

STS 83-0002B

SPACE SHUTTLE ORBITER  
OPERATIONAL  
LEVEL C  
FUNCTIONAL SUBSYSTEM SOFTWARE REQUIREMENTS  
GUIDANCE, NAVIGATION, AND CONTROL  
PART A  
GUIDANCE  
GUIDANCE ASCENT/RTLS

June 30, 1987

Contract NAS9-14000  
IRD SE-694D  
WBS 19.9.1

Approved by

*E. L. Freddolino* 12/14/87

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E.L. Freddolino, Director  
Software Engineering  
Systems Engineering



Rockwell International

Space Transportation  
Systems Division

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PAGE CHANGE NOTICE NO: PCN-3 0I-8C  
CHANGE DATE: May 6, 1988  
PAGE 1 OF 1

DOCUMENT NO./REV: STS 83-0002B  
TITLE: Space Shuttle Orbiter Operational Level C  
Functional Subsystem Software Requirements  
Guidance, Navigation, and Control Part A:  
Guidance Ascent/RTLS  
DATE: May 6, 1988

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PAGE 1 OF 1

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TITLE:

Space Shuttle Orbiter Operational Level C

Functional Subsystem Software Requirements

Guidance, Navigation, and Control Part A:

Guidance Ascent/RTLS

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CHANGE DATE March 25, 1988  
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REPORT NO. STS 83-0002B

TITLE Space Shuttle Orbiter Operational Level C Functional Subsystem  
Software Requirements Guidance, Navigation, and Control Part A  
Guidance: Guidance Ascent/RTLS

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Reviewed by

*J.D. Almanza for 8/19/88*

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

*G.R. Carlson 8/24/88*

G.R. Carlson, Supervisor  
Ascent GN&C

*J.K. Cox 8/16/88*

J.K. Cox, Supervisor  
Flight Software Integration

*E.W. Nelson 8-17-88*

E.W. Nelson, Manager  
Software Requirements  
and Integration

CR89641

Prepared by

*Dianne T. Vega 8/16/88*

D.T. Vega  
Flight Software Integration  
(213) 922-5532

## FOREWORD

The primary avionics software system (PASS) requirements 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 Levels 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.



## 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) November 3, 1987	This issue updates the baseline to OI-8B and includes the following: CR's 89301C and 89461A.
PCN-1 April 29, 1988	This page change notice updates Revision A to include CR's 89556A, 89632A, and 89541.
PCN-2 April 29, 1988	This page change notice updates the previous release to include CR 89622A.
PCN-3 May 6, 1988	This page change notice provides Appendix-X OI-8C release and includes CR 89474B.





## CHANGE REQUEST SUMMARY

The following tabulation lists the paragraphs 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
4.2-4	79646D	8A	Auto-Loft, First-Stage Contingency
4.2.2-2	79646D	8A	Auto-Loft, First-Stage Contingency
4.2.3	79646D	8A	Auto-Loft, First-Stage Contingency
	89219B	8A	Auto-Loft, First-Stage Contingency Cleanup
	89332	8B	Auto-Loft, Oscillation Correct
4.2.3-1	79646D	8A	Auto-Loft, First-Stage Contingency
4.3-4	89140E	8A	Centaur Requirements Deletion
4.6-4F	89474B	8C	PRTLIS Guidance Principal Function MM 601 Data Flow
4.6.1	89301C	8B	Clarification of MM 603 and MM 305 Guidance Initiation Criteria
	89474B	8C	Powered RTLS Guidance Sequence
4.6.3	79645A	8A	Centaur RTLS Guidance Exhaust Velocity Comp
	89140E	8A	Centaur Requirements Deletion
4.6.3-1	79645A	8A	Centaur RTLS Guidance Exhaust Velocity Comp
	89140E	8A	Centaur Requirements Deletion
4.6.4	89140E	8A	Centaur Requirements Deletion
4.6.4T	89301C	8B	Clarification of MM 603 and MM 305 Guidance Initiation Criteria
4.6.4-1	89140E	8A	Centaur Requirements Deletion
4.6.7	89301C	8B	Clarification of MM 603 and MM 305 Guidance Initiation Criteria
	89474B	8C	RTLS Contingency Abort Task (RTLS CNTG ABT TSK)

Paragraph	CR No.	OI	Title
4.6.7-2T	89301C	8B	Clarification of MM 603 and MM 305 Guidance Initiation Criteria
	89474B	8C	RTLS Contingency Abort Task Outputs
4.6.8-1	89474B	8C	Powered Return to Launch Site Guidance
4.7.10-2	89622A	8B	ILOAD Category Change (Ref. G4.210)
4.8.7	89140E	8A	Centaur Requirements Deletion
4.8.7-1	89140E	8A	Centaur Requirements Deletion
4.8.7-2	79645A	8A	Centaur RTLS Guidance Exhaust Velocity Comp
4.8.8	89140E	8A	Centaur Requirements Deletion
4.8.8-1	89140E	8A	Centaur Requirements Deletion
4.8.8-2	79645A	8A	Centaur RTLS Guidance Exhaust Velocity Comp
	89140E	8A	Centaur Requirements Deletion
N/A	89461	8B	FSSR STS 83-0002B OI-8B Errata/Baseline

## 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
2559	PEG POSITION CONSTRAINTS RELEASE--STS-1
2449D	CONTINGENCY ABORT REQUIREMENTS--STS-1
12019	STANDARD FSSR FUNCTIONS--STS-1
12071A	MANEUVER EXECUTE DISPLAY--STS-1
12336	I-LOAD OFT-1 BASELINE--STS-1
12337	I-LOAD OFT-1 BASELINE--STS-1
12338	I-LOAD OFT-1 BASELINE--STS-1
12339	I-LOAD OFT-1 BASELINE--STS-1
12105	REINSTATE 6.25 Hz MASS AND MASS FILL--STS-1
12132A	TIME TO COMMAND MECO--STS-1
12202A	GAMMA COMPENSATION FOR RTLS MECO--1
2492C	VEHICLE MASS DEFINITION--STS-1
12201	AOA OMS-2 DATA FOR OPS-3 XFER--STS-2
12225B	GN&C LEVEL C UPLINK REQUIREMENTS--STS-1 AND -2
12293	PRTLS THROTTLE SETTING--STS-1
12316	GN&C SWITCH RM PROCESSING--STS-1
12443	I-LOAD FOR ENTRY FACI--STS-1
12134A	TLM REQUIREMENTS, ASC GUIDANCE--STS-1
12342A	OMS MANEUVER, OUT OF PLANE VELOCITY--STS-1
12425	REMOVE FPL RESTRICTION--STS-2
12190D	ASC/RTLS GUIDANCE PFG MODE TM CHANGES--STS-1
12465	ORBITAL ATTITUDE AND TIME TASK--STS-1
12404A	PROPOSED FCS 9 AND ASC CHANGES--STS-1
12510	PEG TIME TO GO AND THRUST INTEGRAL MODS--STS-1
2411B	OMS ENGINE FDI SIMPLIFICATION--STS-1
12478	UPDT TO VEHICLE MASS--STS-1 AND -4
12343B	MAXIMUM INTEGRATION STEP SIZE--PEG--STS-1 GRAVITY PREDICTION
12442A	INTEGRATED NAV INTERFACES--STS-1
12524B	FIRST-STAGE GUIDANCE TABLES--STS-1
12358V	MANUAL THROTTLING ADDITIONS--STS-1
12313C	ADDITION OF TLM REQUIREMENTS--STS-1
12557A	RTLS MATED COAST AND -Z TRANSLATION--STS-1
12588A	RECYCLE OMS IGNITION CAPABILITY--STS-1
12689B	COMMANDED BODY ATTITUDE DURING OMS--STS-1
12701	INTEGRATED MANUAL GUIDANCE/THROTTLING--STS-1



CR No.	Title
12719	RTLS TURNAROUND PREDICTION MODIFICATION--STS-1
12672C	JAN SEQUENCE MODE TEAM MAKE WORK--STS-1
12345	TIME-TO-NEXT-APSYS CORRECTIONS--STS-2
12521A	VARIABLE IY TARGETING--STS-2
12744	VU THRUST, BODY GEOMETRY GUIDANCE--STS-1
12781A	VEHICLE OMS TRIM--STS-1
12681	INITIALIZATION OF MASS--STS-2
12745	DELETION OF OMS/OMS INTERCONNECT S/W--STS-1
12862A	CLARIFICATIONS TO VARIABLE IY TARGETING--STS-2
12948	ADDITION OF AUTOMATIC MANEUVER--STS-7
12586	INTEGRATED INTERFACES FOR 6.35, 6.46, AND MANEUVER DIPS
12899A	ASCENT FCS FSSR CLEANUP
12924A	CLEANUP TO CR 12588A
12600C	INTEGRATED MSID FOR UPLINK D&C, GN&C
12938A	XXXXXX TRAJ IDD
12948	ADDITION OF AUTO MNVR CAPABILITY
12993	I-LOADS
12994	I-LOADS
19038	I-LOADS
19054	I-LOADS
19100	FSSR UPDATE
19097A	ADDITION TO MPAD I-LOAD UPDATE
19144	POSITION CONSTRAINT RELEASE CORRECTION
19169	MPAD I-LOAD CYCLE 2 UPDATE
19198	CLEANUP OMS RECYCLE
19103A	ABORT CONT SEQUENCE
19066B	CORRECT AND DEFINE MECO
19072A	COMM FAULT ADDITION TO OMS TVC FB
19145A	MANUAL PRTLS CORRECTIONS TO CR 12701
19101A	I-LOAD CORRECTIONS FOR ASCENT FCS
19385	JSC I/L DISCREP TO ROCKWELL I-LOAD
19386A	DEL OF MULTIPLE DEFINED I-LOAD PARAMETERS
19031C	CORRECTION OF INTERFACE DISCREPANCIES
19405A	GUID/UPP USE OF FLIGHT PATH ANGLE
19455	MEASUREMENT ATTRIBUTE CORRECTIONS
19425	PEG ENGINE FAILURE COMPENSATION LOGIC UPDATE
19379	CLARIFICATION OF UPLINK TARGET CONSTRAINTS
19286A	RTLS THROTTLING AND TURNAROUND PRED
19300	FSSR UPDATE NO. 2
19408B	RTLS PPD GUID/UPP USE OF FLIGHT PATH ANGLE STS-7
19452B	I-LOAD CORRECTIONS NECESSARY FOR 3/19 RELEASE
19467B	I-LOAD CORRECTIONS TO IDB NO. 3
19487	ABORT TARGETING AFTER ENGINE FAILURE
19560A	I-LOAD UPDATES AS A RESULT OF IBM TESTING
19500	FSSR UPDATE NO. 3
19550	DOC CHANGE TO REFLECT CR 19220A
19552	CYCLIC UPDATE OF VEHICLE WT AND PRPLT ON MNVR DISPLAY (STS-2)

CR No.	Title
19553C	CREW OVERRIDE OV OMS TARGETS VIA ITEM ENTRY (STS-2)
19678	OMS GUIDANCE/RM CLEANUP
19694A	DELETE ENTRY PREC PRED FROM OPS-1 AND 6 S/W (ASC GUID)
19696	DELETION OF PEG THRUST PHASE I-LOAD
19712	CORRECTIONS TO I-LOAD DATA TAPE FOR FSW/CPDS
19707	FSSR CLEANUP TO POWERED RTLS GUID SEQ REPLACES CR's 19327 AND 19328
19872A	TVR-ROLL I-LOAD AND FORMULATION CHANGES--STS-2
19888	I-LOAD CHANGE TO FIX INCORRECT IMPLEMENTATION CR 19101A--STS-1
19899	DOC CHANGE TO ASC GUID RTLS CNTG ABT TSK--STS-1
19950A	AOA SHALLOW TARGET I-LOAD--STS-1
19958A	ASC FLIGHT CONTROL DOCUMENTATION CLEANUP--STS-1
19970	LEV C GN&C GUID ASC/RTLS (PART A)--STS-2
29005B	AUTO ADS/NAVDAD SWITCH BY ALTITUDE--STS-2
29022	REDUCTIONS OF LOX RESIDUALS FOR ENGINE OUT LOW LEVEL SHUTDOWNS--STS-2
29071	STS-1 CORRECTIONS TO OMS EVALUATION CONSTRAINT LOGIC
29072	CLARIFY VARIABLE IY TARGETING REQUIREMENTS--STS-2
29142B	MPAD I-LOAD UPDATE NO. 4 FOR STS-1, CYCLE 3
29162A	I-LOAD CHANGES RESULTING FROM "OWNER AUDIT"
29131B	MOD OF CR 19553C TO REDUCE THE NUMBER OF TARGET SET (STS-2)
29263A	CORRECTION TO CR 29022 (STS-2)
29269	CLARIFY AND COMPLETE I/L REQUIREMENTS AUTHORIZED BY CR 12521 (STS-2)
29316	CLARIFY REQMTS ON WHEN THE MPS GUID CUTOFF TASK IS TERMINATED IN MM 102 AND MM 601 (STS-1)
29300A	FSSR UPDATE 6
29500	FSSR UPDATE 7
29407C	MNV EXEC DISP PFS 18/BFS 12--STS-3
29441A	MANUAL THROTTLE - RTLS--STS-2
29502	ATT HOLD AFTER SRB SEP (REF ONLY)
29396A	I/L CHANGES FOR ARMING LOW LEVEL SENSORS (REF ONLY)
29559A	GUID VEL VECTOR PRECISION CORRECTIONS
29471B	HFE OVERRUN DEFINITION
29726	MANEUVER DIP GUID I/L CLEANUP
29660A	CURRENT VEH MASS UPDATE
29752	UPLINK DOCUMENTATION CLEANUP
29650A	CR IMPLEMENT BASELINE MAY 1980 (REPORT 1037)
29657C	STS-1 CYCLE 3.1.1 MPAD I/L
29149B	ADD PROGRAM INTERRUPT HANDLING TO LEVEL A CPDS
29694B	STS-1 CYCLE 3.1.1 MPAD ABORT I-LOADS
29777	I/L CREW OVERRIDE OMS TGTS
29900	CHANGE VALUE OF DT MAX
29908B	3.1.1 I-LOAD CHANGES FOR RTLS PROFILE
29938	STS-1 CYCLE 3.2.2 AOA TO EDW
19164A	I-LOAD VALUE UPDATES FOR CYC 2 S/W BUILD (REF ONLY)



CR No.	Title
29974	FSSR CLEANUP AOA/ATO TARGET
29976A	OPS 3 MASS INITIALIZATION (REF ONLY)
39085	1ST STAGE SSME OUT PROF I/L'S
39097	CYCLE 3.3.2 OMS TGT AND RELQUAT (REF ONLY)
39106A	CYCLE 3.3.2 OMS TGT ABORT
39114	CYCLE 3.3.2 MASS CHANGES
39121	STS-1 CYCLE 3.3.2 AOA TO EDWARDS I-LOAD
19385	JSC I-LOAD DISCREPANCY TO RI I-LOAD (REF ONLY)
39132C	CREATE SECONDARY THROTTLE SET
39135A	DELETE I-LOAD NMAX BURN
39173	I/L DISCREPANCY CLEAN UP (REF ONLY)
39184E	STS-2 CYCLE 1 MPAD I-LOADS (REF ONLY)
39192A	CYCLE 3.3.3 I-LOADS (REF ONLY)
39218A	CYCLE 3.3.3 MPAD I/L--ABORT (REF ONLY)
39225A	MPS LOW LEVEL ARM
39280A	STS-2 CYCLE 1 NOM ASC AND E/O
39323A	STS-2 CYCLE 1 MPAD ABORT I/L
39336	STS-2 CYCLE 1 MSID CORRECTION (REF ONLY)
39348	UPDATE BFS I/L DATA BASE (REF ONLY)
39353B	RTLS FUEL DISSIPATION MOD
39400	FSSR UPDATE 10 (R18) AND 1 (R19)
39102	N OMS INITIALIZATION IN AOA
39390A	PRE-MECO OMS DUMP-ATO ABORT
39401A	TRANSATLANTIC ABORT LANDING (TAL STS-3)
39467A	DR CLOSEOUT--DOC CLEANUP
39472A	STS-2 CYCLE 1 AOA TO EDW-GUID (superseded by CR 39530F)
39530F	STS-2 CYCLE 2 I-LOADS (REF ONLY)
39569	STS-2 CYCLE 2 AOA TO NOR (REF ONLY)
39595A	CR IMPLEMENTATION BASELINE--AUGUST, 1981
39601	STS-3 CYCLE 2 ASCENT ENTRY AND ABORT (STS-3, REF ONLY)
39640	FSSR UPDATE 11 (R18) AND 2 (R19)
39653A	TAL GUIDANCE CORRECTIONS (STS-3)
39658E	STS-4 CYCLE 1 MPAD I-LOADS (STS 4; REF ONLY)
39604B	STS-3 CYCLE 2 AOA TO NOR-GUID (STS-3; REF ONLY)
39697B	STS-2 CY 3 NOM--SEASON UPDATE (REF ONLY)
39698	STS-2 CY 3 ABT SEASON UPDATE (REF ONLY)
39710A	STS-4 CYCLE 1 MPAD ASC ABORT I-LOADS (STS-4; REF ONLY)
39790A	CR IMPLEMENTATION BASELINE--NOV., 1981
39920A	STS-3 CYCLE 3--SEASONAL UPDATE (REF ONLY)
39927	STS-3 CYCLE 3 NOMINAL ASCENT (REF ONLY)
39935	STS-3 CYCLE 3 ASCENT ABORT (REF ONLY)
39939	MPS LOW LEVEL SENSOR ARM (STS-3; REF ONLY)
39950	FSSR UPDATE 12 (R18) AND 3 (R19) (REF ONLY)
39980A	CR IMPLEMENTATION BASELINE--FEB., 1982
59015	STS-4 CYCLE 3 NOMINAL SEASONAL UPDATE (REF ONLY)
59020A	RD RTLS CHANGE FOR STS-4 (REF ONLY)
59024	STS-4 CYCLE 3 ENGINE OUT SEASONAL UPDATE (REF ONLY)
59025A	STS-4 CYCLE 3 AS/ABORT IL UPDATE (REF ONLY)

CR No.	Title
59050	FSSR UPDATE 13 (R18) AND 4 (R19) (REF ONLY)
29602A	MAKE PFG I-LOADS CONSTANTS
39099A	ELIMINATE VEL EXTRAPOLATION
39300B	PRTLS GUID RUNWAY RE-DESIGNATE
39311	RTLS GUIDANCE CORRECTIONS
39400	FSSR UPDATE 1 (R19) AND 10 (R18)
39640	FSSR UPDATE 2 (R19) AND 11 (R18)
39778A	REINSTATE RADIUS NEP I/L (REF ONLY)
39803C	LAUNCH DELAY WINDOW
39904	RADIUS NEP I-LOAD TO I-COMMON (STS-5; REF)
39966	MAKE DT FCD A CONSTANT
39988F	STS-5 CYCLE 3 DES/ENT I-LOADS (STS-5; REF)
39990E	STS-5 CYCLE 3 ASC I-LOADS (STS-5; REF)
59016D	STS-5 CY 3 ASCENT ABORT (STS-5; REF)
59043E	STS-6 CYCLE 2 NAV/ENT I-LOADS (STS-6 ONLY; REF)
59055	DOWNLIST R&D CMD B
59059F	STS-6 CY 2 NOM ASC I-LOADS (STS-6 ONLY; REF)
59064A	STS-4 CYCLE 5 NOM ASC UPDATE (REF ONLY)
59082A	STS-4 CYCLE 5 ENG OUT I-LOADS (REF ONLY)
59086A	STS-6 CY 2 ASC CAT II/III I-LOADS (STS-6 ONLY; REF)
59095A	1ST STAGE ENGINE OUT GUIDANCE (STS-8)
59097	RTLS GUID CMD THROTTLE CORR (STS-5)
59108B	PEG PREDICTION CORRECTIONS
59111A	CORRECT STS-5 CYCLE 3 I-LOADS (STS-5; REF)
59117C	ASC GUID ON-BOARD CUES
59125A	RD RTLS CHANGE FOR STS-5 (STS-5 ONLY; REF)
59126H	RCS XFEED MCA OPTIMIZATION
59128	STS-4 CYCLE 5 TAL TO DAKAR (REF)
59131B	STS-6 CYCLE 2 ASCENT ABORT (STS-6 ONLY; REF)
59146	STS-5 CYCLE 4 SSME TAILOFF (STS-5; REF)
59150	STS-4 MASS I-LOAD UPDATE (REF)
59161A	STS-5 CYCLE 4 TAL TO DAKAR-GUID (STS-5; REF)
59220B	CR IMPLEMENTATION BASELINE-JULY--1982
59228	X NEP I-LOAD FOR OPS 3 (REF ONLY)
59253B	CORRECTION TO 39803C (IDD ONLY)
59261	STS-5 CY 5 ASCENT/ABORT IL (STS-5 ONLY)
59267C	ADAPTIVE FIRST STAGE GUIDANCE
59273C	ABT CONT SEQ-SELECT INTERCNCT
59277A	STS-6 I-LOAD UPDATE FOR PRTLS (STS-6 ONLY)
59279A	SSME PITCH PARALLEL 2ND STAGE (STS-8)
59322	SSME-OUT SAFING TASK (STS-5)
59362A	TERMINATE PRECISE PREDICTOR (IDD ONLY)
59375A	CR IMPLEMENTATION BASELINE, SEPT. 1982
59379D	TAL ONBOARD IY CALCULATION
59450	FSSR UPDATE NO. 7 (R19) AND 1 (R20) (REF ONLY)
59458A	ASC FLIGHT DESIGN-SUMMER (STS-8 IL REF ONLY)
59522C	I-LOAD DEPENDENCY CHANGE (IL STS-7 REF ONLY)
59553B	GUIDANCE REINITIALIZATION
59631	STS-9 CY 1 ASC ABORT I-LOADS (REF ONLY)
59650C	CR IMPLEMENTATION BASELINE - MARCH 1983



CR No.	Title
59721	MASS THRESHOLD TEST IN OPS-1
59748	CORRECT CR 59117--ASC GUID CUE
59750	FSSR UPDATE NO. 8 (R19), FSSR UPDATE NO. 2 (R20)
59751	UPDATE MNVR DATA AT DISP RATE
59865A	RTLS MBO CALCULATION
69001	1STG AGT CAPABILITY IMPROVEMENT
69021	STS-8 MPS THROTTLE SW CMD CHG (I-LOADS ONLY)
69036	CORRECTION TO CR 69021 (REF ONLY)
69070	FSSR UPDATE
69088	STS 9.3 OPTION B ASCENT I-LOADS (ONLY)
69114	STS 9.3 A TO DUMP I-LOADS (ONLY)
69220F	CENTAUR ABORT DUMP
69237A	STS-13.1 ASCENT I-LOAD UPDATES
69555A	TAL/RTLS WEATHER ALTERNATE
69600D	OMS GUIDANCE IMPROVEMENTS (3)
69691	STS-51B CYC 1 ASCENT/ABORT I/L'S
69738A	A2T CATEGORY UPDATE
69773D	DOC CLEANUP OF CR 29886C
69866	41D(R) ASCENT/ABORT I/L'S
69877I	TAL/RTLS WEATHER ALTERNATE CLEANUP
69904A	PEG PREDICTION CORRECT UPDATES
69978A	51-D CYCLE 1 ASCENT/ABORT I/L'S
69979	51-D I/L FOR WX ALT TO MORON
79019	51-E I/L FOR WX ALT TO MORON
79033	51A 67% THROTTLE I/L'S
79041	51B I/L FOR WX ALT TAL MORON
79042	51B CYCLE 2 ASCENT/ABORT I/L'S
79048A	51F CYCLE 1 ASCENT/ABORT I/L'S
79050	STS-51F I/L FOR WX ALT TAL
79091	51G I/L FOR WX ALT TAL MORON
79092A	51G CYCLE 1 ASCENT/ABORT I/L'S
79181B	TL CYCLE 1 ASCENT/ABORT I/L'S
79208	STS-TL.1 PRTLS I/L OCCURRENCE MOD
79247	51G CYCLE 2 ASCENT/ABORT I/L'S
79275C	51-I CYCLE 1 ASCENT/ABORT I/L'S
79280A	51-B CYCLE 3 ASCENT/ABORT I/L'S
79281	51-B I/L FOR WX ALT TO MORON
79288	51-B.3 ATO DUMP I/L OCCURRENCE
79298E	LASH-UP REQUIREMENTS 59273C, 69635B
79328	51-D CYCLE 3 ASCENT/ABORT I/L'S
79366	STS-61A CYCLE 1 I-LOAD WX ALT MORON
79385	51-B AGT THROTTLE I/L OCCURRENCE
79499	FSSR UPDATE
79645A	CENTAUR/RTLS GUID V EX COMP
79705	ASCENT HSI OSCILLATION CORR
79740	FSSR DOC CHANGES FOR OI-07
79790	CR IMPLEMENTATION BASELINE--NOV 1985
89121C	ERRATA STS 83-0002A





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**ASCENT/RTLS GUIDANCE  
FSSR/PRD CORRELATION**

<b>PFS FSSR</b>	<b>PRINCIPAL FUNCTION</b>	<b>FSSR PARA</b>	<b>FSSR TITLE</b>	<b>BFS PRD</b>	<b>PRD PARAGRAPH</b>	<b>BFS TITLE</b>
2	G4.1	4.2	ASCENT FIRST STAGE GUIDANCE	MG038104	3.2.3.1.10.2	FIRST STAGE GUIDANCE
2	G4.2	4.3	ASCENT SECOND STAGE GUIDANCE	MG038104	3.2.3.1.10.3	SECOND STAGE GUIDANCE
2	G4.3	4.4	ORBIT INSERTION GUIDANCE	MG038104	3.2.3.1.10.4	OMS GUIDANCE
2	G4.4	4.6	POWERED RTLS GUIDANCE	MG038104	3.2.3.1.10.3.2	POWERED RTLS GUIDANCE
2	G4.13	4.5	ABORT-ONCE-AROUND/ABORT-TO-ORBIT TARGETING	MG038104	3.2.3.1.10.3	SECOND STAGE GUIDANCE
2	G4.210	4.7	ASCENT MANUEVER DISPIAY INTERFACE PROCESSING	MG038104	3.2.3.1.10.11	OMS MANEUVER DISPLAY INTERFACE PROCESSOR

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STS 83-0002B  
May 6, 1988  
PCN-3, 01-8C

For Information Only





## 1.0 INTRODUCTION

### 1.1 PURPOSE

The purpose of the Level C Guidance document is to present the detailed requirements and formulations of the Level B Guidance functional requirements for the orbiter flight software.

