begin{pmatrix} CAZ & SAZ & 0 \\ -SAZ & CAZ & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Figure 5.3-16. EF_TO_RUNWAY (FUNCTION)

EF_TO_SCANNER(LAT_GEOD, LON, AZ) = (M) EF_TO_RUNWAY(LAT_GEOD, LON,AZ)	5-102

where: M is calculated within the function as

$$M = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{pmatrix}$$

Figure 5.3-17. EF_TO_SCANNER (FUNCTION)

EF_TO_GEODETIC

IN LIST = R_EF

OUT LIST: LAT_GEOD, LON, ALT

FLATCON = $1.0 - (1.0 - ELLIPT)^2$

A_0 = 1.0 - FLATCON

$R\_XY = R\_EF_1^2 + R\_EF_2^2$

$R = (R\_XY + R\_EF_3^2)^{1/2}$

$SIN\_P = R\_EF_3/R$

$COS\_P = (R\_XY)^{1/2}/R$

$RAD\_P = EARTH\_RADIUS\_EQUATOR/(1.0 + FLATCON\ SIN\_P^2/A\_0)^{1/2}$

$DEL = (FLATCON\ SIN\_P\ COS\_P)/(1.0 - FLATCON\ COS\_P^2)$

DEL_LAT = RAD_P DEL/R

PHI = ARCTAN(SIN_P/COS_P)

LAT_GEOD = PHI + DEL_LAT

$LON = ARCTAN2(R\_EF_2, R\_EF_1)$

ALT = (R-RAD_P) (1.0 - 0.50 DEL DEL_LAT)

Figure 5.3-18. EF_TO_GEODETIC

GEODETIC_TO_EF (FUNCTION)

GEODETIC_TO_EF(LAT_GEOD, LON, ALT) = R_EF

where: R_EF is calculated within the FUNCTION as:

CLAT = cos (LAT_GEOD), SLAT = sin (LAT_GEOD)

DUM = $(1 - \text{ELLIPT})^2$

DUM1 = EARTH_RADIUS_EQUATOR/ $\sqrt{\text{CLAT}^2 + \text{SLAT}^2 \text{ DUM}}$

R_EF_EQUAT = (DUM1 + ALT) CLAT

R_EF = (R_EF_EQUAT cos (LON), R_EF_EQUAT sin (LON), (DUM DUM1 + ALT) SLAT)

Figure 5.3-19. GEODETIC_TO_EF (FUNCTION)

UVW_TO_M50 (FUNCTION)

IN LIST : R, V

```
U = R/|R|
W = (R x V)/|R x V|
I = (W x U)
UVW_TO_M50(1 TO 3, 1) = U
UVW_TO_M50(1 TO 3, 2) = I
UVW_TO_M50(1 TO 3, 3) = W
```

Figure 5.3-20. UVW_TO_M50 (FUNCTION)

SBODY_TO_M50

IN LIST: Q_FIFTY_BODY

OUT LIST: MAT

MATRIX = QUAT_TO_MAT(Q_FIFTY_BODY)	5-108
$MAT_{1,1} = -MATRIX_{1,1}$	
$MAT_{1,2} = MATRIX_{2,1}$	
$MAT_{1,3} = -MATRIX_{3,1}$	
$MAT_{2,1} = -MATRIX_{1,2}$	
$MAT_{2,2} = MATRIX_{2,2}$	
$MAT_{2,3} = -MATRIX_{3,2}$	
$MAT_{3,1} = -MATRIX_{1,3}$	
$MAT_{3,2} = MATRIX_{2,3}$	
$MAT_{3,3} = -MATRIX_{3,3}$	

Figure 5.3-21. SBODY_TO_M50

QUAT_TO_MAT (FUNCTION)

QUAT_TO_MAT(Q) = A

WHERE A IS CALCULATED WITHIN THE FUNCTION AS:

$P2 = Q_2 * Q_2$

$P3 = Q_3 * Q_3$

$P4 = Q_4 * Q_4$

$P5 = P2\ Q_2$

$P6 = P4\ Q_4$

$TEMP = 1.0 - P3\ Q_3$

$A_{1,1} = TEMP - P6$

$A_{2,2} = 1.0 - P5 - P6$

$A_{3,3} = TEMP - P5$

$P5 = P2\ Q_3$

$P6 = P4\ Q_1$

$A_{1,2} = P5 - P6$

$A_{2,1} = P5 + P6$

$P5 = P2\ Q_4$

$P6 = P3\ Q_1$

$A_{1,3} = P5 + P6$

$A_{3,1} = P5 - P6$

$P5 = P3\ Q_4$

$P6 = P_2\ Q_1$

$A_{2,3} = P5 - P6$

$A_{3,2} = P5 + P6$

Figure 5.3-22. QUAT TO MAT (FUNCTION)

ASC_PRECISE_PREDICTOR

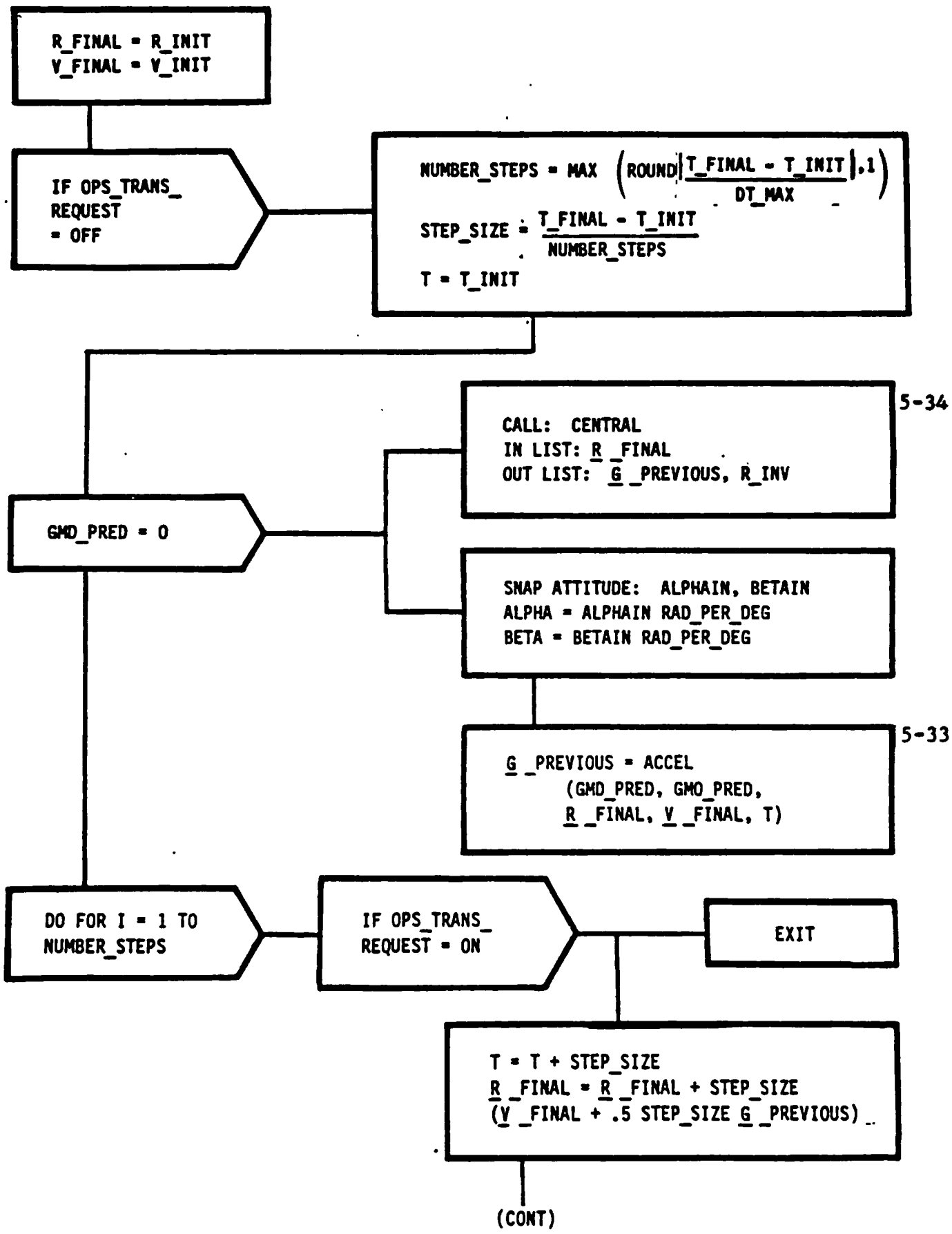


Figure 5.3-23. ASC_PRECISE_PREDICTOR

ASC_PRECISE_PREDICTOR

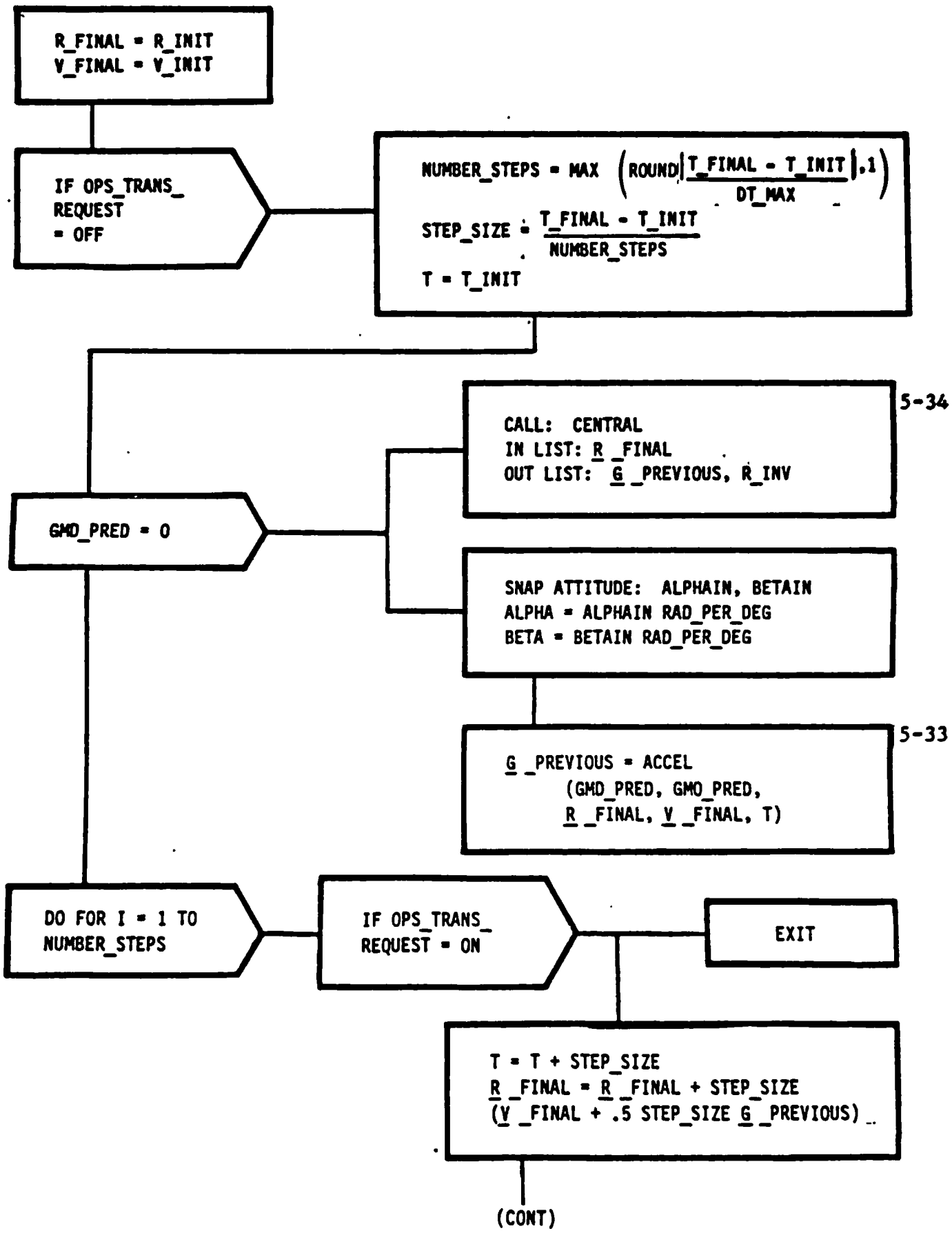


Figure 5.3-23. ASC_PRECISE_PREDICTOR

ASC_PRECISE_PREDICTOR (CONT)

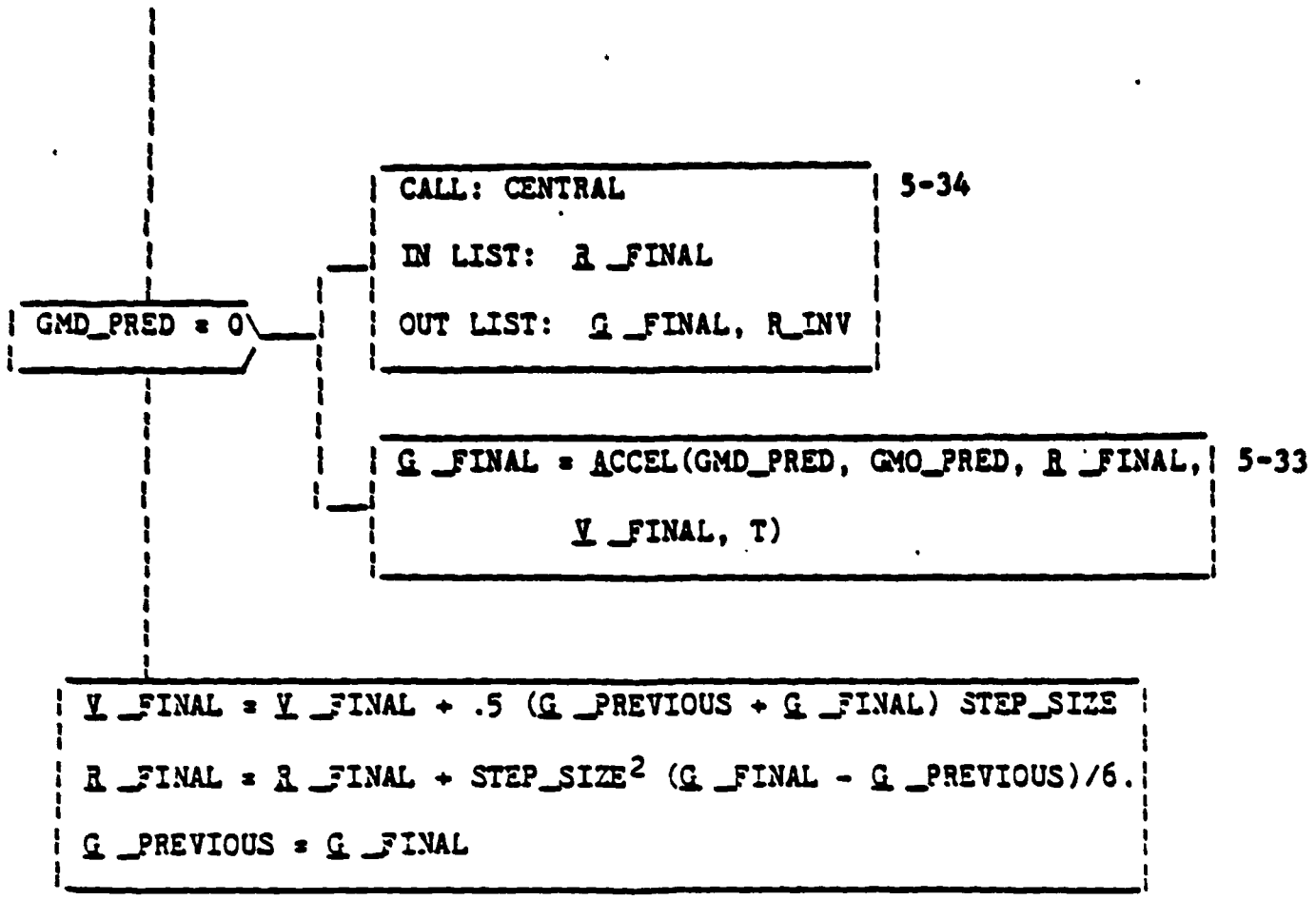


Figure 5.3-23. ASC_PRECISE_PREDICTOR (Cont)

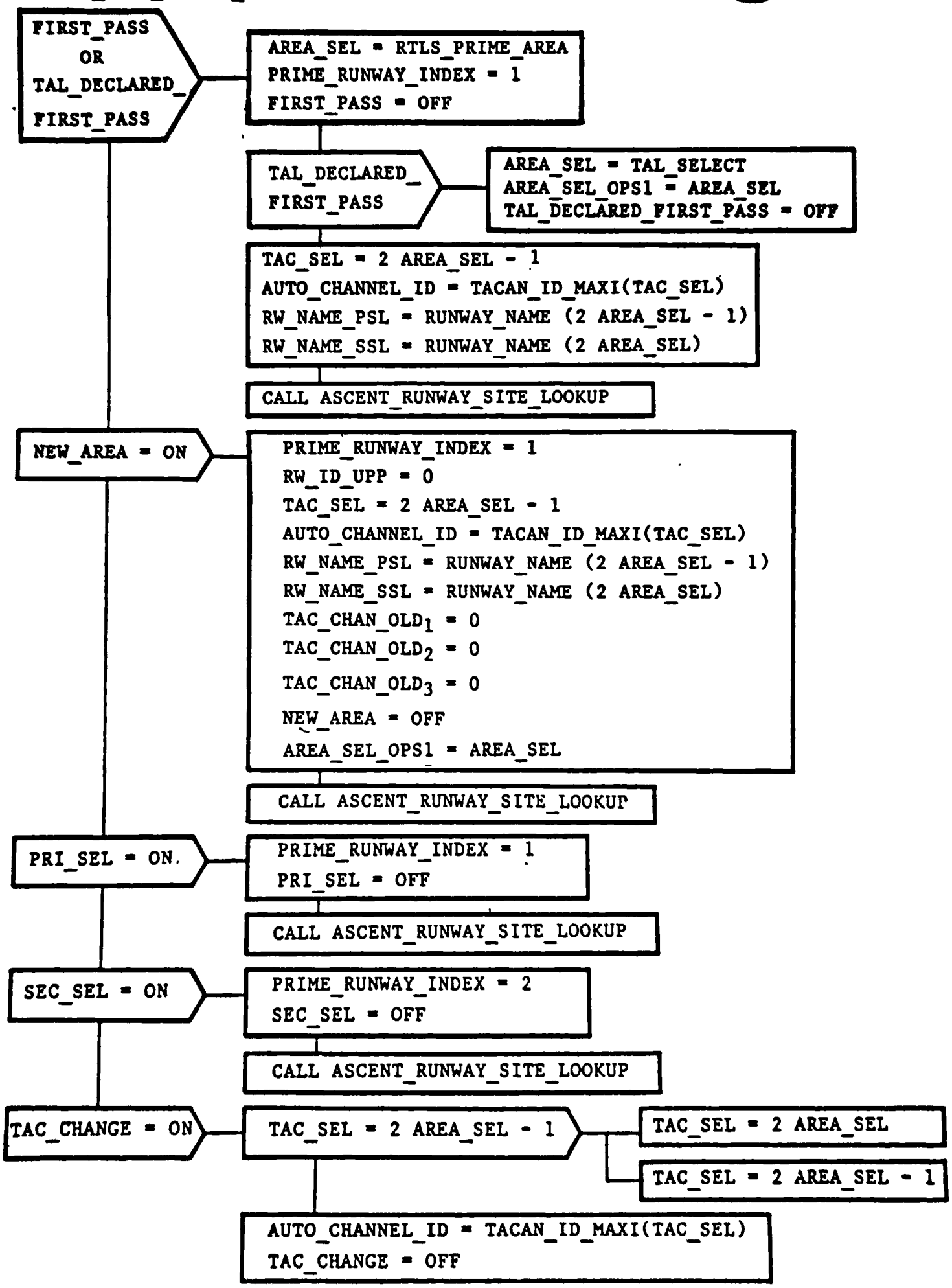


Figure 5.3-24. ASC_SITE_LOOKUP_INIT

ASCENT_RUNWAY_SITE_LOOKUP

```
J = AREA_SEL
PRIME_RUNWAY_INDEX = 1
    L = 2J-1
    RW_SELECT = ON
    L = 2J
    RW_SELECT = OFF
RW_NAME = L
LAT = RW_LAT(L)
LON = RW_LON(L)
ALT_RW = RUNWAY_ALT(L)
AZIMUTH_RW = RW_AZIMUTH(L)
LENGTH_RW = RW_LENGTH(L)
DELH_MSL_ELLIPSOID_RW = RW_DELH(L)
ANGLE_CORR_TNTOMAG_RW = RW_MAG_VAR(L)
K = RW_MSBLS_INDEX(L)
MLS_AVAIL = OFF
M_EFTORW = EF_TO_RUNWAY (LAT, LON, AZIMUTH_RW)        5-102
R_LS_EF = GEODETIC_TO_EF (LAT, LON, ALT_RW)           5-105
R_CC_L_PRI = R_LS_EF + M_EFTORW^T R_HAC_RW_L
R_CC_R_PRI = R_LS_EF + M_EFTORW^T R_HAC_RW_R
R_CC_LMAG_PRI = |R_CC_L_PRI|
R_CC_RMAG_PRI = |R_CC_R_PRI|
K > 0
    LAT_MSL_R_AZ = LAT_MLS_R_AZ(K)
    LONG_MLS_R_AZ = LONG_MLS_R_AZ(K)
    ALT_MLS_R_AZ = ALT_MLS_R_AZ(K)
    R_AZ_SCANNER_BEARING = R_AZ_RADAR_BEARING(K)
    LAT_MLSEL = LAT_MLSEL(K)
    LONG_MLSEL = LONG_MLSEL(K)
    ALT_MLSEL = ALT_MLSEL(K)
    EL_SCANNER_BEARING = EL_SCANNER_BEARING(K)
    BIAS_MLS_RANGE = BIAS_MLS_RANGE(K)
    BIAS_ELMLS = BIAS_ELMLS(K)
    BIAS_AZMLS = BIAS_AZMLS(K)
    X_DMEAZ_RW = X_DMEAZ_RW(K)
    X_EL_RW = X_EL_RW(K)
    Y_DMEAZ_RW = Y_DMEAZ_RW(K)
    MLS_AVAIL = ON
    M_EFTORAD_R_AZ = EF_TO_SCANNER (LAT_MLS_R_AZ                5-103
                     LONG_MLS_R_AZ, R_AZ_SCANNER_BEARING)
    M_EFTORAD_EL = EF_TO_SCANNER(LAT_MLSEL, LONG_MLSEL,        5-103
                   EL_SCANNER_BEARING)
    R_RMLS_EF = GEODETIC_TO_EF(LAT_MLS_R_AZ, LONG_MLS_R_AZ,    5-105
                ALT_MLS_R_AZ)
    R_AZMLS_EF = R_RMLS_EF
    R_ELMLS_EF = GEODETIC_TO_EF(LAT_MLSEL, LONG_MLSEL,         5-105
                 ALT_MLSEL)
```

Figure 5.3-25. ASC_RUNWAY_SITE_LOOKUP

ASCENT_TACAN_SITE_LOOKUP

```
J = AREA_SEL
TAC_CHAN_VALID_SL_LRU_ID = OFF
TACAN_ID_LRU_ID = NEW_STATION_ID

DO FOR I = 2J-1, 2J

TAC_ID_LRU_ID = TACAN_ID_MAXI(I)

LAT_TACAN_SL_LRU_ID = LATITUDE_GEODETIC_MAXI(I)
LONG_TACAN_SL_LRU_ID = LONGITUDE_EAST_MAXI(I)
ALT_TACAN_SL_LRU_ID = ALT_ABOVE_ELLIPSOID_MAXI(I)
DH_TACAN_SL_LRU_ID = MSL_ABOVE_ELLIPSOID_MAXI(I)
ANGLE_CORR_TNTOMAG_SL_LRU_ID = MAGNETIC_VARIATION_MAXI(I)
RD_TAC_MSL_SL_LRU_ID = (1.-ELLIPT)^2 EARTH_RADIUS_EQUATOR/
                       (1. + SIN^2 (LAT_TACAN_SL_LRU_ID) ELLIPT (ELLIPT-2))^1/2
                       + DH_TACAN_SL_LRU_ID
R_TACAN_EF_SL_LRU_ID = GEODETIC_TO_EF (LAT_TACAN_SL_LRU_ID,                    5-105
                       LONG_TACAN_SL_LRU_ID, ALT_TACAN_SL_LRU_ID)
M_EFTOTD_TACAN_SL_LRU_ID = EF_TO_TOPDET (LAT_TACAN_SL_LRU_ID,LONG_TACAN_SL_LRU_ID)  5-101
TAC_CHAN_VALID_SL_LRU_ID = ON
```

Figure 5.3-26. ASC_TACAN_SITE_LOOKUP

5.4 AREA NAVIGATION FLOW CHARTS, VARIABLE NAMES, AND DESCRIPTIONS

This section provides supplemental material for area navigation in the form of functional flow charts (Figures 5.4-1 through 5.4-9). Table 5.4-1 provides the variable list which supports this material. The following data will aid in interpreting Table 5.4-1.