### 1.2 SCOPE

This document contains the detailed requirements and formulations for those guidance functions that are operative during ascent, abort-once-around (AOA), abort-to-orbit (ATO), and transatlantic abort landing (TAL) in operational sequence one (OPS-1) and the powered phases of return-to-launch-site (RTLS) aborts in operational sequence six (OPS-6), as defined in the Level B GN&C computer program development specifications (CPDS) document. These functions are ascent first-stage guidance, ascent second-stage guidance, orbit insertion guidance, AOA/ATO targeting, powered RTLS guidance, and ascent maneuver display interface processor. In addition, several general guidance and targeting tasks, which are used by one or more of the principal functions previously stated, are defined in this document.

In general, the performance requirements and vehicle constraints, from which the software requirements are derived, are not discussed in this 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 Supplementary Material

#### Appendixes

- A. Detailed Flow Charts
- B. Temporary Variables
- C. OPS-1 Utility Routines



Section 1 defines the purpose, scope, and organization. Section 2 lists the applicable documents. Section 3 provides an overview of the software functions. Section 4 specifies the detailed requirements. It also contains applicable tables (IDD inputs/outputs, I-loads, K-loads, and constants) according to the principal functions. Section 5 provides supplemental material, including coordinate systems, acronyms and abbreviations, and HAL programming language syntax. The appendixes contain detailed flow charts (Appendix A), temporary variables (Appendix B), and OPS-1 utility routines (Appendix C).

## 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
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 Subsystem Software Requirements; Guidance, Navigation, and Control, Part A, Guidance Ascent/RTLs
STS 83-0003	Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part A, Guidance On-Orbit/Deorbit
STS 83-0004	Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part B, Entry Through Landing Navigation
STS 83-0005	Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part B, Navigation Ascent/RTLs
STS 83-0006	Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part B, On-Orbit Navigation



STS 83-0007      Operational Flight Level C, Functional Subsystem  
Software Requirements; Guidance, Navigation, and  
Control, Part C, Flight Control Entry--GRTLS

STS 83-0008      Operational Flight Level C, Functional Subsystem  
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 Subsystem  
Software Requirements; Guidance, Navigation, and  
Control, Part C, Flight Control Orbit DAP

STS 83-0010      Operational Flight Level C, Functional Subsystem  
Software Requirements; Guidance, Navigation, and  
Control, Part D, Redundancy Management

STS 83-0013      Operational Flight Level C, Functional Subsystem  
Software Requirements; Guidance, Navigation, and  
Control, Part E, Inertial Measurement Unit  
Subsystem Operating Program

STS 83-0014      Operational Flight Level C, Functional Subsystem  
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 Subsystem  
Software Requirements; Guidance, Navigation, and  
Control, Part E, Subsystem Operating Programs, FC  
Sensor/Controller

STS 83-0016      Operational Flight Level C, Functional Subsystem  
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 INTERFACE CONTROL 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

#### 3.1 OPERATIONAL FLIGHT PROGRAM

The operational flight program (OFP) is the total computer program in the orbiter general-purpose flight computer subsystem. The requirements are specified at three levels: system level (A), functional level (B), and detailed level (C). The Level B and C requirements are specified in separate documents for guidance, navigation, and control (GN&C) and for system management (SM).

The basic GN&C components of the OFP are guidance, navigation, flight control, redundancy management, subsystem operating programs, and displays and controls. Each of these major components contain several software major functions; e.g., the first-stage guidance is a principal function. The GN&C principal functions are defined in the Level B GN&C computer program development specifications (CPDS).

The guidance software functions described in Section 4 are activated by the software scheduling function at the proper times so that the required guidance inputs from other software elements (such as navigation) and guidance outputs to flight control, etc., are available when required. The guidance interfaces with other software functions are defined by tables and illustrations in Section 4.

This document is the guidance part of the GN&C Level C OFP requirements for ascent, abort-once-around (AOA), abort-to-orbit (ATO), and transatlantic abort landing (TAL) in operation sequence one (OPS-1), and the powered phases of RTLS abort in operation sequence six (OPS-6).

#### 3.2 ASCENT

The primary objective of ascent guidance is to provide guidance commands to the Space Shuttle during the ascent phases of flight, accomplish the nominal mission objective, and support the abort requirements. Figure 3-1 depicts the Space Shuttle ascent scenario for ascent operations (OPS-1) and return-to-launch-site (RTLS) aborts.

The ascent flight phase begins at lift-off and ends at insertion into a circular or elliptical orbit. It consists of four subphases: first stage, second stage, OMS-1, and OMS-2.

##### 3.2.1 Aborted Missions

The general approach to abort targeting is discussed in the introduction to Section 4.5.



### 3.3 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.

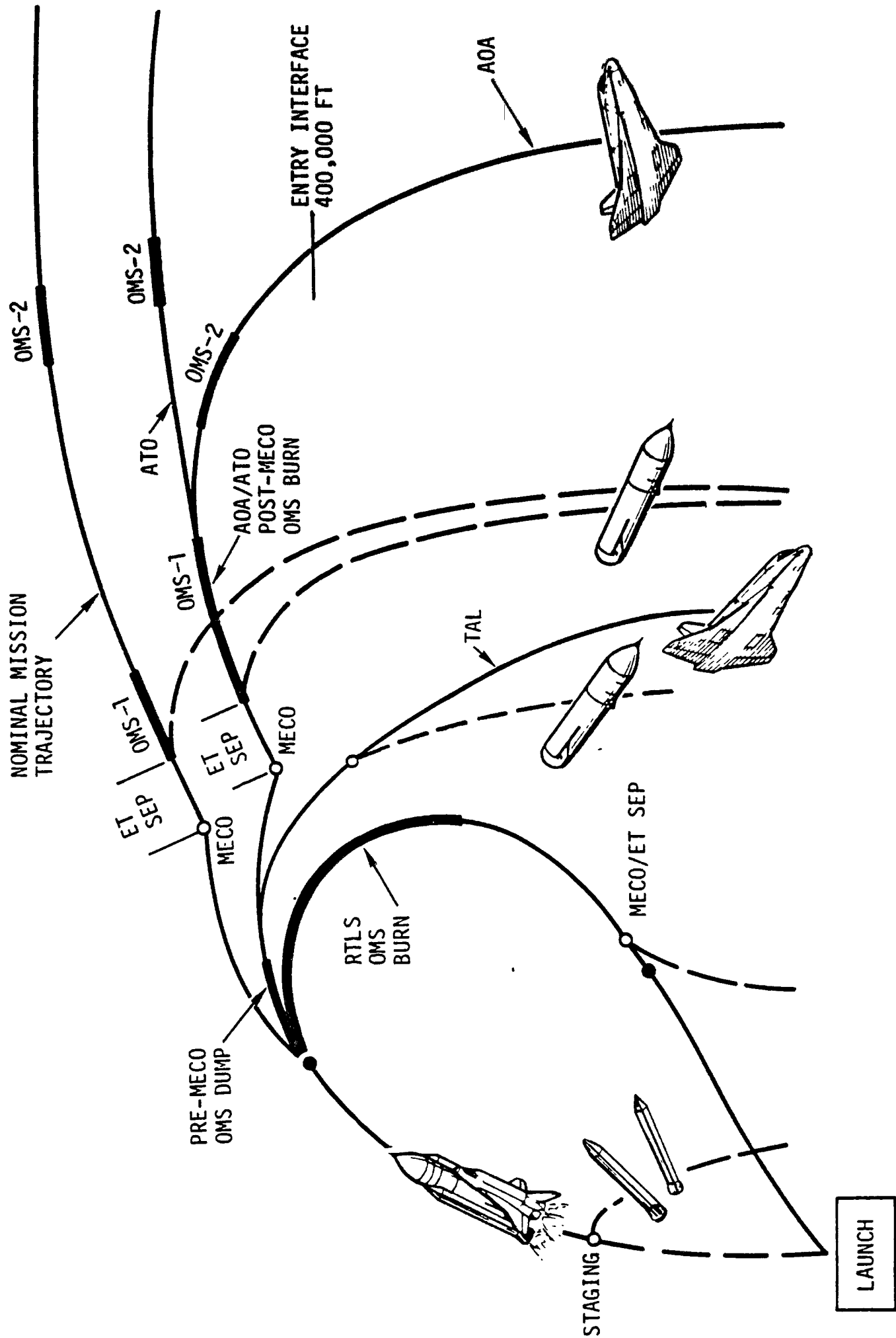


Figure 3-1. Space Shuttle Ascent Scenario



#### 4.0 GUIDANCE FUNCTIONAL SOFTWARE REQUIREMENTS

This section presents Level C detailed guidance and targeting requirements for the ascent program (OPS-1 and OPS-6) of the Shuttle orbital flight test project. This set of requirements covers both normal mission ascent phases, AOA, TAL, and ATO ascent abort phases, and the RTLS abort powered phase.

Software requirements are defined at three levels in the following subsections: principal function, task, and subtask. Principal functions in this Level C document agree with those defined in the CPDS, Level B, GN&C document. Tasks and subtasks are convenient partitionings of the total requirements for each principal function. The task and subtask breakdown has been adopted to clarify the software requirements only and is not meant to define blocks of code or the flight program structure. Definitions of the three levels of requirements are:

Principal Function. A set of requirements which, when taken together, satisfy a particular mission objective and the associated vehicle constraints. For example, the second-stage guidance principal function performs the guidance calculations and issues thrust attitude and SSME commands to achieve desired trajectory conditions at MECO without exceeding the 3g acceleration limit. In some cases, the partitioning of the overall software requirements into principal functions is based on historical precedent.

Task. A group of related requirements which constitute part of the overall requirements for a principal function or functions. The partitioning of a principal function into tasks may be based on differences in execution rate or time span for the various requirements. The aggregate of tasks of a principal function when properly sequenced satisfies the requirements of the principal function.

Subtask. A single requirement or small set of related requirements which are a further division of the task requirements. Subtasks generally are unique to a specific task. Subtasks within a task may be executed over different time spans.

A principal function is defined for the guidance requirement for each of the ascent or RTLS phases as follows:

1. Terminal count requirements (MM 101)
2. First-stage requirements (MM 102)
3. Second-stage requirements (MM 103)



4. Orbit insertion requirements (MM's 104 and 105)
5. Powered RTLS requirements (MM 601)

The detailed requirements for these principal functions are described in Sections 4.1 through 4.4 and Section 4.6. Each major mode description contains a discussion of the conditions necessary to initiate and terminate the mode, the desired terminal conditions, the maneuvers required, the maneuver constraints imposed, and a typical time line. In addition, traceability to Level B documentation is provided by identification of major modes, principal functions, and their major events.

Two other guidance-related principal functions are required to support the guidance software:

1. AOA/ATO targeting (MM's 103, 104, 105, and 106)
2. Ascent maneuver display interface processing (MM's 104, 105, and 106)

The requirements for these principal functions are contained in Sections 4.5 and 4.7.

The I-load and K-load parameters used in the ascent and powered RTLS guidance and targeting functions are listed for each principal function within Section 4.

Interface (input/output and constant) tables for each principal function also appear in Section 4.

A diagram of the OPS-1 guidance-related principal functions and major mode progression is shown in Figure 4-1.

Each principal function contains, or executes, several tasks which are further divided (in most cases) into subtasks. Each task description contains the detailed requirements, interface requirements (between other guidance/targeting tasks and other principal functions), processing requirements, and initialization requirements for the task. Task interface variables (input and output) are defined as a group at the end of each task section. A functional flow to assist in understanding the logic decisions of each task is presented for those task descriptions whose complexity requires this additional aid.

Several tasks are required to support more than one principal function, such as the powered explicit guidance (PEG), which supports the second-stage, orbit insertion, and powered RTLS requirements. These tasks are grouped together under Section 4.8, General Guidance and Targeting Tasks. In general, these tasks perform the detailed guidance and targeting calculations. Other functions, such as H\_ELLIPSOID and MAT\_TO\_QUAT, which are documented in other FSSR's, are assumed to be available (see Appendix C). Other principal functions which supply input data to one or more of the principal functions described herein are precision state prediction (A/E PREC PRED), ascent user parameter processing (ASCENT UPP), OMS fault detection and identification (OMS

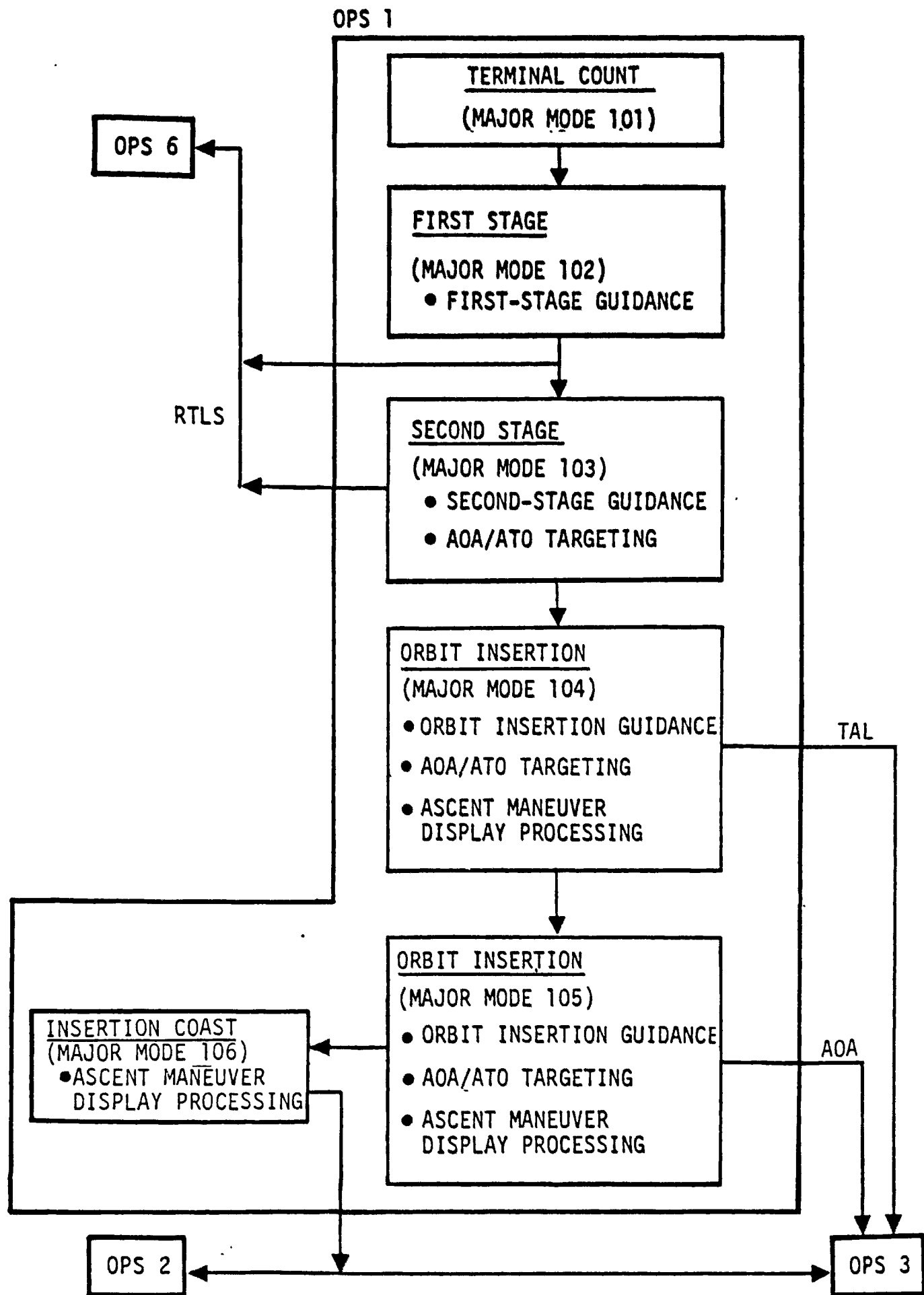


Figure 4-1. Guidance Principal Functions by Major Mode for OPS-1



RM), attitude processing (A/E ATT PROC), RTLS user parameter processing (RTLS UPP), GN&C switch processor (GN&C SW RM), SSME subsystem operating program (SSME SOP), abort control sequencer (ABT CNTL SEQ), and maneuver display (MNVR DISP).

Section 5.1 defines the four Cartesian coordinate systems upon which the guidance software is based, and which are sometimes referred to in the text. These coordinate systems are:

1. Aries-mean-of-1950 Cartesian coordinate system (Figure 5.1-1)
2. Boost reference coordinate system (Figure 5.1-2)
3. UVW coordinate system (Figure 5.1-3)
4. Body axis coordinate system (Figure 5.1-4)

The first and fourth systems are pertinent to all flight phases while the second and third are pertinent only to the first-stage and orbit insertion phases respectively. The first three systems are inertial (the third is quasi-inertial) with respect to the first system. The first system is referred to throughout this document as M50. The fourth, or body axis system, is used to relate guidance attitude commands to flight control attitude commands and is generally implicitly referenced.

In addition to the above coordinate systems, the PEG equations utilize a Cartesian system referenced to the expected thrust cutoff point in which the X-axis is radial, the Z-axis is downrange, and the Y-axis is normal to the direction of travel. These three axes are oriented to form a right-handed system.

Throughout this document, HAL programming language equations and symbols will be used for illustrative purposes. The symbols and equations are not constraining; however, the requirements represented by these symbols and equations are constraining. Certain deviations from the HAL programming language syntax were used to facilitate readability for those not familiar with HAL syntax. Specifically, extra parentheses were added for clarity, and the HAL vector cross product symbol (\*) was changed to the more conventional symbol, x. In addition, the following symbols, when placed above the variable name, were used to denote types of variables: vectors (-), matrices (\*), quaternions (+), and Booleans (.). Further information on these symbols can be obtained by referring to the HAL language specification document. Definitions of the HAL syntax used in this document are listed in Section 5.2.

Acronyms used in this document for the purpose of conciseness are defined in Section 5.3.

Appendix A presents detailed flow charts for each task and subtask of Section 4. If there is a conflict between the data in the flow diagrams and the written requirements, the written requirements shall have precedence.

Appendix B lists the variables internal to the various tasks and their precision.

Appendix C gives the input variable lists for other routines (e.g., MAT\_TO\_QUAT, ASC PREC PRED) used by the guidance and targeting functions in this document.

#### 4.0.1 Software Implementation Constraints

Several constraints and assumptions apply to the flight software implementation of the requirements in the following sections. These constraints are discussed in the following paragraphs.

Variables listed in the interface tables for each task and principal function are characterized as single precision (SP) or double precision (DP). The SP or DP designations are requirements only, and do not preclude a single precision variable from being coded in double precision if that simplifies the software design. In general, the only variables which require double precision are clock or event time in GMT, position components and related variables such as altitude or range angle, accumulated sensed velocity, and the PEG thrust integrals.

It is assumed in defining the software requirements that all vectors, quaternions, and matrices computed in the guidance and targeting principal functions and transferred to other principal functions are time homogeneous.

The guidance flight software shall be capable of recovering from transient erroneous inputs without causing a processing halt. Check or error interrupts shall be prevented by appropriate safeguards. Specifically, the standard fixup described in Level A CPDS, Section 4.6.4 shall be provided and processing continued.

#### 4.0.2 Traceability of Requirements

The software baseline documents shall provide for identifying like and related requirements so that traceability of these requirements can be established up and down through the different levels of the software documentation hierarchy. For this Level C document, including traceability back to Level B documentation (Reference 1) is sufficient. Table 4.0.2-1 provides this traceability. Each major section (two-digit section number) is referenced back to a Level B principal function name and paragraph number in this table. The interfaces between the identified principal function(s) and other principal functions are illustrated in the appropriate Level C document section.

#### 4.0.3 Documented Requirements Precedence

Requirements precedence in this document shall be as follows:

1. If there is a conflict between the data in the function subtables and the standard principal function tables, the principal function tables shall have precedence.

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

Table 4.0.2-1 Level C to Level B Traceability

Level C Document Section	Level B Principal Function Name(s)	Level B Principal Function Paragraph Number(s)
4.1 Terminal count requirement	N/A	N/A
4.2 First-stage requirement	Ascent first-stage guidance	4.1
4.3 Second-stage requirement	Ascent second-stage guidance	4.2
4.4 Orbit insertion requirement	Orbit insertion guidance	4.3
4.5 AOA and ATO targeting requirement	AOA/ATO targeting	4.13
4.6 PRTLS guidance requirement (MM 601)	Powered RTLS guidance	4.4
4.7 Ascent maneuver display processing requirement	Ascent maneuver DIP	4.210
4.8 General guidance and targeting modules	Ascent first-stage guidance Ascent second-stage guidance Orbit insertion guidance Powered RTLS guidance AOA/ATO targeting AS MNVR DIP	4.1 4.2 4.3 4.4 4.13 4.210

4.2 FIRST-STAGE REQUIREMENTS (MM 102)

#### 4.1 TERMINAL COUNT REQUIREMENTS (MM 101)

This section is reserved for the guidance requirements for the terminal count major mode. At the present time there are no known requirements.





#### 4.2 FIRST-STAGE REQUIREMENTS (MM 102)

Principal function AS 1STG GUID (CPDS, Level B, Section 4.1). The general guidance and targeting task required to perform this principal function is the SSME-Out Safing task (Section 4.8.9).

The first-stage major mode begins at the SRB ignition command (Event 19) and terminates at the SRB separation command (Event 28) (Figure 4.2-1).

Note: The SRB ignition is inhibited until terminal count requirements are met, including all three SSME's producing at least 90 percent rated power level (RPL) thrust.

The first-stage trajectory must be designed so that aerodynamic loads are within the Shuttle mated vehicle structural capability for nominal and perturbed conditions, the Shuttle avoids contact with the launch tower and recontact with the jettisoned SRB's, and vehicle performance is near maximum. An attitude versus velocity history that satisfies these requirements is determined prior to the mission. The proposed guidance and flight control attitude profile is simulated with launch vehicle and flight environment dispersions to verify that performance loads are within acceptable limits in all cases.

The first-stage trajectory is divided into two distinct phases--a vertical rise phase and a tilt phase. During the vertical rise phase, the launch pad nominal attitude is commanded until a specified earth-relative velocity magnitude sufficient to assure launch tower clearance is achieved. The tilt maneuver begins upon termination of the vertical rise phase. Preprogrammed pitch, yaw, and roll attitude angle histories (as a function of earth-relative velocity) determine the desired Shuttle attitude during first stage. These Euler angles are defined in the boost reference coordinate system (refer to Section 5.1, Figure 5.1-2), and the order of body rotations is yaw, pitch, and roll (refer to Section 5.1, Figure 5.1-4).

The first-stage guidance principal function calculates the desired Shuttle attitude in the form of a quaternion, and the guidance and control steering interface principal function calculates the body attitude errors from this quaternion. Preprogrammed SSME throttling is performed (except in the case of an SSME failure or when manual throttling is being performed) to limit the maximum dynamic pressure and to achieve the required performance during atmospheric flight. The throttle profile is determined prior to the mission. Throttle commands are issued to the SSME SOP principal function. Also, in the event of an acceleration dispersion (primarily SRB), the pitch attitude and throttle commands are modified to maintain design dynamic pressure.

If an SSME failure occurs during the first-stage ascent, the two remaining SSME's are set to the maximum power level ( $K_{CMD} = K_{MAX}$ ), unless manual throttling is being performed, to obtain maximum performance. Additionally, a pitch bias to the nominal pitch attitude history is calculated. The bias to the nominal pitch attitude history lofts the trajectory, but does not violate mated vehicle structural limits.