HSI_SEQUENCER

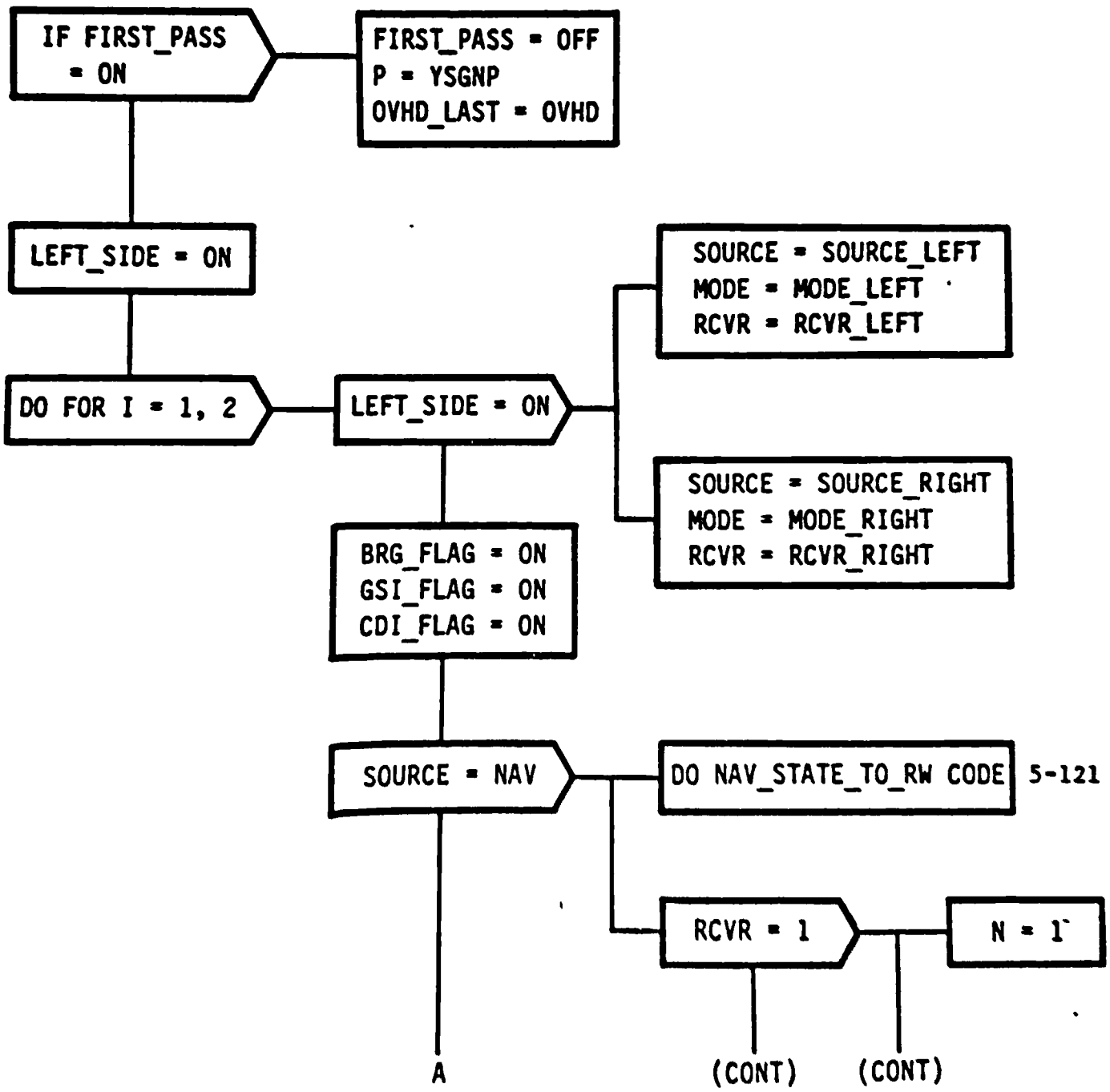


Figure 5.4-1. HSI SEQUENCER

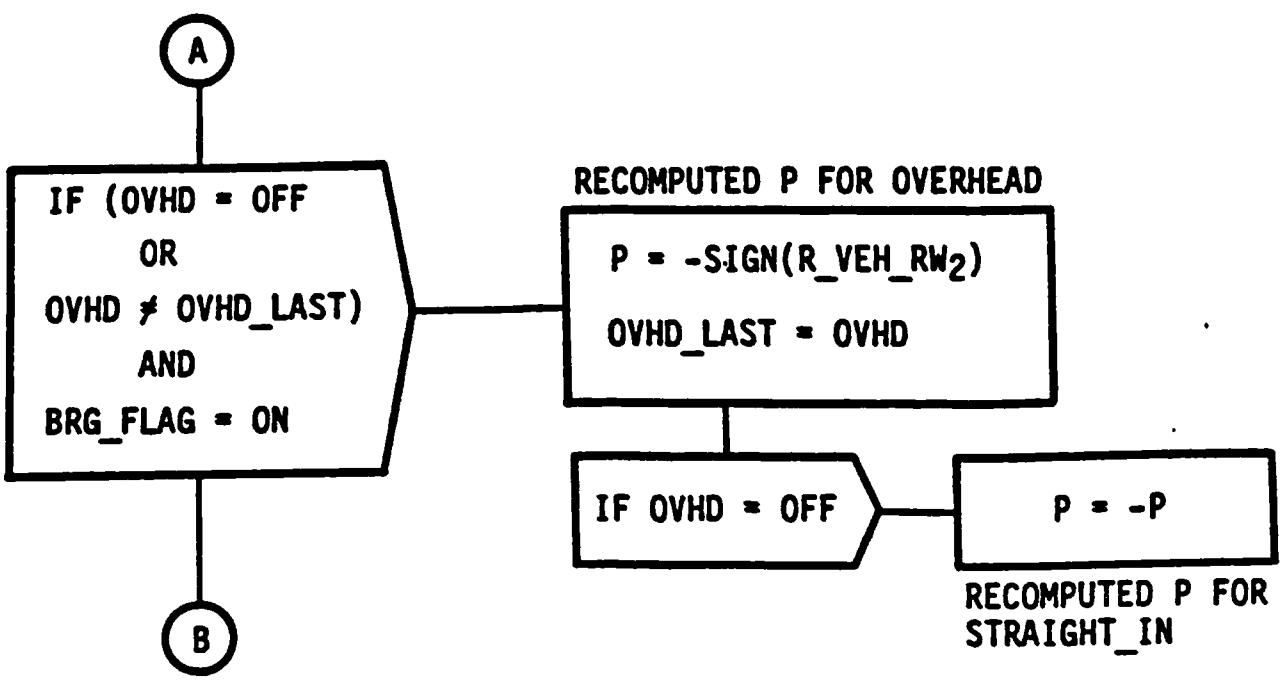


Figure 5.4-1. HSI_SEQUENCER (Cont)

HSI_SEQUENCER (CONT)

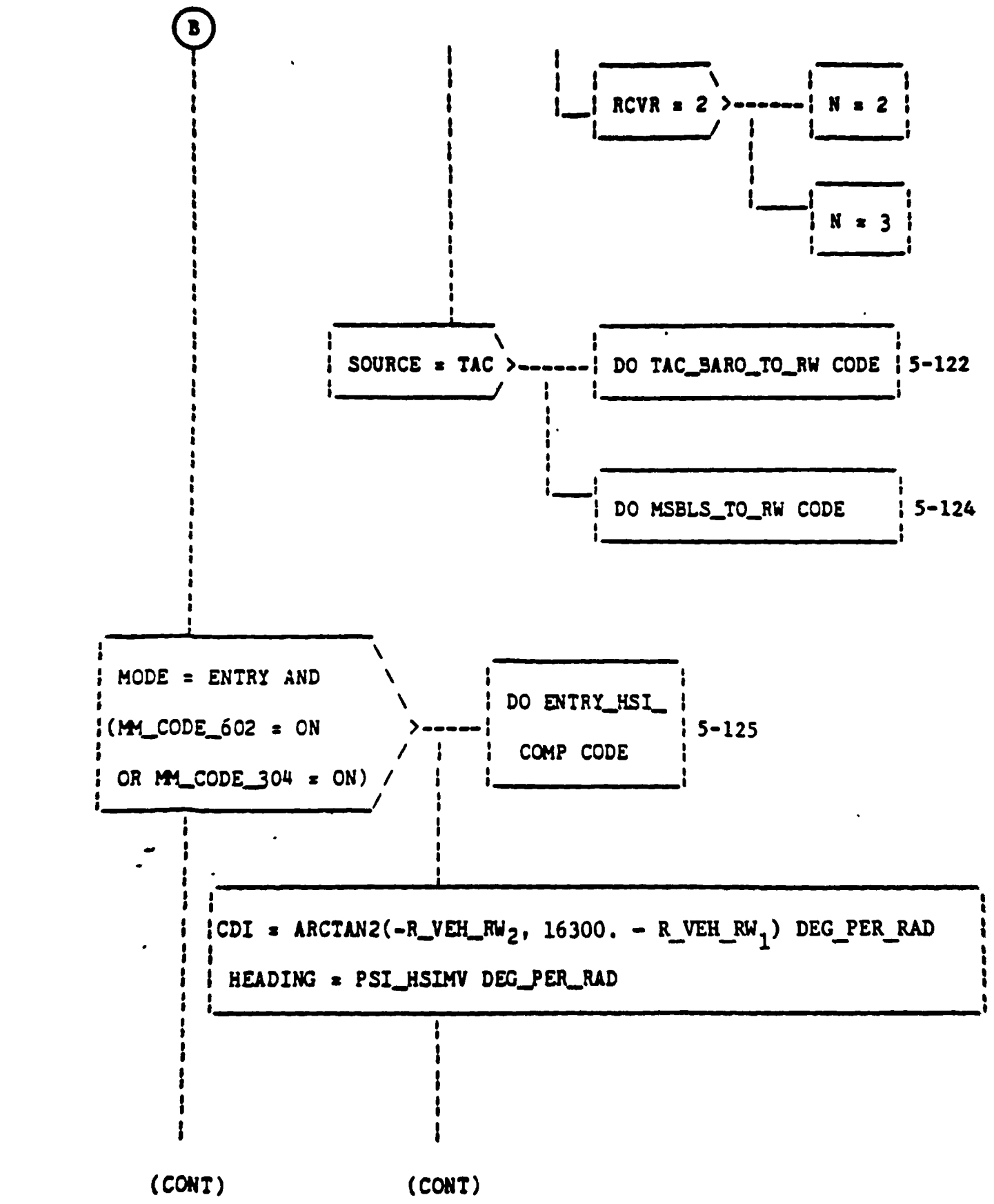


Figure 5.4-1. HSI_SEQUENCER (Cont)

HSI_SEQUENCER (CONT)

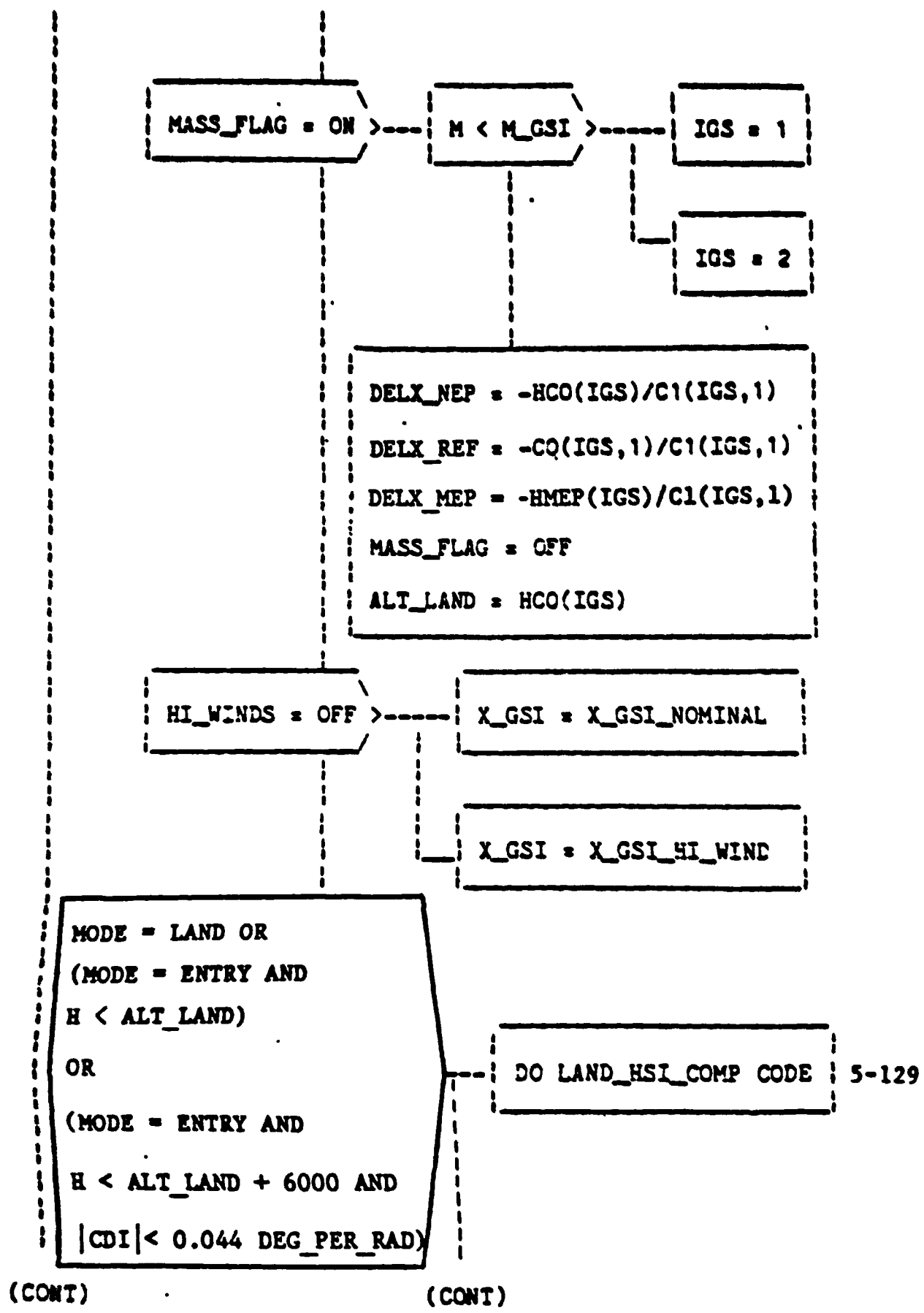


Figure 5.4-1. HSI_SEQUENCER (Cont)

HSI_SEQUENCER (CONT)

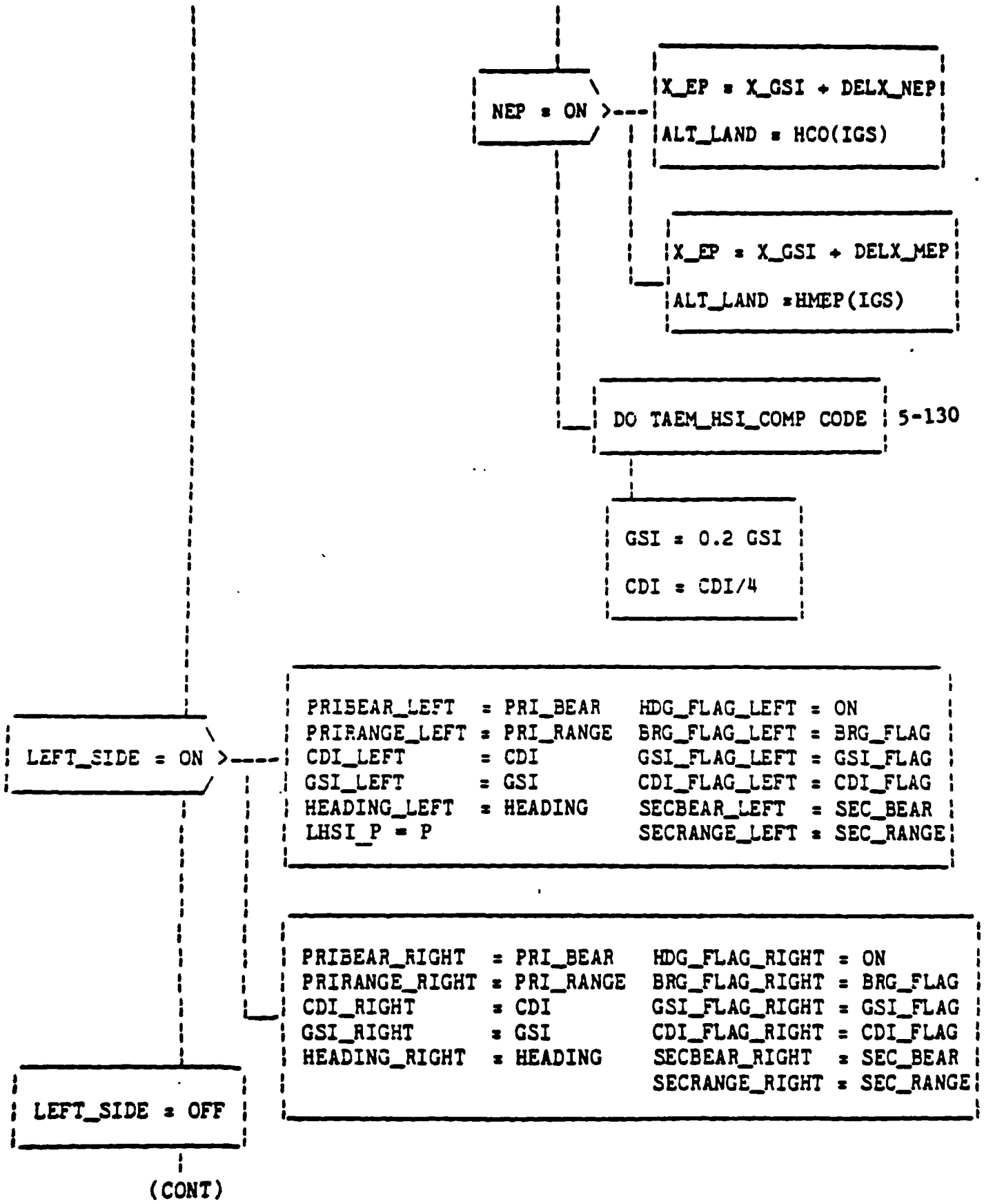


Figure 5.4-1. HSI_SEQUENCER (Cont)

HSI SEQUENCER (CONT)

Figure 5.4-1. HSI_SEQUENCER (Cont)

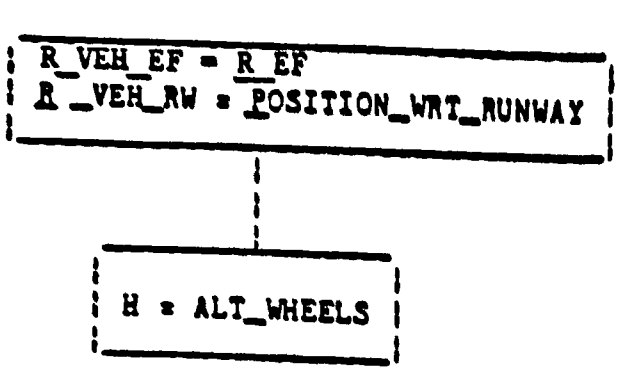


Figure 5.4-2. NAV_STATE_TO_RW CODE

TAC_BARO_TO_RW CODE

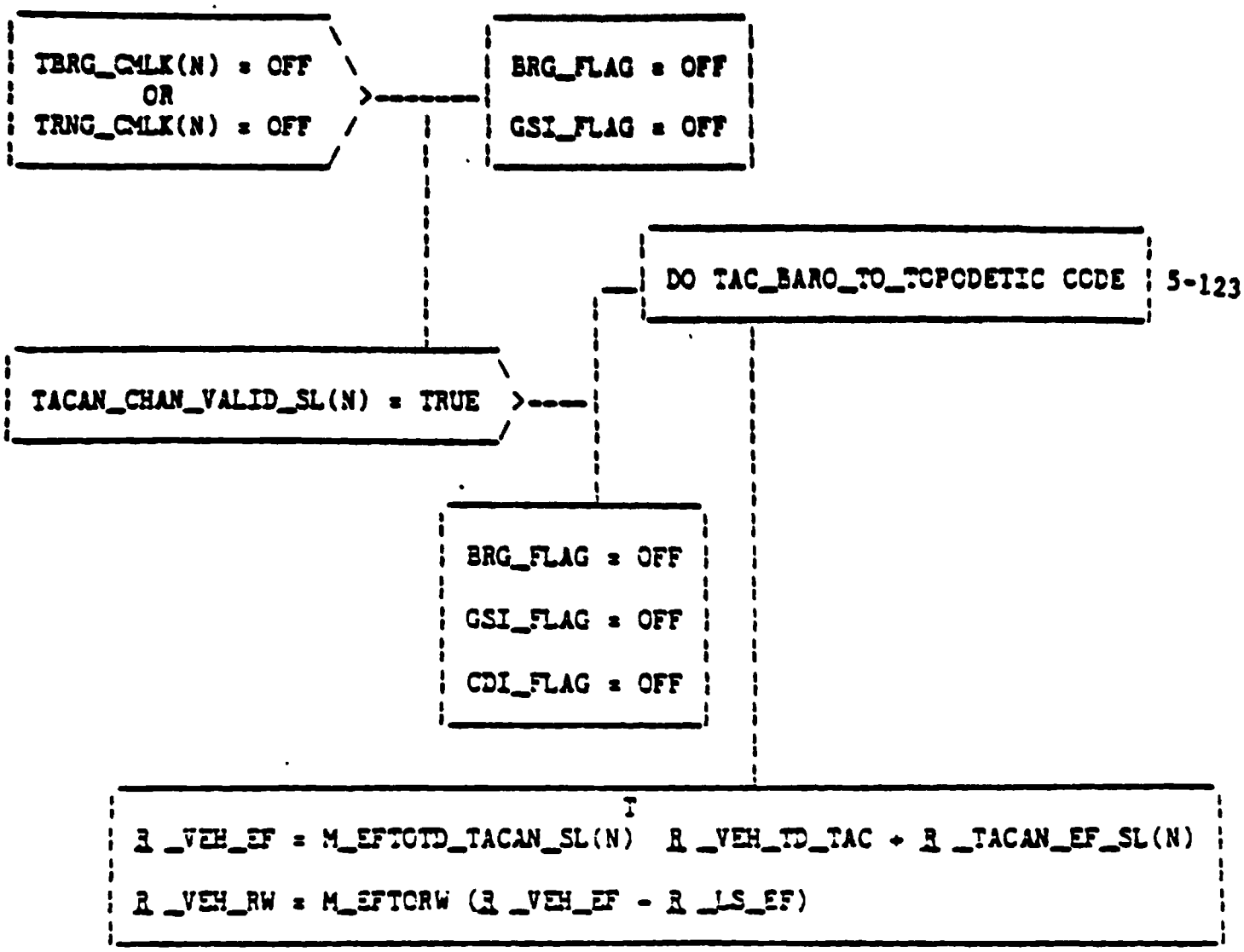


Figure 5.4-3. TAC_BARO_TO_RW CODE

TAC_BARO_TO_TOPODETIC CODE

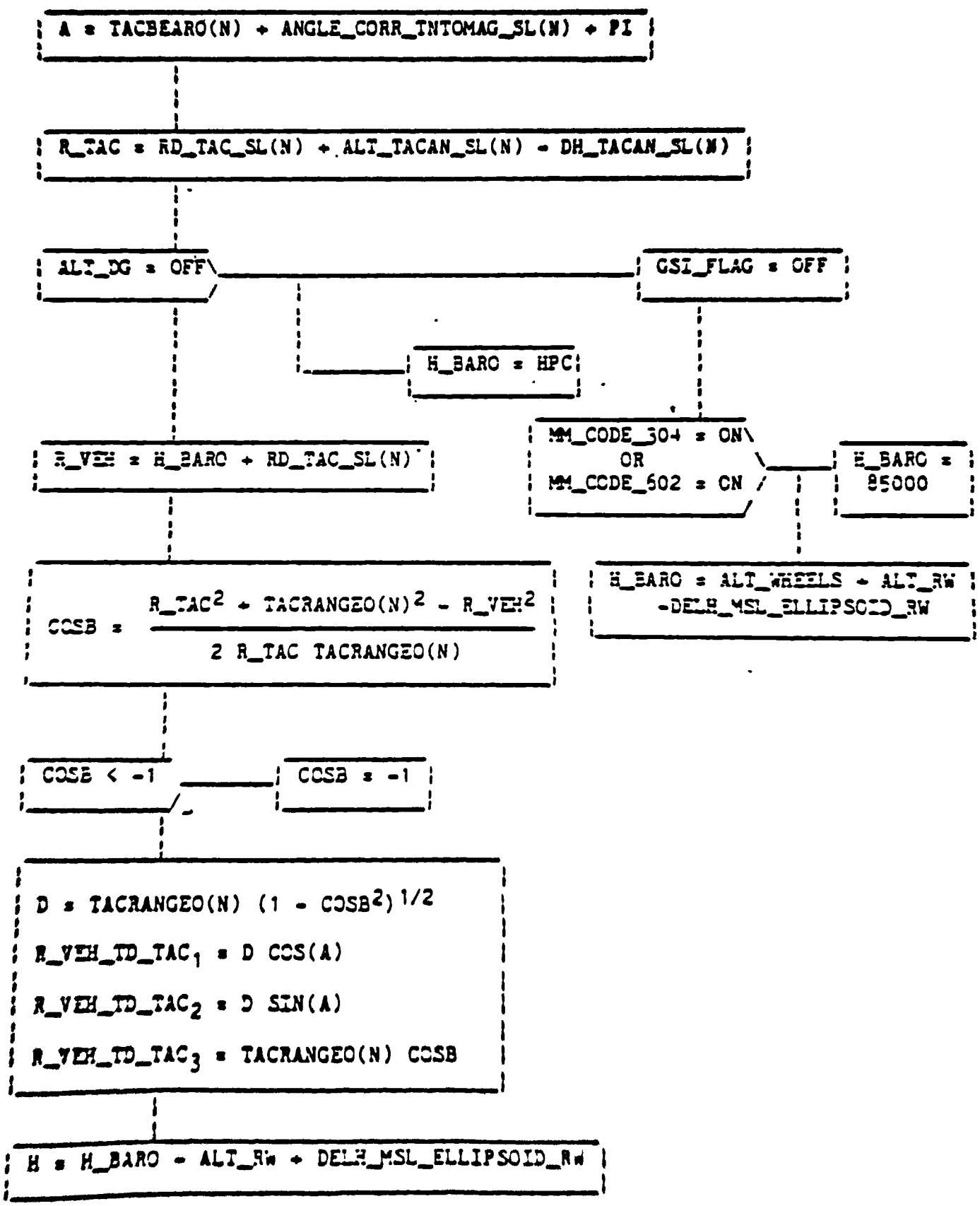


Figure 5.4-4. TAC BARO TO TOPODETIC CODE

MSBLS_TO_RW CODE

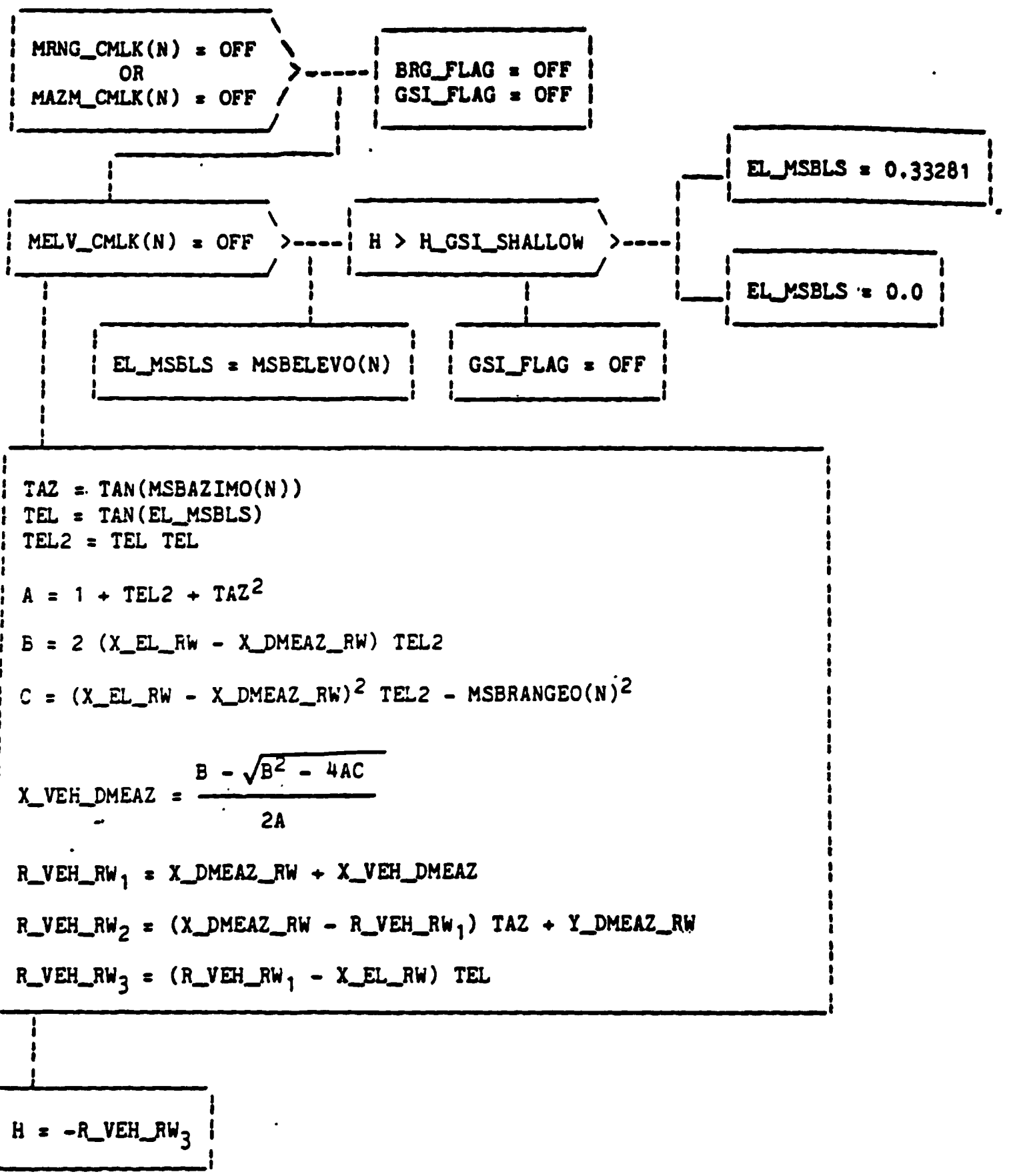


Figure 5.4-5. MSBLS_TO_RW CODE

ENTRY_HSI_COMP CODE

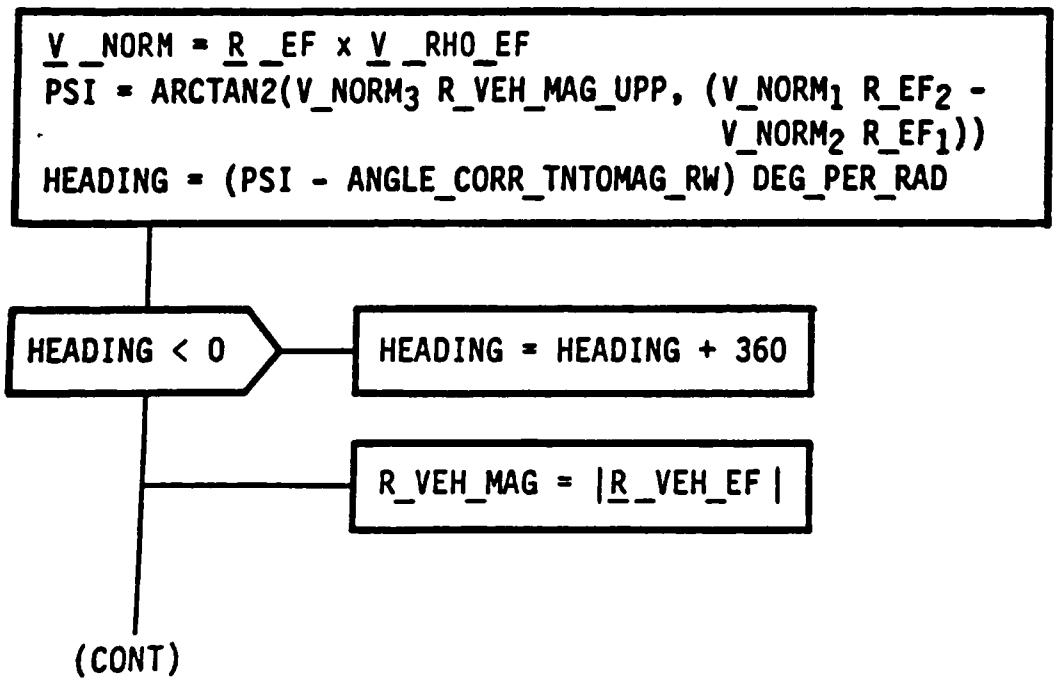


Figure 5.4-6. ENTRY_HSI_COMP CODE

ENTRY_HSI_COMP CODE (CONT)

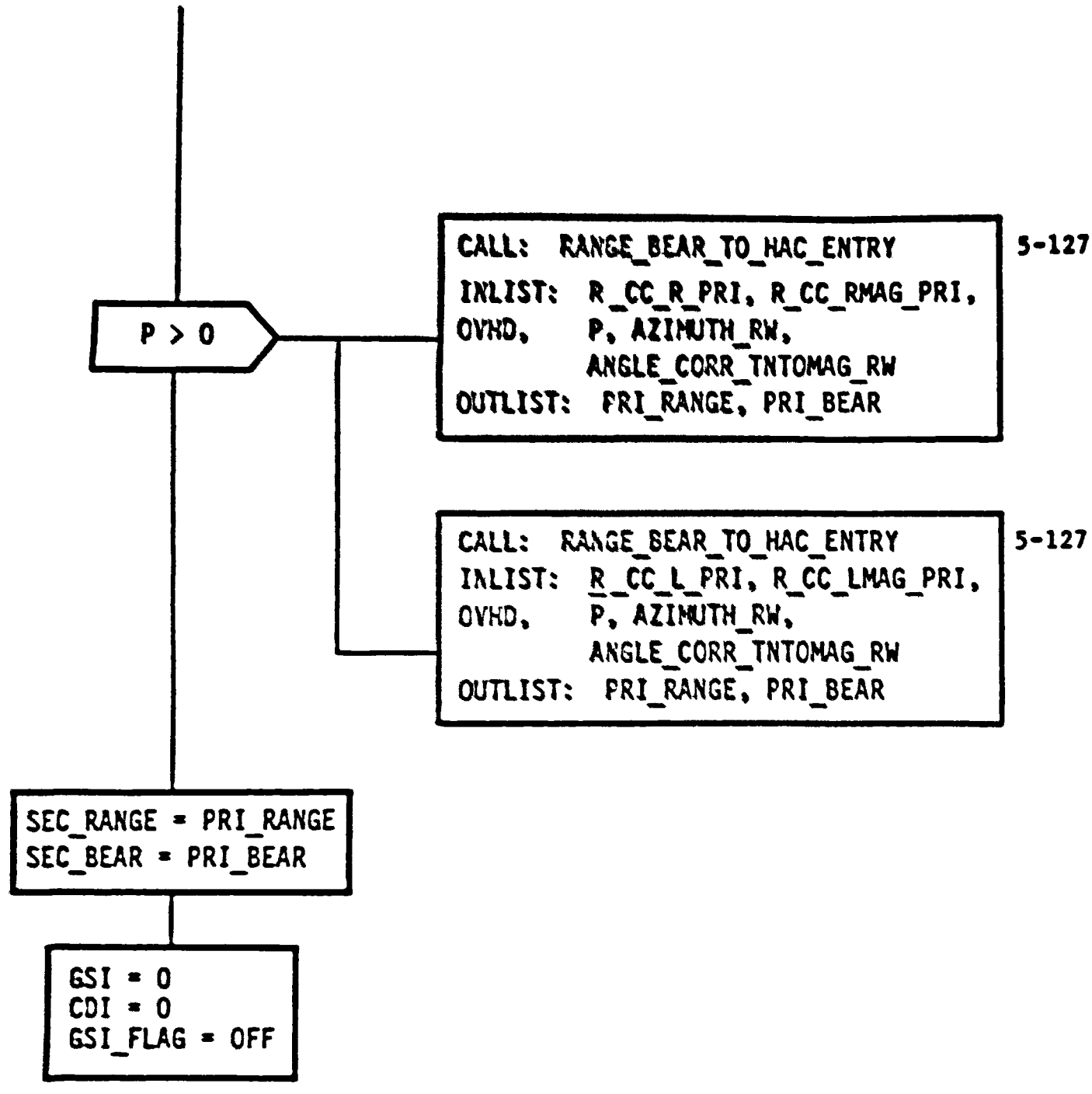


Figure 5.4-6. ENTRY_HSI_COMP CODE (Cont)

RANGE_BEAR_TO_HAC_ENTRY

INLIST: R_CC_EF, R_CC_MAG, P, AZIMUTH_RW,
ANGLE_CORR_TNTOMAG_RW

OUTLIST: RANGE, BEARING

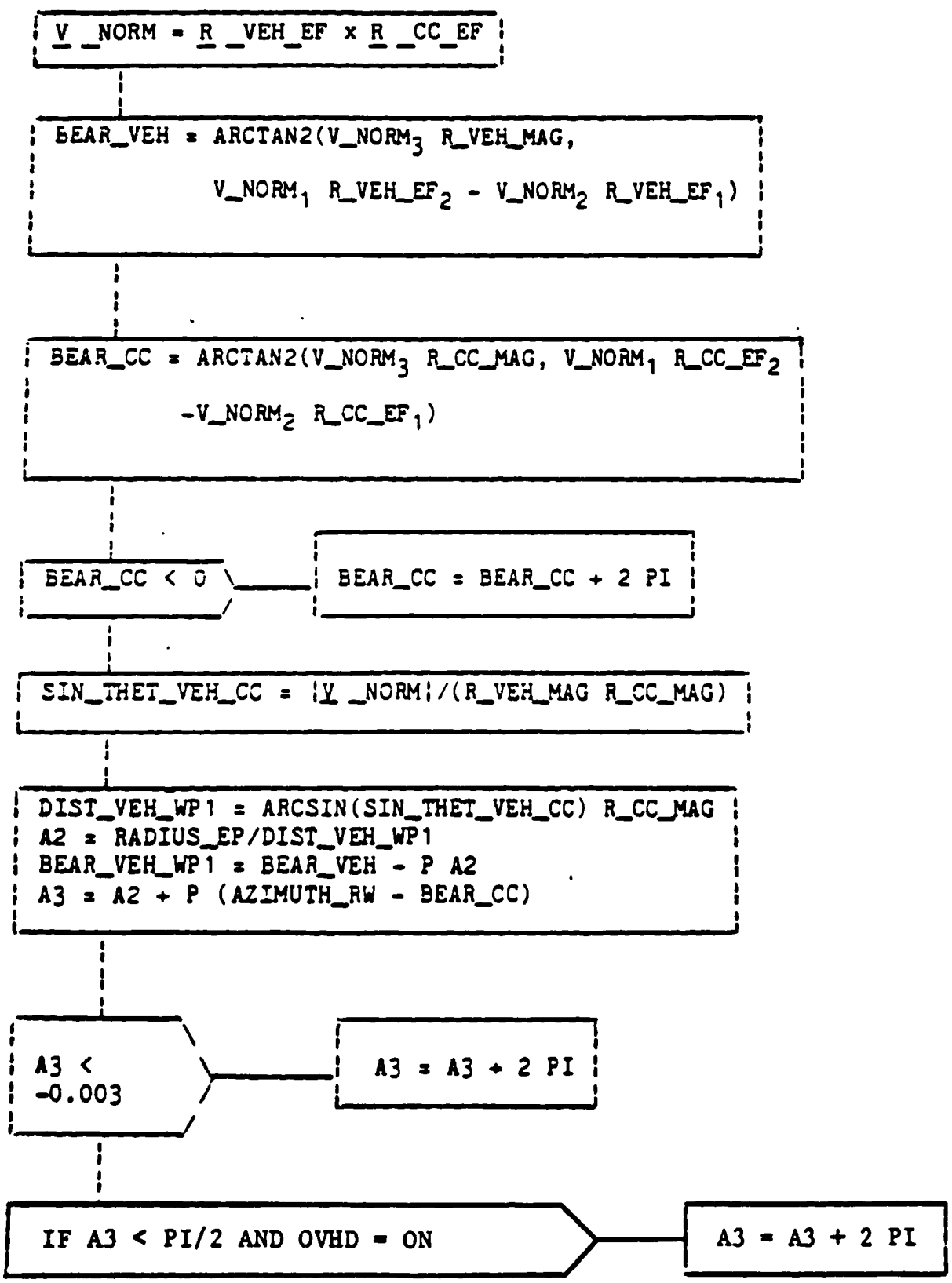


Figure 5.4-7. RANGE_BEAR_TO_HAC_ENTRY

RANGE_BEAR_TO_HAC_ENTRY (CONT)

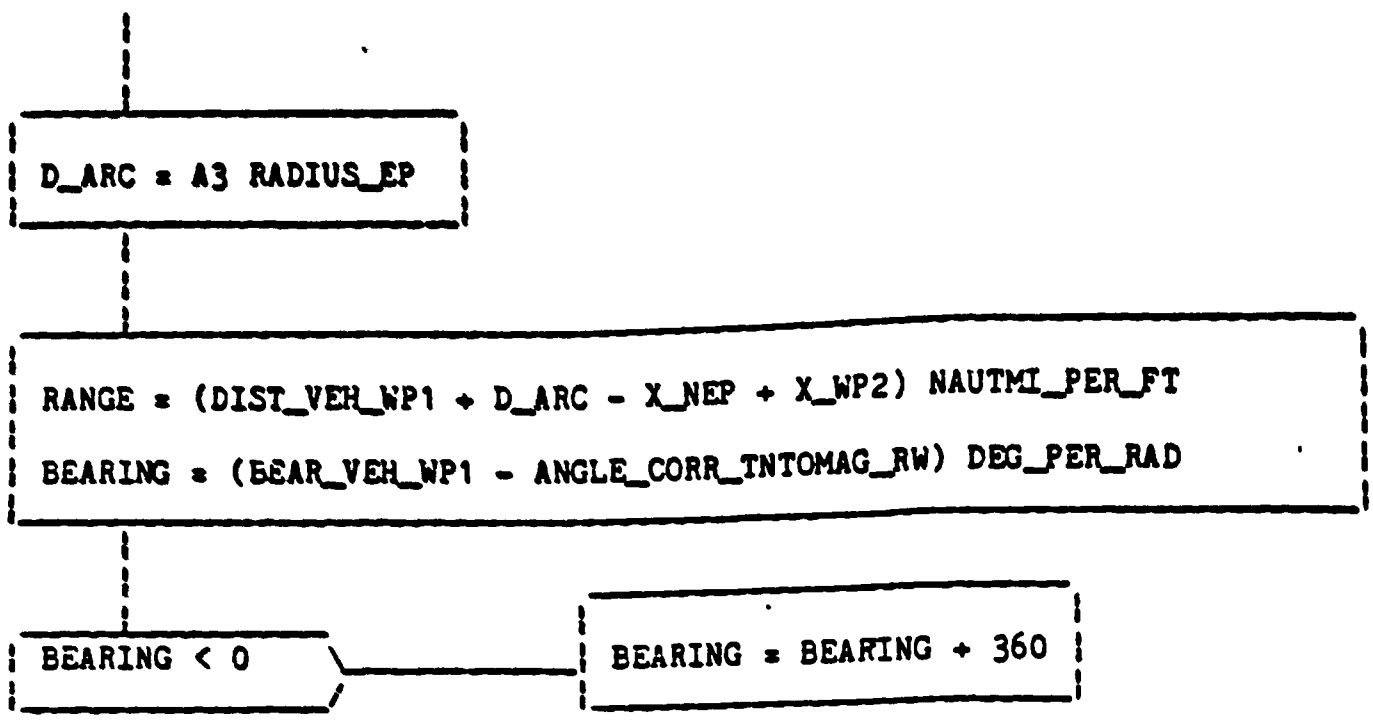


Figure 5.4-7. RANGE_BEAR_TO_HAC_ENTRY (Cont)

LAND_HSI_COMP CODE

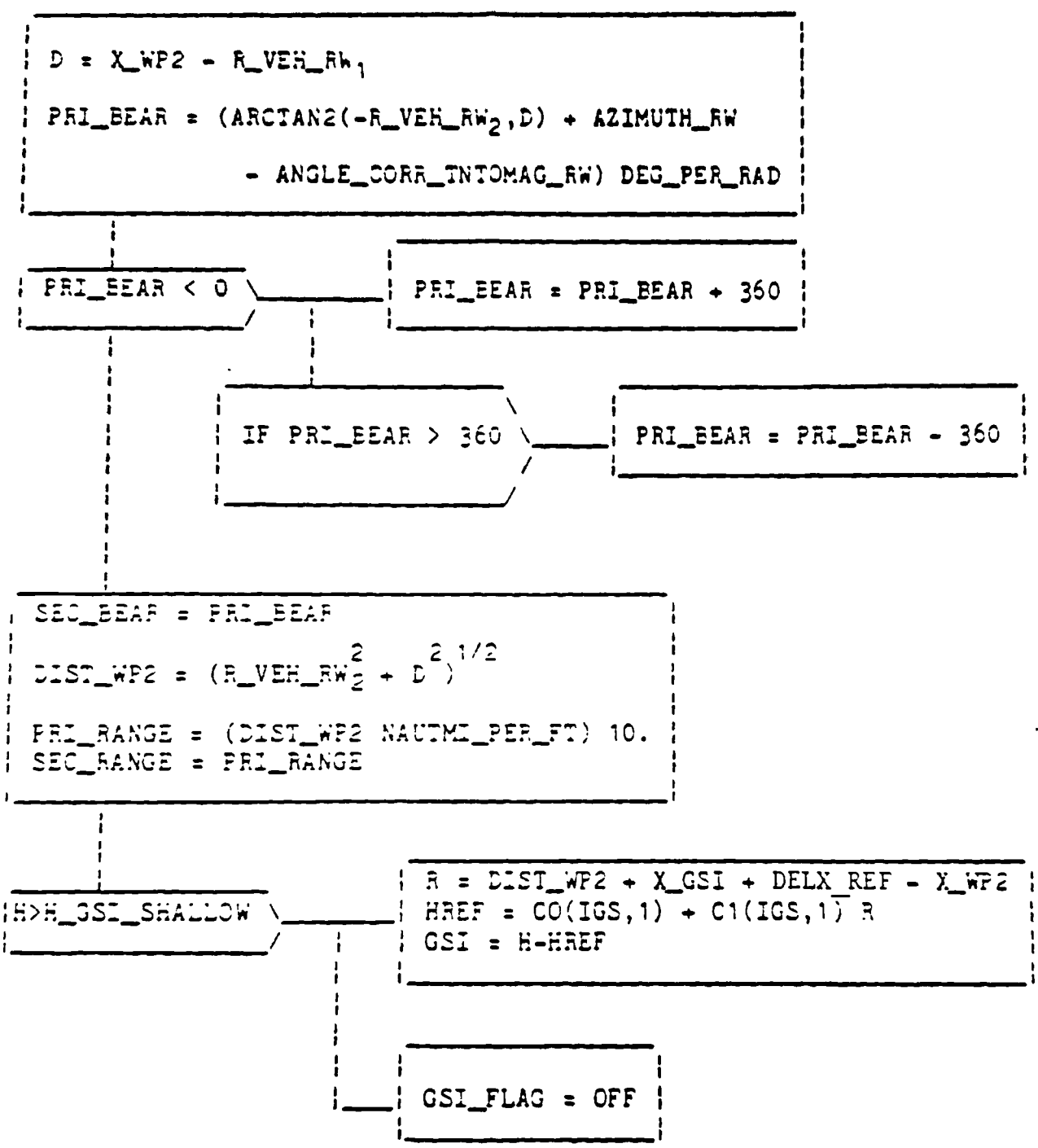


Figure 5.4-8. LAND_HSI_COMP CODE

TAEM_HSI_COMP CODE

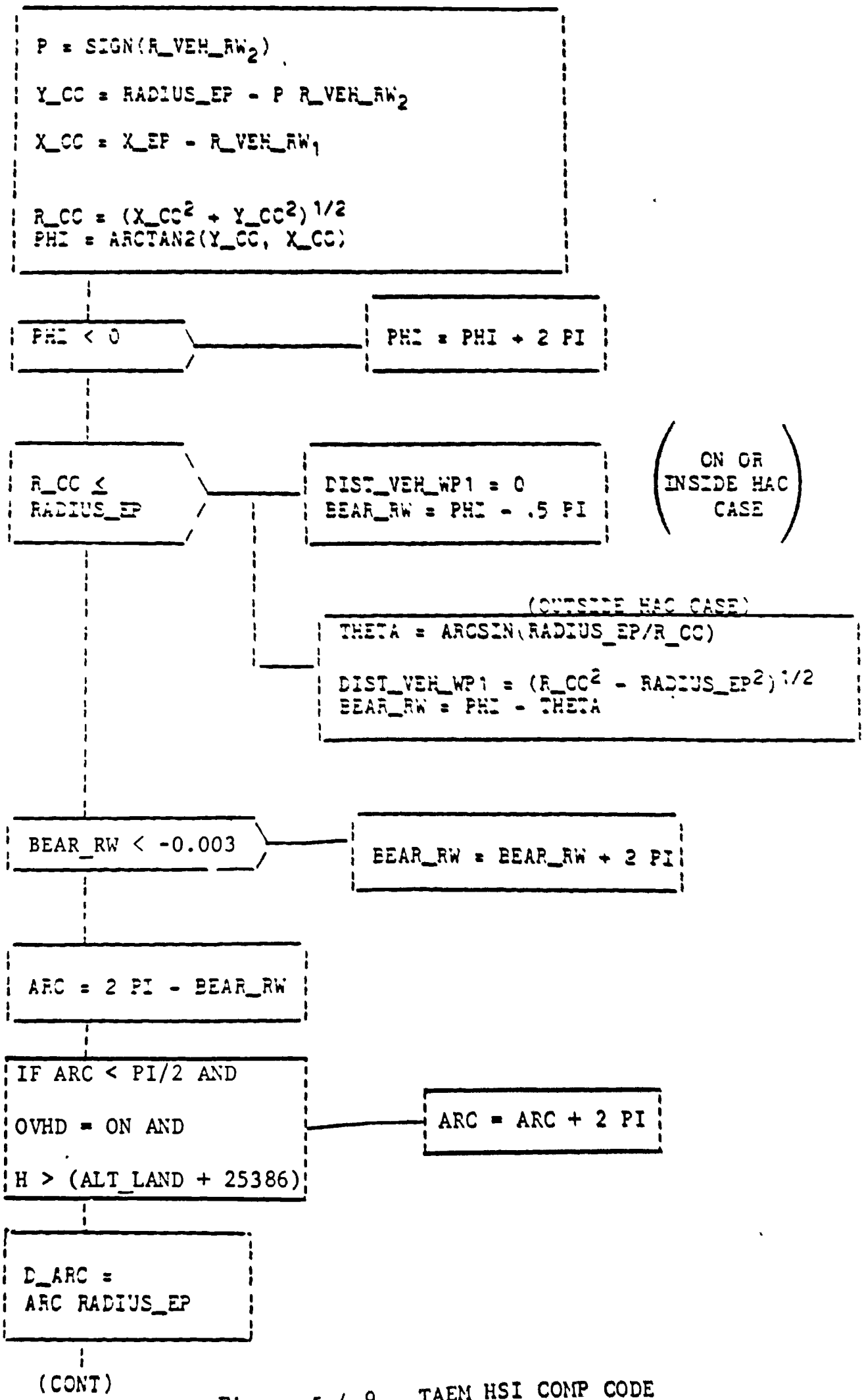


Figure 5.4-9. TAEM_HSI_COMP CODE

CR89947A

TAEM_HSI_COMP CODE (CONT)