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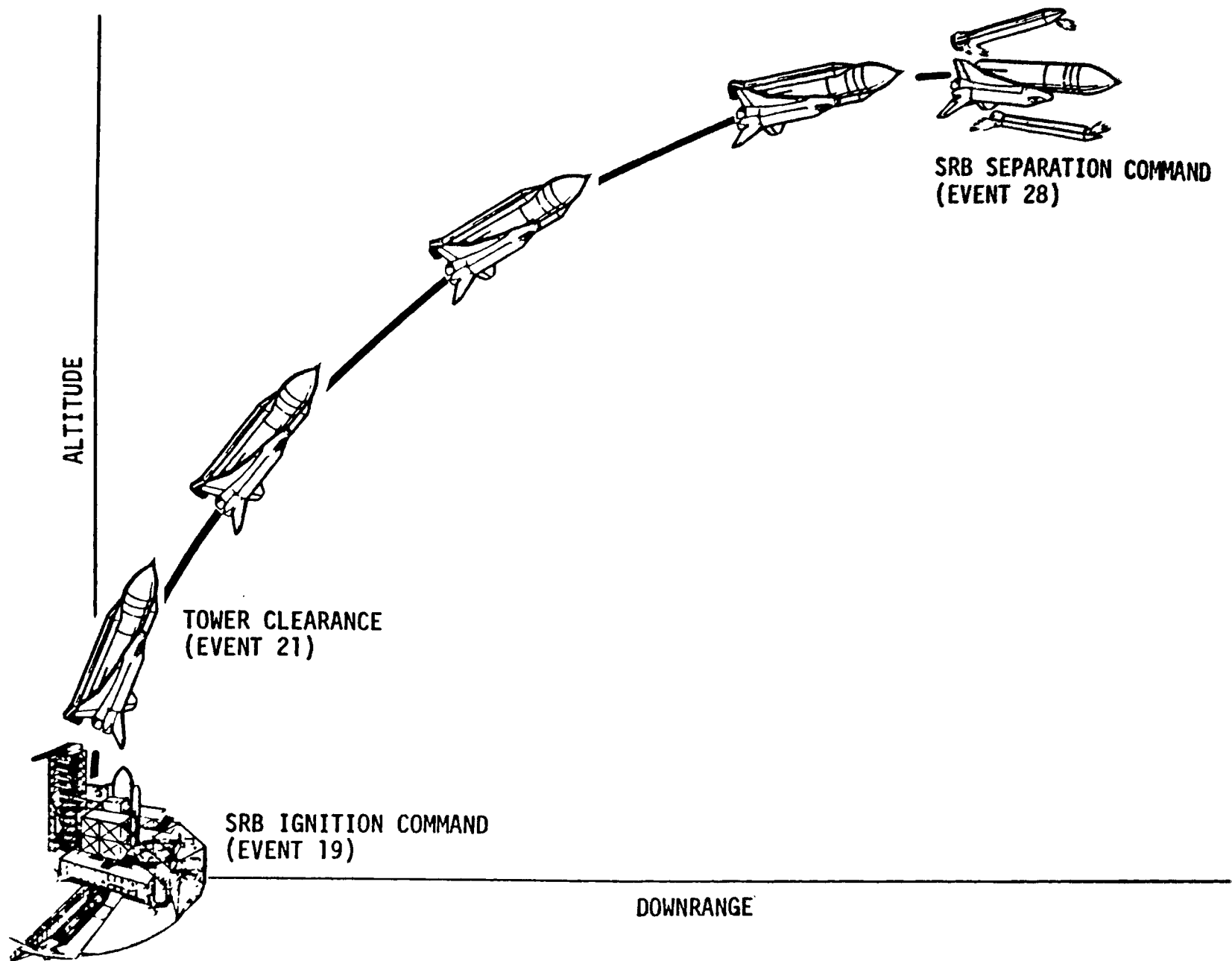


Figure 4.2-1. Typical Shuttle First-Stage Ascent Sequence of Events

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Four tasks are performed to complete this principal function. These tasks are:

1. First-stage guidance input task (1STG GUID INP TSK)
2. Boost guidance task (BST GUID TSK)
3. Boost throttling task (BST THROT TSK)
4. SSME-out safing task (SSME-OUT SAF TSK)

A functional organization of the first-stage guidance principal function is shown in Figure 4.2-2. A detailed description of the first three tasks is contained in Sections 4.2.2 through 4.2.4. The SSME-out safing task is described in Section 4.8.9.

A functional flow and data flow for the first-stage guidance principal function are shown in Figures 4.2-3 and 4.2-4. The input and output principal function interface parameters are given in Section 4.2.5.

File e 4 1 1 1 title First- stage Ascent Sequence of Events

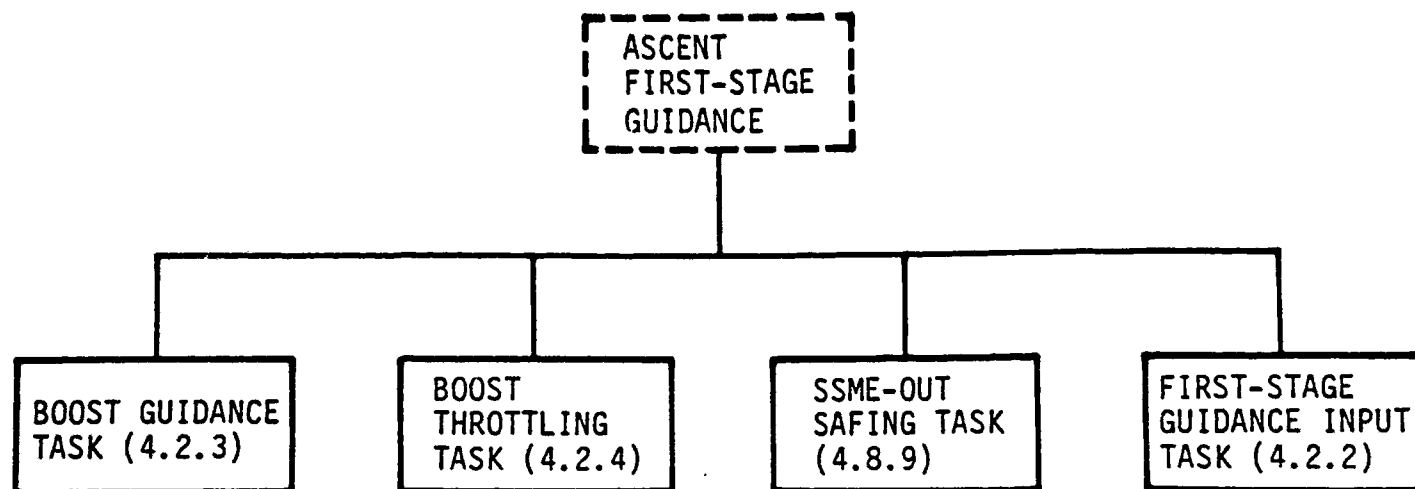


Figure 4.2-2. Ascent First-Stage Guidance Principal Function  
Task Organization

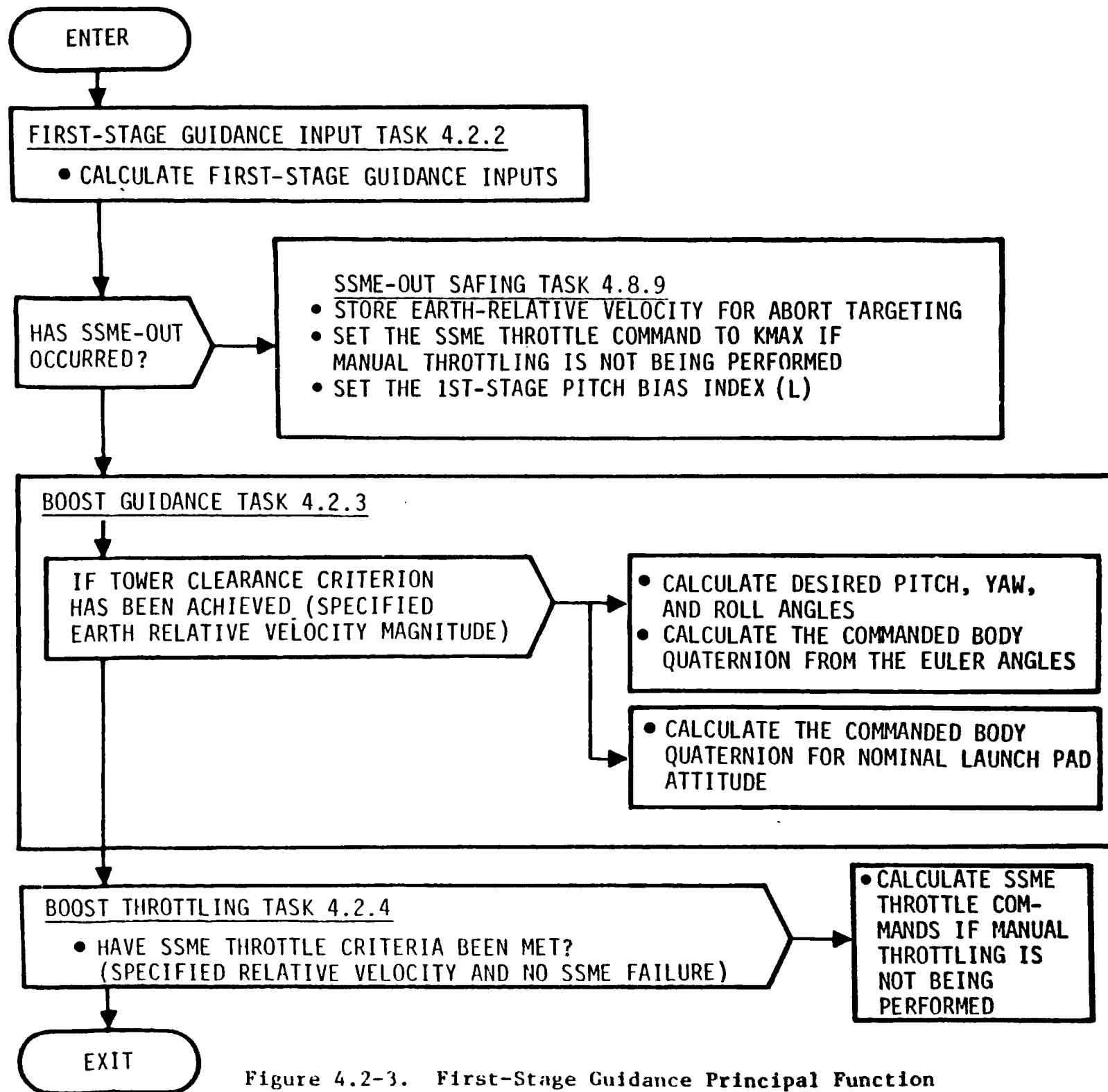


Figure 4.2-3. First-Stage Guidance Principal Function

Logic Flow

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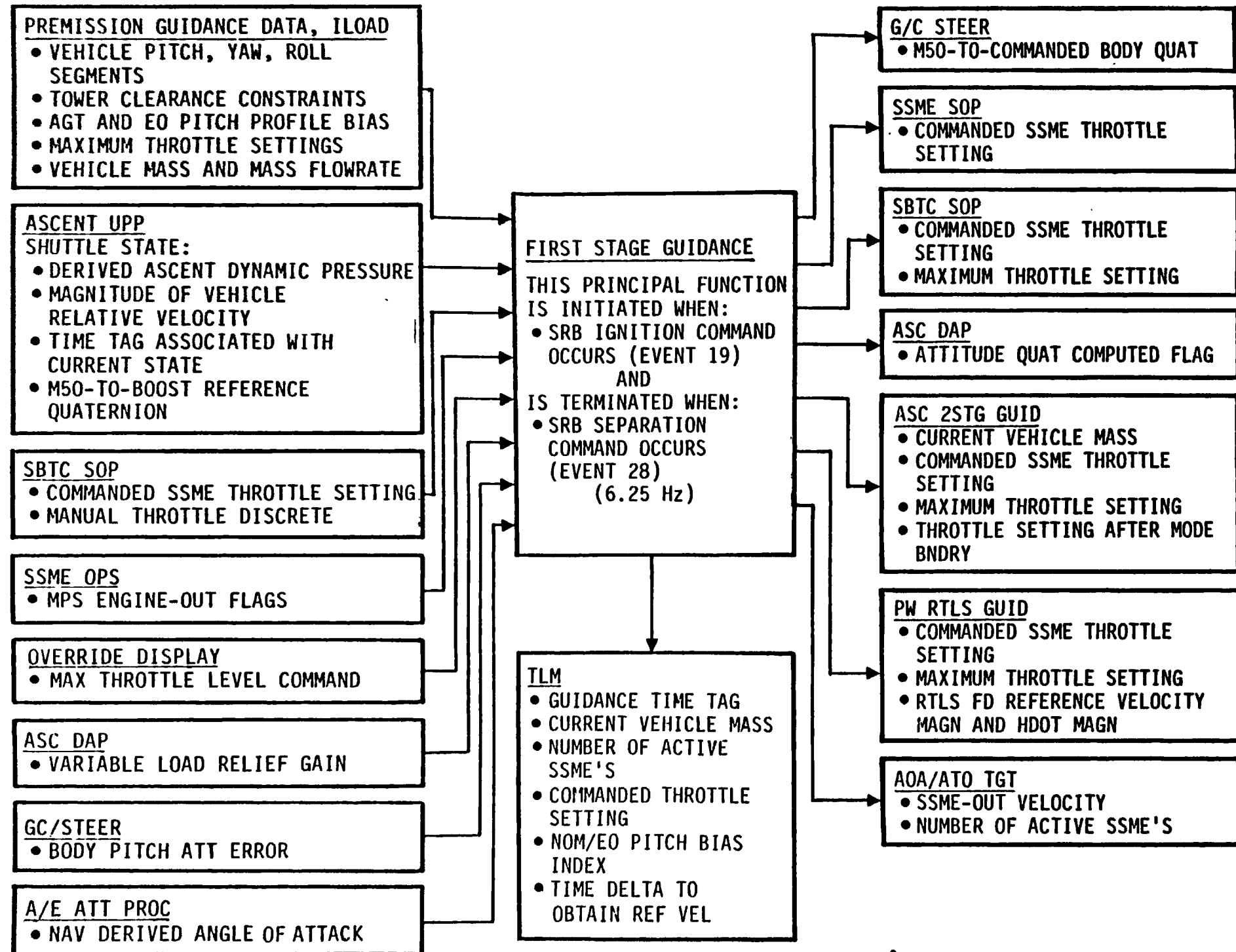


Figure 4.2-4. First-Stage Guidance Principal Function Data Flow

#### 4.2.1 First-Stage Sequencing (1STG SEQ)

In first-stage ascent, several tasks that support the first-stage guidance principal function are performed periodically or on specific events. (These events are identified in the CPDS, Level B, Volume 5, Book 1.) These tasks are:

1. First-stage guidance input task (1STG GUID INP TSK)
2. Boost guidance task (BST GUID TSK)
3. Boost throttling task (BST THROT TSK)
4. SSME-out safing task (SSME-OUT SAF TSK)

The tasks must be sequenced as follows:

1. The first-stage guidance input task is performed repetitively from the SRB ignition command (Event 19) to the SRB separation command (Event 28). This task should precede the other tasks.
2. The boost guidance task is performed repetitively from Event 19 to Event 28.
3. The boost throttling task is performed repetitively from Event 19 to Event 28 except for an SSME failure.
4. The SSME-out safing task is performed when an SSME fails (Section 4.8.9).

Recommended execution rates for the tasks are:

Tasks 1-3	0.16 second
Task 4	One time within 0.16 second of event

#### 4.2.2 First-Stage Guidance Input Task (1STG GUID INP TSK)

This task calculates an input for the boost guidance task, the number of thrusting SSME's, and the orbiter mass to be used in second-stage or powered RTLS guidance.

##### A. Detailed Requirements. The following subtasks are performed:

1. TGD is set to T\_NAV upon initial entry into this task.

2. The number of thrusting SSME's is calculated

$$N\_SSME = 3 - \text{SUM}[\text{INTEGER}(S\_EO\_E1, S\_EO\_E2, S\_EO\_E3)]$$

3. The calculations for boost guidance input and mass integration are as follows:

$$DTGD = T\_NAV - TGD$$

$$TGD = T\_NAV$$

$$M = M - .01 (DTGD K\_CMD MDOT\_SSME N\_SSME)$$

4. If an SSME fails during MM 102, the RTLS fuel dissipation reference velocity magnitude (V\_RTLS\_FD) must be set to the magnitude of vehicle relative velocity (V\_RHO\_MAG) and the reference altitude rate (H\_DOT\_FD) must be set to the magnitude of the vehicle altitude rate (H\_DOT\_ELLIPSOID) at the end of the last guidance cycle of MM 102:

$$V\_RTLS\_FD = V\_RHO\_MAG$$

$$H\_DOT\_FD = H\_DOT\_ELLIPSOID$$

5. On the cycle that the maximum throttle level command is actuated (MAX\_THROT\_CMD = ON), the following must occur:

a. KMAX = KMAX\_SECONDARY

b. K\_CMD\_MODE\_BNDRY = KMAX\_SECONDARY

c. In addition, if manual throttling is not being performed, and the number of thrusting SSME's is less than three (N\_SSME < 3), then the following should be executed:

$$K\_CMD = KMAX\_SECONDARY$$

B. Interface Requirements. The input and output parameters for the first-stage guidance input task are given in Tables 4.2.2-1 and 4.2.2-2.





C. Processing Requirements. Subtask 1 is performed only once upon initial entry into the task. Subtasks 2, 3, 4, and 5 are performed every first-stage guidance input cycle.

D. Initialization Requirements. There are no special initialization requirements. The initial mass of the orbiter plus the external tank is I-loaded.



Table 4.2.2-1. First-Stage Guidance Input Task Inputs

Definition	Symbol	Source	Precision	Units
Commanded SSME throttling setting	K_CMD	BST THROT TSK, SSME-OUT SAF TSK, SBTC SOP	I	pct
SSME mass flow rate	MDOT_SSME	I-LOAD	SP	slug/sec
Current vehicle mass (orbiter/ET only)	M	I-LOAD	SP	slugs
Time tag associated with current state	T_NAV	ASC UPF	DP	sec
Magnitude of vehicle relative velocity	V_RHO_MAG	ASC UPF	SP	fps
MPS engine-out flags	S_EO_E1, S_EO_E2, S_EO_E3	SSME OPS	D	N/A
Manual throttling discrete	S_MAN_THROT	SBTC SOP	D	N/A
Maximum throttle level command	MAX_THROT_CMD	OVERRIDE DISPLAY	D	N/A
Secondary maximum throttle setting	KMAX_SECONDARY	I-LOAD	I	pct
Est altitude rate	H_DOT_ELLIPSOID	ASC UPF	SP	fps

Table 4.2.2-2. First-Stage Guidance Input Task Outputs

Definition	Symbol	Destination	Precision	Units
Current vehicle mass (orbiter with external tank only)	M	ACC MASS UPD TSK, TLM, OMS RM	SP	slugs
Number of active SSME's	N_SSME	AOA/ATO MECO TGT SEL TSK, TLM, BST_GUID TSK	I	N/A
RTLS fuel dissipation reference velocity magnitude	V_RTLS_FD	PITCH CMD TSK	SP	fps
Guidance time tag	TGD	TLM, BST GUID TSK	DP	sec
Maximum throttle setting for SSME	KMAX	RTLS INIT TSK, G-LIM TSK, SSME-OUT SAF TSK, SBTC SOP, PEG TSK, PPD TSK	I	pct
Commanded SSME throttle setting	K_CMD	SSME SOP, THRST PRM TSK, FLYBK TSK, FUEL DISS TSK, G-LIM TSK, SSME-OUT SAF TSK, SBTC SOP	I	pct
Nominal SSME throttle setting after RTLS/AOA mode boundary	K_CMD_ MODE_BNDRY	GUID PRMT RINT TSK	I	pct
RTLS Fuel Dissp Ref HDOT	H_DOT_FD	PITCH CMD TSK	SP	fps

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### 4.2.3 Boost Guidance Task (BST GUID TSK)

This task provides pitch and yaw commands which achieve the desired  $\alpha$  and  $\beta$  histories for both the nominal and SSME-out ascent, and a roll command which achieves the desired roll attitude after the vertical rise. During the vertical rise, the nominal launch pad attitude is commanded.

A. Detailed Requirements. The following subtasks are performed in the boost guidance task.

1. The correct segment of the tilt maneuver attitude table is determined. If  $V\_RHO\_MAG \geq PPOLY_{I+1}$ , I is incremented by one ( $I = I+1$ ) while  $V\_RHO\_MAG \geq PPOLY_{I+1}$  and  $I < 29$ . The following calculations are then made:

$$TMET = TGD - T\_GMTLO$$

$$DENOM = PPOLY_{I+1} - PPOLY_I$$

$$THETP = (THET_{I+1} - THET_I) / DENOM$$

$$PSIP = (PSI_{I+1} - PSI_I) / DENOM$$

If  $I < 15$ ,

$$PHIP = (PHI_{I+1} - PHI_I) / DENOM$$

2. The change in independent variable is computed as:

$$DELT = V\_RHO\_MAG - PPOLY_I$$

3. The desired pitch angle is evaluated.

$$THETC = THET_I + THETP \ DELT$$

4. For acceleration dispersion detected at the reference velocity, the throttle and pitch commands are modified as follows.

When  $V\_RHO\_MAG$  becomes greater than  $VREF\_ADJUST$  with no engine failures, a one time computation of the time difference to obtain  $VREF\_ADJUST$  from design is computed. The pitch and throttle factors are reset for the low acceleration case ( $TDEL\_ADJUST > 0$ ). Also, a new throttle profile is computed for control of maximum dynamic pressure.

If  $V\_RHO\_MAG > VREF\_ADJUST$  and  $S\_THRT\_INIT = OFF$  and  $L = 1$ , then:

$$S\_THRT\_INIT = ON$$

$$TDEL\_ADJUST = TMET - TREF\_ADJUST$$

AGT



If TDEL\_ADJUST > 0, then:

$$PTCH\_FAC = PTCH\_FACL$$

$$KMIN\_ALT = 65.0$$

$$THRT\_FAC = THRT\_FACL$$

$$L\_THRT = L\_THRTL$$

$$THROT_{L\_THRT} = THROT_{L\_THRT} + ROUND \left( \frac{THRT\_FAC \cdot TDEL\_ADJUST}{QPOLY_{L\_THRT+1} - QPOLY_{L\_THRT}} \right)$$

$$THROT_{L\_THRT} = MIDVAL(KMIN\_ALT, THROT_{L\_THRT}, THROT_4)$$

If an engine fails before VREL\_GAIN\_TAB<sub>3</sub>, the pitch adjustment is set to zero.

If V\_RHO\_MAG < VREL\_GAIN\_TAB<sub>3</sub> and L > 1, then:

$$PTCH\_FAC = 0$$

At the beginning of load relief termination (VREL\_GAIN\_TAB<sub>4</sub>), the pitch adjustment is ramped out with load relief.

If V\_RHO\_MAG > VREL\_GAIN\_TAB<sub>4</sub>, then:

$$K\_RAMP = 0$$

The pitch adjustment is made based on the time difference to obtain the reference velocity and is applied as a function of load relief.

$$THETC = THETC - PTCH\_FAC \cdot TDEL\_ADJUST \cdot (1 + THETC^2) \cdot [K\_RAMP - (K\_RAMP - PTCH\_PCT)(K\_LOAD\_RELIEF)]$$

For engine failure situations, after tower clear the pitch command is calculated as follows:

If I > 1 and L > 1, then

$$DELPT\_BIAS = DELSEL$$

If S\_LOAD\_RMP is set to ON, set

$$DELPT\_BIAS = DELSEL (1 - K\_LOAD\_RELIEF)$$

$$THETC = .25 \cdot DELPT\_BIAS (1 + THETC \cdot THETC) + THETC$$



This allows a pitch bias (DELSEL, calculated in the SSME-OUT SAF TSK) to be added to the nominal pitch table value to loft the engine out cases.

For multiple main engine failure situations after tower clear, the pitch command (THETC) is calculated.

If  $N_{SSME} > 1$  or  $I = 1$ , proceed to step 5.

THETC initially depends only on the relative velocity at the time of the 2nd engine failure.

If  $S_{LOAD\_MEO} = OFF$ , then:

$S_{LOAD\_MEO} = ON$

If  $V_{RHO\_MAG} \geq V_{MULT\_EO}$ , then

If  $V_{RHO\_MAG} \geq V_{RAMP\_MAX}$ , then

$THET\_MULT\_EO = THETC$

Otherwise,  $THET\_MULT\_EO$  is determined as a function of the current relative velocity and pitch command.

$$D\_PITCH\_EO = (THET\_MULT\_EO - THETC) \frac{(V_{RAMP\_MAX} - V_{RHO\_MAG})}{(V_{RAMP\_MAX} - V_{MULT\_EO})}$$

$$THET\_MULT\_EO = THETC + D\_PITCH\_EO$$

On all guidance passes,  $THETC = THET\_MULT\_EO$

If  $K_{ALPH\_LIM} = OFF$  or  $V_{RHO\_MAG} < V_{MULT\_EO}$ , proceed to step 5.

If  $S_{RMP\_MEO} = OFF$  and  $TMET > T_{RMP\_I}$ , proceed to step 5.

The relative velocity is saved when  $V_{RHO\_MAG}$  exceeds  $V_{MULT\_EO}$ .

If  $S_{RMP\_MEO} = OFF$ , then:

$S_{RMP\_MEO} = ON$

$V_{RMP\_I} = V_{RHO\_MAG}$

$THET\_PREV = THETC$

A delta alpha integration scheme is now performed to determine the final, desired value for THETC which will decrease loads while lofting the trajectory. First, the desired navigated angle-of-attack ( $ALPH\_TGT$ ) is determined.

If  $TMET \leq T_{RMP\_I}$ , then:

$ALPH\_TGT$  is calculated from a table look-up as a function of navigated dynamic pressure ( $Q\_BAR\_A$ ).

If  $Q\_BAR\_A < Q\_TAB\_ALP(1)$ ,  $ALPH\_TGT = ALP\_TAB(1)$ ; otherwise,

If  $Q\_BAR\_A \geq Q\_TAB\_ALP(4)$ ,  $ALPH\_TGT = ALP\_TAB(4)$ ; otherwise,

$IX = 1$

$IX$  is incremented ( $IX = IX + 1$ ) until  $Q\_BAR\_A \geq Q\_TAB\_ALP(IX)$  and  $Q\_BAR\_A < Q\_TAB\_ALP(IX + 1)$ ; then:

AUTO-LOFT



$$\text{FACT\_ALP} = (\text{Q\_BAR\_A} - \text{Q\_TAB\_ALP}(\text{IX})) / (\text{Q\_TAB\_ALP}(\text{IX}+1) - \text{Q\_TAB\_ALP}(\text{IX}))$$

$$\text{ALPH\_TGT} = \text{ALP\_TAB}(\text{IX}) + \text{FACT\_ALP} (\text{ALP\_TAB}(\text{IX}+1) - \text{ALP\_TAB}(\text{IX}))$$

The alpha error integration gain (D\_ALP\_GAIN) is now calculated as a function of Q\_BAR\_A.