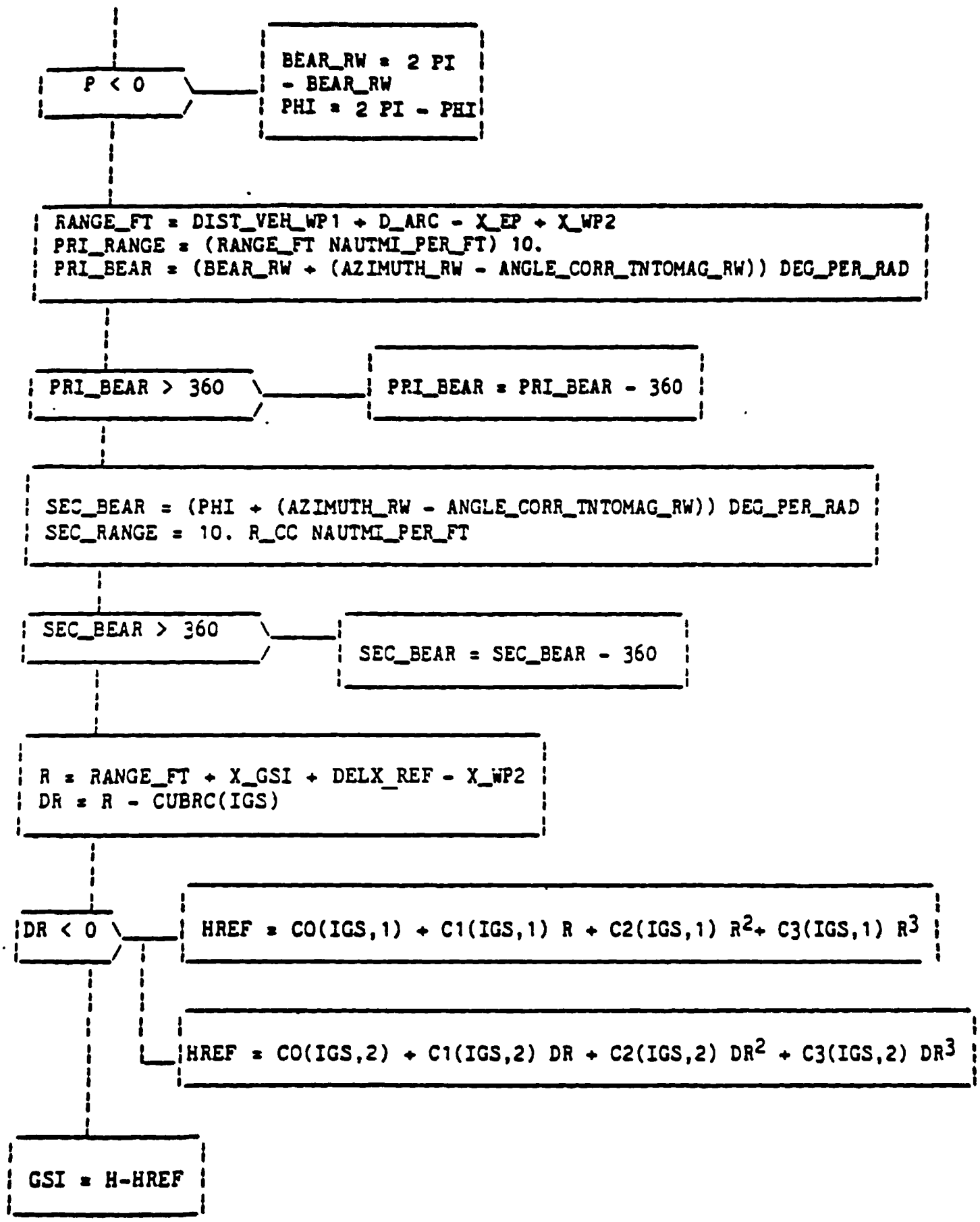


Figure 5.4-9. TAEM_HSI_COMP CODE (Cont)

VARIABLE LIST DEFINITIONS

Code used for variable data type:

S:	scalar
V:	vector
M:	square matrix
INT:	integer
BIT:	bit
CHAR:	character
STR:	structure
ARR:	array
B(M):	binary, M digit bit string

Coordinate frame code and definition:

BODY: (structural)	x:	parallel to the longitudinal axis (positive aft)
	y:	completes right-hand system
	z:	perpendicular to the x-axis, positive upward
M50:	Mean-of-50 reference coordinate system	
RW: (runway coordinates)	x:	down runway centerline in direction of landing
	y:	completes right-hand system
	z:	down, normal to ellipsoid
SCAN: (MLS scanner coordinates)	x:	scanner boresight
	y:	completes right-hand system
	z:	up, normal to ellipsoid
TD: (topodetic coordinates)	x:	north
	y:	east
	z:	down, normal to ellipsoid
EF:	Earth-fixed coordinate system	

Table 5.4-1. Variable List - Area Navigation

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
A	S	0	—	Angle at TACAN from true north to Shuttle
A	S	0	—	Coefficient in quadratic formula
A2	S	0	—	Angle defined by intersection of two great circle planes (one passing through the Shuttle position and HAC center; the other through the Shuttle position and WP1)
A3	S	0	—	Angle at HAC center from WP1 to entry point (ENT_RNG_BEAR)
ALT_DG	BIT	Off	—	Barometric data-good flag
ALT_RW	S	0	—	Altitude above reference ellipsoid of runway reference point
ALT_TACAN_SL(I)	V	0	—	Altitude of TACAN station (each LRU) output from site lookup, I=1, 3
ALT_WHEELS	S	0	—	Altitude of orbiter c.g. (entry) or rear wheels (TAEM and A/L) above runway altitude
ANGLE_CORR_TNTOMAG_RW_SEC	S	0	TD	Angle of magnetic variation from true north at selected secondary runway
ANGLE_CORR_TNTOMAG_SL(I)	V	0	—	Variation of magnetic north from true north at TACAN site (each LRU) output from site lookup, I=1, 3
ARC	S	0	—	Angle from NEP to WP1 measured WRT HAC center
AZIMUTH_RW	S	0	—	Bearing from true north of runway coordinate system +X axis
B	S	0	—	Coefficient in quadratic formula
BEAR_CC	S	0	—	Bearing at HAC center WRT true north

Table 5.4-1. Variable List - Area Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
BEARING	S	0	—	Bearing from Shuttle to WP1
BEAR_RW	S	0	—	Bearing to WP1 (entry/TAEM or WP1 (A/L) measured with respect to RW
BEAR_VEH	S	0	—	Bearing from Shuttle to HAC center WRT true north
ALT_LAND	S	Pad	—	Altitude for automatic switch from TAEM display mode comps to auto land display mode comps
BEAR_VEH_WP1	S	0	—	Bearing to WP1 WRT true north
BRG_FLAG	BIT	Off	—	HSI data validity flag
BRG_FLAG_LEFT	BIT	Off	—	HSI data validity flag
BRG_FLAG_RIGHT	BIT	Off	—	HSI data validity flag
C	S	0		Coefficient in quadratic formula a
CDI	S	0		Course deviation from the ext. runway center line
CDI_FLAG	BIT	Off		HSI data validity flag
CDI_FLAG_LEFT	BIT	Off		HSI data validity flag
CDI_FLAG_RIGHT	BIT	Off		HSI data validity flag
CDI_LEFT	S	0		Course deviation from the ext. runway center line
CDI_RIGHT	S	0		Course deviation from the ext. runway center line
COSB		0		Cosine of the angle at the earth center to Shuttle
D		0	TD	Projection of slant range to Shuttle onto X Y p

Table 5.4-1. Variable List - Area Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
D	S	0	RW	X component of vehicle position with respect to WP2
D_ARC	S	0	--	Arc length around the HAC from WP1 to EP
DELH_MSL_ELLIPSOID_RW	S	0	--	Altitude of mean sea level above reference ellipsoid at runway
DH_TACAN_SL(I)	V	0	--	Altitude of mean sea level above reference ellipsoid at TACAN station (each LRU) output from site lookup, I=1, 3
DIST_VEH_WP1	S	0	--	Surface range from Shuttle to WP1
DIST_WP2	S	0	--	Flat earth range from Shuttle to WP2
EL_MSBLS	S	0	--	MSBLS elevation angle
GSI	S	0	--	Glideslope deviation for primary runway
GSI_FLAG_LEFT	BIT	Off	--	HSI data validity flag
GSI_FLAG_RIGHT	BIT	Off	--	HSI data validity flag
GSI_LEFT	S	0	--	Glideslope deviation for primary runway
GSI_RIGHT	S	0	--	Glideslope deviation for primary runway
H_BARO	S	0	--	Barometric altitude obtained from selection filter
HDG_FLAG	BIT	Off	--	General heading validity indicator
HDG_FLAG_LEFT	BIT	Off	--	Heading validity indicator for left HSI

Table 5.4-1. Variable List - Area Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
HDG_FLAG_RIGHT	BIT	Off	—	Heading validity indicator for right HSI
HEADING	S	0	TD	Heading angle from runway magnetic north (deg)
HEADING_LEFT	S	0	—	Heading of relative velocity vector (entry) or of body X-axis (TAEM or A/L)
HEADING_RIGHT	S	0	—	Heading of relative velocity vector (entry) or of body X-axis (TAEM or A/L)
HPC	S	0	—	Barometric altitude obtained from the air data SOP
I	INT	—	—	Integer-subscript or iteration counter
LEFT_SIDE	BIT	Off	—	Indicates for which HSI the computations are being performed
M_EFTORW	M	0	—	Earth-fixed to prime RW transformation matrix
M_EFTOTD_TACAN_SL(I)	M	0	—	Transformation matrix from earth-fixed to topodetic coordinates at TACAN site (each LRU) output from site lookup, I=1, 3
MM_CODE_602	BIT	0	—	Major mode 602 flag
MODE	CHAR	—	—	Indicates setting of display mode switch (entry, TAEM, or land)
MODE_LEFT	CHAR	—	—	Indicates setting of display mode switch (entry, TAEM or land) for left side HSI
MODE_RIGHT	CHAR	—	—	Indicates setting of display mode switch (entry, TAEM or land) for right side HSI

Table 5.4-1. Variable List - Area Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
MSBAZIMO(I)	S	0	--	MSBLS azimuth for the I-th receiver, I=1, 3
MAZM_CMLK(I)	BIT	Off	--	MSBLS azimuth comm fault/lock-on flag for I-th receiver, I=1, 3
MSBELEVO(I)	S	0	--	MSBLS elevation for the I-th receiver, I=1, 3
MELV_CMLK(I)	BIT	Off	--	MSBLS elevation comm fault/lock-on flag for I-th receiver, I=1, 3
MSBRANGEO(I)	S	0	--	MSBLS range for the I-th receiver, I=1, 3
MRNG_CMLK(I)	BIT	Off	--	MSBLS range comm fault/lock-on flag for the I-th receiver, I=1, 3
N	INT	--	--	Index for site lookup parameters (TACAN) and raw data from SOP (TACAN or MSBLS)
P	S	-1	--	Sign of primary runway L/R HAC indicator
PHI	S	0	--	Angle from runway to HAC center measured WRT Shuttle
POSITION_WRT_RUNWAY	V	0	RW	Vehicle c.g. position vector WRT measured reference point (R_LS_EF)
PRI_BEAR	S	0	--	Primary bearing (to WP1-entry and TAEM, to WP2-land)
PRIBEAR_LEFT	S	0	--	Primary bearing (to WP1-entry and TAEM, to WP2-land)
LHSI_P	S	-	--	P computed for left side HSI
PRIBEAR_RIGHT	S	0	--	Primary bearing (to WP1-entry and TAEM, to WP2-land)

Table 5.4-1. Variable List - Area Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
MSBAZIMO(I)	S	0	--	MSBLS azimuth for the I-th receiver, I=1, 3
MAZM_CMLK(I)	BIT	Off	--	MSBLS azimuth comm fault/lock-on flag for I-th receiver, I=1, 3
MSBELEVO(I)	S	0	--	MSBLS elevation for the I-th receiver, I=1, 3
MELV_CMLK(I)	BIT	Off	--	MSBLS elevation comm fault/lock-on flag for I-th receiver, I=1, 3
MSBRANGEO(I)	S	0	--	MSBLS range for the I-th receiver, I=1, 3
MRNG_CMLK(I)	BIT	Off	--	MSBLS range comm fault/lock-on flag for the I-th receiver, I=1, 3
N	INT	--	--	Index for site lookup parameters (TACAN) and raw data from SOP (TACAN or MSBLS)
P	S	-1	--	Sign of primary runway L/R HAC indicator
PHI	S	0	--	Angle from runway to HAC center measured WRT Shuttle
POSITION_WRT_RUNWAY	V	0	RW	Vehicle c.g. position vector WRT measured reference point ($\underline{R}$_LS_EF)
PRI_BEAR	S	0	--	Primary bearing (to WP1-entry and TAEM, to WP2-land)
PRIBEAR_LEFT	S	0	--	Primary bearing (to WP1-entry and TAEM, to WP2-land)
LHSI_P	S	--	--	P computed for left side HSI
PRIBEAR_RIGHT	S	0	--	Primary bearing (to WP1-entry and TAEM, to WP2-land)

Table 5.4-1. Variable List - Area Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
PRI_RANGE	S	0	—	Primary range to WP2 (via WP1-entry and TAEM, direct-land)
PRIRANGE_LEFT	S	0	—	Primary range to WP2 (via WP1-entry and TAEM, direct-land)
PRIRANGE_RIGHT	S	0	—	Primary range to WP2 (via WP1-entry and TAEM, direct-land)
PSI_HSIMV	S	0	—	Angle between true north and Shuttle X-axis
RADIUS_EP	S	0	—	Radius of entry point heading alinement circle
RANGE	S	0	—	Range from Shuttle to WP2 via WP1
R_CC	S	0	—	Flat earth surface range from Shuttle to the HAC center
R_CC_EF	V	0	EF	Position vector of HAC center in earth-fixed coordinates
R_CC_MAG	S	0	—	Earth radius at HAC center for primary runway
RCVR	INT	—	—	Indicates setting of string selection switch (when source is MSBLS or TACAN)
RCVR_LEFT	INT	0	—	Indicates setting of string selection switch (when source-in MSBLS or TACAN) on left-side HSI
RCVR_RIGHT	INT	0	—	Indicates setting of string selection switch (when source-in MSBLS or TACAN) on right-side HSI
RD_TAC_SL(I)	S	0	—	Geodetic radius of mean sea level at TACAN site to which the I-th receiver is tuned
R_EF	V	0	EF	Shuttle position vector in earth-fixed coordinates

Table 5.4-1. Variable List - Area Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
R_VEH_MAG_UPP	S	0	--	Magnitude of R_AVGG from LIPP
R_LS_EF	V	0	EF	Position vector of runway in earth-fixed coordinates
R_TAC	S	0	--	Magnitude of TACAN position vector
R_TACAN_EF_SL(I)	V	0	EF	Earth-fixed position vector of TACAN station (each LRU) output from site lookup, I=1, 3
R_VEH	S	0	--	Magnitude of Shuttle vector computed from HBARO and TACAN position
R_VEH_EF	V	0	EF	Position vector of Shuttle in earth-fixed coordinates
R_VEH_MAG	S	0	--	Magnitude of R_VEH_EF
R_VEH_MAG_UPP	S	0	--	Magnitude of R_AVGG from UPP
R_VEH_RW	V	0	RW	Position vector of the Shuttle in runway coordinates
RANGE_FT	S	0	--	Range to WP2 in feet
R_VEH_TD_TAC	V	0	--	Position vector of Shuttle in TACAN topodetic coordinates
SEC_BEAR	S	0	--	Bearing from Shuttle to WP1 for secondary runway-entry, bearing from Shuttle to center of selected HAC for primary runway-TAEM
SECBEAR_LEFT	S	0	--	Bearing from Shuttle to WP1 for secondary runway-entry, bearing from Shuttle to center of selected HAC for primary runway-TAEM
SECBEAR_RIGHT	S	0	--	Bearing from Shuttle to WP1 for secondary runway-entry, bearing from Shuttle to center of selected HAC for primary runway-TAEM

Table 5.4-1. Variable List - Area Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
SEC_RANGE	S	0	—	Secondary range to WP2 via WP1-entry, direct-land, horizontal distance to center of selected HAC for primary runway-TAEM
SECRANGE_LEFT	S	0	—	Secondary range to WP2 via WP1-entry, direct-land, horizontal distance to center of selected HAC for primary runway-TAEM
SECRANGE_RIGHT	S	0	—	Secondary range to WP2 via WP1-entry, direct-land, horizontal distance to center of selected HAC for primary runway-TAEM
SIN_THET_VEH_CC	S	0	—	Sine of range angle from Shuttle to center of HAC
SOURCE	CHAR	—	—	Indicates which data source (MSBLS, TACAN, or NAV) switch is on
SOURCE_LEFT	CHAR	--	—	Indicates which data source (MSBLS, TACAN, or NAV) switch is on for left-side HSI
SOURCE_RIGHT	CHAR	--	—	Indicates which data source (MSBLS, TACAN, or NAV) switch is on for right-side HSI
TACAN_CHAN_VALID_SL(I)	BIT	Off	—	Switch indicating (on) a valid TACAN channel has been selected (site lookup output)
TACBEARO(I)	S	0	—	TACAN bearing data obtained from the SOP for each receiver, I=1, 3
TBRG_CMLK(I)	BIT	Off	—	TACAN azimuth comm fault/lock-on flag for the I-th receiver, I=1, 3
TRNG_CMLK(I)	BIT	Off	—	TACAN range comm fault/lock-on flag for the I-th receiver, I=1, 3
TACRANGEO(I)	S	0	—	TACAN range data obtained from the SOP for each receiver, I=1, 3

Table 5.4-1. Variable List - Area Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
TAZ	S	0	—	Tangent of MSBLS azimuth angle
TEL	S	0	—	Tangent of MSBLS elevation angle
TEL2	S	0	—	Square of tangent of MSBLS elevation angle
THETA	S	0	—	Angle which corrects Shuttle heading from the center of HAC to WP1
V_NORM	V	0	EF	Vector normal to the great circle plane containing the Shuttle and the HAC center
X_CC	S	0	RW	X-component of vector from the Shuttle to HAC center in runway coordinates
X_DMEAZ_RW	S	0	RW	X-component of range/azimuth antenna in runway coordinates
X_EL_RW	S	0	RW	X-component of elevation antenna in runway coordinates
X_EP	S	0	RW	Runway X-component of the HAC center
X_GSI	S	Pad	RW	Glideslope intercept point on extended runway center line
X_NEP	S	Pad	RW	Runway X-component of the HAC center
X_VEH_DMEAZ	S	0	RW	X-component of Shuttle position WRT MSBLS antenna
X_WP2	S	Pad	RW	Runway X-component of WP2
Y_CC	S	0	RW	Y-component of vector from the Shuttle to HAC center in runway coordinates
Y_DMEAZ_RW	S	0	RW	Y-component of range azimuth antenna in runway coordinates

Table 5.4-1. Variable List - Area Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
V_RHO_EF	V	0	EF	Vehicle relative velocity vector in earth-fixed coordinates
C0(1,1), C1(1,1), C2(1,1), C3(1,1), C0(1,2), C1(1,2), C2(1,2), C3(1,2)	Arr	Pad	--	Coefficients used in analytical expressions for reference altitude versus range for nominal steep glidepath angle
C0(2,1), C1(2,1), C2(2,1), C3(2,1), C0(2,2), C1(2,2), C2(2,2), C3(2,2)	Arr	Pad	--	Coefficients used in analytical expressions for reference altitude versus range for high mass steep glidepath angle
CUBRC(I), I=1,2	Arr	Pad	--	Distance from the MEP to the transition point for two analytical expressions for reference altitude versus range
DELX_NEP	S	0	--	Distance from glideslope intercept point and the NEP
DELX_MEP	S	0	--	Distance from glideslope intercept point and the MEP
DR	S	0	--	Distance from vehicle ground position to the transition point for two analytical expressions for reference altitude versus range
H	S	0	--	Altitude above runway
HCO(1)	Arr	0	--	Reference altitude evaluated at the NEP for nominal steep glidepath angle
HCO(2)	Arr	0	--	Reference altitude evaluated at the NEP for high mass steep glidepath angle

Table 5.4-1. Variable List - Area Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
HI_WINDS	BIT	Off	--	Flag denoting high or low winds at runway during landing
H_GSI_SHALLOW	S	Pad	--	Altitude at which final flare begins and GSI_FLAG is set to OFF
HREF	S	0	--	Reference altitude used to compute the glideslope deviation
IGS	S	0	--	Glideslope index
M	S	0	--	Vehicle mass
MASS_FLAG	BIT	ON	--	Flag denoting computation of quantities pertinent to the NEP and MEP
M_GSI	S	Pad	--	Boundary of high vehicle mass and low vehicle mass
NEP	BIT	OFF	--	Flag denoting switch from NEP to MEP circle
R	S	0	--	Distance from the vehicle ground position to the MEP by way of the HAC
X_GSI_HI_WIND	S	Pad	RW	Glideslope intercept point on extended runway centerline for high wind condition
X_GSI_NOMINAL	S	Pad	RW	Glideslope intercept point on extended runway centerline for low wind condition
R_CC_L_PRI	V	0	EF	Position vector of the HAC center on the left-side (-Y) of the runway centerline
R_CC_R_PRI	V	0	EF	Position vector of the HAC center on the right-side (+Y) of the runway centerline
R_CC_LMAG_PRI	S	0	--	Magnitude of the vector R_CC_L_PRI

Table 5.4-1. Variable List - Area Navigation (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
R_CC_RMAG_PRI	S	0	—	Magnitude of the vector R_CC_R_PRI
HMEP	V	Mission Depen-dent	RW	Altitude (AGL) of minimum energy entry point
YSGNP	S	—	—	Initial L/R HAC indicator - PRI
OVHD	B	—	—	Overhead/straight discrete
OVHD_LAST	B	—	—	Previous PLSS overhead/straight discrete
FIRST_PASS	B	ON	—	First pass flag: reset to off after each execution
DELX_REF	S	—	RW	Distance from glideslope intercept point to the polynomid reference point

5.5 SPECIALIST FUNCTION NAVIGATION SUPPORT FLOW CHARTS, VARIABLE NAMES, AND DESCRIPTIONS

This section provides supplemental material for Specialists Functions Navigation Support Formulations in the form of functional flow charts (Figures 5.5-1 and 5.5-2). Table 5.5-1 provides the variable list which supports this material.

Table 5.5-1. Variable List - Specialist Functions Navigation Support Formulations

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
DO_DELTA_ UPDATE	BIT	Off	—	Flag indicating (ON) that a delta state update is to be performed
DO_DELTA_ UPDATE_UP	BIT	Off	—	Flag indicating (ON) that a delta state update has been received via command uplink
DA_RU	V	0	RW	Ground computed position deviations to update onboard state vector deviations received via command uplink
DV_RW	V	0	RW	Ground computed velocity deviations to update onboard state vector
DV_RW_UP	V	0	RW	Ground computed velocity deviations received via command uplink
OP_CODE	B	0	—	Command uplink indentification code
R_GND	V	0	M50	Uplinked Shuttle M50 position vector
T_GND	S	0	--	Time tag of uplinked state vector
V_GND	V	0	M50	Uplinked Shuttle M50 velocity vector

ASCENT_UPLINK_PROCESSOR

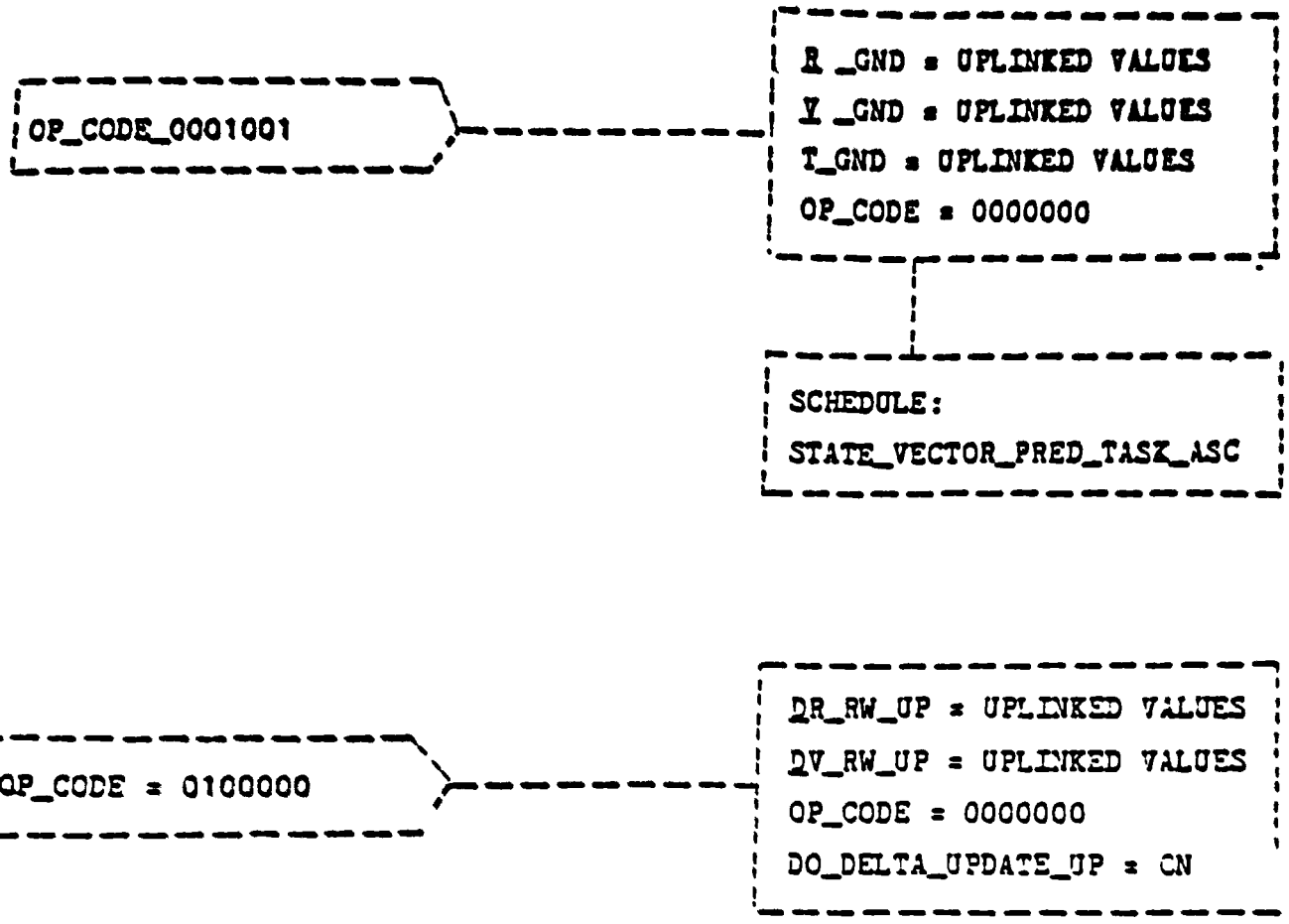


Figure 5.5-1. ASCENT_UPLINK_PROCESSOR

KEYBOARD PROCESSOR

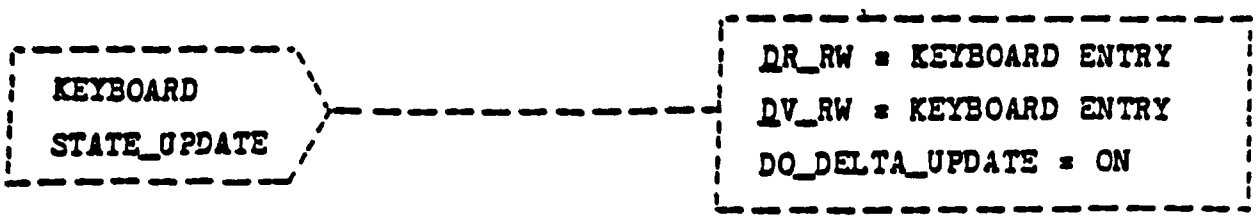


Figure 5.5-2. KEYBOARD PROCESSOR

KEYBOARD PROCESSOR

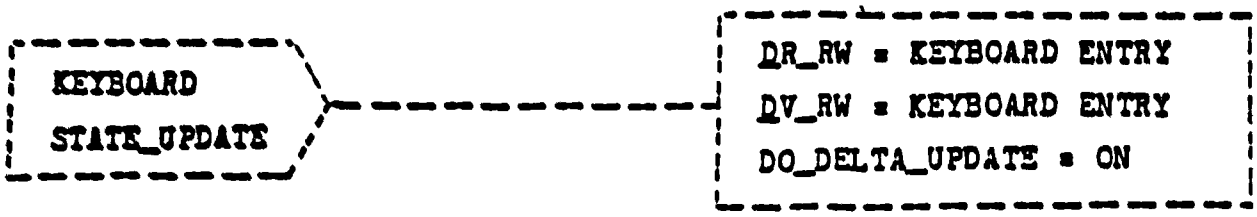


Figure 5.5-2. KEYBOARD PROCESSOR

5.6 USER PARAMETER FLOW CHARTS, VARIABLE NAMES, AND DESCRIPTIONS

This section provides supplemental material for User Parameter Processing in the form of functional flowcharts (Figures 5.6-1 through 5.6-9). Table 5.6-1 provides the variable list which supports this material. The following data will aid in interpreting Table 5.6-1.

VARIABLE LIST DEFINITIONS

Code used for variable data type:

S:	scalar
V:	vector
M:	square matrix
INT:	integer
BIT:	bit
CHAR:	character
STR:	structure
ARR:	array

Coordinate frame code and definition:

BODY: (structural)	x:	parallel to the longitudinal axis (positive aft)
	y:	completes right-hand system
	z:	perpendicular to the x-axis, positive upward
M50:		Mean-of-50 reference coordinate system
RW: (runway coordinates)	x:	down runway centerline in direction of landing
	y:	completes right-hand system
	z:	down, normal to ellipsoid
SCAN: (MLS scanner coordinates)	x:	scanner boresight
	y:	completes right-hand system
	z:	up, normal to ellipsoid
TD: (topodetic coordinates)	x:	north
	y:	east
	z:	down, normal to ellipsoid
EF:		Earth-fixed coordinate system

Table 5.6-1. Variable List User Parameters

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
A2	S	0		Angle defined by the intersection of the two great circle planes (one passing through the Shuttle position and the HAC center and the other through the Shuttle position and WP1)
A3	S	0	--	Angle at HAC center from WP1 to entry point
A3_TOL	S	Design Dependent	--	Tolerance for correcting the range of the angle A3
ACC_DRAG	S	0	--	Vehicle drag acceleration
ACC_VERT	S	0	--	Vertical component of vehicle c.g. acceleration WRT earth rotating frame
ACC_VERT_OLD	S	0	--	Previous value of vertical acceleration
ALPHA_N	S	0	--	Navigation derived angle of attack
ALPHA_NAVDAD	S	0	--	Navigation derived angle of attack for use in NAVDAD SOP
ALT	S	0	--	Current orbiter altitude above reference ellipsoid
ALT_NAV_EVLT	V	Design Dependent	--	Altitude regions for nav event lamp processing
ALT_RW	S	0	--	Altitude above reference ellipsoid of runway reference point
ALT_S_I	V	Design Dependent	--	Exponential atmosphere scale height for layered atmosphere model

Table 5.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
ALT_TAB_I	V	Design Dependent	--	Altitudes for layered atmosphere model
ALT_WHEELS	S	0	--	Altitude of the bottom of the rear wheels above the runway altitude in MM602 and MM603. Altitude of the NAV base above the runway altitude for major modes other than 602 and 603
$ANGLE\_CORR\_TNTOMAG\_SL_I$	V	0	--	Magnetic variation at TACAN site (each LRU) output from site lookup, I = 1,3
A_O	S	0	--	One minus earth eccentricity squared
ASCENT_INIT_COMPLETE	BIT	Off	--	Navigation initialization event flag
A _SENSED	V	0	M50	Ratio of difference of selected accelerometer sensed velocities to the difference of their time tags
AZIMUTH_RW	S	0	--	Bearing from true north of runway coordinate system +X-axis
BEAR_CC	S	0	--	Bearing at HAC center WRT true north
BIAS_ELMLS	S	0	--	MSBLS elevation mesurement bias (currently used to define slope of runway)
BIAS_RADALT	S	K-Load	--	Radar altimeter bias
CNODE	S	0	--	Cosine of DELTA_NODE
COSTH	S	0	--	Cosine of Shuttle's pitch Euler angle (TD to body)
COURSE_WRT_RUNWAY	S	0	--	Vehicle velocity direction WRT runway centerline

Table 5.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
D_ARC	S	0	--	Arc length around the HAC from WP1 to EP
DEG_PER_RAD	S	Constant	--	Conversion factor, radians to degrees
DELTA_ACC_ VERT	S	0	--	Difference between two most recent values of ACC_VERT, no filter update
DELTA_NODE	S	0	--	Angle of nodal regression between nominal and actual launch times
DELTA_T	S	NON-ZERO	--	Delta time associated with DELTA_ACC_VERT
DG_RADALT	BIT	Off	--	Radar altimeter data-good flag
DIST_VEH_WP1	S	0	--	Surface range from Shuttle to WP1
DT	S	0	--	State vector
DT_IMU	S	0	--	State vector average-G integration time step
DV	V	0	M50	Velocity change
DV_S	V	0	M50	IMU-sensed velocity change
EARTH_POLE	V	Constant	M50	Unit vector in direction of earth's axis of rotation
EARTH_RADIUS_ EQUATOR	S	Constant	--	Earth equatorial radius
EAS	S	0	--	Equivalent airspeed
EF_PLANE_SW	BIT	Mission Dependent	--	Earth-fixed plane constraint switch
EVENT_19	BIT	Off	--	SRB ignition command event flag

CR89596C

CR89596C

Table 5.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
EVENT_28	BIT	Off	--	SRB separation command event flag
EVENT_31	BIT	Off	--	Guidance fine countdown initiate
EVENT_32	BIT	Off	--	MECO command event flag
EVENT_36	BIT	Off	--	Transition to mode 104
EVENT_45	BIT	Off	--	Initiate guidance for OMS-2
EVENT_A30	BIT	Off	--	SRB separation command event flag
EVENT_A31	BIT	Off	--	Mode transition from 103 to 601 event flag
EVENT_A34A	BIT	Off	--	MECO monitor event flag
EVENT_A39	BIT	Off	--	Mode transition from 601 to 602 event flag
EVENT_A39B	BIT	Off	--	Mode transition from 104 to 602 event flag
FILT_UPDATE	S	0	--	Switch indicating (ON) that the current navigation cycle is complete
FLATCON	S	0	--	Earth eccentricity squared
FLT_PATH_ANG	S	0	--	Angle between navigation base relative velocity vector and ellipsoid horizontal
G _OLD	V	0	M50	Copy of G _RESET for use in user parameter integrator
G _RESET	V		M50	Gravitational acceleration vector reserved for reset of the user parameter integration gravity vector
GRAV_SEA_ LEVEL	S	Constant	--	Acceleration of gravity at sea level

Table 5.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
EVENT_28	BIT	Off	--	SRB separation command event flag
EVENT_31	BIT	Off	--	Guidance fine countdown initiate
EVENT_32	BIT	Off	--	MECO command event flag
EVENT_36	BIT	Off	--	Transition to mode 104
EVENT_45	BIT	Off	--	Initiate guidance for OMS-2
EVENT_A30	BIT	Off	--	SRB separation command event flag
EVENT_A31	BIT	Off	--	Mode transition from 103 to 601 event flag
EVENT_A34A	BIT	Off	--	MECO monitor event flag
EVENT_A39	BIT	Off	--	Mode transition from 601 to 602 event flag
EVENT_A39B	BIT	Off	--	Mode transition from 104 to 602 event flag
FILT_UPDATE	S	0	--	Switch indicating (ON) that the current navigation cycle is complete
FLATCON	S	0	--	Earth eccentricity squared
FLT_PATH_ANG	S	0	--	Angle between navigation base relative velocity vector and ellipsoid horizontal
G OLD	V	0	M50	Copy of G RESET for use in user parameter integrator
G RESET	V		M50	Gravitational acceleration vector reserved for reset of the user parameter integration gravity vector
GRAV SEA LEVEL	S	Constant	--	Acceleration of gravity at sea level

Table 5.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
H_DOT	S	0	--	Radial component of relative velocity
H_DOT_ ELLIPSOID	S	0	--	Estimated topodetic altitude rate
H_DOT_LAST	S	0	--	Previous value of H_DOT_ ELLIPSOID
HEADING_RW	S	0	--	Bearing from Shuttle position to landing site referenced to the desired orbit plane
HEADING_V_I	S	0	--	Angle formed by the inertial velocity vector and the orbit plane
HEADING_V_REL	S	0	--	Angle formed by the relative velocity and the orbit plane
I_DR	V	0	EF	Unit vector in plane containing the vehicle and the HAC and directed downrange
I_MAX	INT	5	--	Number of altitude regions
IMU_SFC	V	0,0,0	--	IMU selection filter control vector
IMU_SFC_PREV	V	1,1,1	--	Previous value of IMU selection filter control vector
IPHASE	INT	0	--	Flag denoting various phases of TAEM guidance
IX	V	0	M50	Unit vector in the orbit plane directed downrange
I_YD	V	Design Dependent	EF/M50	Unit vector normal to desired orbit plane in EF or M50 coordinates
I_YD_M50	V	0	M50	Unit vector normal to desired orbit plane in M50 coordinates
LOAD_TOTAL	S	0	--	Total load factor

Table 5.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
M_EFTORW	M	0	--	Earth-fixed to prime RW transformation matrix
M_EFTOTD	M	0	--	Earth-fixed to topodetic coordinate transformation matrix
M_EFTOTD_TACAN_SL$_I$	M	0	--	Transformation matrix from earth-fixed to topodetic coordinates at TACAN site (each LRU) output from site lookup, I = 1,3
MLS_AVAIL	BIT	Off	--	MLS availability
M_M50TOBR	M	0	--	M50 to boost reference coordinate transformation matrix
MM_CODE_102	BIT	0	--	Major mode 102 flag
MM_CODE_103	BIT	0	--	Major mode 103 flag
MM_CODE_601	BIT	0	--	Major mode 601 flag
MM_CODE_602	BIT	0	--	Major mode 602 flag
MM_CODE_603	BIT	0	--	Major mode 603 flag
M_NODE_ADJ	M	0	--	Node adjustment matrix
M_TEMP_TXPOS	M	0	--	Transpose of earth-fixed to Mean 50 transformation matrix
NAUTMI_PER_FT	S	Constant	--	Feet to nautical miles
NAVBASE_LAT_ZERO	S	Design Dependent	--	Latitude of vehicle navigation base at reference point on pad
NAVBASE_LONG_ZERO	S	Design Dependent	--	Longitude of vehicle navigation base at reference point on pad
NAV_EL_FLAG	BIT	Off	--	Temporary event lamp flag
NODE_SLOPE	S	Mission Dependent	--	Nodal regression slope

Table 3.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
N_SEQ_MAX	INT	Design Dependent	--	Number of sequential failures of the nav event lamp test criteria allowed before activating the nav event lamp (event lamp five)
N_SEQ_RA	INT	1	--	Sequential counter for radar altimeter validity indicator
OHALRT	BIT	Off	--	Flag denoting TAEM guidance request to downmode
OVHD	BIT	On	--	A flag denoting overhead or straight-in approach
P	S	1	--	Sign of runway Y-component of the Shuttle
PI	S	Constant	--	The constant Pi
POSITION_WRT_RUNWAY	V	0	RW	Vehicle c.g. position vector WRT runway reference point (R_LS_EF)
PSHA	S	Design Dependent	--	Initial value of HAC turn angle
PSHARS	S	Design Dependent	--	Initial value of HAC turn angle
Q_BAR_A	S	0	--	Vehicle's current dynamic pressure
Q_M50TOBR	V	0	--	Quaternion, M50 to boost reference
Q_RADALT	S	0	--	Radar altimeter measurement
RA_FLAG	BIT	Off	--	Radar altimeter validity indicator
RAD_P	S	0	--	Radius of the earth at the geocentric angle of the Shuttle position vector

CR89947A

Table 5.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
RAD_PER_DEG	S	Constant	--	Conversion factor, degrees to radians
RADALT_ANG	S	Hard Code	--	Radar altimeter antenna angle with body X-axis
RADALT_NB_DIST	S	Hard Code	--	Navigation base to RA antenna distance
RADIUS_NEP	S	Mission Dependent	--	Radius of nominal HAC
RAMP	S	0	--	Variable used in Autoland phase for transition from horizontal to sloping runway coordinates
RAW_RA_PROC	BIT	Off	--	Radar altimeter processing flag
R _AVGG	V	0	M50	Current Shuttle position vector
R _C_EF	V	0	EF	Position vector HAC center in earth-fixed coordinates
R _CC_L_PRI	V	0	--	Position vector of the HAC center on the left-side (-Y) of the runway centerline
R_CC_LMAG_PRI	S	0	--	Magnitude of the vector R _CC_ L_PRI
R_CC_MAG	S	0	--	Earth radius at HAC center for primary runway
R _CC_R_PRI	V	0	--	Position vector of the HAC center on the right-side (+Y) of the runway centerline
R_CC_RMAG_PRI	S	0	--	Magnitude of the vector R _CC_ R_PRI
R _EF	V	0	EF	Shuttle position vector in earth-fixed coordinates

Table 5.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
REL_VEL_MAG	S	0	--	Magnitude of vehicle relative velocity
R_EST	V	0	EF	Difference between Shuttle position and TACAN site location in earth-fixed coordinates (TACAN range in earth-fixed coordinates)
R_GO_RAMP	S	Design Dependent	--	Horizontal distance of vehicle from runway reference point below which radar altimeter measurements will be incorporated in UPP state
RHO_A	S	0	--	Local air density computed during ascent
RHO_B_I	V	Design Dependent	--	Exponential atmosphere base density for layered atmosphere model
RI	S	Design Dependent	--	Initial value of spiral radius
R_LS_EF	V	0	EF	Position vector of runway reference point in Earth-fixed coordinates
R_LS_M50	V	0	M50	Position vector of runway in M50 coordinates
R_M50_AT_LIFTOFF	V	0	M50	M50 Shuttle position vector snapped at SRB ignition command event (used to approximately M50 launch site position)
RNG_TO_RW_THRESH	S	0	--	Surface range from Shuttle to RW threshold
R_RESET	V	0	M50	Vehicle position vector after all navigation updates reserved for reset of user parameter integrator position vector R_AVGG

Table 5.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
$\underline{R}$ _TACAN_EF_ SL_I	V	0	EF	Earth-fixed position vector to TACAN station (each LRU) output from site lookup, I = 1,3
$\underline{R}$ _TEMP	V	0	TD	Position vector to the Shuttle from the selected TACAN in topodetic coordinates at TACAN site
R_VEH_MAG	S	0	--	Magnitude of $\underline{R}$ _AVGG
R_VEH_MAG_ UPP	S	0		Magnitude of $\underline{R}$ _AVGG
R _VEH_RW	V	0	RW	Position vector of the Shuttle in runway coordinates
RW_ID_UPP	INT		--	Selected runway ID
RW_NAME	INT		--	Selected runway ID
SIGNY	INT	0		Vehicle side of primary runway centerline
SIN_THET_ VEH_CC	S	0	--	Sine of range angle from Shuttle to center of HAC
SINTH	S	0	--	Sine of Shuttle's pitch Euler angle (TD to body)
SNODE	S	0	--	Sine of DELTA_NODE
START_ POSITION	S	Design Dependent	--	X-runway position where conversion from horizontal to sloping runway coordinates begins
STOP_ POSITION	S	Design Dependent	--	X runway position where conversion from horizontal to sloping runway coordinates is completed
TACAN_CHAN_ VALID_SL_I	BIT	Off	--	Switch indicating (ON) a valid TACAN channel has been selected (site lookup output)

Table 5.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
$TACBEARO_I$	V	0	--	TACAN bearing data obtained from the SOP for each receiver, I = 1,3
TAC_MODE	BIT	On	--	Switch indicating "ON" when ABS_MODE is selected for HSD DISP and "OFF" when DELTA_MODE is selected
TAC_MODE_ DISP	BIT	On	--	Switch for the HSD display indicating "ON" when ABS_MODE is selected and "OFF" when DELTA_MODE is selected
TAC_AZ_I	V	0	--	TACAN azimuth for display in the ABS_MODE or delta azimuth in the DELTA_MODE
$TACRANGEO_I$	V	0	--	TACAN range data obtained from the SOP for each receiver, I = 1,3
TAC_RNG_I	V	0	--	TACAN range for display in the ABS_MODE or delta range when in the DELTA_MODE
TAL_ABORT_ DECLARED	BIT	Off	--	TAL ABORT declared flag
TCG	V	0	--	Total sensed acceleration vector
TEMP	S	0	--	Internal variable used in computation of topodetic unit vector (ASCENT_RTLS_COMPS); azimuth difference for each TACAN (TACAN_DISP_COMPS); internal variable used in transformation from horizontal to sloping runway coordinates (GUIDECOMP)
TEST_VNT_DR	BIT	On	--	Internal single pass flag

Table 5.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
TG_END	BIT	Off	--	TAEM guidance termination flag: OFF = TAEM; ON = Autoland
T_GMTLO_REF	S	Mission Dependent	--	Nominal lift-off-time
THETA	S	0	--	Euler angle from TD frame to body (pitch)
TIME_BIAS_ RADALT	S		--	Pad loaded bias used to correct radar altimeter time tag
T_CURRENT	S		--	Current time
T_IMU	S	0	--	Time associated with current read IMU velocity counts from the IMU detection filter (RM)
T_IMU_LAST	S	0	--	Previous value of T_IMU
TOGHAC	BIT	Off	--	Flag denoting crew request to change approach type (OVHD/STRT)
T_RADALT	S	0	--	Time at which radar altimeter measurement was read
T_RESET	S	0	--	Time associated with reserved reset state
T_STATE	S	0	--	Time tag for current user parameter state vector
T_STATE_LAST	S	0	--	Value of T_STATE at previous pass through user parameter processing
T_STATE_OLD	S	0	--	Previous value of T_STATE
T_STATE_PREV	S	Large Negative Value	--	Previous value of T_STATE

CR89596C CR89596C

Table 5.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
UK	S	0	--	Vector dot product of VNOR and EARTH_POLE
UNIT	S	0	--	Absolute value of V_NORM, the vector normal to the great circle plane containing the Shuttle and HAC center
UPP_UPDATE	BIT	Off	--	Flag indicating UPP state has been updated by navigation filter
USE_IMU_DATA	BIT	0	--	Flag used to indicate that IMU data will be employed in computing acceleration
UX	V	0	M50	X-vector component of the +Z topodetic unit vector in topocentric coordinates
V_AVGG	V	0	M50	Shuttle current velocity vector
V_GROUNDSPEED	S	0	--	Vehicle c.g. groundspeed WRT runway (A/L), reference ellipsoid (TAEM)
V_HORIZ_DNRNG	S	0	--	Downrange component of the Shuttle's horizontal, Earth-relative velocity
V_IMU_CURRENT	V	0	M50	Current selected accumulated IMU velocity
V_IMU_OLD	V	0	M50	Current accumulated IMU velocity
V_IMU_PREV	V	0	--	Previous value of vector V_IMU_OLD
V_IMU_RESET	V	0	M50	Copy of V_CURRENT_FILT reserved as velocity count at start of extrapolation interval when user parameter integrator is reset

Table 5.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
V_IMU_LAST	V	0	M50	Previous value of V_IMU_CURRENT
V_INERTIAL_MAG	S	0	--	Magnitude of vehicle inertial velocity
VNOR	V	0	M50	Unit vector colinear with the Shuttle position vector and directed in the opposite sense
VNORM	V	0	M50	Vector normal to the plane containing the Shuttle and the landing site
VNT_DR_SEQ	BIT	Off	--	Flag which instructs MSC to initiate the VENT_DOOR_CNTL_SEQ principal function
VNTDR_VEL_THRSH_SEQ_	.S	Design Dependent	--	Threshold value of the relative velocity below which the VNT_DR_INIT flag is set to ON
V_RESET	V	0	M50	Vehicle velocity vector after all navigation update reserved for reset of user parameter integrator velocity V_AVGG
V_RHO	V	0	M50	Vehicle relative velocity vector
V_RHO_EF	V	0	EF	Vehicle relative velocity vector in earth-fixed coordinates
VELOCITY_WRT_RUNWAY	V	0	RW	Vehicle velocity vector WRT runway reference point (R_LS_EF)
WBR	V	0	Body	Body rate in degrees/second
X_NB_CG	S	K-load	RW	X_STRUCT_BODY distance from navigation base to c.g.
X_NEP	S	Mission Dependent	--	Runway X-component of the HAC center

Table 5.6-1. Variable List - User Parameters (Cont)

Variable Name	Data Type	Initial Value	Coord Frame	Variable Description
X_NB_WH	S	Hard Code	--	X_STRUCT_BODY distance from rear wheels to navigation base
YSGNP	INT	0	--	Commanded HAC side of primary runway centerline
Z_NB_CG	S	K-Load	--	Z_STRUCT_BODY distance from c.g. to navigation base
Z_NB_WH	S	Hard Code	--	Z_STRUCT_BODY distance from rear wheels to navigation base