IF Q\_BAR\_A < Q\_TAB\_GAIN(1), D\_ALP\_GAIN = GAIN\_TAB(1); otherwise,  
if Q\_BAR\_A ≥ Q\_TAB\_GAIN(4), D\_ALP\_GAIN = GAIN\_TAB(4); otherwise,

IX = 1  
IX is incremented (IX=IX+1) until Q\_BAR\_A ≥ Q\_TAB\_GAIN(IX)  
and Q\_BAR\_A < Q\_TAB\_GAIN(IX+1); then:

$$\text{FACT\_GAIN} = (\text{Q\_BAR\_A} - \text{Q\_TAB\_GAIN}(\text{IX})) / (\text{Q\_TAB\_GAIN}(\text{IX} + 1) - \text{Q\_TAB\_GAIN}(\text{IX}))$$

$$\text{D\_ALP\_GAIN} = \text{GAIN\_TAB}(\text{IX}) + \text{FACT\_GAIN} (\text{GAIN\_TAB}(\text{IX}+1) - \text{GAIN\_TAB}(\text{IX}))$$

Otherwise, (TMET > T\_RMP\_I) the following calculation is performed for purposes of ramping ALPH\_TGT to the desired SRB tail-off value (ALPH\_TO).

IF S\_ALPH\_TO = OFF, then:  
S\_ALPH\_TO = ON  
ALPHD = ALPHA\_N RAD PER DEG - 4.0 DELT\_ALP / (1.0 + THET\_PREV THET\_PREV)  
D\_ALP\_GAIN = GAIN\_TAB(1)

The following calculations are now made:

IF TMET > T\_RMP\_I, then  
ALPH\_TGT = ALPHD - (ALPHD - ALPH\_TO) (TMET - T\_RMP\_I) / (T\_RMP\_F - T\_RMP\_I)  
IF TMET > T\_RMP\_F or V\_RMP\_I > V\_ALPH\_TO, then  
ALPH\_TGT = ALPH\_TO  
D\_ALP\_GAIN = GAIN\_TAB(1)

The following calculations are performed to determine DELT\_ALP for the integration of THETC:

$$\text{DELT\_ALP} = 0.25 (\text{ALPHA\_N RAD PER DEG} - \text{ALPH\_TGT}) (1.0 + \text{THET\_PREV THET\_PREV})$$

$$\text{THET\_CHK} = \text{THET\_PREV} - 0.25 \text{EBFB2 RAD PER DEG} (1.0 + \text{THET\_PREV THET\_PREV})$$

IF TMET ≤ T\_RMP\_I and THET\_LIM - THET\_CHK < DELT\_ALP, then  
DELT\_ALP = THET\_LIM - THET\_CHK

IF V\_RHO\_MAG < V\_RMP\_I + VRAMP, then  
DELT\_ALP = DELT\_ALP (V\_RHO\_MAG - V\_RMP\_I) / VRAMP



Finally, the integration is performed:

$$\begin{aligned} D\_ALP\_INT &= D\_ALP\_INT + D\_ALP\_GAIN \Delta\_ALP \\ THETC &= THETC + \Delta\_ALP + D\_ALP\_INT \\ THET\_PREV &= 0.5 (THETC + THET\_PREV) \end{aligned}$$

5. The desired yaw and roll angles and their sines and cosines are evaluated.

$$PSIC = PSI_I + PSIP \Delta T$$

If  $V\_RHO\_MAG \geq PPOLY_2$  then

$$PSIC = PSIC + \Delta PSI (1 + PSIC^2)/4$$

$$CTHET = 2./(1. + THETC^2)$$

$$STHET = CTHET THETC$$

$$CTHET = CTHET - 1.$$

$$CPSI = 2./(1. + PSIC^2)$$

$$SPSI = CPSI PSIC$$

$$CPSI = CPSI - 1.$$

If  $I > 14$ , set  $PHIC = PHI_{15}$ ; otherwise ( $I < 15$ ),

$$PHIC = PHI_I + PHIP \Delta T$$

For all values of  $I$

$$CPHI = 2./(1. + PHIC^2)$$

$$SPHI = CPHI PHIC$$

$$CPHI = CPHI - 1.$$

6. The M50-to-commanded-body quaternion  $Q\_GCB\_I$  is calculated as the product of  $Q\_GCB\_BR$  and  $Q\_BR\_M50$ . The scalar element of  $Q\_GCB\_BR$  is  $CPSI CTHET CPHI + SPSI STHET SPHI$ , and its vector part is  $SPSI STHET CPHI - CPSI CTHET SPHI$ ,  $- CPSI STHET CPHI - SPSI CTHET SPHI$ ,  $CPSI STHET SPHI - SPSI CTHET CPHI$ .

Then

$$Q\_GCB\_I = QUAT\_MULT(Q\_GCB\_BR, Q\_BR\_M50)$$

and

$$S\_QUAT = ON$$

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B. Interface Requirements. The input and output parameters for the boost guidance task are given in Tables 4.2.3-1 and 4.2.3-2.

During OPS-9, the I-loaded values of the boost guidance parameters can be updated via uplink. The following data sets and corresponding OPS codes can be linked: PPOLY<sub>I</sub> (0001011), PSI<sub>I</sub> (0001100), and THET<sub>I</sub> (0001101). The data sets LAUNCH TARGETING (0001111) and OMS TARGETING (0011001) can be uplinked during OPS-9 and OPS-1. The subscript I takes the value 1 to 30 for each data set. Replacement of the original I-load data with uplinked data will be transparent to the flight software.

C. Processing Requirements. Subtasks 1 and 2 are performed every boost guidance cycle only when  $V\_RHO\_MAG \geq PPOLY_2$ . The remaining subtasks are performed in the order shown every boost guidance cycle.

D. Initialization Requirements. The following variables must be initialized:

DELT = 0.0

THETP = 0.0

PSIP = 0.0

DELSEL = 0.0

S\_LOAD\_RMP = OFF

S\_LOAD\_MEO = OFF

S\_RMP\_MEO = OFF

S\_ALPH\_TO = OFF

PHIP = 0.0

I = 1

LL = 1

L = 1

S\_QUAT = OFF

K\_RAMP = 1

TDEL\_ADJUST = 0

S\_THRT\_INIT = OFF

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E. Supplemental Information. L and LL are set to 2 or 3 in the SSME-OUT SAF TSK (Section 4.8.9) when an SSME fails.

These requirements are predicated upon a G/C STEER sampling interval of 0.16 second from Event 19 to Event 28.

During the vertical rise ( $V\_RHO\_MAG < PPOLY_2$ ), the command values of THETC, PSIC, and PHIC are  $THET_1$ ,  $PSI_1$ , and  $PHI_1$ . The attitude tangent interpolation (Subtasks 1 and 2) is bypassed during vertical rise to maintain the commanded attitude at the nominal launch pad attitude until the tower is cleared.

The values THET, PSI, and PHI are tangents of Euler quarter angles to simplify the commanded body quaternion computation.



Table 4.2.3-1. Boost Guidance Task Inputs

Definition	Symbol	Source	Precision	Units
M50-to-boost reference quaternion	Q_BR_M50	ASC UPP	SP	ND
Segment start velocities for independent values of pitch and yaw polynomial	FPOLY <sub>I</sub> (I=1,30)	I-LOAD	SP	fps
Segment start value for dependent values of yaw polynomial	PSI <sub>I</sub> (I=1,30)	I-LOAD	SP	ND
Segment start values for dependent values of pitch polynomial (Ith segment, Lth polynomial)	THET <sub>I</sub> (I=1,30)	I-LOAD	SP	ND
Magnitude of vehicle relative velocity	V_RHO_MAG	ASC UPP	SP	fps
Index for nominal/engine-out pitch and yaw polynomials	L	SSME-OUT SAF TSK	I	N/A
Segment start values for dependent values of roll polynomial	PHI <sub>I</sub> (I=1,15)	I-LOAD	SP	ND
Yaw bias for launch delay	DELTA_PSI	I-LOAD	SP	ND
Engine out pitch bias	DELSEL	SSME-OUT SAF TSK	SP	rad
Engine out pitch bias load ramp discrete	S_LOAD_RMP	SSME-OUT SAF TSK	D	N/A
Variable load relief gain	K_LOAD_RELIEF	ASC DAP	SP	ND
Minimum throttle required to satisfy altitude constraint	KMIN_ALT	I-LOAD	I	pct
Throttle index for hot SRB's	L_THRT	I-LOAD	I	ND
Throttle index for cold SRB's	L_THRTL	I-LOAD	I	ND
Pitch adjustment factor for hot SRB's	PTCH_FAC	I-LOAD	SP	rad/sec
Pitch adjustment factor for cold SRB's	PTCH_FACL	I-LOAD	SP	rad/sec
Compensated Nav-derived angle of attack	ALPHA_N	A/E ATT PROC	SP	deg
Pitch attitude error for TVC loops	EBFB2	G/C STEER	SP	deg
Vehicles current dynamic pressure	Q_BAR_A	ASC UPP	SP	psf
Degree to radian conversion	RAD_PER_DEG	CONSTANT = 1.7453293 E-02	SP	rad/deg
Contingency lofting, alpha limiting on/off switch	K_ALPH_LIM	I-LOAD	I	N/A
Alpha target ramp velocity	VRAMP	I-LOAD	SP	fps

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Table 4.2.3-1. Boost Guidance Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
Attitude hold command velocity breakpoint for contingency lofting	V_RAMP_MAX	I-LOAD	SP	fps
Contingency lofting alpha target velocity breakpoint	V_ALPH_TO	I-LOAD	SP	fps
Time to begin ramping in tail-off alpha for contingency lofting	T_RMP_I	I-LOAD	SP	sec
Time to end ramping of tail-off alpha	T_RMP_F	I-LOAD	SP	sec
Contingency lofting SRB tail-off alpha target	ALPH_TO	I-LOAD	SP	rad
Contingency lofting pitch limit	THET_LIM	I-LOAD	SP	N/A
Segment start dynamic pressures for independent values of alpha target	Q_TAB_ALP(4)	I-LOAD	SP	psf
Segment start values for dependent values of alpha target	ALP_TAB(4)	I-LOAD	SP	rad
Segment start dynamic pressures for independent values of integration gain	Q_TAB_GAIN(4)	I-LOAD	SP	psf
Segment start values for dependent values of integration gain	GAIN_TAB(4)	I-LOAD	SP	ND
Percent pitch adjustment during load relief for SRB disp	PTCH_PCT	I-LOAD	SP	ND
Tabular values of independent variable for boost throttling	QPOLY <sub>j</sub> (J=1,4)	I-LOAD	SP	fps
Tabular values for boost throttling	THROT <sub>j</sub> (J=1,4)	I-LOAD	I	pct
Throttle adjustment factor for hot SRB's	THRT_FAC	I-LOAD	SP	pct*fps/sec
Throttle adjustment factor for cold SRB's	THRT_FACL	I-LOAD	SP	pct*fps/sec
Guidance time tag	TGD	1STG GUID INP TSK	DP	sec
Time of lift-off in GMT	T_GMTLO	FCOS	DP	sec
Design reference time to obtain reference velocity	TREF_ADJUST	I-LOAD	SP	sec
VREL breakpoint for beginning of maximum load relief	VREL_GAIN_TAB <sub>3</sub>	I-LOAD	SP	fps
VREL breakpoint for beginning of load relief termination	VREL_GAIN_TAB <sub>4</sub>	I-LOAD	SP	fps
Design reference velocity for SRB adaptive guidance	VREF_ADJUST	I-LOAD	SP	fps
Number of active SSME's	N_SSME	1STG GUID INP TSK	I	N/A
Reference velocity for multiple engine failures	V_MULT_EO	I-LOAD	SP	fps
Pitch command for multiple engine failures	THET_MULT_EO	I-LOAD	SP	N/A

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Table 4.2.3-2. Boost Guidance Task Outputs

Definition	Symbol	Destination	Precision	Units
M30-to-commanded-body quaternion	Q_GCB_I	G/C STEER	SP	RD
Attitude quaternion computed flag	S_QUAT	ASC DAP	D	N/A
Index for nominal/engine-out pitch and yaw polynomials	L	ILM	I	N/A
Tabular values for boost throttling	THROT <sub>J</sub> (J=1,4)	BST THROT TSK	I	pct
Time difference to obtain reference velocity	TDEL_ADJUST	ILM	SP	sec
Index for selecting RILS flight path angle target	LL	PEG TSK	I	N/A

#### 4.2.4 Boost Throttling Task (BST THROT TSK)

This task provides an open-loop SSME throttle command to limit the maximum value of dynamic pressure and to gain the desired performance. If an SSME fails ( $N_{SSME} \neq 3$ ), then this task is not performed and the throttle command is set to the maximum allowable by the safing task if manual is not being performed.

A. Detailed Requirements. The throttle command ( $K_{CMD}$ ) at lift-off is initialized in the LPS to 100 percent. When the relative velocity magnitude equals or exceeds one of the stored throttling-point velocities ( $V_{RHO\_MAG} \geq QPOLY_J$ ),  $K_{CMD}$  is changed to the stored value  $THROT_J$  and the boost throttling segment index is incremented by one ( $J = J + 1$ ) if manual throttling is not being performed ( $S_{MAN\_THROT} = OFF$ ). A maximum of four throttle changes is provided.

B. Interface Requirements. The input and output parameters for the boost throttling task are given in Tables 4.2.4-1 and 4.2.4-2.

C. Processing Requirements. This task is performed on every boost throttling task cycle while  $J$  is less than 5, unless an SSME failure has occurred.

D. Initialization Requirements.  $J = 1$ .

Table 4.2.4-1. Boost Throttling Task Inputs

Definition	Symbol	Source	Precision	Units
Magnitude of vehicle relative velocity	V_RHO_MAG	ASC UPF	SP	fps
Tabular values of independent variable for boost throttling	QPOLY <sub>J</sub> (J=1,4)	I-LOAD	SP	fps
Tabular values for boost throttling	THROT <sub>J</sub> (J=1,4)	I-LOAD, BST GUID TSK	I	per
Manual throttle discrete	S_MAN_THROT	SBTC SOP	D	W A

Table 4.2.4-2. Boost Throttling Task Outputs

Definition	Symbol	Destination	Precision	Units
Commanded SSME throttle setting	K_CMD	SSME SOP, 1STG GUID INP TSK, TLM, SBTC SOP, G-LIM TSK, SSME-OUT SAF TSK, THRST PRM TSK, FUL DISS TSK	I	W



#### 4.2.5 Parameter Tables for First-Stage Guidance

The IDD inputs and outputs are listed in Table 4.2.5-1. Values for the I-loads are contained in the I-load requirements document (JSC-19350); however, I-load definitions applicable to this principal function are listed in Table 4.2.5-2. K-loads are listed in Table 4.2.5-3. Constants are listed in Table 4.2.5-4. The input variable cross-references are listed in Table 4.2.5-5.

Table 4.2.5-1. Ascent First Stage Guidance (G4.1) Input/Output Functional Parameters

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FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE
ALPHA N	V90H2246C	NAV DERIVED ANGLE OF ATTACK	A/E ATT PROC	DEG	SPL
DEL_CST(1)	V99U7540C	CONST ENG OUT PITCH BIAS (1)	UL	RAD	
DEL_CST(2)	V99U7541C	CONST ENG OUT PITCH BIAS (2)	UL	RAD	
DELTA PSI	V99U7440C	AZIMUTH BIAS	UL		
EBFB(2)	V95H3521C	BODY PITCH ATT ERROR	G/C STEER	DEG	SPL
H_DOT_ELLIPSOID/H_DOT	V95L0265CE	EST ALTITUDE RATE	ASC UPP	FT/S	
K_CMD	V90U1948CE	COMMANDED SSME THROTTLE SETTING	SBTC SOP	PCT	
K_LOAD_RELIEF	V90J1704C	VAR LOAD RELIEF GAIN	ASC DAP		
MAX_THROT_CMD	V93X5349X	MAXIMUM THROTTLE LEVEL COMMAND	6.47		BD
ME1_FAIL_SHUTDOWN	V95X1207X	MPS E1 FAIL FLAG	SSME OPS		BD
ME2_FAIL_SHUTDOWN	V95X1208X	MPS E2 FAIL FLAG	SSME OPS		BD
ME3_FAIL_SHUTDOWN	V95X1209X	MPS E3 FAIL FLAG	SSME OPS		BD
MM_CODE_102/MM_102	V90X8158X	MAJOR MODE 102 FLAG	MSC		
MM_CODE_103/MM_103	V90X8156X	MAJOR MODE 103 FLAG	MSC		
P_INT(1)	V99U7538C	INT ENG OUT PITCH BIAS (1)	UL	RAD	
P_INT(2)	V99U7539C	INT ENG OUT PITCH BIAS (2)	UL	RAD	
P_SLP(1)	V99U7536C	SLOPE ENG OUT PITCH BIAS (1)	UL	RAD/FPS	
P_SLP(2)	V99U7537C	SLOPE ENG OUT PITCH BIAS (2)	UL	RAD/FPS	
PHI(01)	V97U4451C	SEGMT BNDRY TAN ROLL ANG/4 (01)	UL		
PHI(02)	V97U4452C	SEGMT BNDRY TAN ROLL ANG/4 (02)	UL		
PHI(03)	V97U4453C	SEGMT BNDRY TAN ROLL ANG/4 (03)	UL		
PHI(04)	V97U4454C	SEGMT BNDRY TAN ROLL ANG/4 (04)	UL		
PHI(05)	V97U4455C	SEGMT BNDRY TAN ROLL ANG/4 (05)	UL		
PHI(06)	V97U4456C	SEGMT BNDRY TAN ROLL ANG/4 (06)	UL		
PHI(07)	V97U4457C	SEGMT BNDRY TAN ROLL ANG/4 (07)	UL		
PHI(08)	V97U4458C	SEGMT BNDRY TAN ROLL ANG/4 (08)	UL		
PHI(09)	V97U4459C	SEGMT BNDRY TAN ROLL ANG/4 (09)	UL		
PHI(10)	V97U4460C	SEGMT BNDRY TAN ROLL ANG/4 (10)	UL		
PHI(11)	V97U4461C	SEGMT BNDRY TAN ROLL ANG/4 (11)	UL		
PHI(12)	V97U4462C	SEGMT BNDRY TAN ROLL ANG/4 (12)	UL		
PHI(13)	V97U4463C	SEGMT BNDRY TAN ROLL ANG/4 (13)	UL		
PHI(14)	V97U4464C	SEGMT BNDRY TAN ROLL ANG/4 (14)	UL		
PHI(15)	V97U4465C	SEGMT BNDRY TAN ROLL ANG/4 (15)	UL		
PPOLY(01)	V97U4486C	PYR ANG SEGMT BNDRY VREL(01)	UL	FT/S	
PPOLY(02)	V97U4487C	PYR ANG SEGMT BNDRY VREL(02)	UL	FT/S	
PPOLY(03)	V97U4488C	PYR ANG SEGMT BNDRY VREL(03)	UL	FT/S	
PPOLY(04)	V97U4489C	PYR ANG SEGMT BNDRY VREL(04)	UL	FT/S	
PPOLY(05)	V97U4490C	PYR ANG SEGMT BNDRY VREL(05)	UL	FT/S	
PPOLY(06)	V97U4491C	PYR ANG SEGMT BNDRY VREL(06)	UL	FT/S	
PPOLY(07)	V97U4492C	PYR ANG SEGMT BNDRY VREL(07)	UL	FT/S	
PPOLY(08)	V97U4493C	PYR ANG SEGMT BNDRY VREL(08)	UL	FT/S	
PPOLY(09)	V97U4494C	PYR ANG SEGMT BNDRY VREL(09)	UL	FT/S	
PPOLY(10)	V97U4495C	PYR ANG SEGMT BNDRY VREL(10)	UL	FT/S	
PPOLY(11)	V97U4496C	PYR ANG SEGMT BNDRY VREL(11)	UL	FT/S	
PPOLY(12)	V97U4497C	PYR ANG SEGMT BNDRY VREL(12)	UL	FT/S	
PPOLY(13)	V97U4498C	PYR ANG SEGMT BNDRY VREL(13)	UL	FT/S	
PPOLY(14)	V97U4499C	PYR ANG SEGMT BNDRY VREL(14)	UL	FT/S	
PPOLY(15)	V97U4500C	PYR ANG SEGMT BNDRY VREL(15)	UL	FT/S	
PPOLY(16)	V97U4501C	PYR ANG SEGMT BNDRY VREL(16)	UL	FT/S	
PPOLY(17)	V97U4502C	PYR ANG SEGMT BNDRY VREL(17)	UL	FT/S	
PPOLY(18)	V97U4503C	PYR ANG SEGMT BNDRY VREL(18)	UL	FT/S	
PPOLY(19)	V97U4504C	PYR ANG SEGMT BNDRY VREL(19)	UL	FT/S	

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FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	REC
PPOLY(20)	V97U4505C	PYR ANG SEGMT BNDRY VREL(20)	UL	FT/S		
PPOLY(21)	V97U4506C	PYR ANG SEGMT BNDRY VREL(21)	UL	FT/S		
PPOLY(22)	V97U4507C	PYR ANG SEGMT BNDRY VREL(22)	UL	FT/S		
PPOLY(23)	V97U4508C	PYR ANG SEGMT BNDRY VREL(23)	UL	FT/S		
PPOLY(24)	V97U4509C	PYR ANG SEGMT BNDRY VREL(24)	UL	FT/S		
PPOLY(25)	V97U4510C	PYR ANG SEGMT BNDRY VREL(25)	UL	FT/S		
PPOLY(26)	V97U4511C	PYR ANG SEGMT BNDRY VREL(26)	UL	FT/S		
PPOLY(27)	V97U4512C	PYR ANG SEGMT BNDRY VREL(27)	UL	FT/S		
PPOLY(28)	V97U4513C	PYR ANG SEGMT BNDRY VREL(28)	UL	FT/S		
PPOLY(29)	V97U4514C	PYR ANG SEGMT BNDRY VREL(29)	UL	FT/S		
PPOLY(30)	V97U4515C	PYR ANG SEGMT BNDRY VREL(30)	UL	FT/S		
PSI(01)	V97U4516C	SEGMT BNDRY TAN YAW ANG/4 (01)	UL			
PSI(02)	V97U4520C	SEGMT BNDRY TAN YAW ANG/4 (02)	UL			
PSI(03)	V97U4524C	SEGMT BNDRY TAN YAW ANG/4 (03)	UL			
PSI(04)	V97U4528C	SEGMT BNDRY TAN YAW ANG/4 (04)	UL			
PSI(05)	V97U4532C	SEGMT BNDRY TAN YAW ANG/4 (05)	UL			
PSI(06)	V97U4536C	SEGMT BNDRY TAN YAW ANG/4 (06)	UL			
PSI(07)	V97U4540C	SEGMT BNDRY TAN YAW ANG/4 (07)	UL			
PSI(08)	V97U4544C	SEGMT BNDRY TAN YAW ANG/4 (08)	UL			
PSI(09)	V97U4548C	SEGMT BNDRY TAN YAW ANG/4 (09)	UL			
PSI(10)	V97U4552C	SEGMT BNDRY TAN YAW ANG/4 (10)	UL			
PSI(11)	V97U4556C	SEGMT BNDRY TAN YAW ANG/4 (11)	UL			
PSI(12)	V97U4560C	SEGMT BNDRY TAN YAW ANG/4 (12)	UL			
PSI(13)	V97U4564C	SEGMT BNDRY TAN YAW ANG/4 (13)	UL			
PSI(14)	V97U4568C	SEGMT BNDRY TAN YAW ANG/4 (14)	UL			
PSI(15)	V97U4572C	SEGMT BNDRY TAN YAW ANG/4 (15)	UL			
PSI(16)	V97U4576C	SEGMT BNDRY TAN YAW ANG/4 (16)	UL			
PSI(17)	V97U4580C	SEGMT BNDRY TAN YAW ANG/4 (17)	UL			
PSI(18)	V97U4584C	SEGMT BNDRY TAN YAW ANG/4 (18)	UL			
PSI(19)	V97U4588C	SEGMT BNDRY TAN YAW ANG/4 (19)	UL			
PSI(20)	V97U4592C	SEGMT BNDRY TAN YAW ANG/4 (20)	UL			
PSI(21)	V97U4596C	SEGMT BNDRY TAN YAW ANG/4 (21)	UL			
PSI(22)	V97U4600C	SEGMT BNDRY TAN YAW ANG/4 (22)	UL			
PSI(23)	V97U4604C	SEGMT BNDRY TAN YAW ANG/4 (23)	UL			
PSI(24)	V97U4608C	SEGMT BNDRY TAN YAW ANG/4 (24)	UL			
PSI(25)	V97U4612C	SEGMT BNDRY TAN YAW ANG/4 (25)	UL			
PSI(26)	V97U4616C	SEGMT BNDRY TAN YAW ANG/4 (26)	UL			
PSI(27)	V97U4620C	SEGMT BNDRY TAN YAW ANG/4 (27)	UL			
PSI(28)	V97U4624C	SEGMT BNDRY TAN YAW ANG/4 (28)	UL			
PSI(29)	V97U4628C	SEGMT BNDRY TAN YAW ANG/4 (29)	UL			
PSI(30)	V97U4632C	SEGMT BNDRY TAN YAW ANG/4 (30)	UL			
Q BAR A	V95P0500C	DERIVED ASCENT DYNAMIC PRESS	ASC UPP	LB/FT2		SPL
Q M50TOBR(1)	V95U0503C	M50-TO BOOST REF QUATERNION ELE 1	ASC UPP			
Q M50TOBR(2)	V95U0504C	M50-TO BOOST REF QUATERNION ELE 2	ASC UPP			
Q M50TOBR(3)	V95U0505C	M50-TO BOOST REF QUATERNION ELE 3	ASC UPP			
Q M50TOBR(4)	V95U0506C	M50-TO BOOST REF QUATERNION ELE 4	ASC UPP			
REL VEL MAG	V95L0151C	GND REL VEL MAGNITUDE IN M50 SYS	ASC UPP	FT/S		BD
S MAN THROT	V96X0006X	MANUAL THROTTLE DISCRETE	SBTC SOP			
T GMTLO	V90W4380C	TIME OF LIFTOFF IN GMT	FCOS	S		
T STATE	V95W0200CD	TIME TAG ASSOC WITH CURRENT STATE	ASC UPP			
THET(01)	V97U4667C	SEGMT BNDRY TAN PITCH ANG/4 (01)	UL			
THET(02)	V97U4671C	SEGMT BNDRY TAN PITCH ANG/4 (02)	UL			
THET(03)	V97U4675C	SEGMT BNDRY TAN PITCH ANG/4 (03)	UL			