ASCENT_UPP_SEQ

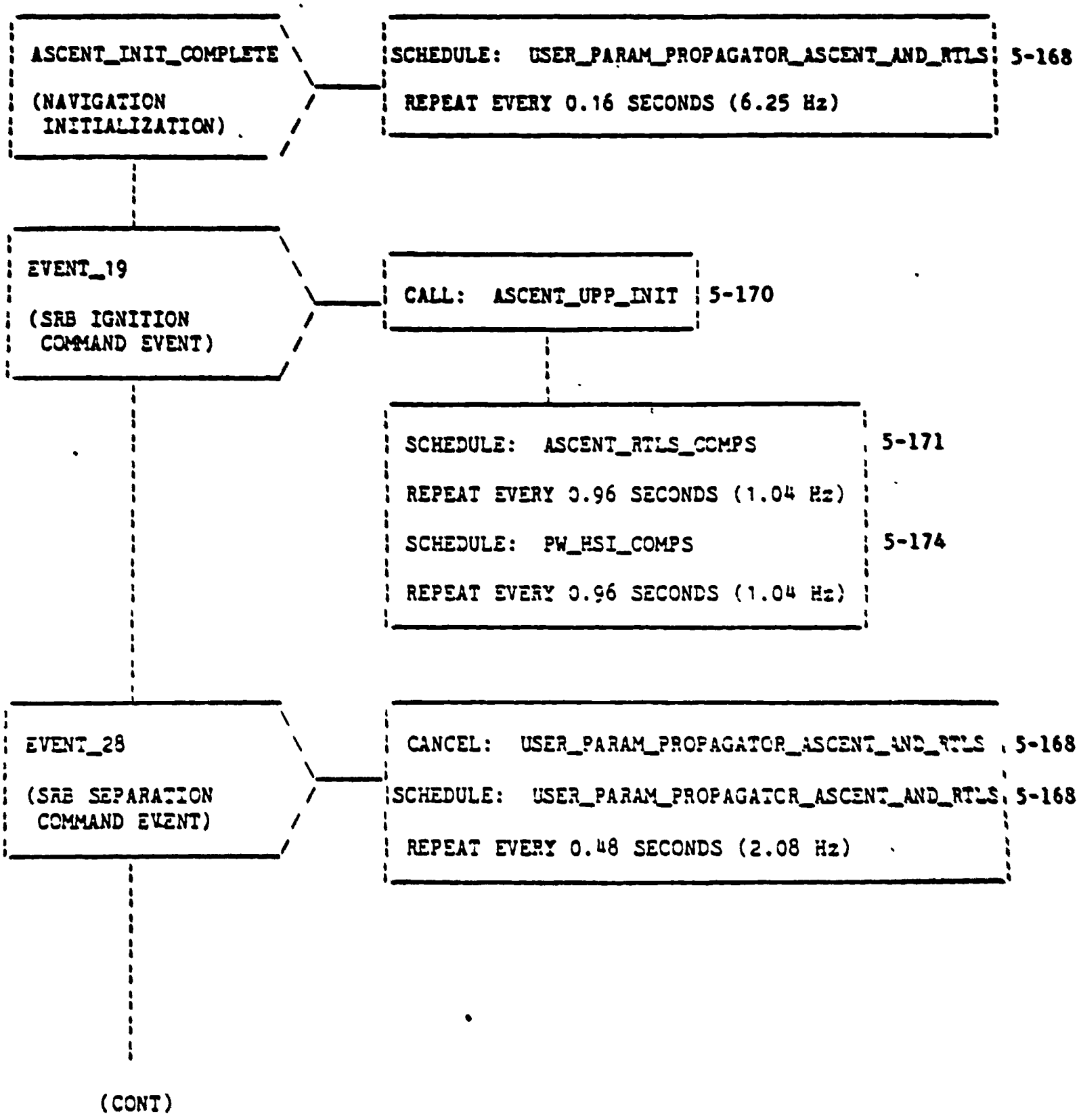
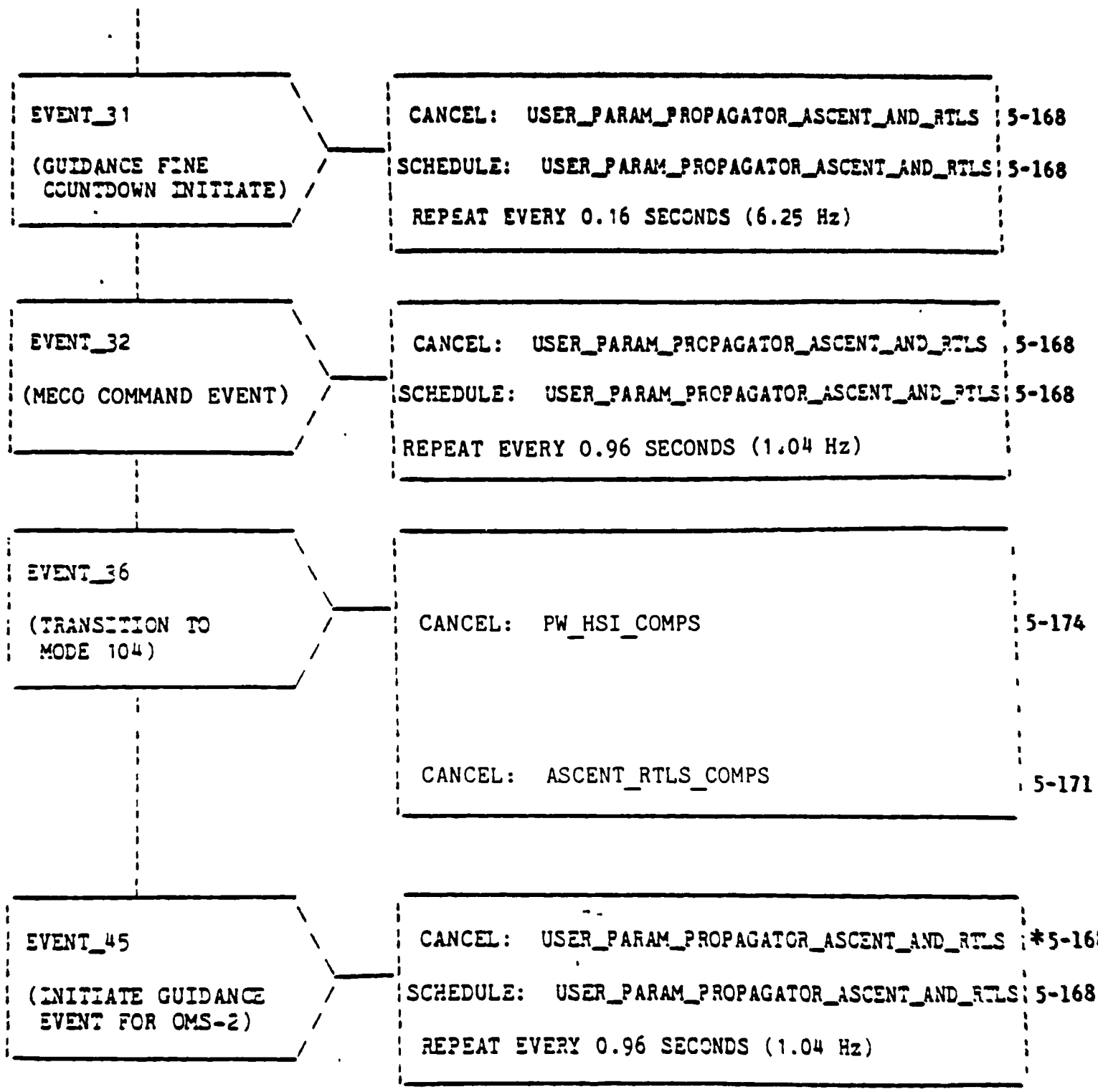


Figure 5.6-1. ASCENT_UPP_SEQ

ASCENT_UPP_SEQ (CONT)



*THE PURPOSE OF THIS CANCEL AND RESCHEDULE IS TO SYNCHRONIZE THESE MODULES WITH THE EXECUTIONS OF THE GUIDANCE PROGRAM.

Figure 5.6-1. ASCENT_UPP_SEQ (Cont)

USER_PARAM_PROPAGATOR_ASCENT_AND_RTLS

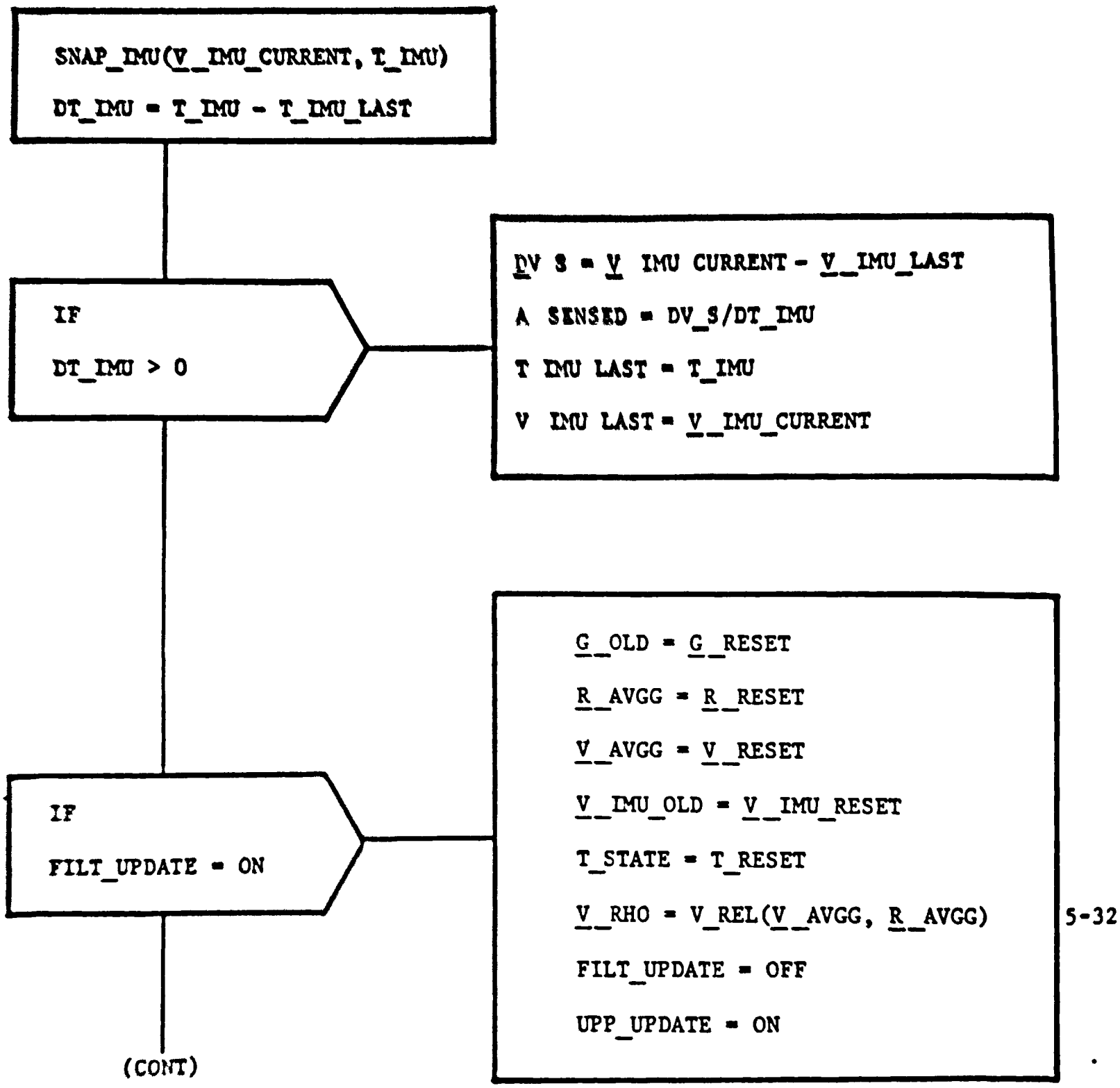


Figure 5.6-2. USER_PARAM_PROPAGATOR_ASCENT_AND_RTLS

USER_PARAM_PROPAGATOR_ASCENT_AND_RTLS (Cont)

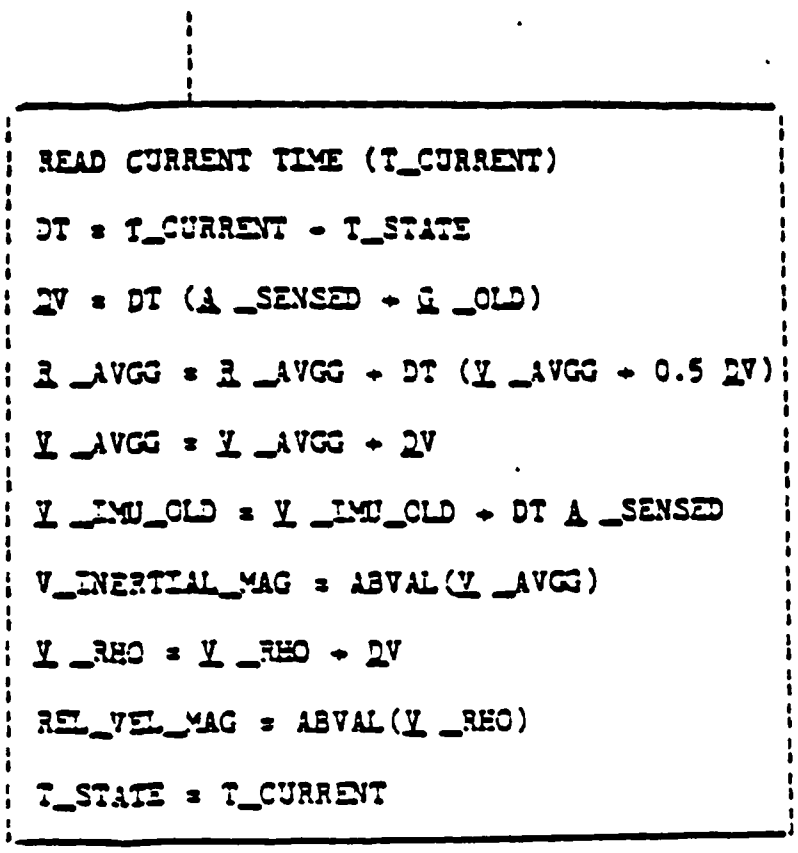
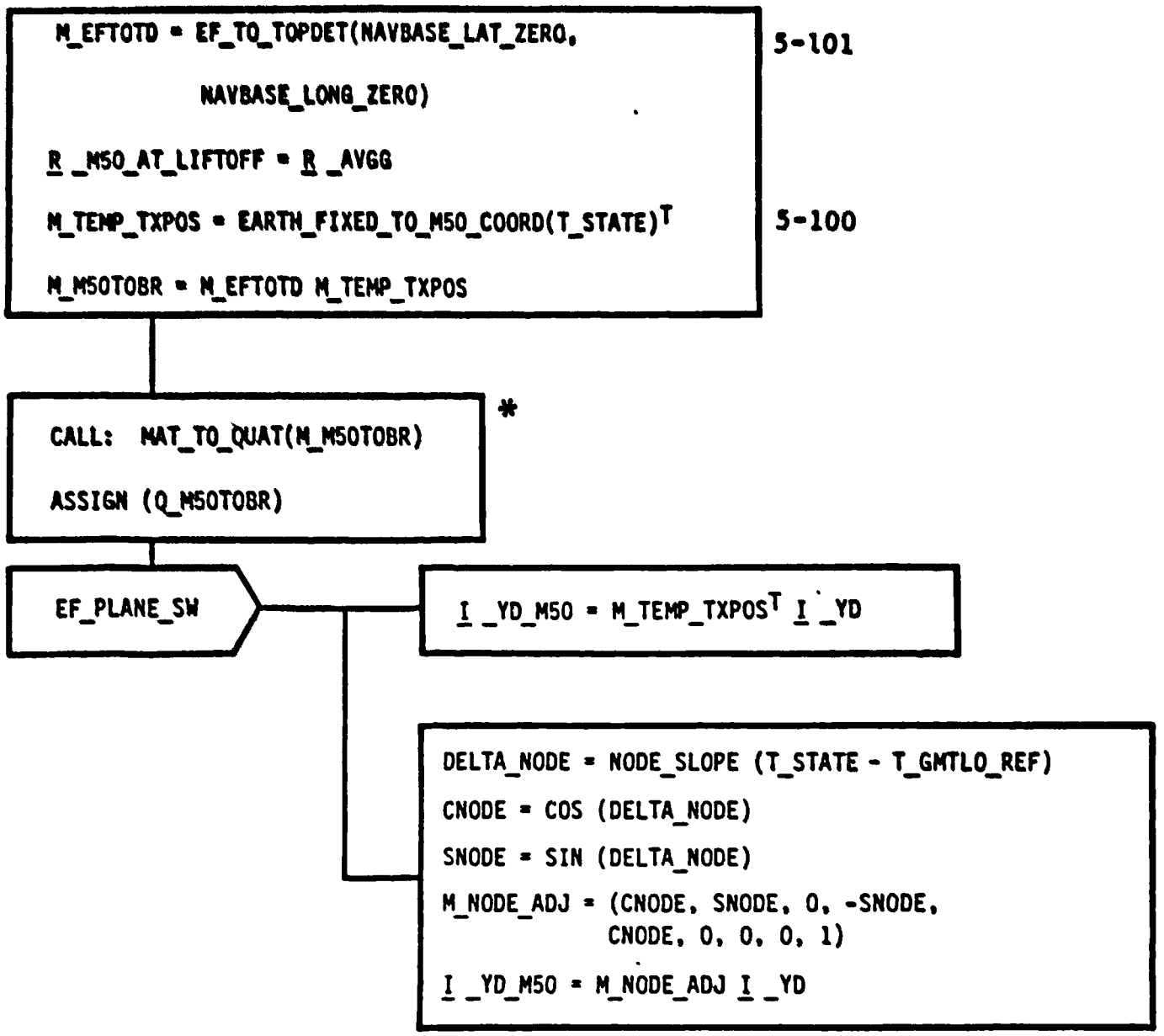


Figure 5.6-2. USER_PARAM_PROPAGATOR_ASCENT_AND_RTLS (Cont)

ASC_UPP_INIT



* MAT_TO_QUAT IS A MATRIX TO QUATERNION CONVERSION ROUTINE WHICH IS DOCUMENTED IN THE FLIGHT CONTROL FSSR - ATTITUDE SECTION.

Figure 5.6-3. ASCENT_UPP_INIT

ASCENT_RTLS_COMPS

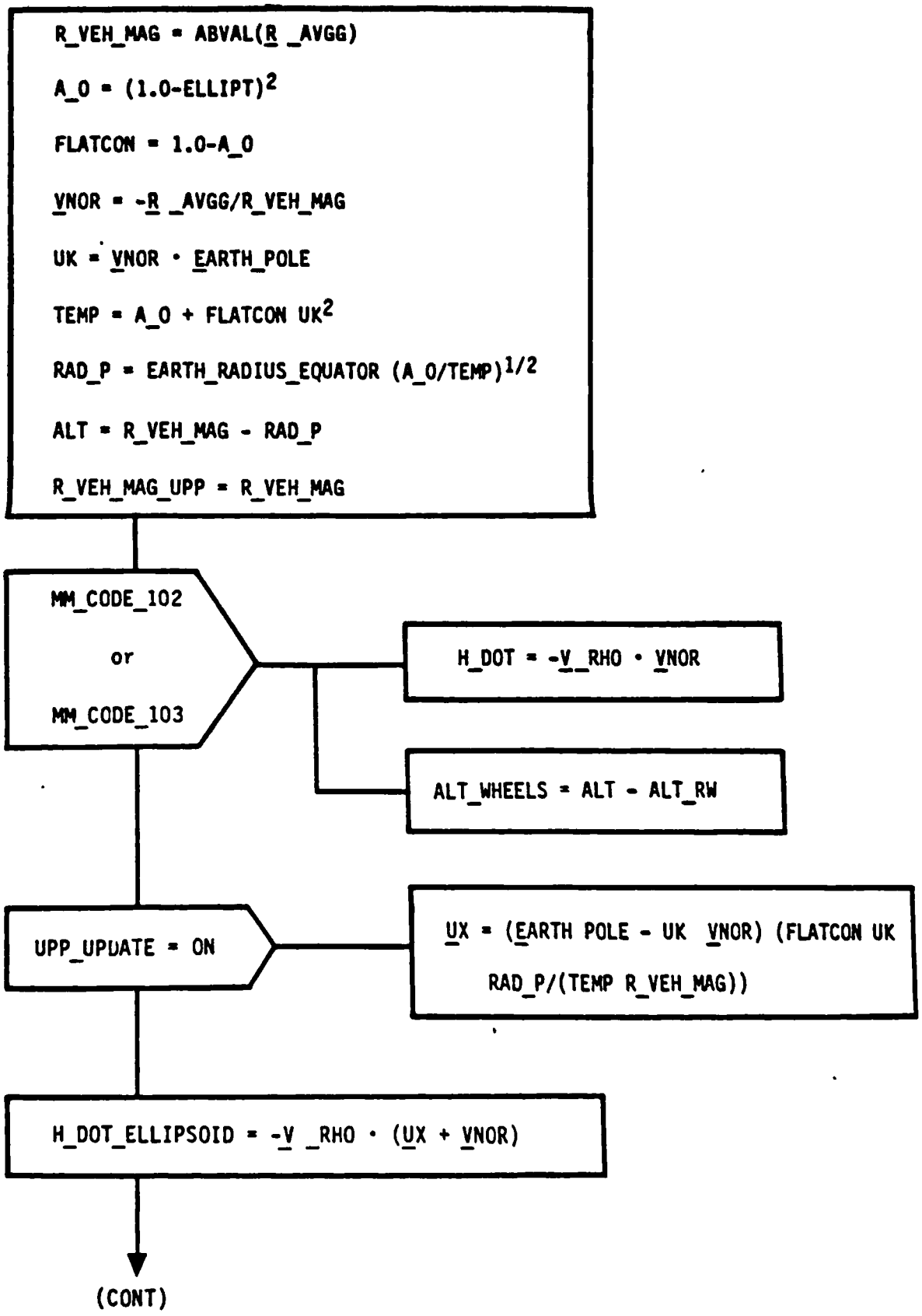


Figure 5.6-4. ASCENT_RTLS_COMPS

ASCENT_RTLS_COMPS (CONT)

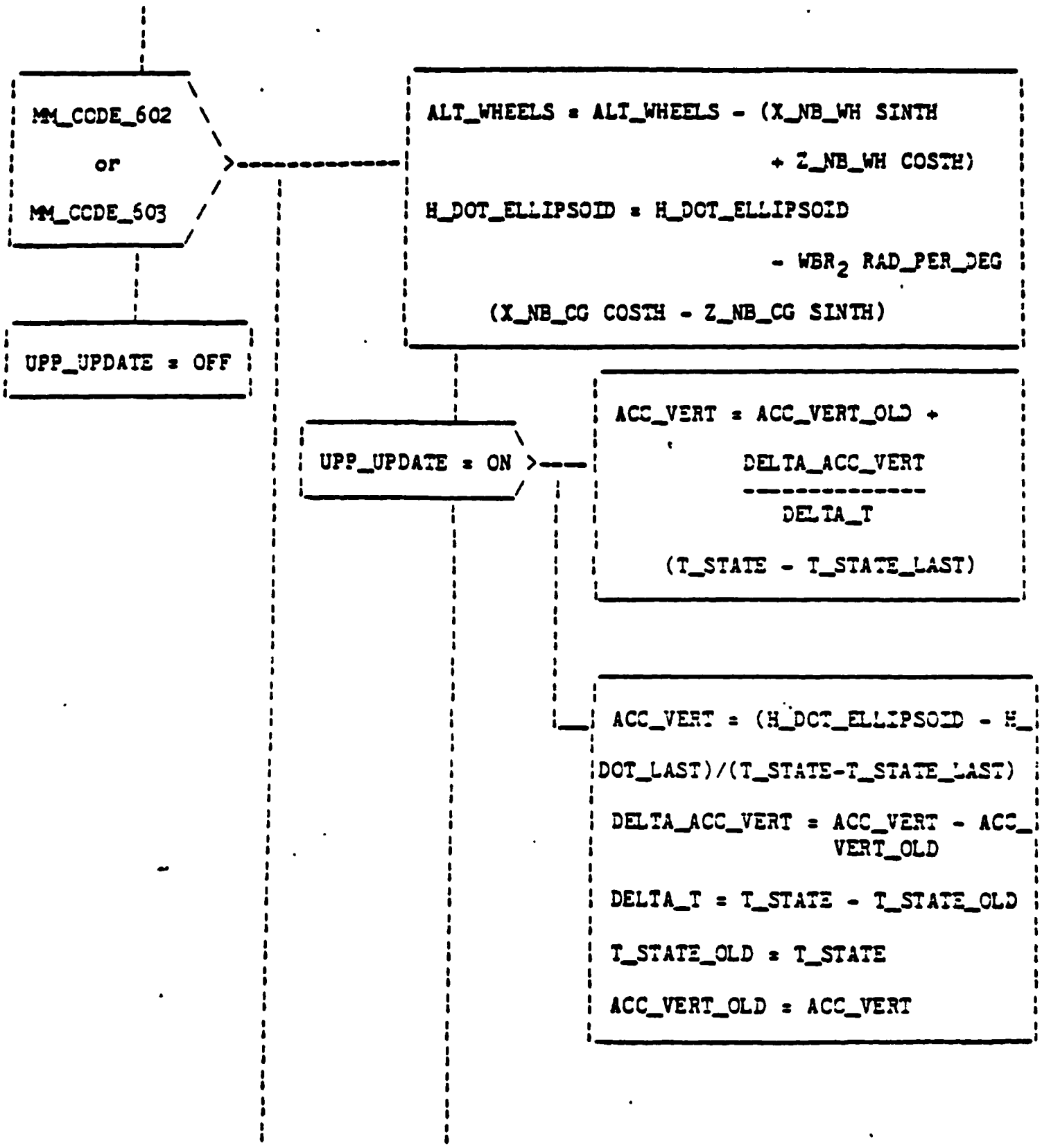


Figure 5.6-4. ASCENT_RTLS_COMPS (Cont)