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FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE
THET(04)	V97U4679C	SEGMT BNDRY TAN PITCH ANG/4 (04)	UL		
THET(05)	V97U4683C	SEGMT BNDRY TAN PITCH ANG/4 (05)	UL		
THET(06)	V97U4687C	SEGMT BNDRY TAN PITCH ANG/4 (06)	UL		
THET(07)	V97U4691C	SEGMT BNDRY TAN PITCH ANG/4 (07)	UL		
THET(08)	V97U4695C	SEGMT BNDRY TAN PITCH ANG/4 (08)	UL		
THET(09)	V97U4699C	SEGMT BNDRY TAN PITCH ANG/4 (09)	UL		
THET(10)	V97U4703C	SEGMT BNDRY TAN PITCH ANG/4 (10)	UL		
THET(11)	V97U4707C	SEGMT BNDRY TAN PITCH ANG/4 (11)	UL		
THET(12)	V97U4711C	SEGMT BNDRY TAN PITCH ANG/4 (12)	UL		
THET(13)	V97U4715C	SEGMT BNDRY TAN PITCH ANG/4 (13)	UL		
THET(14)	V97U4719C	SEGMT BNDRY TAN PITCH ANG/4 (14)	UL		
THET(15)	V97U4723C	SEGMT BNDRY TAN PITCH ANG/4 (15)	UL		
THET(16)	V97U4727C	SEGMT BNDRY TAN PITCH ANG/4 (16)	UL		
THET(17)	V97U4731C	SEGMT BNDRY TAN PITCH ANG/4 (17)	UL		
THET(18)	V97U4735C	SEGMT BNDRY TAN PITCH ANG/4 (18)	UL		
THET(19)	V97U4739C	SEGMT BNDRY TAN PITCH ANG/4 (19)	UL		
THET(20)	V97U4743C	SEGMT BNDRY TAN PITCH ANG/4 (20)	UL		
THET(21)	V97U4747C	SEGMT BNDRY TAN PITCH ANG/4 (21)	UL		
THET(22)	V97U4751C	SEGMT BNDRY TAN PITCH ANG/4 (22)	UL		
THET(23)	V97U4755C	SEGMT BNDRY TAN PITCH ANG/4 (23)	UL		
THET(24)	V97U4759C	SEGMT BNDRY TAN PITCH ANG/4 (24)	UL		
THET(25)	V97U4763C	SEGMT BNDRY TAN PITCH ANG/4 (25)	UL		
THET(26)	V97U4767C	SEGMT BNDRY TAN PITCH ANG/4 (26)	UL		
THET(27)	V97U4771C	SEGMT BNDRY TAN PITCH ANG/4 (27)	UL		
THET(28)	V97U4775C	SEGMT BNDRY TAN PITCH ANG/4 (28)	UL		
THET(29)	V97U4779C	SEGMT BNDRY TAN PITCH ANG/4 (29)	UL		
THET(30)	V97U4783C	SEGMT BNDRY TAN PITCH ANG/4 (30)	UL		
TREF_ADJUST	V99U7566C	REFERENCE VELOCITY TIME	UL		
V_FO SW	V99U7542C	ENG OUT SW VEL	UL	SEC FT/S	

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Table 4.2.5-1. Ascent First Stage Guidance (G4.1) Input/Output Functional Parameters (Cont)

DBFN: D2B039-A PN: VP707100026P00L MAY 31, 1988  
 OUTPUT FUNCTIONAL PARAMETERS FROM ASCENT FIRST STAGE GUIDANCE

ASC 1STG GUID OI8B REV00 G4.1

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 R  
 DATA  
 TYPE C

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS
H_DOT_FD	V90R2098CA	RTLS FUEL DISSP REF HOOT	PW RTLS GUID	FT/S
K_CMD	V90U1948CB	COMMANDED SSME THROTTLE SETTING	SSME SOP,ASC 2STG GUID, PW RTLS GUID,SBTC SOP,TLM	PCT
K_CMD_MODE_BNDRY	V97U4420C	NOM SSME THROT SET-RTLS/AOA BNDRY	ASC 2STG GUID	PCT
K_MAX	V97U4424CA	MAXIMUM THROTTLE SETTING OF SSME	SBTC SOP,ASC 2STG GUID, PW RTLS GUID	PCT
L	V90J1943C	1ST STG ATTITUDE PROFILE SELECTOR	TLM	HXS
LL	V90J2007CA	RTLS FLIGHT PATH ANG TARGET INDEX	PW RTLS GUID	SLUGS
M/CURR_ORB_MASS/WEIGHT	V90U1961CF	CURRENT VEHICLE MASS	ASC 2STG GUID,PW RTLS GUID, OMS RM,TLM	
N_SSME	V90U1962CA	NUMBER OF ACTIVE SSME'S	AOA/ATO TGT,TLM	
Q_CB_M50(1)/Q_GCB_1	V90U1949CA	M50-TO-CMD BODY QUATERNION ELE 1	G/C STEER	
Q_CB_M50(2)/Q_GCB_2	V90U1950CA	M50-TO-CMD BODY QUATERNION ELE 2	G/C STEER	
Q_CB_M50(3)/Q_GCB_3	V90U1951CA	M50-TO-CMD BODY QUATERNION ELE 3	G/C STEER	
Q_CB_M50(4)/Q_GCB_4	V90U1952CA	M50-TO-CMD BODY QUATERNION ELE 4	G/C STEER	
S_QUAT	V90U1952CA	M50-TO-CMD BODY QUATERNION ELE 4	G/C STEER	
TDEL_ADJUST	V90X1987X	ATTITUDE QUATERNION COMPUTED FLAG	ASC DAP	S
TGD	V90W2003C	REF VEL TIME DIFFERENCE FROM DESIG	TLM	S
V_ME_OUT	V90W1994CA	GUIDANCE TIME TAG	TLM	FT/S
V_RTLS_FD	V90L1947CA	SSME ENGINE-OUT VELOCITY	AOA/ATO TGT,TLM	FT/S
	V90U1967CA	RTLS FUEL DISSIPATION REF VEL MAG	PW RTLS GUID	

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Table 4.2.5-2. Ascent First Stage Guidance (G4.1) I-Loads  
Ascent First Stage Guidance

OI8B MISSIONS FSSR NAME	MSID	ENG UNIT	DT PR D S PR FCTN	CAT
ALP_TAB(1)	V99U9879C	RAD	F S M P G4.1	A1C0
ALP_TAB(2)	V99U9880C	RAD	F S M P G4.1	A1C0
ALP_TAB(3)	V99U9881C	RAD	F S M P G4.1	A1C0
ALP_TAB(4)	V99U9882C	RAD	F S M P G4.1	A1C0
ALPH_TO	V99U9873C	RAD	F S M P G4.1	A1C0
DEL_CST(1)	V99U7540C	RAD	F S M C G4.1	A1P0
DEL_CST(2)	V99U7541C	RAD	F S M C G4.1	A1P0
DELTA_PSI	V99U7440C	ND	F S M C G4.1	ARCO
GAIN_TAB(1)	V99U9887C	ND	F S M P G4.1	A1C0
GAIN_TAB(2)	V99U9888C	ND	F S M P G4.1	A1C0
GAIN_TAB(3)	V99U9889C	ND	F S M P G4.1	A1C0
GAIN_TAB(4)	V99U9890C	ND	F S M P G4.1	A1C0
K_ALPH_LIM	V99U9867C	NONE	I S M P G4.1	A1C0
K_CMD_MODE_BNDRY	V97U4420C	PCT	F S M X G4.1 G4.2	A2P1
KMAX	V97U4424C	PCT	I S M C G4.1 G4.2 G4.4 G4.55	A2P1
KMAX_SECONDARY	V99U7107C	PCT	I S M C G4.1 G4.2 G4.4	A2P1
KMIN	V97U4425C	PCT	I S D C G4.1 G4.2 G4.4 G4.55	A2P1
KMIN_ALT	V99U7558C	PCT	I S M C G4.1	A1S3
L_THRT	V99U7559C	ND	I S M C G4.1	A1S3
L_THRTL	V99U7560C	ND	I S M C G4.1	A1S3

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Table 4.2.5-2. Ascent First Stage Guidance (G4.1) I-Loads  
Ascent First Stage Guidance (Cont)

MISSIONS FSSR NAME	MSID	ENG UNIT	DT PR D S PR FCTN	CAT
M	V97U4429C	SLUGS	F S M X G4.1 G4.158 G4.211	AMC2 ZF22 AMC2 ZF22 AMC2
MDOT_SSME	V97U4442C	SLUGS/SEC	F S D C G4.1 G4.2 G4.4	ZF12
P_INT(1)	V99U7538C	RAD	F S M C G4.1	A1P0
P_INT(2)	V99U7539C	RAD	F S M C G4.1	A1P0
P_SLP(1)	V99U7536C	RAD*SEC/FT	F S M C G4.1	A1P0
P_SLP(2)	V99U7537C	RAD*SEC/FT	F S M C G4.1	A1P0
PHI(01)	V97U4451C	ND	F S M C G4.1	ZF12
PHI(02)	V97U4452C	ND	F S M C G4.1	YD10
PHI(03)	V97U4453C	ND	F S M C G4.1	YD10
PHI(04)	V97U4454C	ND	F S M C G4.1	YD10
PHI(05)	V97U4455C	ND	F S M C G4.1	YD10
PHI(06)	V97U4456C	ND	F S M C G4.1	YD10
PHI(07)	V97U4457C	ND	F S M C G4.1	YD10
PHI(08)	V97U4458C	ND	F S M C G4.1	YD10
PHI(09)	V97U4459C	ND	F S M C G4.1	YD10
PHI(10)	V97U4460C	ND	F S M C G4.1	YD10
PHI(11)	V97U4461C	ND	F S M C G4.1	YD10
PHI(12)	V97U4462C	ND	F S M C G4.1	YD10
PHI(13)	V97U4463C	ND	F S M C G4.1	YD10
PHI(14)	V97U4464C	ND	F S M C G4.1	YD10
PHI(15)	V97U4465C	ND	F S M C G4.1	YD10
PPOLY(01)	V97U4486C	FT/SEC	F S M C G4.1	A1N2
PPOLY(02)	V97U4487C	FT/SEC	F S M C G4.1	A1N2

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Table 4.2.5-2. Ascent First Stage Guidance (G4.1) I-Loads  
Ascent First Stage Guidance (Cont)

OI8B MISSIONS

FSSR NAME	MSID	ENG 'UNIT	DT PR D S PR FCTN	CAT
PPOLY(03)	V97U4488C	FT/SEC	F S M C G4.1	A1N2
PPOLY(04)	V97U4489C	FT/SEC	F S M C G4.1	A1N2
PPOLY(05)	V97U4490C	FT/SEC	F S M C G4.1	A1N2
PPOLY(06)	V97U4491C	FT/SEC	F S M C G4.1	A1N2
PPOLY(07)	V97U4492C	FT/SEC	F S M C G4.1	A1N2
PPOLY(08)	V97U4493C	FT/SEC	F S M C G4.1	A1N2
PPOLY(09)	V97U4494C	FT/SEC	F S M C G4.1	A1N2
PPOLY(10)	V97U4495C	FT/SEC	F S M C G4.1	A1N2
PPOLY(11)	V97U4496C	FT/SEC	F S M C G4.1	A1N2
PPOLY(12)	V97U4497C	FT/SEC	F S M C G4.1	A1N2
PPOLY(13)	V97U4498C	FT/SEC	F S M C G4.1	A1N2
PPOLY(14)	V97U4499C	FT/SEC	F S M C G4.1	A1N2
PPOLY(15)	V97U4500C	FT/SEC	F S M C G4.1	A1N2
PPOLY(16)	V97U4501C	FT/SEC	F S M C G4.1	A1N2
PPOLY(17)	V97U4502C	FT/SEC	F S M C G4.1	A1N2
PPOLY(18)	V97U4503C	FT/SEC	F S M C G4.1	A1N2
PPOLY(19)	V97U4504C	FT/SEC	F S M C G4.1	A1N2
PPOLY(20)	V97U4505C	FT/SEC	F S M C G4.1	A1N2
PPOLY(21)	V97U4506C	FT/SEC	F S M C G4.1	A1N2
PPOLY(22)	V97U4507C	FT/SEC	F S M C G4.1	A1N2
PPOLY(23)	V97U4508C	FT/SEC	F S M C G4.1	A1N2
PPOLY(24)	V97U4509C	FT/SEC	F S M C G4.1	A1N2
PPOLY(25)	V97U4510C	FT/SEC	F S M C G4.1	A1N2
PPOLY(26)	V97U4511C	FT/SEC	F S M C G4.1	A1N2
PPOLY(27)	V97U4512C	FT/SEC	F S M C G4.1	A1N2
PPOLY(28)	V97U4513C	FT/SEC	F S M C G4.1	A1N2

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Table 4.2.5-2. Ascent First Stage Guidance (G4.1) I-Loads  
Ascent First Stage Guidance (Cont)

OI88 MISSIONS FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
PPOLY(29)	V97U4514C	FT/SEC	F	S	M	C	G4.1		A1N2
PPOLY(30)	V97U4515C	FT/SEC	F	S	M	C	G4.1		A1N2
PSI(01)	V97U4516C	ND	F	S	M	C	G4.1		A1N2
PSI(02)	V97U4520C	ND	F	S	M	C	G4.1		A1N2
PSI(03)	V97U4524C	ND	F	S	M	C	G4.1		A1N2
PSI(04)	V97U4528C	ND	F	S	M	C	G4.1		A1N2
PSI(05)	V97U4532C	ND	F	S	M	C	G4.1		A1N2
PSI(06)	V97U4536C	ND	F	S	M	C	G4.1		A1N2
PSI(07)	V97U4540C	ND	F	S	M	C	G4.1		A1N2
PSI(08)	V97U4544C	ND	F	S	M	C	G4.1		A1N2
PSI(09)	V97U4548C	ND	F	S	M	C	G4.1		A1N2
PSI(10)	V97U4552C	ND	F	S	M	C	G4.1		A1N2
PSI(11)	V97U4556C	ND	F	S	M	C	G4.1		A1N2
PSI(12)	V97U4560C	ND	F	S	M	C	G4.1		A1N2
PSI(13)	V97U4564C	ND	F	S	M	C	G4.1		A1N2
PSI(14)	V97U4568C	ND	F	S	M	C	G4.1		A1N2
PSI(15)	V97U4572C	ND	F	S	M	C	G4.1		A1N2
PSI(16)	V97U4576C	ND	F	S	M	C	G4.1		A1N2
PSI(17)	V97U4580C	ND	F	S	M	C	G4.1		A1N2
PSI(18)	V97U4584C	ND	F	S	M	C	G4.1		A1N2
PSI(19)	V97U4588C	ND	F	S	M	C	G4.1		A1N2
PSI(20)	V97U4592C	ND	F	S	M	C	G4.1		A1N2
PSI(21)	V97U4596C	ND	F	S	M	C	G4.1		A1N2
PSI(22)	V97U4600C	ND	F	S	M	C	G4.1		A1N2
PSI(23)	V97U4604C	ND	F	S	M	C	G4.1		A1N2
PSI(24)	V97U4608C	ND	F	S	M	C	G4.1		A1N2

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Table 4.2.5-2. Ascent First Stage Guidance (G4.1) I-Loads  
Ascent First Stage Guidance (Cont)

OIBS MISSIONS					
FSSR NAME	MSID	ENG UNIT	DT	PR D S PR FCTN	CAT
PSI(25)	V97U4612C	ND	F	S H C G4.1	A1N2
PSI(26)	V97U4616C	ND	F	S H C G4.1	A1N2
PSI(27)	V97U4620C	ND	F	S H C G4.1	A1N2
PSI(28)	V97U4624C	ND	F	S H C G4.1	A1N2
PSI(29)	V97U4628C	ND	F	S H C G4.1	A1N2
PSI(30)	V97U4632C	ND	F	S H C G4.1	A1N2
PTCH_FAC	V99U7561C	RAD/SEC	F	S H C G4.1	A1T1
PTCH_FACL	V99U7562C	RAD/SEC	F	S H C G4.1	A1T1
PTCH_PCT	V99U7563C	ND	F	S D C G4.1	A1T1
Q_TAB_ALP 1)	V99U9875C	LBS/FT**2	F	S H P G4.1	A1C0
Q_TAB_ALP 2)	V99U9876C	LBS/FT**2	F	S H P G4.1	A1C0
Q_TAB_ALP 3	V99U9877C	LBS/FT**2	F	S H P G4.1	A1C0
Q_TAB_ALP 4	V99U9878C	LBS/FT**2	F	S H P G4.1	A1C0
Q_TAB_GAINW1	V99U9883C	LBS/FT**2	F	S H P G4.1	A1C0
Q_TAB_GAINW2)	V99U9884C	LBS/FT**2	F	S H P G4.1	A1C0
Q_TAB_GAINW3)	V99U9885C	LBS/FT**2	F	S H P G4.1	A1C0
Q_TAB_GAIN 4)	V99U9886C	LBS/FT**2	F	S H P G4.1	A1C0
QPOLY 1)	V97U4640C	FT/SEC	F	S H C G4.1	A1S3
QPOLY(2)	V97U4641C	FT/SEC	F	S H C G4.1	A1S3
QPOLY(3)	V97U4642C	FT/SEC	F	S H C G4.1	A1S3
QPOLY(4)	V97U4643C	FT/SEC	F	S H C G4.1	A1S3
T_RMP_F	V99U9872C	SEC	F	S H P G4.1	A1C0
T_RMP_I	V99U9871C	SEC	F	S H P G4.1	A1C0
THET(01)	V97U4667C	ND	F	S H C G4.1	A1N2
THET(02)	V97U4671C	ND	F	S H C G4.1	A1N2
THET(03)	V97U4675C	ND	F	S H C G4.1	A1N2

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Table 4.2.5-2. Ascent First Stage Guidance (G4.1) I-Loads  
Ascent First Stage Guidance (Cont)

MISSIONS FSSR NAME	MSID	ENG UNIT	DT PR D S PR FCTN	CAT
THET(04)	V97U4679C	ND	F S M C G4.1	A1N2
THET(05)	V97U4683C	ND	F S M C G4.1	A1N2
THET(06)	V97U4687C	ND	F S M C G4.1	A1N2
THET(07)	V97U4691C	ND	F S M C G4.1	A1N2
THET(08)	V97U4695C	ND	F S M C G4.1	A1N2
THET(09)	V97U4699C	ND	F S M C G4.1	A1N2
THET(10)	V97U4703C	ND	F S M C G4.1	A1N2
THET(11)	V97U4707C	ND	F S M C G4.1	A1N2
THET(12)	V97U4711C	ND	F S M C G4.1	A1N2
THET(13)	V97U4715C	ND	F S M C G4.1	A1N2
THET(14)	V97U4719C	ND	F S M C G4.1	A1N2
THET(15)	V97U4723C	ND	F S M C G4.1	A1N2
THET(16)	V97U4727C	ND	F S M C G4.1	A1N2
THET(17)	V97U4731C	ND	F S M C G4.1	A1N2
THET(18)	V97U4735C	ND	F S M C G4.1	A1N2
THET(19)	V97U4739C	ND	F S M C G4.1	A1N2
THET(20)	V97U4743C	ND	F S M C G4.1	A1N2
THET(21)	V97U4747C	ND	F S M C G4.1	A1N2
THET(22)	V97U4751C	ND	F S M C G4.1	A1N2
THET(23)	V97U4755C	ND	F S M C G4.1	A1N2
THET(24)	V97U4759C	ND	F S M C G4.1	A1N2
THET(25)	V97U4763C	ND	F S M C G4.1	A1N2
THET(26)	V97U4767C	ND	F S M C G4.1	A1N2
THET(27)	V97U4771C	ND	F S M C G4.1	A1N2
THET(28)	V97U4775C	ND	F S M C G4.1	A1N2
THET(29)	V97U4779C	ND	F S M C G4.1	A1N2

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Table 4.2.5-2. Ascent First Stage Guidance (G4.1) I-Loads  
Ascent First Stage Guidance (Cont)

MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	THET(30)	V97U4783C	ND	F	S	H	C	G4.1		A1N2
	THET_LIM	V99U9874C	NONE	F	S	M	P	G4.1		A1C0
	THET_MULT_EO	V99U9803C	NONE	F	S	M	P	G4.1		A1C0
	THROT(1)	V97U4808C	PCT	F	S	H	X	G4.1		A1S3
	THROT(2)	V97U4809C	PCT	F	S	H	X	G4.1		A1S3
	THROT(3)	V97U4810C	PCT	F	S	H	X	G4.1		A1S3
	THROT(4)	V97U4811C	PCT	F	S	H	X	G4.1		A1S3
	THRT_FAC	V99U7564C	PCT*(FT/SEC)/SEC	F	S	H	C	G4.1		A1S3
	THRT_FACL	V99U7565C	PCT*(FT/SEC)/SEC	F	S	H	C	G4.1		A1S3
	TREF_ADJUST	V99U7566C	SEC	F	S	H	C	G4.1		ATA0
	V_ALPH_TO	V99U9870C	FT/SEC	F	S	M	P	G4.1		A1C0
	V_EO_SH	V99U7542C	FT/SEC	F	S	H	C	G4.1		A1P0
	V_MULT_EO	V99U9802C	FT/SEC	F	S	M	P	G4.1		A1C0
	V_PYR_SH	V97U4821C	FT/SEC	F	S	H	C	G4.1		A1P0
	V_RAMP_MAX	V99U9869C	FT/SEC	F	S	M	P	G4.1		A1C0
	VRAMP	V99U9868C	FT/SEC	F	S	M	P	G4.1		A1C0
	VREF_ADJUST	V99U7567C	FT/SEC	F	S	H	C	G4.1		A1T1
	VREL_GAIN_TAB(03)	V97U2287C	FT/SEC	F	S	D	C	G4.176 G4.1		ADG2
	VREL_GAIN_TAB(04)	V97U2288C	FT/SEC	F	S	D	C	G4.176 G4.1		ADG2

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PCN-2, 01-8B

DBFN:0464

DATE:07/29/88

Space Transportation  
Systems Division



Rockwell  
International

Table 4.2.5-3. K-Loads (G4.1 First-Stage Guidance)

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

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Table 4.2.5-4. First-Stage Guidance (G4.1) Constants

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NROKRM.FSSR2.DATA(X21)BOOK2  
PFS CONSTANTS UPDATE B/L

FSSR NAME DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
RAD PER DEG DEGREE PER RADIAN CONVERSION	V97U0383C		.017453293	RAD/DEG	F	S	P			

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Table 4.2.5-5. AS 1STG GUID Input  
Variable Cross-Reference

MSID	Local Name	Source Name
V95L0151CE	V_RHO_MAG	REL_VEL_MAG
V95W0200CD	T_NAV	T_STATE
V95U0503C, 4C, 5C, 6C	Q_BR_M50	Q_M50TOBR
V95X1207X	S_É0_E1	ME1_FAIL_SHUTDOWN
V95X1208X	S_É0_E2	ME2_FAIL_SHUTDOWN
V95X1209X	S_É0_E3	ME3_FAIL_SHUTDOWN
	MM102	MM_CODE_102
V90X8156X	MM103	MM_CODE_103
V95H3521C	EBFB2	EBFB(2)

4.3 SECOND-STAGE REQUIREMENTS (MM 103)



### 4.3 SECOND-STAGE REQUIREMENTS (MM 103)

Principal function AS 2STG GUID (CPDS, Level B, Section 4.2). Execution of this principal function requires the general guidance and targeting tasks PFG-Input (Section 4.8.8), G-Limiting (Section 4.8.3), MPS Guidance Cutoff (Section 4.8.5), SSME-Out Safing (Section 4.8.9), Powered Explicit Guidance (Section 4.8.1), Acceleration-Mass Update (Section 4.8.2), Thrust Parameters (Section 4.8.7), and RTLS/TAL Target Selection (4.8.11).

The second-stage major mode begins at the separation command of the SRB's from the SRB/orbiter/external tank (ET) vehicle configuration and normally terminates after separation of the ET from the orbiter/ET configuration as either an automatic transition upon completion of the -Z translation maneuver (Event 35) or a crew-initiated transition (PRO) to the OMS-1 insertion MM 104 (Figure 4.3-1). The trajectory conditions at which ET separation occurs are chosen preflight to allow the ET to impact the earth on a free-fall trajectory while sufficient orbital propellant is provided to allow the OMS engines to insert the Shuttle into orbit. If an RTLS abort is initiated during this major mode, the second-stage MM (103) will be terminated, and transition to abort MM 601 will occur. If an ATO or TAL is selected, no transition occurs. In the event of two SSME failures,  $N_{SSME} < 2$  (a contingency abort), the ET low level sensor arm command will be issued by AS 2STG GUID.