ASCENT_RTLS_COMPS (CONT)

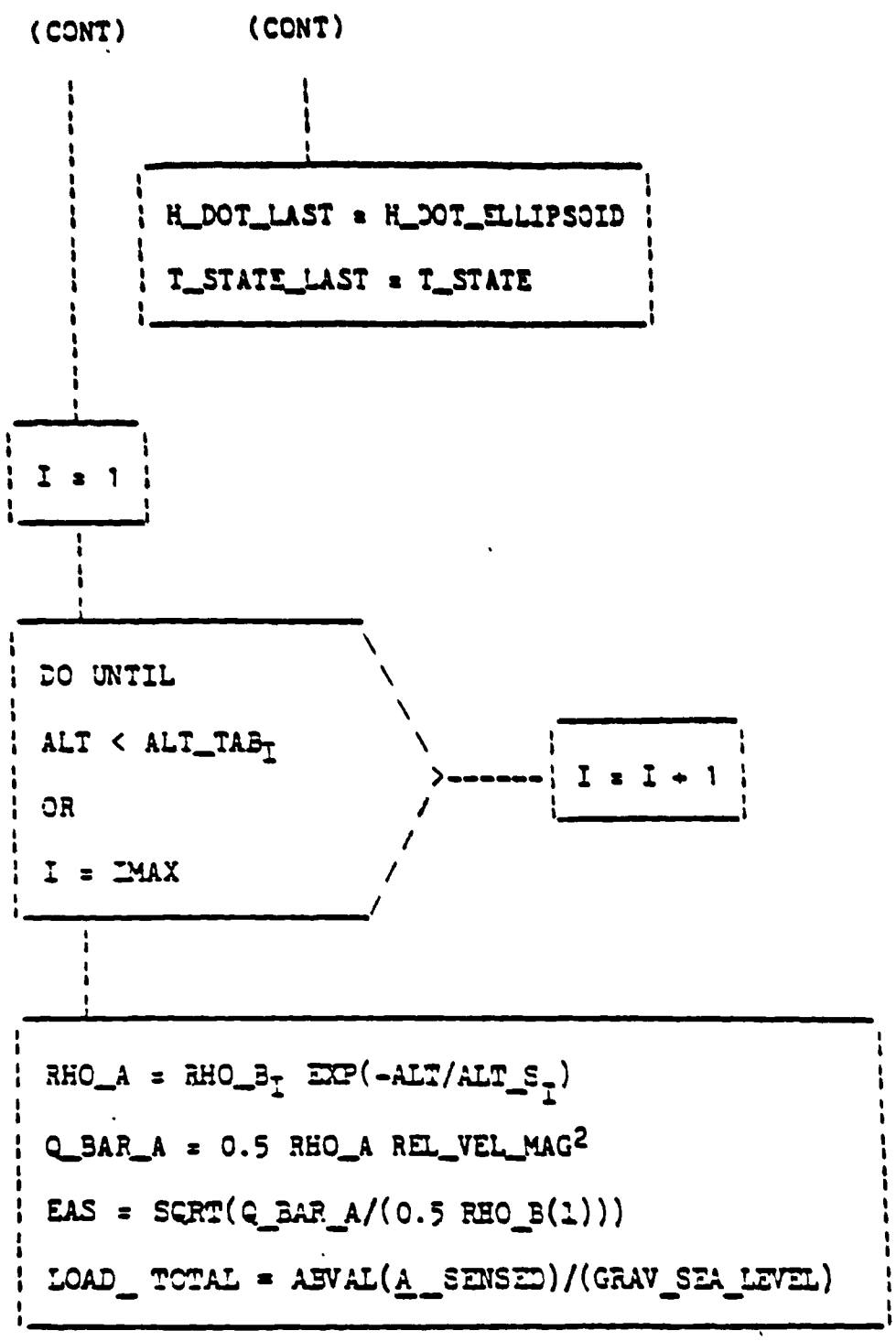


Figure 5.6-4. ASCENT_RTLS_COMPS (Cont)

PW_HSI_COMPS

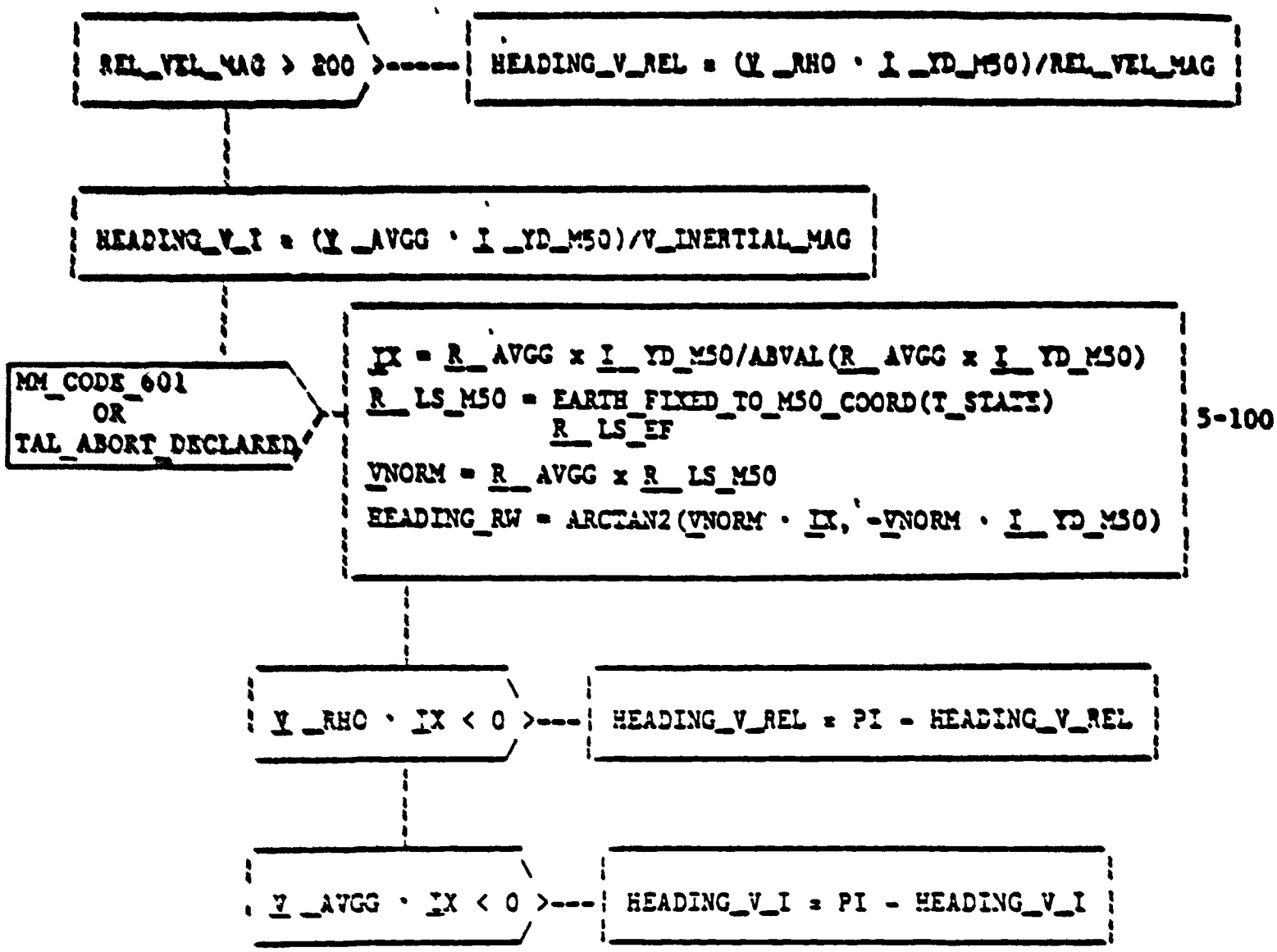


Figure 5.6-5. PW_HSI_COMPS

RTLS_UPP_SEQ

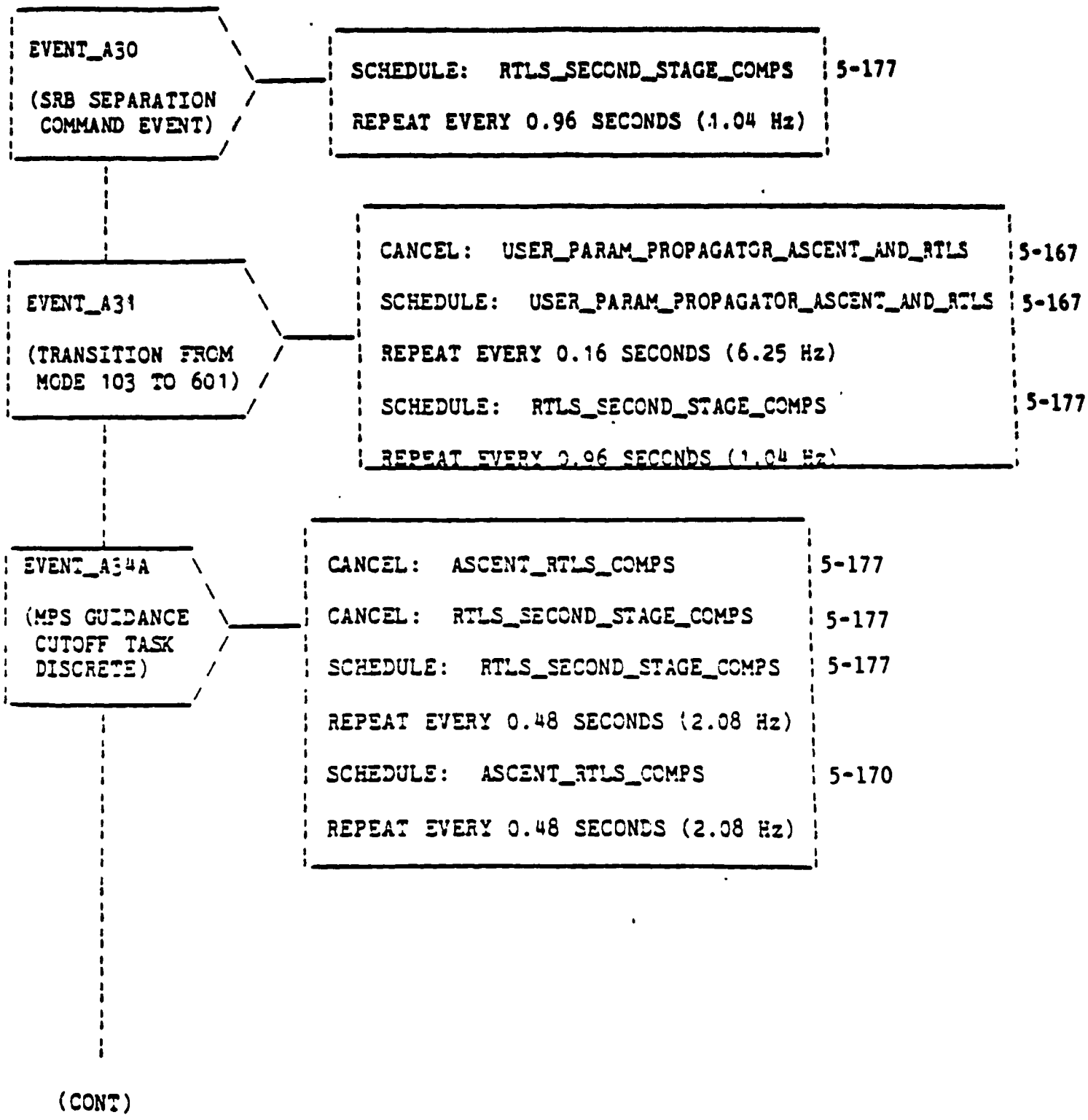


Figure 5.6-6. RTLS_UPP_SEQ

RTLS_UPP_SEQ (CONT)

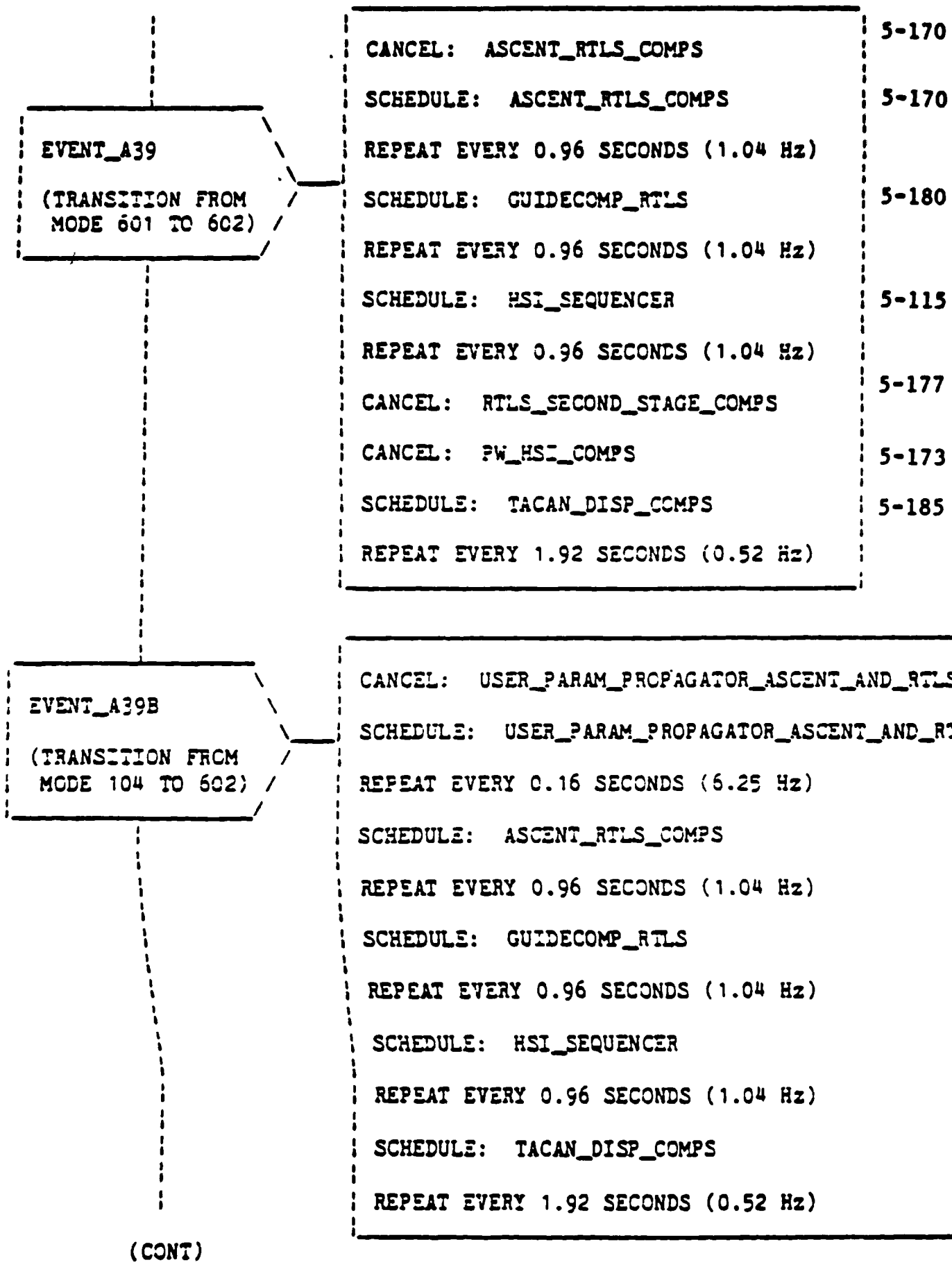


Figure 5.6-6. RTLS_UPP_SEQ (Cont)

RTLS_UPP_SEQ (CONT)

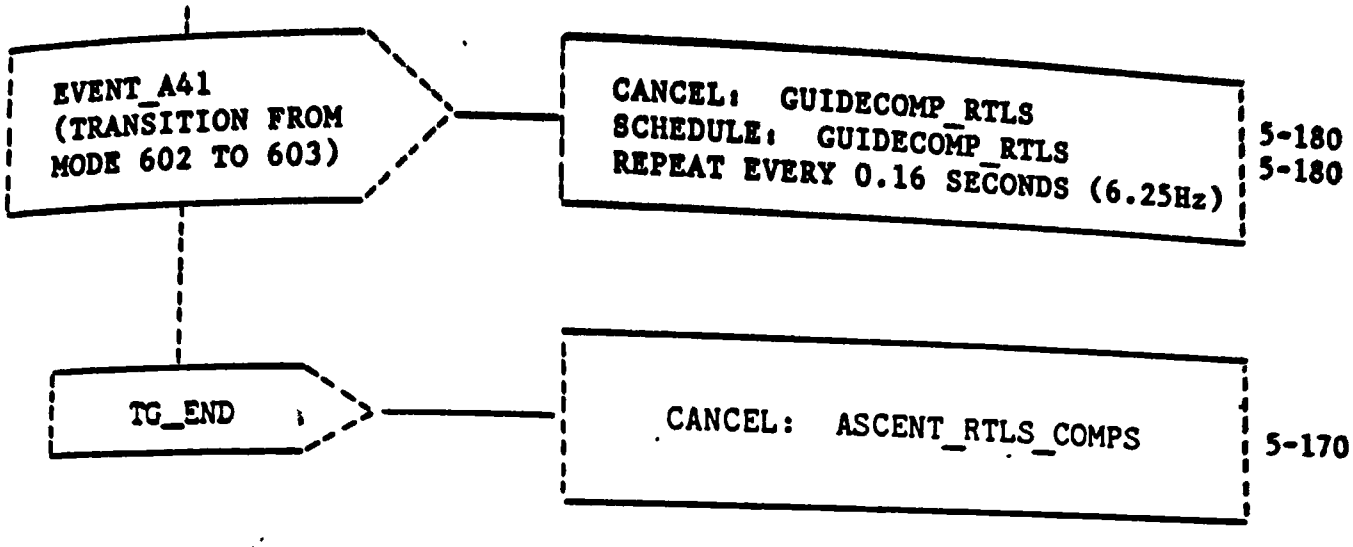


Figure 5.6-6. RTLS_UPP_SEQ (Cont)

RTLS_SECOND_STAGE_COMPS

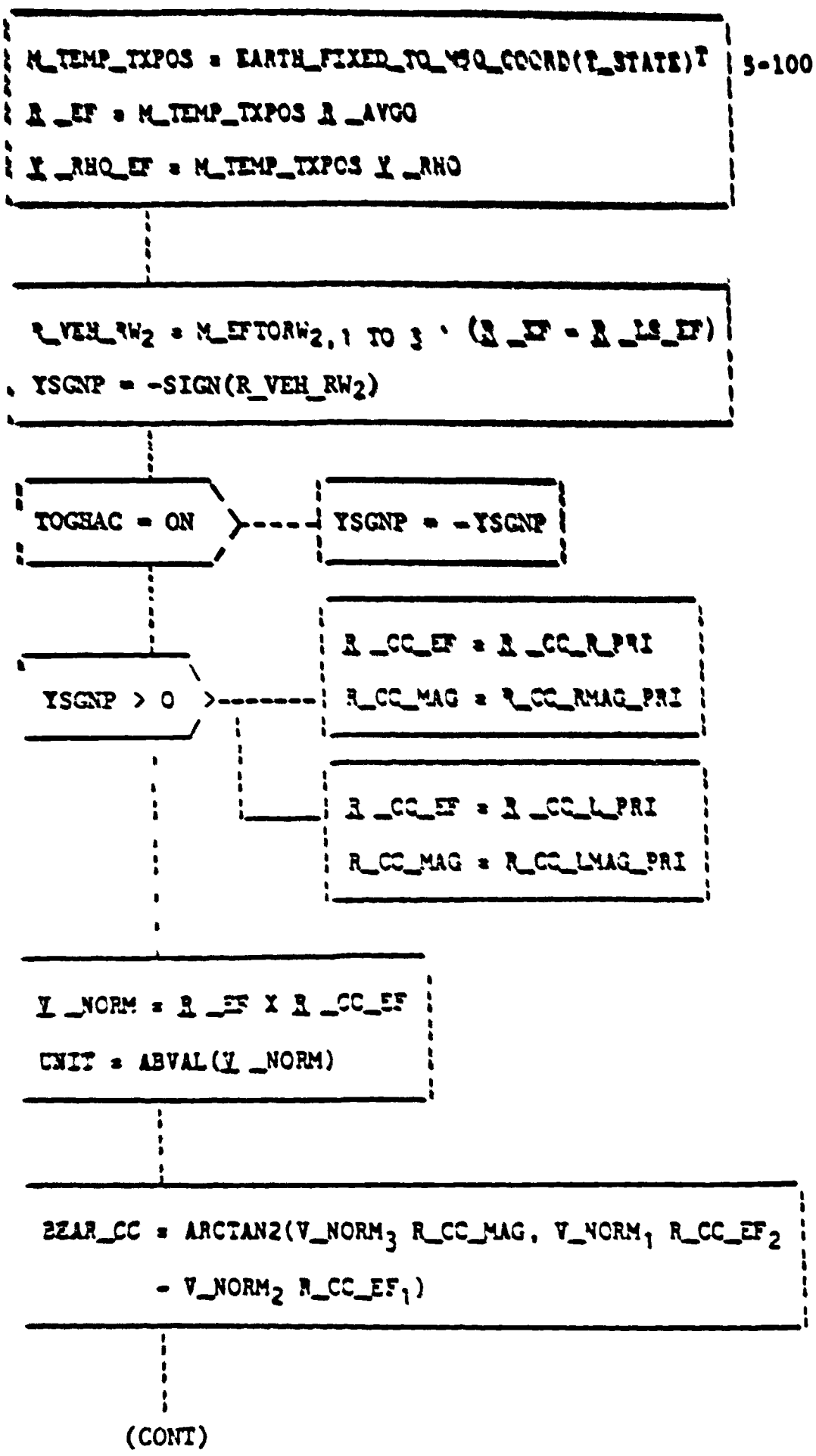


Figure 5.6-7. RTLS_SECOND_STAGE_COMPS

RTLS_SECOND_STAGE_COMPS (CONT)

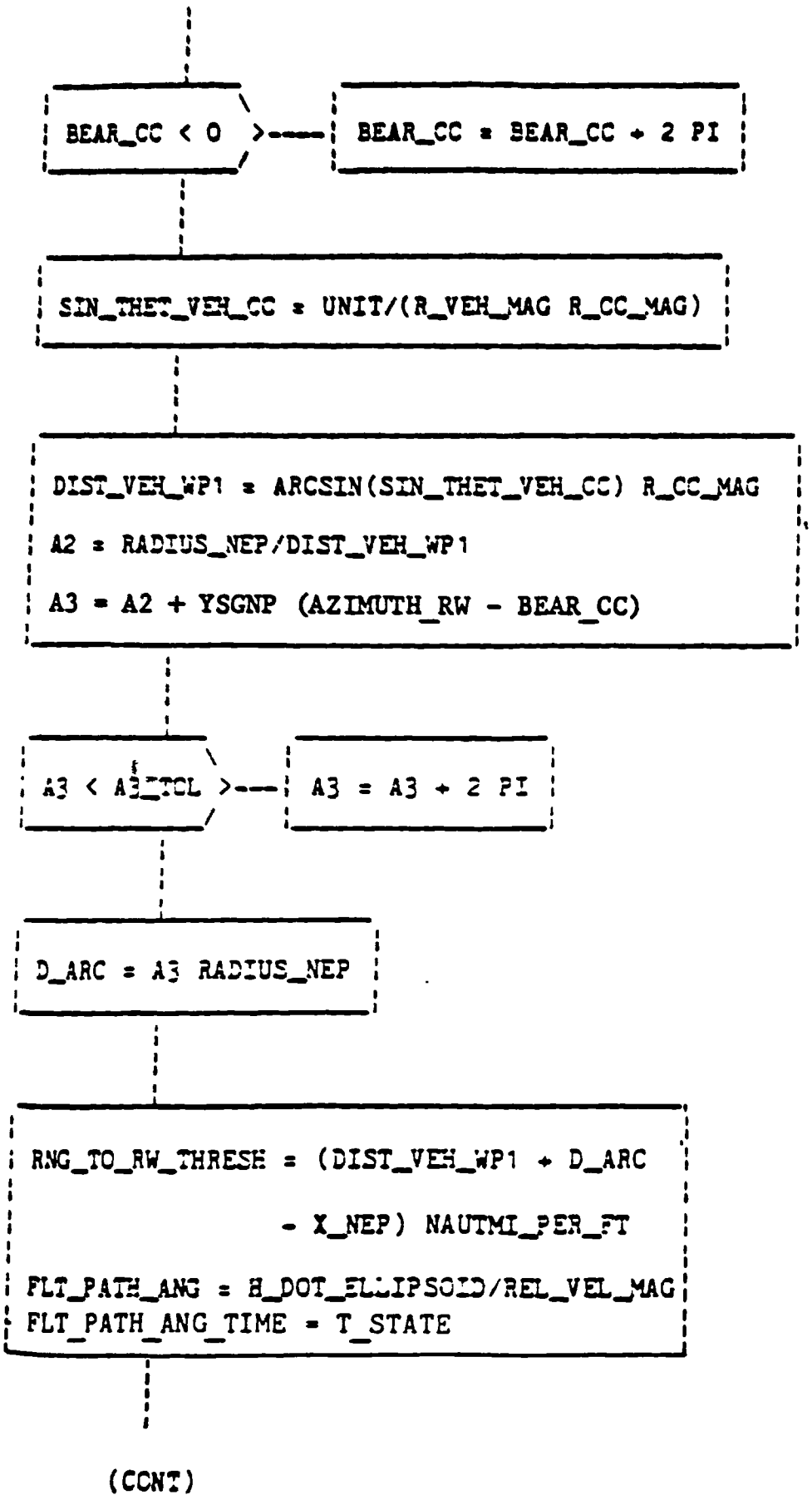


Figure 5.6-7. .RTLS_SECOND_STAGE_COMPS (Cont)