The SSME's are used to boost the orbiter/ET vehicle along an ascending powered flight trajectory until the desired trajectory conditions (altitude, velocity, flight path angle, and orbital plane) are achieved. The SSME thrust is then terminated by the SSME OPS principal function using a desired cutoff time supplied by the ascent second-stage guidance principal function.

The second-stage major mode is characterized by two flight phases. The powered flight phase begins at SRB separation command (Event 28) and terminates at MECO confirmed (Event 33). The coasting flight phase begins at Event 33 and terminates at transition to MM 104 (Event 36).

The mission-shaping techniques used for abort-critical missions, those in which a gap would normally occur between latest RTLS capability and earliest AOA capability, may require that the AOA MECO target set and the SSME full power level be used until the abort gap is eliminated. From the RTLS/AOA mode boundary until MECO, the nominal mission MECO target set and the SSME rated power level are used, unless a transatlantic abort landing (TAL) has been selected. If a TAL is in progress, TAL targets override the nominal targets.

Prior to MECO, the thrust acceleration will normally reach 3 g's. The time at which this occurs is variable and depends upon thrust performance and vehicle weight. After a 3-g acceleration is achieved, the SSME's are throttled to maintain the average acceleration at 3 g's until a few seconds prior to MECO, at which time the SSME's will be throttled to minimum thrust for cut-off preparation.

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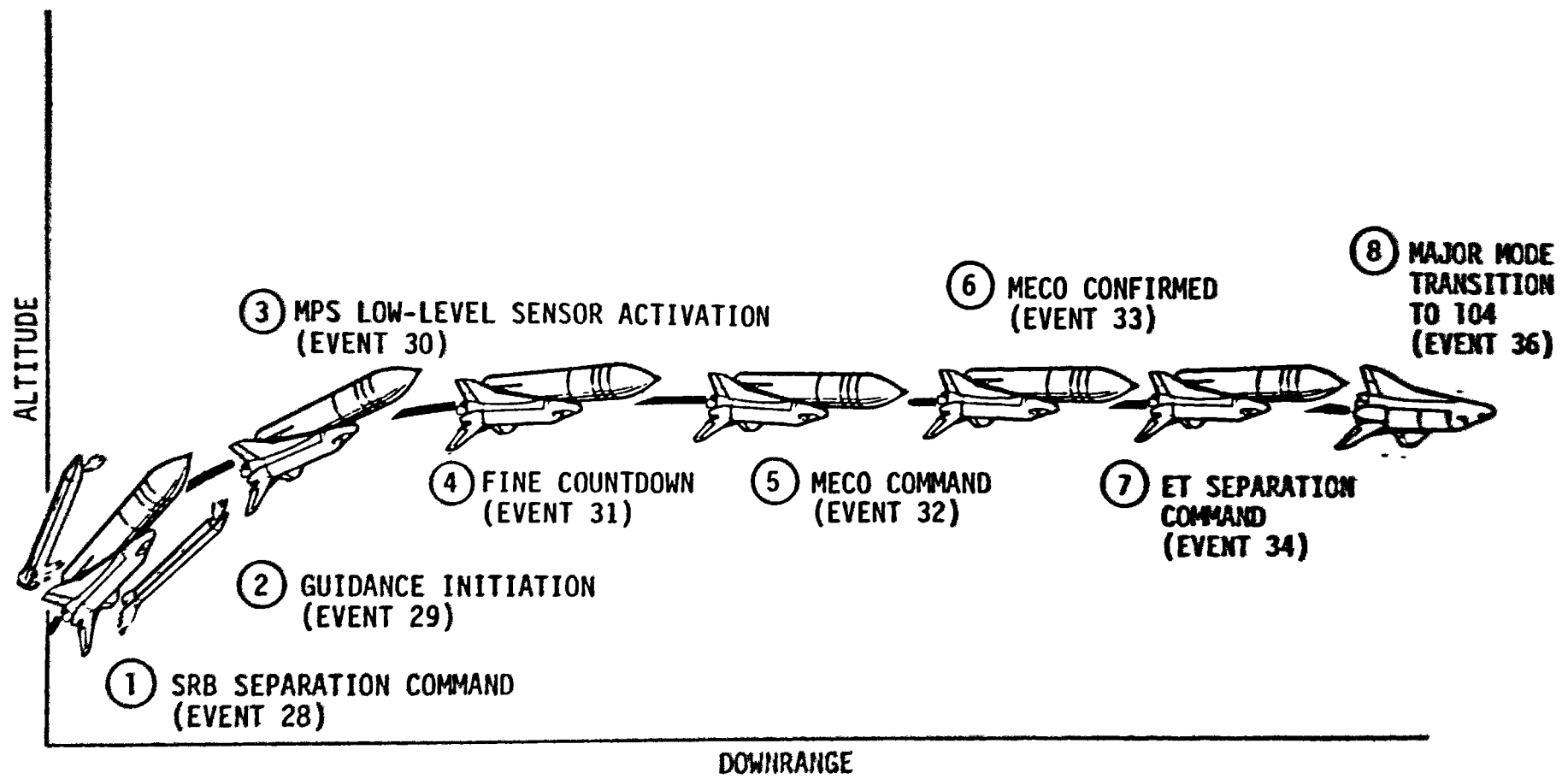


Figure 4.3 1. Typical Ascent Second Stage Sequence of Events

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During the second stage, an ATO may be initiated by the crew by setting the abort-mode rotary switch to the ATO position and pressing the ABORT pushbutton. These actions will cause the guidance to interrogate the AOA/ATO targeting logic, which may change the desired MECO targets to the appropriate abort MECO targets.

The ascent second-stage guidance principal function will be initiated at SRB separation command and will be terminated at MECO confirm (Event 33) or upon transition to RTLS second-stage MM 601. The tasks to be performed by the ascent second-stage guidance principal function are:

1. PFG input task (PFG INP TSK)
2. Acceleration-mass update task (ACC-MASS UPD TSK)
3. ET low-level sensor arm command task (ET LLS ARM TSK)
4. TVC retrim task (TVC RT TSK)
5. G-limiting task (G-LIM TSK)
6. SSME-out safing task (SSME-OUT SAF TSK)
7. Guidance parameter reinitialization task (GUID PRMT RINT TSK)
8. RTLS/TAL target selection task (RTLS/TAL TGT SEL TSK)
9. Second-stage ascent guidance task (ASC GUID TSK)
10. MPS guidance cutoff task (MPS GUID C/O TSK)
11. MECO time display task (T MECO DISP TSK)
12. MECO preparation task (MECO PREP TSK)

Figures 4.3-2, 4.3-3, and 4.3-4 illustrate the ascent second-stage guidance task organization, functional flow, and data flow for the MM 103. The principal function interfaces are given in Section 4.3.4.

During manual guidance, the G/C STEER principal function ignores automatic guidance inputs and accepts manual inputs. During manual throttling, the manual throttle command replaces the auto command and auto throttling is inhibited.

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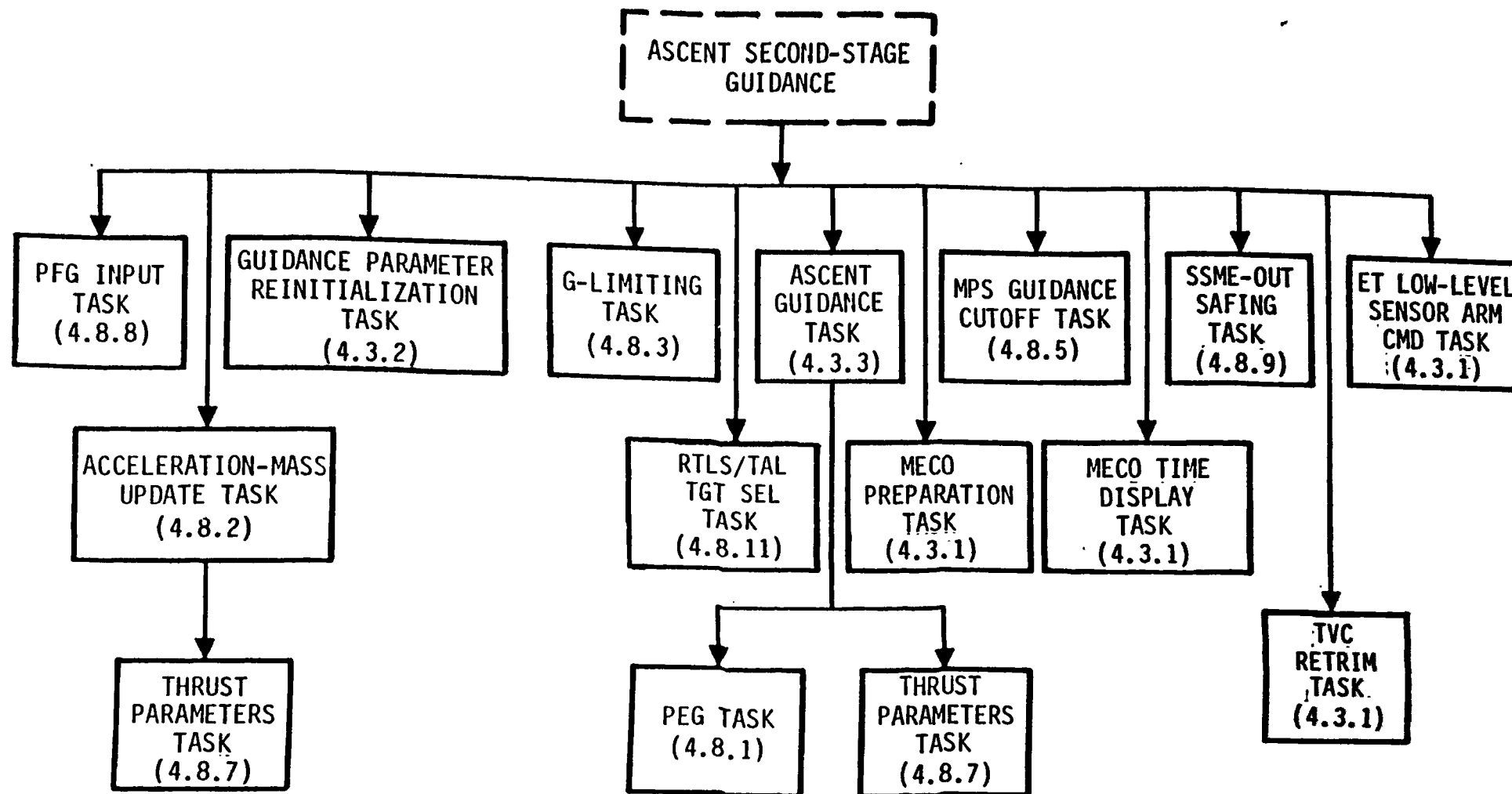
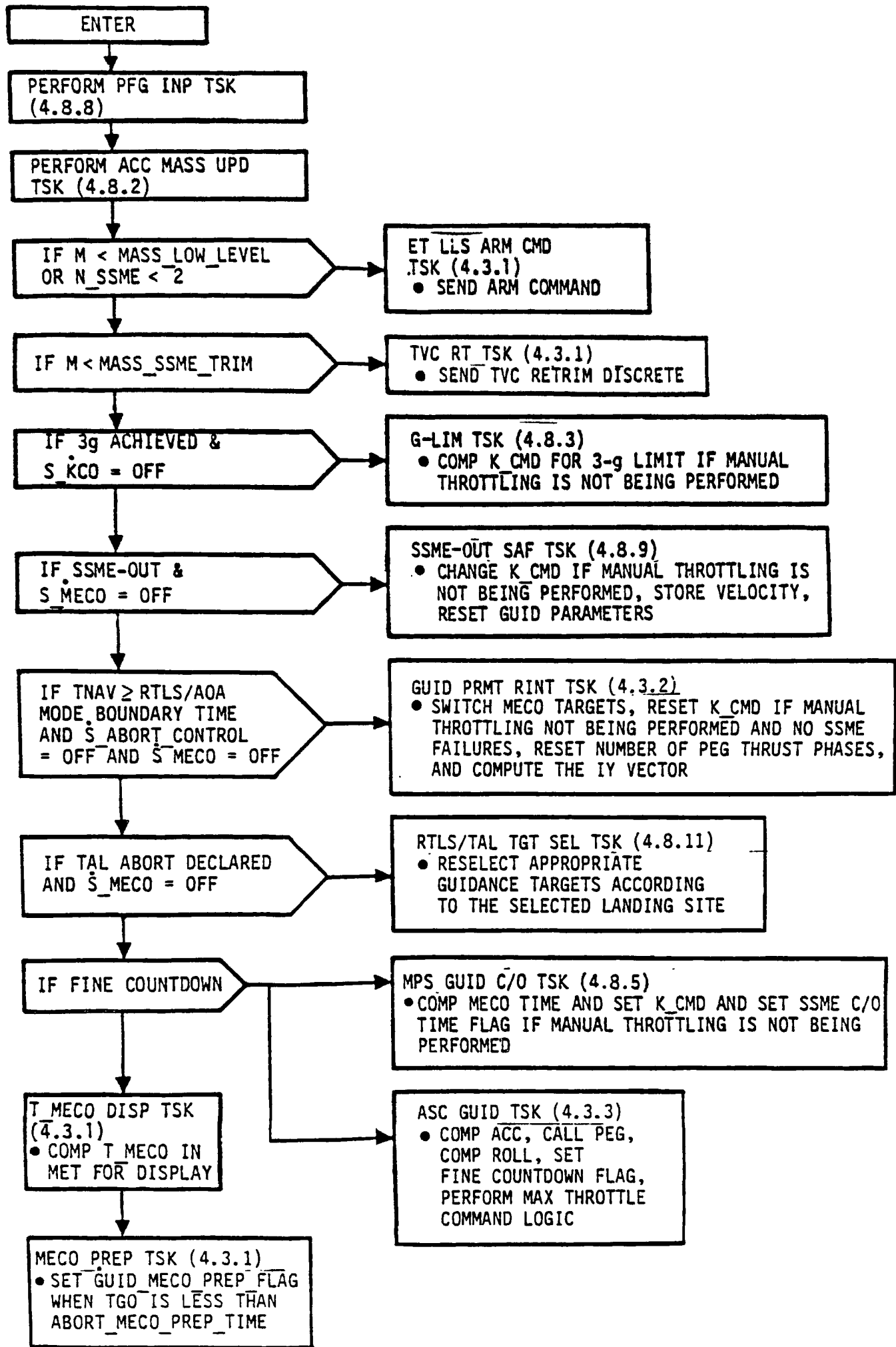


Figure 4.3-2. Ascent Second-Stage Guidance Principal Function Task Organization

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Figure 4.3-3. Ascent Second-Stage Guidance Functional Flow

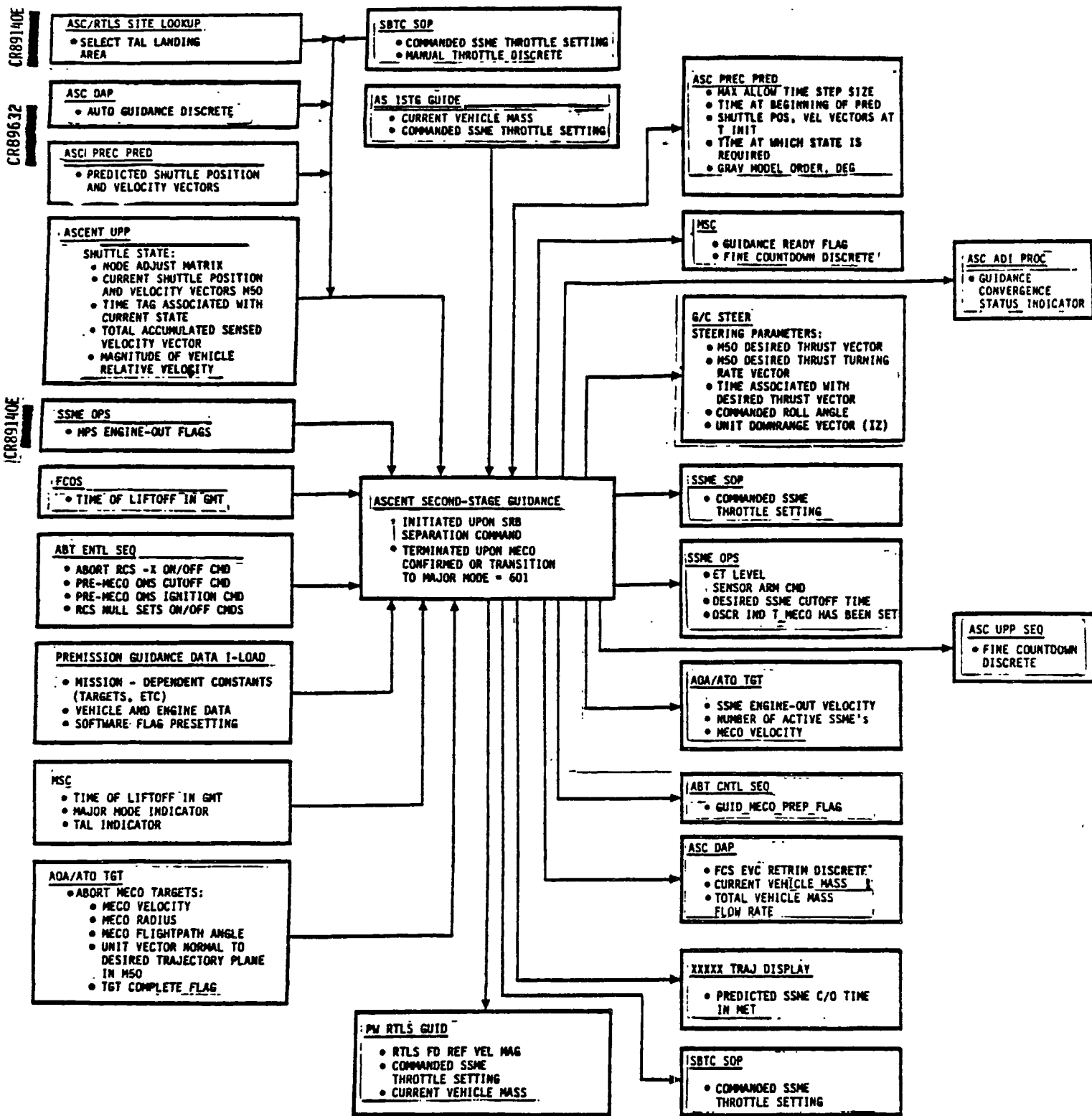


Figure 4.3-4. Ascent Second-Stage Guidance Principal Function (Major Mode 103) Data Flow

#### 4.3.1 Second-Stage Guidance Sequencing (2STG SEQ)

Several tasks that support the ascent second-stage guidance must be performed periodically, or on specific events identified in the CPDS, Level B GN&C, Volume V, Book 1. These tasks are as follows:

1. PFG input task (PFG INP TSK)
2. Acceleration-mass update task (ACC-MASS UPD TSK)
3. ET low-level sensor arm command task (ET LLS ARM TSK)
4. TVC retrim task (TVC RT TSK)
5. G-limiting task (G-LIM TSK)
6. SSME-out safing task (SSME-OUT SAF TSK)
7. Guidance parameters reinitialization task (GUID PRMT RINT TSK)
8. RTLS/TAL target selection task (RTLS/TAL TGT SEL TSK)
9. Ascent guidance task (ASC GUID TSK)
10. MPS guidance cutoff task (MPS GUID C/O TSK)
11. MECO time display task (T MECO DISP TSK)
12. MECO preparation task (MECO PREP TSK)

Task 1. The PFG input task must be performed repetitively from SRB separation command (Event 28) until the SSME cutoff confirmation (Event 33). The detailed requirements for this task are given in Section 4.8.8.

Task 2. The acceleration-mass update task must be performed repetitively from Event 28 until MECO confirmation (Event 33). The detailed requirements of this task are given in Section 4.8.2.

Task 3. The ET low-level sensor arm command task must be performed during the guidance cycle in which current mass (M) first becomes less than a premission load (MASS\_LOW\_LEVEL) or in the event of two SSME failures ( $N_{SSME} < 2$ ). The requirement of this task is to send the ET low-level sensor arm command (Event 30) to the SSME OPS.

Task 4. The TVC retrim task must be performed during the guidance cycle in which current mass (M) first becomes less than a premission load (MASS\_SSME\_TRIM), during second stage, or less than TAL MASS\_SSME\_TRIM during a TAL abort (TAL\_ABORT\_DECLARED = ON). The requirement of this task is to send the FCS TVC retrim discrete to the ASC DAP.

Task 5. The g-limiting task must be performed repetitively from Event 28 until the SSME's are commanded to K CO in preparation for MECO or to Event 33 during manual throttling. The detailed requirements for this task are given in Section 4.8.3.

Task 6. The SSME-out safing task must be performed during the first guidance cycle after an SSME-out occurs from Event 28 until the discrete S MECO is set to ON (Event 31). The detailed requirements for this task are given in Section 4.8.9.

Task 7. The guidance parameter reinitialization task must be performed between Event 28 and Event 31 when the following condition occurs:

During the guidance cycle in which the navigation time (T\_NAV) first becomes greater than or equal to the RTLS/AOA mode boundary time (T\_RTLS\_AOA + T\_GMTLO), if AOA/ATO targeting has not been executed (S\_ABORT\_CONTROL = OFF) and a TAL has not been selected (TAL\_ABORT\_DECLARED = OFF).

The detailed requirements of this task are given in Section 4.3.2.

Task 8. The RTLS/TAL target selection task must be performed on the first guidance pass after a TAL abort has been declared (TAL\_ABORT\_DECLARED = ON) and then repetitively until fine countdown (S\_MECO = ON). The detailed requirements of this task are given in Section 4.8.11.

Task 9. The ascent guidance task must be performed repetitively from Event 28 until Event 31. The detailed requirements of this task are given in Section 4.3.3.

Task 10. The MPS guidance cutoff task must be performed from Event 31 until the SSME cutoff time discrete (S\_TMECO) has been set (internal to this task) or to Event 33 during manual throttling. The detailed requirements for this task are given in Section 4.8.5.

Task 11. The MECO time display task must be performed repetitively from Event 28 until S\_TMECO has been set or to Event 33 during manual throttling. The detailed requirement for this task is to compute the predicted mission elapsed time of MECO as follows:

$$TMET\_MECO = T\_NAV + TGO - T\_GMTLO$$

Task 12. The MECO PREP TASK must be performed from Event 28 until the MECO preparation discrete (GUID\_MECO\_PREP\_FLAG) is set. The detailed requirement for this task is to set the discrete (GUID\_MECO\_PREP\_FLAG) when the time to MECO (TGO) is less than ABORT\_MECO\_PREP\_TIME.



The input and output parameters for second-stage guidance task sequencing are given in Tables 4.3.1-1 and 4.3.1-2.

The recommended execution rates for each task are given as follows:

- Task 1: 1.92 seconds from Event 28 until Event 31, 0.32 second from Event 31 until Event 33
- Task 2: 1.92 seconds from Event 28 until Event 31, 0.32 second from Event 31 until Event 33
- Task 3: One time only within 1.92 seconds of event
- Task 4: One time only within 1.92 seconds of event
- Task 5: 1.92 seconds from Event 28 until Event 31, 0.32 second from Event 31 until the SSME's are commanded to K\_CO or during manual throttling until Event 33
- Task 6: Each time within 1.92 seconds of event
- Task 7: One time only within 1.92 seconds of event
- Task 8: Every 1.92 seconds from first guidance pass after TAL abort has been declared until S\_ME $\dot{C}$ O is set ON
- Task 9: 1.92 seconds from Event 28 until Event 31
- Task 10: 0.32 second from Event 31 until S\_TM $\dot{E}$ CO is set or during manual throttling to Event 33
- Task 11: 1.92 seconds from Event 28 until Event 31, 0.32 second from Event 31 until S\_TM $\dot{E}$ CO is set or during manual throttling to Event 33
- Task 12: 1.92 seconds from Event 28 until GUID\_ME $\dot{C}$ O\_PREP\_FLAG is set

The execution of these tasks should occur in the order in which they are listed.



Table 4.3.1-1. Second-Stage Guidance Sequencing Inputs

Definition	Symbol	Source	Precision	Units
Number of active SSME's	N_SSME	PFG INP TSK	I	N/A
Fine countdown discrete	S_MECO	ASC GUID TSK	D	N/A
Time tag associated with current state	T_NAV	ASC UPF	DP	sec
Mission elapsed time defining RTLS/AOA mode boundary	T_RTLS_AOA	I-LOAD	SP	sec
Value of mass for enabling MPS low-level sensing	MASS_LOW_LEVEL	I-LOAD	SP	slugs
Current vehicle mass	M	ACC-MASS UPD TSK	SP	slugs
Value of mass for TVC retrim	MASS_SSME_TRIM	I-LOAD	SP	slugs
Time-to-go	TGO	PEG TSK, MPS GUID C/O TSK	SP	sec
Time of lift-off in GMT	T_GMTLO	FCOS	DP	sec
Discrete to indicate pre-MECO throttle-down complete	S_KCO	MPS GUID C/O TSK	D	ND
TGO for MECO preparation	ABORT_MECO_PREP_TIME	K-LOAD	SP	sec
Manual throttle discrete	S_MAN_THROT	SBTC SOP	D	N A
Discrete to indicate that pre-MECO_AOA/ATO targeting is completed	S_ABORT_CONTROL	AOA/ATO OMS/RCS PRE-MECO BRN DET TSK	D	N A
Discrete to indicate that a TAL abort is in progress	TAL_ABORT_DECLARED	MSC	D	N/A
TVC retrim mass for a TAL abort	TAL_MASS_SSME_TRIM	I-LOAD	SP	slugs
Discrete indicating T_MECO has been set	S_TMECO	MPS GUID C/O TSK	D	N/A





Table 4.3.1-2. Second-Stage Guidance Sequencing Outputs

Definition	Symbol	Destination	Precision	Units
ET level sensor arm CMD	S_LOW_LEVEL	SSME OPS, TLM	D	N/A
FCS TVC retrim discrete	S_SSME_TRIM	ASC DAP, TLM	D	N/A
Predicted SSME C/O time in MET	TMET_MECO	XXXXXX TRAJ, TLM	SP	sec
MECO preparation discrete	GUID_MECO PREP_FLAG	ABT CNTL SEQ	D	N/A



4.3.2 Second-Stage Guidance Parameter Reinitialization Task  
(GUID PRMT RINT TSK)

The subtasks to be performed for the guidance parameter reinitialization task are:

1. Reinitialize the MECO targets for the guidance calculations.
2. Reset the SSME throttle command.
3. Reset the number of PEG thrust phases for optimum nominal ascent guidance and reset the guidance phase counter.
4. Compute the unit vector normal to the desired trajectory plane for nominal second stage.