RTLS_SECOND_STAGE_COMPS (CONT)

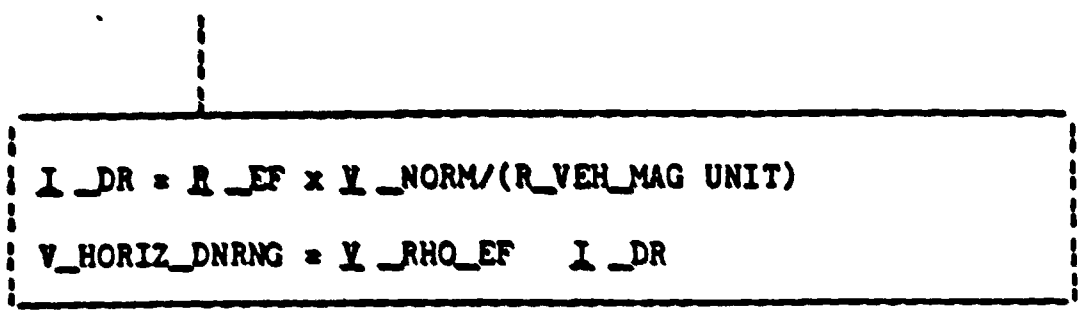


Figure 5.6-7. RTLS_SECOND_STAGE_COMPS (Cont)

GUIDECOMP_RTLS

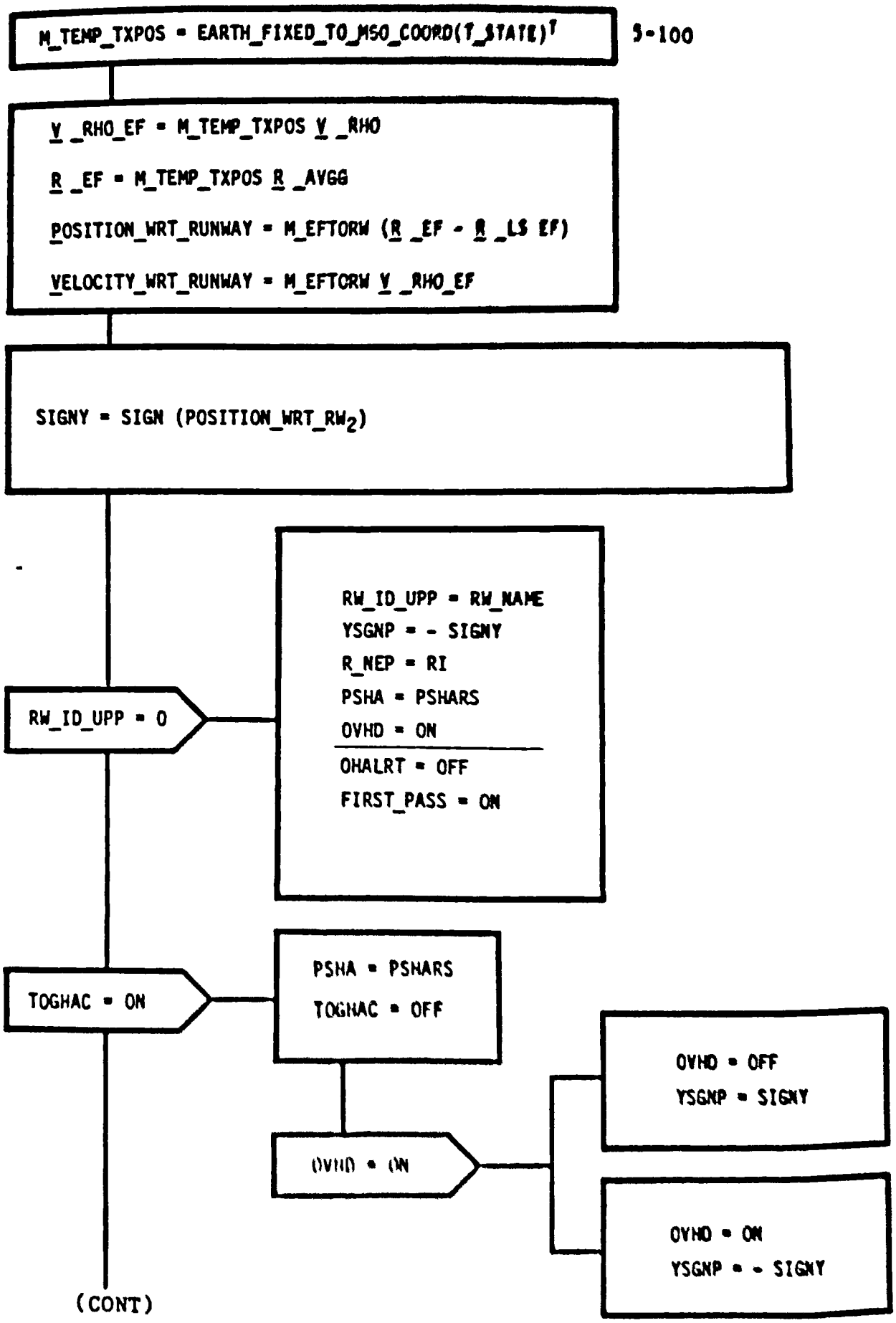


Figure 3.0-8 GUIDECOMP RTLS

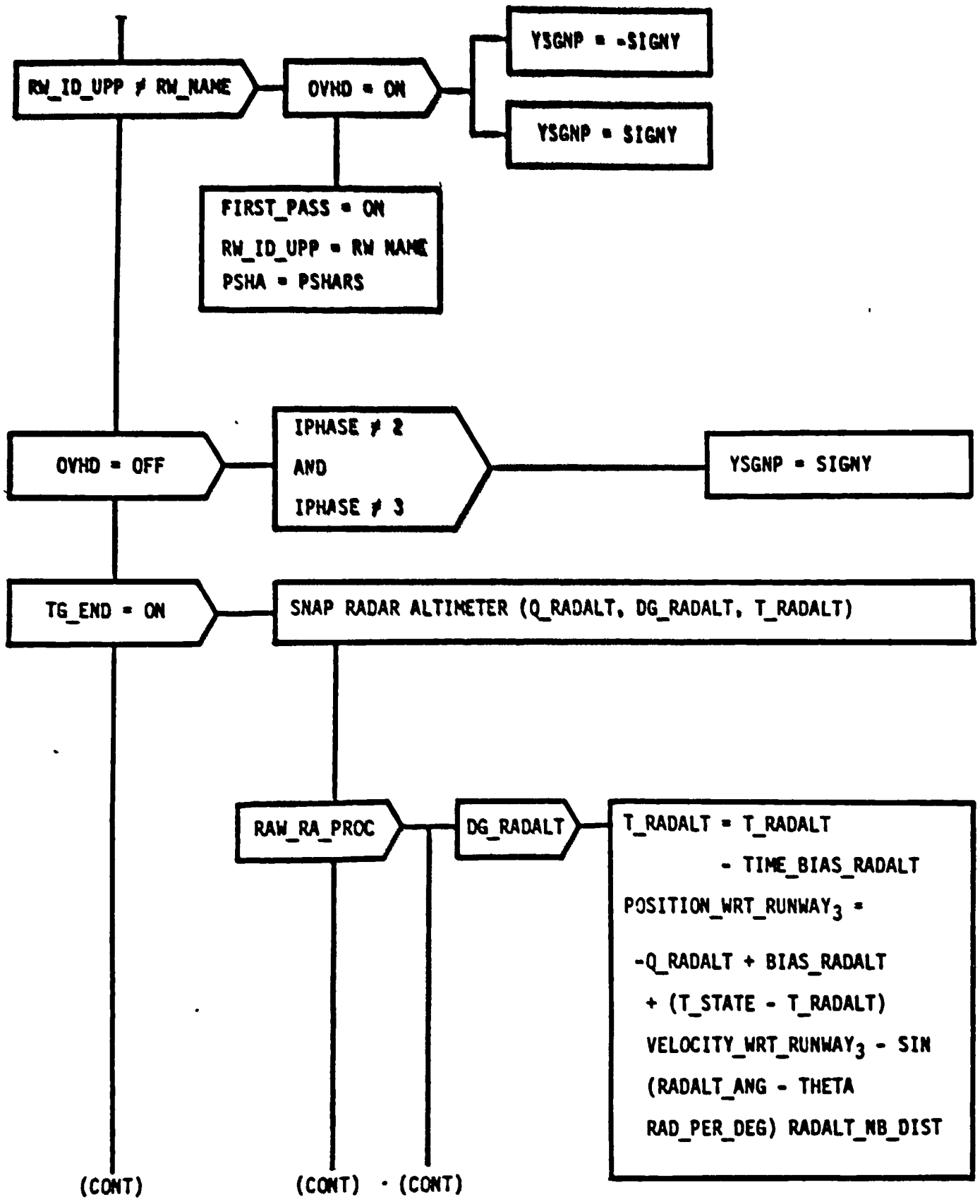


Figure 5.6-8. GUIDECOMP_RTLS (Cont)

GUIDECOMP_RTLS (CONT)

(POSITION_WRT_RUNWAY$_1$2
+ POSITION_WRT_RUNWAY$_2$2)
< R_GO_RAMP2

RAW_RA_PROC = ON

MLS_AVAIL = ON

```
TEMP = (POSITION_WRT_RUNWAY1 -
       START_POSITION) / (STOP_POSITION-
       START_POSITION)
RAMP = MIDVAL (0, TEMP, 1)
TEMP = RAMP BIAS_ELMLS
POSITION_WRT_RUNWAY3 = POSITION_WRT_RUNWAY3 +
      TEMP POSITION_WRT_RUNWAY1
VELOCITY_WRT_RUNWAY3 = VELOCITY_WRT_RUNWAY3 +
      TEMP VELOCITY_WRT_RUNWAY1
```

```
ALT_WHEELS = -POSITION_WRT_RUNWAY3 - (X_NB_WH SINTH + Z_NB_WH COSTH)
ALT = ALT_WHEELS + ALT_RW
H_DOT_ELLIPSOID = - VELOCITY_WRT_RUNWAY3 - WBR2 RAD_PER_DEG
     (X_NB_CB COSTH - Z_NB_CG SINTH)
ACC_VERT = (H_DOT_ELLIPSOID - H_DOT_LAST)/(T_STATE - T_STATE_LAST)
H_DOT_LAST = H_DOT_ELLIPSOID
T_STATE_LAST = T_STATE
```

COURSE_WRT_RW = ARCTAN2(VELOCITY_WRT_RUNWAY$_2$, VELOCITY_WRT_RUNWAY$_1$)

COURSE_WRT_RW < 0

COURSE_WRT_RW = COURSE_WRT_RW + 2 PI

(CONT)

Figure 5.6-8. GUIDECOMP RTLS (Cont)

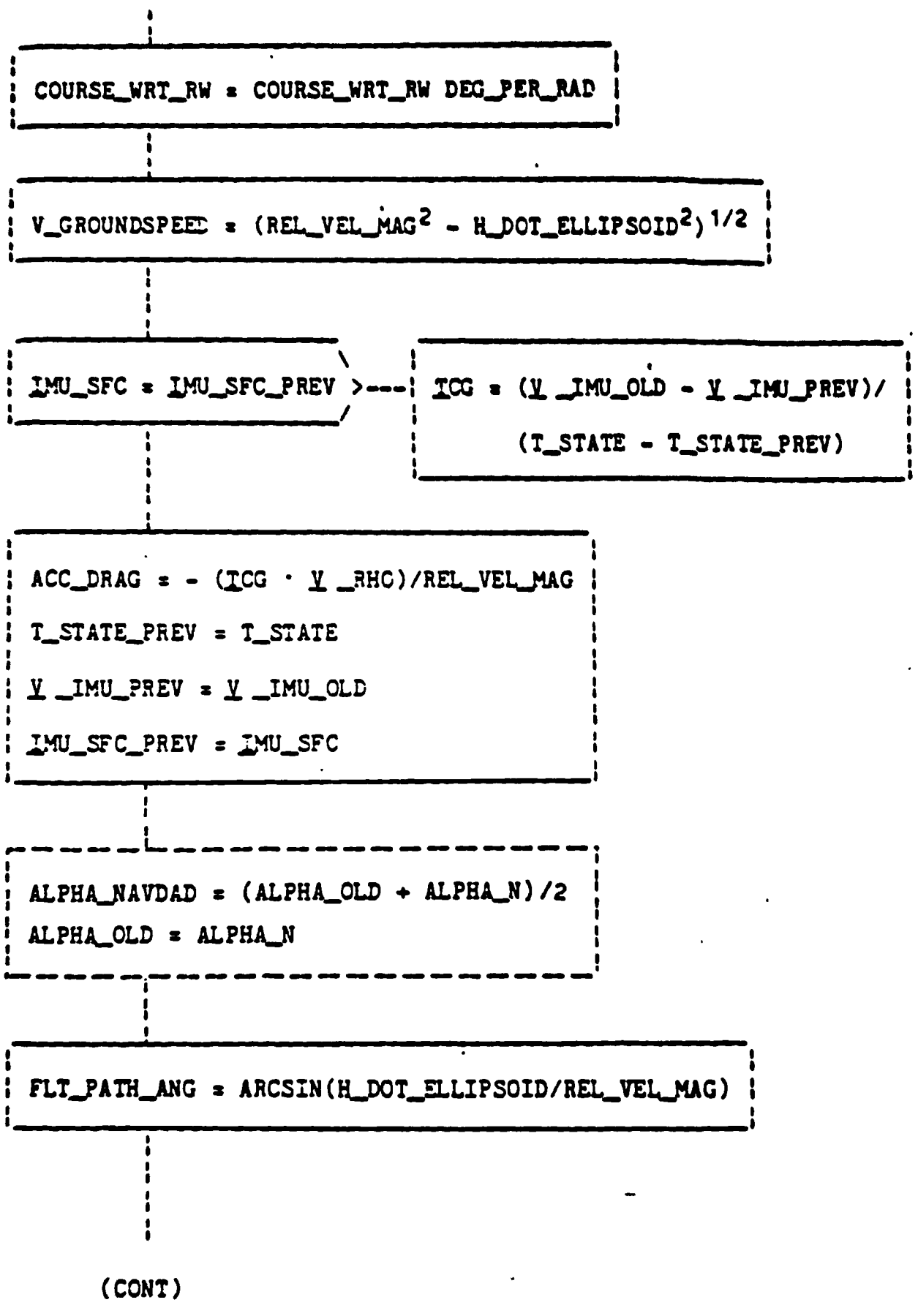


Figure 5.6-8. GUIDECOMP_RTLS (Cont)

GUIDECOMP_RTLS (CONT)

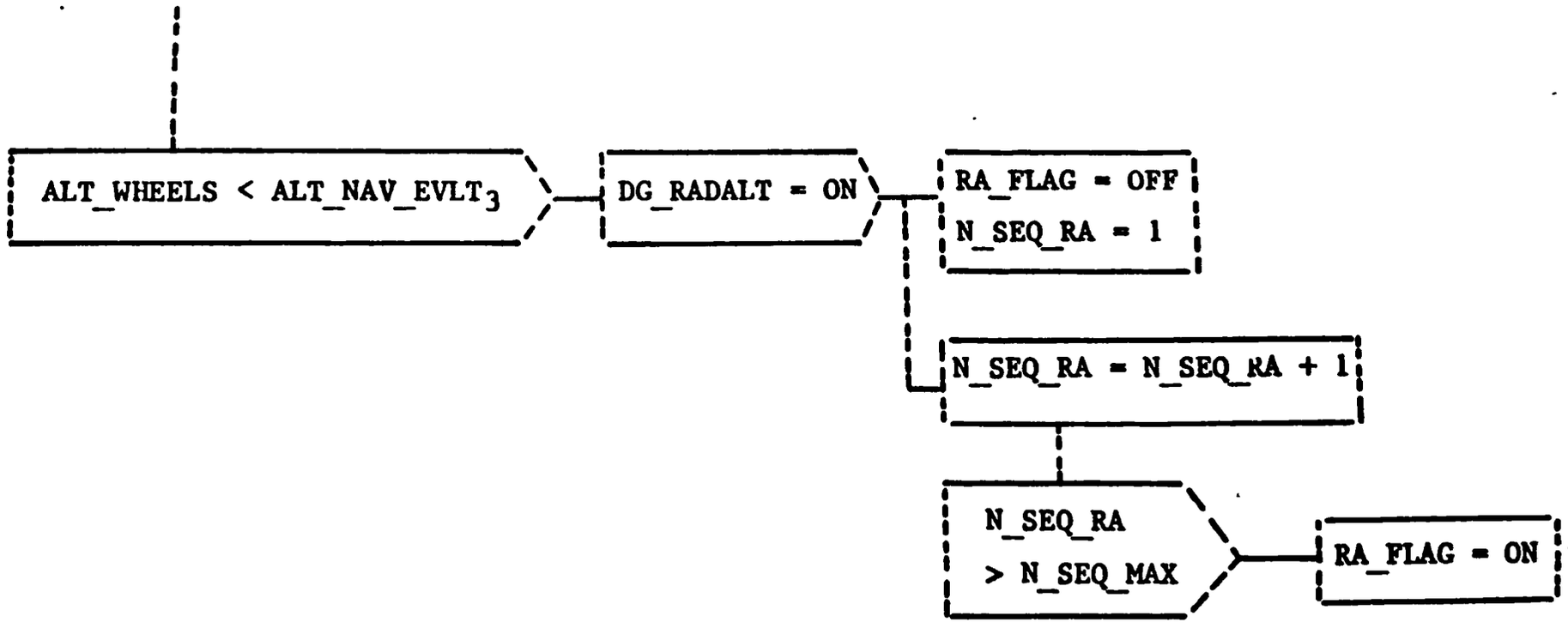


Figure 5.6-8. GUIDECOMP_RTLS (Cont)

Space Transportation Systems Division
Rockwell International

TACAN_DISP_COMPS

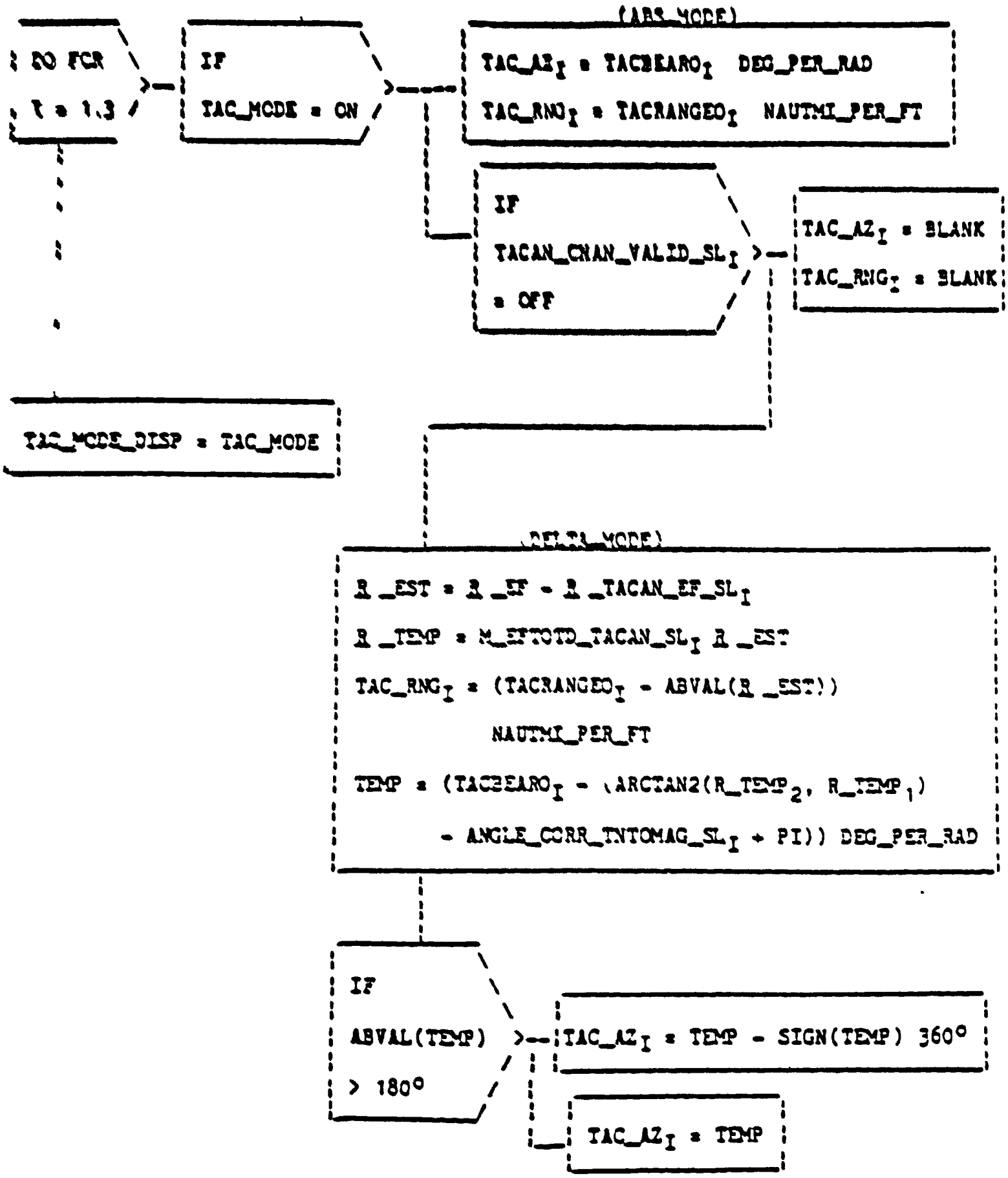


Figure 5.6-9. TACAN_DISP_COMPS

IDENTIFICATION NUMBER SE-694D DOCUMENT NUMBER STS83 0005

TITLE FUNCTIONAL SUBSYSTEM SOFTWARE REQUIREMENTS NAVIGATION ASCENT/RTLS

DATE OF LIST 5-10-88

DISTRIBUTION:

NASA/JSC
CB/R Mastracchio
DC44/Humbert
D 2/C. Cal x
DF4/G. Pc ock
DF62/L brary (3)
DF63/L brary
DG67/D Beckm n
DH4/Po nt ng L brary
DH6/L.brary
DM
DM3/W Pres ey
DM3/R. Sa om
DM35/J F e ds
DM4/J. Sellers
DM44/F Lowes
DP3/L brary
ED3/D Wh tehead
EH2/H Jackson 2)
EH3 L brary 2)
EH4/P So ock
EP2
FM2
FM46/M Montez
FR2/SSD L brary
FR2/J Newman
NB2/D Horn
NB2/Technica L brary
NS5/W Bates
NS523/J Wr ght
VG/H Hernandez
WG/Library
WG/M Rother

UNISYS
UO7B 16/ K McMurtrie
U08C/A. Price
UO8D/B Watson

RSOC/HOUSTON
R12A/B Hawkins (2)
R12B 16/J Moore
R16B/B Picka
R16B/R. Schmidgall
R16D/Descent Library
R16E/M Kocen
R16E/Traj Ops. Library
R18A/R Cole
R18B/R. Solis
R18B/R Hager
~~030B/STSOC Library (2)~~

ROCKWELL/HOUSTON
ZC01 B Weaver
ZC14/G. Yoder

TRW
H5/R Lee

BOE NG HOUSTON
HS01/SR&QA Library
HS02/D Files

FORD AEROSPACE
CC5/D Smith
CC5/P Perez

BM FEDERAL SYSTEMS
D V S ON
5402B/Project Office (50)

MDAC ENGINEERING SERVICES
T5G/R Pritchard
T5E/P Swaim
T3D/C. Nobles
T519/D Hull
T517/L. Guderian

INTERMETRICS
John Hanaway
1750 112th N E.
Suite D151
Bellevue, WA 98004

LEMSCO/HOUSTON
B12/W Schoolmeyer
B16/L. Olson
B16/S. Vickery
CO7/B Strassner

JM86/REMAINDER

FOR CHANGES TO THIS DISTRIBUTION LIST, CONTACT JSC DATA MANAGEMENT/JM21 AT 713-483 4006 (TS 5[illegible]-4006). TO REQUEST A COPY, SUBMIT A JSC FORM 614 TO DISTRIBUTION OPS./JM86