A. Detailed Requirements.

1. Replace the previous abort main engine cutoff targets with the actual mission MECO targets.

$$RDMAG = RD\_NOM$$

$$VDMAG = VD\_NOM$$

$$GAMD = GAMD\_NOM$$

2. Set the SSME throttle command to K\_CMD\_MODE\_BNDRY, provided that an SSME failure has not occurred previously (N\_SSME = 3) and manual throttling is not being performed (S\_MAN\_THROT = OFF).

$$K\_CMD = K\_CMD\_MODE\_BNDRY$$

3. Set the number of thrust phases in PEG to two: N = 2 and set the guidance phase counter to one: KPHASE = 1.

4. If the plane constraint is earth-fixed (EF\_PLANE\_SW = ON), compute the unit vector normal to the desired trajectory plane,  $\bar{I}Y$ , by converting  $\bar{I}YD\_NOM$  from earth-fixed to M50 coordinates.

$$\bar{I}Y = EARTH\_FIXED\_TO\_M50\_COORD(T\_GMTLO) \bar{I}YD\_NOM,$$

Otherwise, compute  $\bar{I}Y$  by rotating  $\bar{I}YD\_NOM$  to adjust for nodal regression.

$$\bar{I}Y = \overset{*}{M}\_NODE\_ADJ \bar{I}YD\_NOM$$

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1. Intersect  
 2. Inital  
 3. Process  
 4. Thrust  
 5. Subst  
 stage pu



B. Interface Requirements. The input and output parameters and functional interfaces for the guidance parameter reinitialization task are given in Tables 4.3.2-1 and 4.3.2-2.

C. Processing Requirements. None.

D. Initialization Requirements. Prior to the earliest time of AOA capability, guidance targets and throttle setting are specified by preflight load.

E. Supplemental Information. Prior to execution of this task (if manual throttling has not been performed), K CMD has the last value set in first-stage guidance, either THROT<sub>4</sub> (nominal) or KMAX (one SSME out).

Table 4.3.2-1. Second-Stage Guidance Parameter Reinitialization Task Inputs

Definition	Symbol	Source	Precision	Units
Nominal ascent terminal flightpath angle constraint	GAMD_NOM	I-LOAD	SP	rad
Nominal ascent terminal radial constraint	RD_NOM	I-LOAD	DP	ft
Desired inertial velocity magnitude at nominal MECO	VD_NOM	I-LOAD	SP	fps
Nominal SSME throttle setting after RTLS/AOA mode boundary	K_CMD_MODE_BNDRY	I-LOAD, 1STG GUID INP TSK, ASC GUID TSK	I	pct
Manual throttle discrete	S_MAN_THROT	SBTC SOP	D	N/A
Time of lift-off in GMT	T_GMTLO	FCOS	DP	sec
Nominal second-stage unit vector normal to desired trajectory plane in earth-fixed or M50 coordinates	IYD_NOM	I-LOAD	DP	ND
Earth-fixed plane switch	E $\hat{F}$ _PLANE_SW	I-LOAD	D	N/A
Node adjustment matrix	*M_NODE_ADJ	ASC UPP	DP	ND
Number of active SSME's	N_SSME	PFG INP TSK	I	N/A

Table 4.3.2-2. Second-Stage Guidance Parameter Reinitialization Task Outputs

Definition	Symbol	Destination	Precision	Units
Desired MECO flightpath angle	GAMD	PEG TSK	SP	rad
Desired MECO radius	RDMAG	PEG TSK	DP	ft
Desired MECO velocity	VDMAG	PEG TSK, MPS GUID C/O TSK, TLM, AOA ONORB TGT SEL TSK	SP	fps
Commanded SSME throttle setting	K_CMD	SSME SOP, THRST PRM TSK, MPS GUID C/O TSK, G-LIM TSK, SSME-OUT SAF TSK, TLM, SBTC SOP, PEG TSK, FUL DISS TSK.	I	pct
Unit vector normal to desired trajectory plane in M50 coordinates	$\bar{IY}$	PEG TSK, AOA ONORB TGT SEL TSK	DP	ND
Number of thrust phases	N	PEG TSK	I	ND
Guidance phase counter	KPHASE	PEG TSK	I	ND

#### 4.3.3 Second-Stage Ascent Guidance Task (ASC GUID TSK)

The following subtasks are necessary to support the ascent guidance calculations:

1. Obtain an estimate of acceleration and exhaust velocity.
2. Execute the powered explicit guidance (PEG) calculations and ensure convergence.
3. Command desired vehicle roll angle.
4. Set the fine countdown discrete (Event 31).

A. Detailed Requirements. On the cycle that the maximum throttle level command is activated ( $MAX\_THROT\_CMD = ON$ ), the following must occur:

- (1)  $KMAX = KMAX\_SECONDARY$
- (2)  $K\_CMD\_MODE\_BNDRY = KMAX\_SECONDARY$
- (3) In addition, if manual throttling is not being performed and g-limiting task is not being executed, then the following should be executed:

$$K\_CMD = KMAX\_SECONDARY$$

Estimates of acceleration and exhaust velocity are computed for use in the PEG calculations. The thrust parameters task (which was previously called by the acceleration-mass update task) is reexecuted to obtain estimates of thrust (FT) and exhaust velocity (VEX) based on the current throttle command (K\_CMD). Acceleration is then computed as follows:

$$ATR = FT\_FACTOR FT/M$$

The ascent guidance task must execute the PEG calculations (Section 4.8.1) until the PEG is either converged, or the number of cycles has reached the maximum allowed each guidance computation cycle. The convergence criterion is determined internal to the PEG task.

In addition, the ascent guidance task must specify the commanded roll angle input to G/C STEER. When the magnitude of vehicle relative velocity ( $V\_RHO\_MAG$ ) first exceeds  $V\_RHO\_PHI$  and  $TAL\_ABORT\_DECLARED = OFF$ , the commanded roll angle is set as

$$PHI\_CMD = PHI\_2STG$$

If  $TAL\_ABORT\_DECLARED = ON$  and  $V\_RHO\_MAG > V\_RHO\_TAL$ , then  $PHI\_CMD = 0$ .

The ascent guidance task must monitor time-to-go for the purpose of initiating the MPS guidance cutoff calculations before thrust termination. This shall be accomplished by comparing the time-to-go (TGO) computed by the PEG equations with an input (TGO\_FCD) for initiating the MPS guidance cutoff calculations. If manual guidance is active (AUTO = OFF), TGO is compared with a different I-load parameter (TGO\_MAN). Whenever TGO becomes less than or equal to TGO\_FCD or less than or equal to TGO\_MAN during manual guidance, a discrete (S\_MECO) is set that terminates the ascent guidance task and initiates the MPS guidance cutoff task, Event 31.

B. Interface Requirements. The input and output parameters for the ascent guidance task are given in Tables 4.3.3-1 and 4.3.3-2.

C. Processing Requirements. The thrust parameters task must be executed once in each guidance interval prior to executing PEG. The subtask to determine initiation of MPS guidance cutoff task should follow the execution of PEG.

D. Initialization Requirements. The following flags must be initialized as indicated:

SMODE = 1

S\_MECO = OFF, S\_GDRDY = OFF

SINIT = ON (PEG INITIALIZATION FLAG)

SSTEER = ON

Table 4.3.3-1. Second-Stage Ascent Guidance Task Inputs

Definition	Symbol	Source	Precision	Units
Maximum number of PEG iterations	N_MAX	I-LOAD	I	N/A
Discrete indicating convergence	S $\dot{C}$ ONV	PEG TSK	D	N/A
Time-to-go	TGO	PEG TSK	SP	sec
Value of TGO to initiate fine countdown for second stage	TGO_FCD	K-LOAD	SP	sec
Total vehicle thrust force	FT	THRST PRM TSK	SP	lbs
Thrust scaling factor	FT_FACTOR	ACC-MASS UPD TSK, SSME-OUT SAF TSK	SP	ND
Current vehicle MASS	M	ACC-MASS UPD TSK	SP	slugs
Commanded roll angle	PHI_CMD	I-LOAD	SP	rad
Desired roll command for second stage	PHI_2STG	I-LOAD	SP	rad
Magnitude of vehicle relative velocity	V_RHO_MAG	ASC UPP	SP	fps
Switch velocity for roll command	V_RHO_PHI	I-LOAD	SP	fps
Value of TGO to initiate fine countdown during manual guidance	TGO_MAN	I-LOAD	SP	sec
Auto guidance discrete	A $\dot{U}$ TO	ASC DAP	D	N/A
Maximum throttle level command	M $\dot{A}$ X_THROT_CMD	OVERRIDE DISPLAY	D	N/A
Secondary maximum throttle setting	KMAX_SECONDARY	I-LOAD	I	pct
G Limit discrete	S $\dot{G}$ LIMIT	G-LIM TSK	D	N/A
Manual throttle discrete	S $\dot{M}$ AN_THROT	SBTC SOP	D	N/A
Discrete to indicate that a TAL abort is in progress	T $\dot{A}$ L_ABORT_DECLARED	MSC	D	N/A
TAL switch velocity for roll command	V_RHO_TAL	I-LOAD	SP	ft/s





Table 4.3.3-2. Second-Stage Ascent Guidance Task Outputs

Definition	Symbol	Destination	Precision	Units
Fine countdown discrete (Event 31)	S_MECO	2STG SEQ, MSC, ASC UPP SEQ, ACC-MASS UPD TSK, TLM	D	N/A
PEG initialization discrete	S_INIT	PEG TSK	D	N/A
PEG maneuver mode flag	S_MODE	PEG TSK	I	N/A
Steering enable flag	S_STEER	PEG TSK	D	N/A
Thrust acceleration estimate input to PEG	ATR	PEG TSK	SP	fps <sup>2</sup>
Commanded roll angle	PHI_CMD	G/C STEER	SP	rad
Guidance ready flag	S_GDRDY	MSC, TLM	D	N/A
Maximum throttle setting for SSME	K_MAX	RTLS INIT TSK, PEG TSK, G-LIM TSK, SSME-OUT SAF TSK, SBTC SOP, PPD TSK	I	pct
Commanded SSME throttle setting	K_CMD	SSME SOP, THRST PRM TSK, FLYBK TSK, FUL DISS TSK, G-LIM TSK, SSME-OUT SAF TSK, SBTC SOP, PEG TSK	I	pct
Nominal SSME throttle setting after RTLS/AOA mode boundary	K_CMD MODE_BNDRY	GUID PRMT RINT TSK	I	pct

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#### 4.3.4 Parameter Tables for Second-Stage Guidance

The IDD inputs and outputs are listed in Table 4.3.4-1. Values for the I-loads are contained in the I-load requirements document (JSC-19350); however, I-load definitions applicable to this principal function are listed in Table 4.3.4-2. K-loads are listed in Table 4.3.4-3. Constants are listed in Table 4.3.4-4. The input variable cross-references are listed in Table 4.3.4-5.

Table 4.3.4-1. Ascent Second Stage Guidance (G4.2) Input/Output Functional Parameters

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DBFN: D2B039-A PN: VP707100026POOL MAY 31, 1988  
 INPUT FUNCTIONAL PARAMETERS FOR ASCENT SECOND STAGE GUIDANCE

ASC 2STG GUID OIBB REV00 G4.2 PAGE 323  
 BOOK: 2

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE
AREA SEL	V93J4392CB	SELECTED AREA	ASC SITE LOOKUP		
AUTO	V90X1710X	AUTO GUIDANCE MODE FLAG	ASC DAP		
GAMD	V90U8497C	DESIRED MECO FLIGHT PATH ANGLE	AOA/ATO TGT	RAD	BD
H_DOT_ELLIPSOID/H_DOT	V95L0265CE	EST-ALTITUDE RATE	ASC UPP	FT/S	
IY(X)	V90U1976CD	X-M50 UNIT VEC NORMAL TO ORB PLANE	AOA/ATO TGT		
IY(Y)	V90U1977CD	Y-M50 UNIT VEC NORMAL TO ORB PLANE	AOA/ATO TGT		
IY(Z)	V90U1978CD	Z-M50 UNIT VEC NORMAL TO ORB PLANE	AOA/ATO TGT		
IYD(X)	V97U4413CB	UNIT VEC NORM TRAJ PLANE X COMP	UL		
IYD(Y)	V97U4414CB	UNIT VEC NORM TRAJ PLANE Y COMP	UL		
IYD(Z)	V97U4415CB	UNIT VEC NORM TRAJ PLANE Z COMP	UL		
IYD NOM (1)	V96U9385C	X-EF/M50 UN VEC NORM TO ORB PLN	UL		
IYD NOM (2)	V96U9386C	Y-EF/M50 UN VEC NORM TO ORB PLN	UL		
IYD NOM (3)	V96U9387C	Z-EF/M50 UN VEC NORM TO ORB PLN	UL		
K_CMD	V90U1948CB	COMMANDED SSME THROTTLE SETTING	ASC 1STG GUID	PCT	
K_CMD	V90U1948CE	COMMANDED SSME THROTTLE SETTING	SBTC SOP	PCT	
K_CMD_MODE_BNDRY	V97U4420C	NOM SSME THROT SET-RTLS/ADA BNDRY	ASC 1STG GUID	PCT	
K_MAX	V97U4424CA	MAXIMUM THROTTLE SETTING OF SSME	ASC 1STG GUID	PCT	
M/CURR_ORB_MASS/WEIGHT	V90U1961CF	CURRENT VEHICLE MASS	ASC 1STG GUID	SLUGS	
M_NODE_ADJ	V95U0512C	NODAL ADJUSTMENT MATRIX	ASC UPP		
MAX_THROT_CMD	V93X5349X	MAXIMUM THROTTLE LEVEL COMMAND	6.47		
ME1_FAIL_SHUTDOWN	V95X1207X	MPS E1 FAIL FLAG	SSME OPS		BD
ME2_FAIL_SHUTDOWN	V95X1208X	MPS E2 FAIL FLAG	SSME OPS		BD
ME3_FAIL_SHUTDOWN	V95X1209X	MPS E3 FAIL FLAG	SSME OPS		BD
MM_CODE_103/MM_103	V90X8156X	MAJOR MODE 103 FLAG	MSC		
MM_CODE_104/MM_104	V90X8152X	MAJOR MODE 104 FLAG	MSC		
MM_CODE_105/MM_105	V90X8623X	MAJOR MODE 105 FLAG	MSC		
MM_CODE_601/MM_601	V90X8194X	MAJOR MODE 601 FLAG	MSC		
OPS_TRANS_REQUEST	V90X0892XB	OPS TRANSITION REQUEST FLAG	ASC PREC PRED		
R_AVGG(1)	V95H0185CB	X-COMP OF CURRENT SHUTTLE POS VCTR	ASC UPP	FT	DPL
R_AVGG(2)	V95H0186CB	Y-COMP OF CURRENT SHUTTLE POS VCTR	ASC UPP	FT	DPL
R_AVGG(3)	V95H0187CB	Z-COMP OF CURRENT SHUTTLE POS VCTR	ASC UPP	FT	DPL
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_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	
RDMAG	V90U8498C	DESIRED MECO RADIUS	AOA/ATO TGT	FT/S	
REL_VEL_MAG	V95L0151CE	GND REL VEL MAGNITUDE IN M50 SYS	ASC UPP		
S_ABORT_CONTROL	V90X8504X	TGT COMPLETE FLAG	AOA/ATO TGT		
S_AOA	V90X8636X	AOA ABORT DECLARED	MSC		
S_ATO	V90X8635X	ATO ABORT DECLARED	MSC		
S_MAN_THROT	V96X0006X	MANUAL THROTTLE DISCRETE	SBTC SOP		BD
S_OMS_CUTOFF	V90X8318XA	OMS CUTOFF CMD	ABT CNTL SEQ		
S_OMS_IGN	V90X8319X	ABORT OMS IGNITION CMD	ABT CNTL SEQ		
S_RCS_IGN	V90X8314X	ABORT RCS +X ON CMD	ABT CNTL SEQ		BD
S_RCS_NULL14	V90X8316X	14 RCS NULL JETS ON CMD	ABT CNTL SEQ		BD
S_RCS_NULL20	V90X8317X	20 RCS NULL JETS ON CMD	ABT CNTL SEQ		BD
S_RCS_NULL8	V90X8315X	8 RCS NULL JETS ON CMD	ABT CNTL SEQ		BD
T_GMTLO	V90W4380C	TIME OF LIFTOFF IN GMT	SCOS	S	
T_STATE	V95W0200CD	TIME TAG ASSOC WITH CURRENT STATE	ASC UPP	S	
TAL_ABORT_DECLARED	V90X8658X	TAL ABORT DECLARED	MSC		

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Table 4.3.4-1. Ascent Second Stage Guidance (G4.2) Input/Output Functional Parameters (Cont)

DBFN: D2B039-A PN: VP707100026P00L MAY 31, 1988  
 INPUT FUNCTIONAL PARAMETERS FOR ASCENT SECOND STAGE GUIDANCE

ASC 2STG GUID OI8B REV00

G4.2

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FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE
V_AVGG(1)	V95L0190CB	X-COMP OF CURRENT SHUTTLE VEL VCTR	ASC UPP	FT/S	SPL
V_AVGG(2)	V95L0191CB	Y-COMP OF CURRENT SHUTTLE VEL VCTR	ASC UPP	FT/S	SPL
V_AVGG(3)	V95L0192CB	Z-COMP OF CURRENT SHUTTLE VEL VCTR	ASC UPP	FT/S	SPL
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_IMU_OLD(1)	V95L0210CB	X-COMP OF CURRENT ACCUM IMU VEL	ASC UPP	FT/S	
V_IMU_OLD(2)	V95L0211CB	Y-COMP OF CURRENT ACCUM IMU VEL	ASC UPP	FT/S	
V_IMU_OLD(3)	V95L0212CB	Z-COMP OF CURRENT ACCUM IMU VEL	ASC UPP	FT/S	
VDMAG	V90U8499CB	DESIRED MECO VELOCITY	AOA/ATO TGT	FT/S	

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Table 4.3.4-1. Ascent Second Stage Guidance (G4.2)  
Input/Output Functional Parameters (Cont)

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DBFN: D2B039-A PN: VP707100026P00L  
OUTPUT FUNCTIONAL PARAMETERS FROM ASCENT SECOND STAGE GUIDANCE

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FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C
AD	V90A1973CA	DESIRED THRUST ACCELERATION	TLM			
DT MAX	V90U8500CA	MAX ALLOW TIME STEP SIZE	ASC PREC PRED	FT/S2		
FT FACTOR	V90U1979CA	THRUST SCALING FACTOR	TLM	S		
GMD PRED	V90U8501CA	GRAVITY MODEL DEGREE	ASC PREC PRED			
GMO PRED	V90U8502CA	GRAVITY MODEL ORDER	ASC PREC PRED			
GUID MECO_PREP_FLAG	V90X1989XA	MECO PREPARATION DISCRETE	ABT CNTL SEQ			
H_DOT_FD	V90R2098CB	RTL5 FUEL DISSP REF HDOT	PW RTL5 GUID	FT/S		
IY(X)	V90U1976CA	X-M50 UNIT VEC NORMAL TO ORB PLANE	AOA/ATO TGT,TLM			
IY(Y)	V90U1977CA	Y-M50 UNIT VEC NORMAL TO ORB PLANE	AOA/ATO TGT,TLM			
IY(Z)	V90U1978CA	Z-M50 UNIT VEC NORMAL TO ORB PLANE	AOA/ATO TGT,TLM			
IZ(X)	V90U2095CA	X-UNIT VECTOR TO LANDING SITE	G/C STEER			
IZ(Y)	V90U2096CA	Y-UNIT VECTOR TO LANDING SITE	G/C STEER			
IZ(Z)	V90U2097CA	Z-UNIT VECTOR TO LANDING SITE	G/C STEER			
K CMD	V90U1948CA	COMMANDED SSME THROTTLE SETTING	SSME SOP,PW RTL5 GUID,SBTC SOP, TLM	PCT		
K MAX	V97U4424CB	MAXIMUM THROTTLE SETTING OF SSME	SBTC SOP,PW RTL5 GUID	PCT		
LAMC(X)	V90U1954CA	X-COMP OF M50 REF THR VECTOR	G/C STEER,TLM			
LAMC(Y)	V90U1955CA	Y-COMP OF M50 REF THR VECTOR	G/C STEER,TLM			
LAMC(Z)	V90U1956CA	Z-COMP OF M50 REF THR VECTOR	G/C STEER,TLM			
LAMDC(X)	V90U1957CA	X-M50 DESIRED THR TRNING RATE VCTR	G/C STEER,TLM	RAD/S		
LAMDC(Y)	V90U1958CA	Y-M50 DESIRED THR TRNING RATE VCTR	G/C STEER,TLM	RAD/S		
LAMDC(Z)	V90U1959CA	Z-M50 DESIRED THR TRNING RATE VCTR	G/C STEER,TLM	RAD/S		
LAMDAG	V90U1968CA	MAGNITUDE OF LAMD	TLM	RAD/S		
LL	V90J2007CB	RTL5 FLIGHT PATH ANG TARGET INDEX	PW RTL5 GUID			
M/CURR_ORB_MASS/WEIGHT	V90U1961CG	CURRENT VEHICLE MASS	PW RTL5 GUID,ASC DAP,OMS RM,TLM	SLUGS		
MDOT	V90R1993CA	TOTAL VEHICLE MASS FLOW RATE	ASC DAP,TLM	SLUGS/S		
N OMS	V90J2031CA	NUMBER OF ACTIVE OMS ENGINES	TLM			
N RCS	V90J1974CA	NUMBER OF ACTIVE RCS ENGINES	TLM			
N RCS NULL	V90J1975CA	NUMBER OF ACTIVE RCS NULL ENGINES	TLM			
PHI CMD	V90H1969CA	COMMANDED ROLL ANGLE	G/C STEER	RAD		
R_INIT(X)	V90H8508CA	X-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT		
R_INIT(Y)	V90H8509CA	Y-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT		
R_INIT(Z)	V90H8510CA	Z-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT		
S_GDRDY	V90X1965XA	GUIDANCE READY FLAG	MSC,TLM			
S_LOW LEVEL	V90X1942XA	ET LEVEL SENSOR ARM CMD	SSME OPS,TLM			
S MECO	V90X1963XB	FINE COUNTDOWN DISCRETE	MSC,ASC UPP SEQ,TLM			
S SSME TRIM	V90X1960XA	FCS TVC RETRIM DISCRETE	ASC DAP,TLM			
S_TMECO	V90X1944XA	SSME C/O TIMING REQUEST FLAG	SSME OPS			
S_UNCONV	V90X2084XA	PEG UNCONVERGED DSCR IND	ASC ADI PROC			
SCONV	V90X1971XA	PEG CONVERGENCE DISCRETE	TLM			
T_FINAL	V90W8506CA	TIME AT WHICH STATE IS DESIRED	ASC PREC PRED	S		
T_INIT	V90W8512CA	TIME AT BEGINNING OF PRED	ASC PREC PRED	S		
T MECO	V90W1945CA	DESIRED SSME C/O TIME	SSME OPS	S		
TGD	V90W1994CB	GUIDANCE TIME TAG	TLM			
TGO	V90W1941CA	TIME TO GO TO ENGINE CUTOFF	TLM	S		
TLAMC	V90W1953CA	TIME ASSOC W REF THR VECTOR	G/C STEER,TLM	S		
TMET MECO	V90W1970CA	PREDICTED SSME C/O TIME IN MET	6.22,TLM			
TP	V90W1946CA	PREDICTED TIME OF THRUST C/O	TLM	S		
V_INIT(X)	V90L8513CA	X-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED	FT/S		
V_INIT(Y)	V90L8514CA	Y-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PRFC PRED	FT/S		
V_INIT(Z)	V90L8515CA	Z-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED	FT/S		
V_ME OUT	V90L1947CB	SSME ENGINE-OUT VELOCITY	AOA/ATO TGT,TLM	FT/S		

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Table 4.3.4-1. Ascent Second Stage Guidance (G4.2)  
Input/Output Functional Parameters (Cont)

DBFN: D2B039-A PN: VP707100026P00L MAY 31, 1988  
OUTPUT FUNCTIONAL PARAMETERS FROM ASCENT SECOND STAGE GUIDANCE

ASC 2STG GUID OIBB REV00 G4.2

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FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	REFERENCE
V RTLS_FD	V90U1967CB	RTLS FUEL DISSIPATION REF VEL MAG	PW RTLS GUID	FT/S		
VDMAG	V90U8499CA	DESIRED MECO VELOCITY	AOA/ATO TGT, TLM	FT/S		
VGOMAG	V90U1966CA	MAGNITUDE OF VGO VECTOR	TLM	FT/S		

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Table 4.3.4-2. Ascent Second Stage Guidance (G4.2) 1 Loads Ascent  
Second Stage Guidance

FSSR NAME	M/S ID	ENG UNIT	DT	PR	D	S	PR	PCTN	CAT
		FT/SEC**2	F	S	D	C	G4.2		2012

Table 4.3.4-2. Ascent Second Stage Guidance (G4.2) I-Loads Ascent  
Second Stage Guidance

OI88 MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
AD_INIT	V97U4306C	FT/SEC**2	F	S	D	C	G4.4 G4.2		ZF12
AL	V97U4307C	FT/SEC**2	F	S	D	C	G4.2 G4.4		ZF12
ALIM_1	V97U4308C	FT/SEC**2	F	S	D	C	G4.4 G4.2		ZF12
ALIM_2	V97U4309C	FT/SEC**2	F	S	D	C	G4.4 G4.2		ZF12
DT_TAILOFF(1)	V96U8335C	SEC	F	S	D	C	G4.2 G4.4		ZF12
DT_TAILOFF(2)	V96U8334C	SEC	F	S	D	C	G4.2 G4.4		ZF12
DTRD	V97U4371C	SEC	F	S	D	C	G4.2 G4.4		ZF12
EF_PLANE_SW	V99U7441C	ND	D		M	C	G4.2 G4.3 G4.19 G4.20 G4.226		A2N1
FT_FACTOR	V97U4389C	ND	F	S	D	C	G4.2 G4.4		ZF12
FT_OMS	V97U4390C	LBF	F	S	D	C	G4.210 G4.13 G4.4 G4.3 G4.2		ZF22
FT_RCS	V97U4391C	LBF	F	S	D	C	G4.2 G4.3 G4.210 G4.4		ZF22
FT_SSHE	V97U4392C	LBF	F	S	D	C	G4.2 G4.4		ZF12
GAMD	V97U4394C	RAD	F	S	M	C	G4.2		APSO
GAMD_NOM	V97U4396C	RAD	F	S	M	C	G4.2 G4.13		A2M1

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Table 4.3.4-2. Ascent Second Stage Guidance (G4.2) I-Loads Ascent  
Second Stage Guidance (Cont)

MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
IYD(1)		V97U4413C	ND	F	D	M	C	G4.226	A2M1	
								G4.226		
								G4.226		
								G4.19		
								G4.20		
								G4.210		
IYD(2)		V97U4414C	ND	F	D	M	C	G4.226	A2M1	
								G4.226		
								G4.226		
								G4.19		
								G4.20		
								G4.210		
IYD(3)		V97U4415C	ND	F	D	M	C	G4.226	A2M1	
								G4.226		
								G4.226		
								G4.19		
								G4.20		
								G4.210		
IYD NOM(1)		V96U9385C	ND	F	D	M	C	G4.2	A2M1	
IYD NOM(2)		V96U9386C	ND	F	D	M	C	G4.2	A2M1	
IYD NOM(3)		V96U9387C	ND	F	D	M	C	G4.2	A2M1	
K_CMD_MODE_BNDRY		V97U4420C	PCT	F	S	M	X	G4.1	A2P1	
								G4.2		
K_CO_MAX		V96U9261C	PCT	I	S	M	C	G4.2	A2P1	
KMAX		V97U4424C	PCT	I	S	M	C	G4.1	A2P1	
								G4.2		
								G4.4		
								G4.55		
KMAX_SECONDARY		V99U7107C	PCT	I	S	M	C	G4.1	A2P1	
								G4.2		
								G4.4		
KMIN		V97U4425C	PCT	I	S	D	C	G4.1	A2P1	
								G4.2		
								G4.4		
								G4.55		
KMISS		V97U4831C	ND	F	S	D	C	G4.209	ZF12	
								G4.2		
								G4.3		
								G4.4		
								G4.210		
								G4.211		

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Table 4.3.4-2. Ascent Second Stage Guidance (G4.2) I-Loads Ascent  
Second Stage Guidance (Cont)

MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	MASS_LOW_LEVEL	V97U4432C	SLUGS	F	S	M	C	G4.4 G4.2		AMC2
	MASS_MIN	V97U9004C	SLUGS	F	S	D	C	G4.2		ZF12
	MASS_SSME_TRIM	V97U4436C	SLUGS	F	S	M	C	G4.2 G4.4		AMC2
	MDOT_OMS	V97U4440C	SLUGS/SEC	F	S	D	C	G4.210 G4.13 G4.4 G4.3 G4.2		ZF22
	MDOT_SSME	V97U4442C	SLUGS/SEC	F	S	D	C	G4.1 G4.2 G4.4		ZF12
	N_MAX	V97U4445C	ND	I	S	D	P	G4.2 G4.3 G4.4 G4.209		ZF12
	NMAX_CYCLES_UNCONV	V96U7796C	ND	I	S	D	P	G4.2 G4.4		ZF12
	NSEG	V97U4447C	ND	I	S	D	P	G4.2 G4.3 G4.4 G4.209 G4.211		ZF12 ZF22
	PHI_CMD	V97U4481C	RAD	F	S	D	C	G4.2		ZF12
	PHI_2STG	V97U4482C	RAD	F	S	D	C	G4.2 G4.4		ZF12
	PHIDOT_MAX	V97U9003C	RAD/SEC	F	S	D	C	G4.3 G4.210 G4.2 G4.4		ZF12
	RD_NOM	V97U4645C	FT	F	D	M	C	G4.2 G4.13		A2M1
	RD MAG	V97U4647C	FT	F	D	M	C	G4.2		APSO
	RTLS_PRIME_AREA	V99U8961C	ND	I	S	M	C	G4.2 G4.4 G4.238		AAPO
	T_RTLS_AOA	V97U4661C	SEC	F	S	M	C	G4.2		APSO

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Table 4.3.4-2. Ascent Second Stage Guidance (G4.2) I-Loads Ascent  
Second Stage Guidance (Cont)

MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	TAL_MASS_SSME_TRIM	V99U7556C	SLUGS	F	S	M	C	G4.2		AMC2
	TAL_PRIME_AREA	V99U8962C	ND	I	S	M	C	G4.2 G4.4 G6.21		AAPO
	TARGET1(1)	V99U8901C	ND	I	S	M	C	G4.2 G4.4 G5.7		AA10
	TARGET1(2)	V99U8913C	ND	I	S	M	C	G4.2 G4.4 G5.7		AA20
	TARGET1(3)	V99U8925C	ND	I	S	M	C	G4.2 G4.4 G5.7		AA30
	TARGET1(4)	V99U8937C	ND	I	S	M	C	G4.2 G4.4 G5.7		AA40
	TARGET1(5)	V99U8949C	ND	I	S	M	C	G4.2 G4.4 G5.7		AA50
	TARGET10(1)	V99U8910C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET10(2)	V99U8922C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET10(3)	V99U8934C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET10(4)	V99U8946C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET10(5)	V99U8958C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET11(1)	V99U8911C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET11(2)	V99U8923C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET11(3)	V99U8935C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET11(4)	V99U8947C	ND	F	S	M	C	G4.2 G4.4		AA40

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Table 4.3.4-2. Ascent Second Stage Guidance (G4.2) I-Loads Ascent  
Second Stage Guidance (Cont)

MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	TARGET11(5)	V99U8959C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET12(1)	V99U8912C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET12(2)	V99U8924C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET12(3)	V99U8936C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET12(4)	V99U8948C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET12(5)	V99U8960C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET13(1)	V99U8963C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET13(2)	V99U8964C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET13(3)	V99U8965C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET13(4)	V99U8966C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET13(5)	V99U8967C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET2(1)	V99U8902C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET2(2)	V99U8914C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET2(3)	V99U8926C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET2(4)	V99U8938C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET2(5)	V99U8950C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET3(1)	V99U8903C	ND	F	S	M	C	G4.2 G4.4		AA10

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Table 4.3.4-2. Ascent Second Stage Guidance (G4.2) I-Loads Ascent  
Second Stage Guidance (Cont)

OIBB MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	TARGET3(2)	V99U8915C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET3(3)	V99U8927C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET3(4)	V99U8939C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET3(5)	V99U8951C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET4(1)	V99U8904C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET4(2)	V99U8916C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET4(3)	V99U8928C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET4(4)	V99U8940C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET4(5)	V99U8952C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET5(1)	V99U8905C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET5(2)	V99U8917C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET5(3)	V99U8929C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET5(4)	V99U8941C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET5(5)	V99U8953C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET6(1)	V99U8906C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET6(2)	V99U8918C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET6(3)	V99U8930C	ND	F	S	M	C	G4.2 G4.4		AA30

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Table 4.3.4-2. Ascent Second Stage Guidance (G4.2) I-Loads Ascent  
Second Stage Guidance (Cont)

Table 4.3.4-2. Ascent Second Stage Guidance (G4.2) I-Loads Ascent  
Second Stage Guidance (Cont)

MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	TARGET6(4)	V99U8942C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET6(5)	V99U8954C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET7(1)	V99U8907C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET7(2)	V99U8919C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET7(3)	V99U8931C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET7(4)	V99U8943C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET7(5)	V99U8955C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET8(1)	V99U8908C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET8(2)	V99U8920C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET8(3)	V99U8932C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET8(4)	V99U8944C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET8(5)	V99U8956C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET9(1)	V99U8909C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET9(2)	V99U8921C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET9(3)	V99U8933C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET9(4)	V99U8945C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET9(5)	V99U8957C	ND	F	S	M	C	G4.2 G4.4		AA50
	IFAIL	V96U9384C	SEC	F	S	M	C	G4.2		ZF12

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Table 4.3.4-2. Ascent Second Stage Guidance (G4.2) I-Loads Ascent  
Second Stage Guidance (Cont)

QI88 MISSIONS FSSR NAME	MSID	ENG UNIT	DT PR D S PR FCTN	CAT
TGO_MAN	V97U9002C	SEC	F S D P G4.2 G4.4	ZF12
V_RHO_PHI	V97U4823C	FT/SEC	F S D C G4.4 G4.2	ZF12
V_RHO_TAL	V97U9693C	FT/SEC	F S M C G4.2	ZF12
VO_NOM	V97U4827C	FT/SEC	F S M C G4.2 G4.13	A2M1
VDMAG	V97U4828C	FT/SEC	F S M C G4.2	APSO

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2STG Guidance (G4.2) K-Loads Ascent  
Guidance

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Table 4.3.4-3. Ascent 2STG Guidance (G4.2) K-Loads Ascent  
Second Stage Guidance

0188 MISSIONS FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT PR S PR FCTN	LAST CR EQTN MSID
ABORT_MECO_PREP_TIME	V98U7961C	01 +1.0	E+01 SEC	F S C G4.2 G4.4	59955
DT_FCD	V97U4347C	+3.200	E-01 SEC	F S C G4.4 G4.2	89541
DT MIN K DES TIME MIN THRUST LEVEL	V97U4350C	+6.871	E+00 SEC	F S C G4.2	59955
DTMAX	V97U4369C	+1.00	E+20 SEC	F S C G4.209 G4.13 G4.4 G4.3 G4.2	89541
MAX STEP SIZE, ASC PREC PRED DTMIN	V97U4370C	01 +2.0 02 +3.00 03 +2.0	E+00 SEC E+02 E+00	F S C G4.211 G4.210 G4.209 G4.158 G4.13 G4.4 G4.3 G4.2	29975A
EPS-X CRIT REJ THRUST SCALING FACTOR	V97U4380C	+2.0	E-02 ND	F S C G4.2 G4.4	59955
EPSTGO	V97U4381C	+4.0	E-02 ND	F S C G4.2 G4.3 G4.4 G4.210	59955
PEG INHIBIT STEERING OUTPUT ETB	V97U4382C	+5.0000000	E+00 SEC	F S C G4.2 G4.4	59955
MIN TBN-1 COMPUTATION OF TGO FTF_MIN	V97U4838C	+6.5	E-01 ND	F S C G4.2 G4.4	29602A
K_INT G-LIMITING INTEGRAL GAIN	V97U4418C	+1.0	E-02 SEC**-2	F S C G4.4 G4.2	59955
K_PROP PROPORTIONAL GAIN	V97U4419C	+1.5	E-01 SEC**-1	F S C G4.4 G4.2	59955

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Table 4.3.4-3. Ascent 2STG Guidance (G4.2) K-Loads Ascent  
Second Stage Guidance (Cont)

GI&B MISSIONS	MSID	HC KLOAD VALUE	ENG UNIT	DT PR S PR FCTN	LAST CR EQTN MSID
FSSR NAME DESCRIPTION					
KDOT MAX THROTTLE CHG RATE	V97U4422C	+1.0000000	E+01 PCT/SEC	F S C G4.2	89541
MDOT_RCS	V97U4441C	+1.0655714	E-01 SLUGS/SEC	F S C G4.210 G4.2 G4.13 G4.4 G4.3	89661A
NOMINAL RCS MASS FLOW RATE					
RHOMAG SCAL DAMP FAC VMISS TO CORR VGO	V97U4650C	+1.0000000	E+00 ND	F S C G4.2	89541
TGO_FCD TGO INITIATE FINE COUNTDOWN	V97U4663C	+1.0000000	E+01 SEC	F S C G4.2	59955
TLAG THROTTLE LAG TIME	V97U4834C	+5.0000000	E-01 SEC	F S C G4.2 G4.4	59955

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Table 4.3.4-4. Second-Stage Guidance (G4.2) Constants

NROKRMM.FSSR2.DATA(X22)BOOK2  
PFS CONSTANTS UPDATE B/L

FSSR NAME DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
EARTH MU EARTH'S GRAVITATIONAL CONSTANT	V97U4378C		1.40764487566 E+16	FT**3/ SEC**2	F	D	P			
MUP TH MINIMUM CHANGE IN MASS REQUIRED FOR MASS TO BE UPDATED			.3	SLUGS	F	S	P			

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Table 4.3.4-5. AS 2STG GUID Input Variable Cross-Reference

MSID	Local Name	Source Name
V95L0151CE	V_RHO_MAG	REL_VEL_MAG
V95H0185CB, 6CB, 7CB	$\bar{R}_{NAV}$	$\bar{R}_{AVGG}$
V95L0190CB, 1CB, 2CB	$\bar{V}_{NAV}$	$\bar{V}_{AVGG}$
V95W0200CD	T_NAV	T_STATE
V95L0210CB, 1CB, 2CB	$\bar{V}_S$	$\bar{V}_{IMU\_OLD}$
V95X1207X	S_ÉO_E1	ME1_FAIL_SHUTDOWN
V95X1208X	S_ÉO_E2	ME2_FAIL_SHUTDOWN
V95X1209X	S_ÉO_E3	ME3_FAIL_SHUTDOWN
V90X8156X	MM103	MM_CODE_103
V90X8152X	MM104	MM_CODE_104
V90X8623X	MM105	MM_CODE_105
V90X8194X	MM601	MM_CODE_601

4.4 ORBIT INSERTION REQUIREMENTS (MM's 104 AND 105)

#### 4.4 ORBIT INSERTION REQUIREMENTS (MM's 104 AND 105)

Principal function ORB INS GUID (CPDS, Level B, Section 4.3). Execution of this principal function requires the general guidance and targeting tasks: PFG Input (Section 4.8.8), Acceleration-Mass Update (Section 4.8.2), Powered Explicit Guidance (Section 4.8.1), Linear Terminal Velocity Constraint (Section 4.8.4), Thrust Parameters (Section 4.8.7), and Commanded Body Attitude Task (Section 4.8.10).

##### 4.4.1 Overview

The orbit insertion guidance principal function supplies the guidance and related support requirements for the post-MECO MM's 104 and 105. The powered maneuvers during these major modes will be performed with the OMS engines or the four +X acceleration translational RCS jets. The crew will have the capability to select the thrust system for the maneuver, change guidance targets, delay the maneuver, etc., via the XXXXX MNVR YYYYY display. Since the requirements of this section are interrelated with the requirements of the ascent maneuver display processing (AS MNVR DIP) principal function, a complete understanding is difficult without first reading the AS MNVR DIP section (4.7). It is recommended that the reader refer to Section 4.7 prior to reading the following guidance requirements section.

The guidance requirements discussed in the following two subsections (4.4.1.1 and 4.4.1.2) span MM's 104 and 105 and support nominal OMS-1/OMS-2 maneuvers, ATO OMS-1/OMS-2 maneuvers, and the AOA OMS-1 maneuver. The AOA OMS-2 maneuver is supported by OPS-3 guidance requirements and will not be discussed in this FSSR document. The guidance requirements do not change as a function of the major mode; however, conditions for entry into the major mode change. Each major mode, therefore, will be discussed independently; the guidance requirements section will follow and will apply to both major modes.

A general overview of the ORB INS GUID principal function task requirements, sequence of events, and related data requirements is discussed in Subsection 4.4.1.3.

4.4.1.1 MM 104. After the SSME burn has been completed (MECO), a short coast period (approximately 18 seconds) follows until the external tank separation command is issued. The first OMS burn (OMS-1) begins at a fixed interval of time from the separation command (this interval is approximately 102 seconds). The purpose of the OMS-1 burn is to raise the orbiter energy to a premission selected apogee altitude. Normally, this burn will be performed with the OMS engines to the premission selected targets which are I-loaded. The apogee direction is constrained during the burn to lie in the target orbit plane. However, for abort burns (both AOA and ATO), the target lies in the current orbit plane. The burn in either case (plane constrained or unconstrained) is near fuel optimal leading to a thrust direction very nearly along the current inertial velocity vector. In the event of a single OMS engine failure (if the burn was initiated with the two OMS engines), the guidance will automatically transition across the failure (given knowledge by the OMS RM of the failure) and will complete the burn with the remaining OMS engine.



Additionally, if the remaining OMS engine (or selected single OMS) fails, then guidance will continue to solve the guidance equations by assuming the thrust level of the 4 +X RCS jets. In the event of a propulsion system failure, the guidance targets remain unchanged throughout the burn.

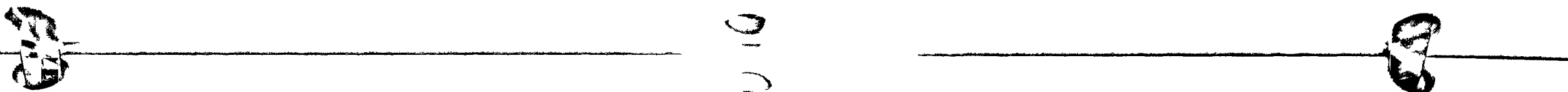
However, as has been stated, the parameters of the OMS-1 burn may be a crew input. Optionally, the crew may choose to alter the guidance targets or the propulsion system configuration. There are other inputs that can be altered, but these two are of primary importance to the guidance function. A general discussion of the handling of these inputs will follow.

The crewman can enter a set of guidance targets in the form of an altitude and range angle relative to the launch site. It should be noted that these targets are not true targets, but are biased to compensate for the non-Keplerian force effects on the orbit. A set of external  $\Delta V$  targets ( $\Delta V_X$ ,  $\Delta V_Y$ ,  $\Delta V_Z$ ) also can be entered. The guidance mode switch will automatically be set by the AS MNVR DIP to be consistent with the most recent target values entered from the display or initialized by I-load or uplink. While this option is available, it is not the planned mode for performing the burn (the external  $\Delta V$  mode is not closed-loop and would produce target misses in the event of propulsion system failures). The orbit insertion guidance principal function will accept either set of inputs if the PEG mode switch is set properly and will complete the automatic burn sequence. It should be noted, when reading the orbit insertion guidance principal function requirements, that an action based upon the guidance mode switch is not necessary at this requirements level. The action based upon the guidance mode switch is necessary only at the PEG level where routing changes are made.

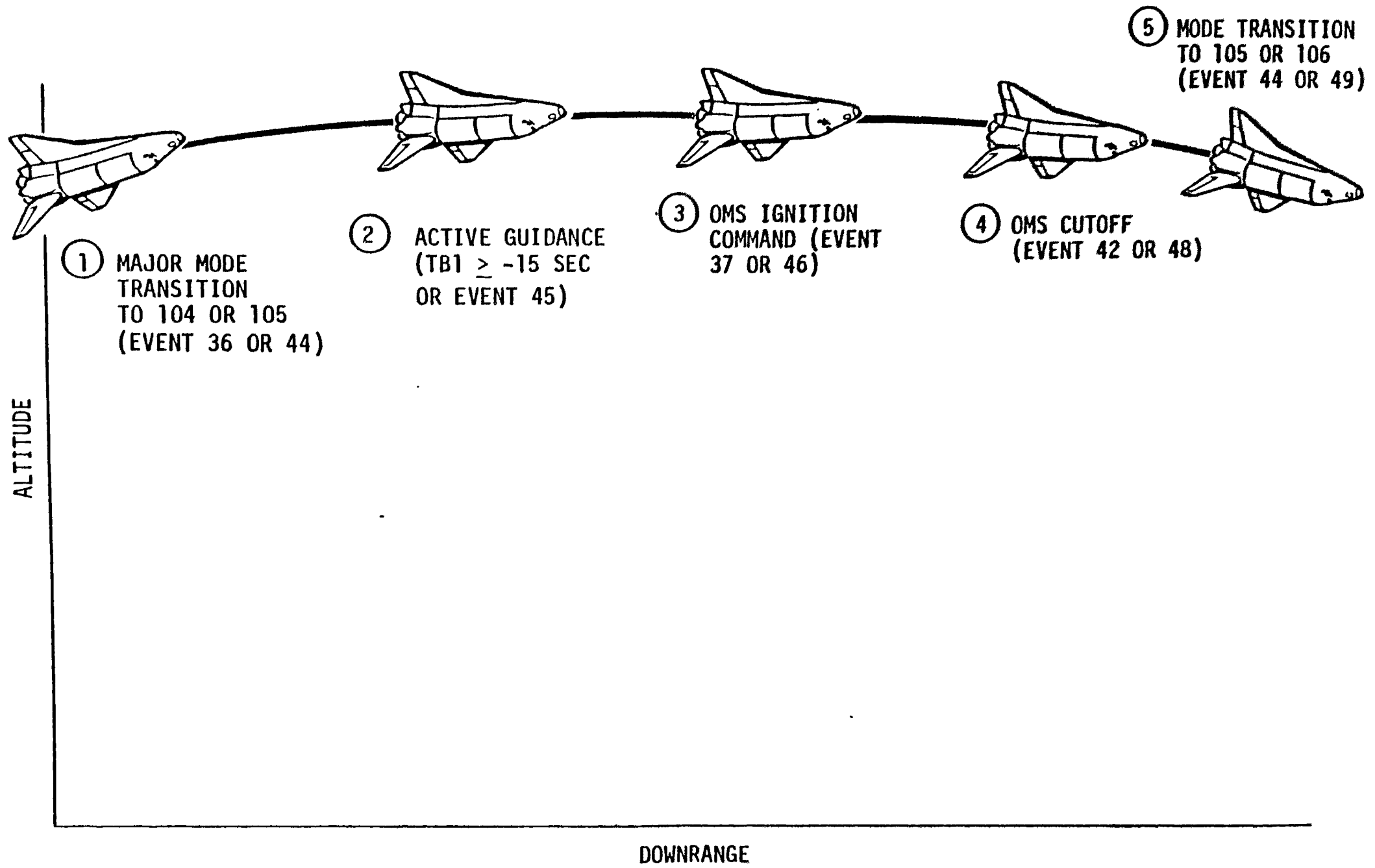
The engine configuration is also selectable by the crewman. The nominal engine configuration for both OMS-1 and OMS-2 would be two OMS engines, but right OMS, left OMS, both OMS, or 4 +X translational RCS jets can be selected. Once the desired configuration is selected, the AS MNVR DIP sets the number of OMS engines or 4 +X RCS jets for input to orbit insertion guidance. The selected engine configuration will be used to converge guidance throughout the burn unless a failure occurs. If the 4 +X translation RCS jets are selected for the maneuver, guidance will perform essentially the same function as performed for the OMS maneuver with one exception. Guidance does not provide an automatic cutoff flag for the RCS engines. It is assumed that the crewman performs cutoff manually from display information.

For a complete discussion of the crewman input capability and its effect upon the guidance principal function, the reader should refer to Section 4.7.

MM 104 begins (Event 36) upon completion of the ET separation burn (-Z translation) or upon an OPS 104 PRO (Figure 4.4-1). (See CPDS, Level B, GN&C, Vol. 5, Book 1.) When the major mode transition occurs, the XXXXX MNVR YYYYYY display is forced onto the CRT and AS MNVR DIP begins to perform pre-thrust calculations. The OMS-1 planned time of ignition (TIG) is calculated by the AS MNVR DIP referenced to the actual ET separation time. For OMS-1 AOA maneuvers which require RCS ullage, the planned OMS ignition is delayed 15 seconds and the RCS ullage is initiated at the regular planned OMS ignition.



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Figure 4.4-1. Typical OMS-1 and OMS-2 Sequence of Events

This TIG delay activity is the responsibility of the Abort Sequencing Principal Function and the MSC. Its delay has no effect on guidance function activities except that the displayed OMS TIG and the actual OMS TIG will be different by 15 seconds.

CR89632 The vehicle is aligned to the prethrust determined attitude and orbit insertion guidance becomes active at the planned time of ignition (Event 37) minus 15 seconds. The MSC sets the Time Base 1 (TB1), and when TB1 becomes zero, if certain criteria from the AS MNVR DIP (i.e., maneuver proceed) have been met, then OMS ignition will be initiated (Event 37) by the software if the crewman has set the proper hardware configuration. The orbit insertion guidance spans the time interval from TIG-15 seconds to the major mode transition (Event 44). The guidance transitions smoothly from the pre-ignition to post-ignition phases.

4.4.1.2 MM 105. The OMS-2 burn is again an energy-raising burn. The burn normally occurs near the apogee of the orbit established by the OMS-1 burn. Normally the purpose of the burn is to circularize the orbit. All burn requirements and constraints are the same as OMS-1.

CR89632 The orbit insertion guidance becomes active at the planned time of ignition minus 15 seconds (Event 45). The OMS-2 insertion major mode begins upon an OPS 105 PRO (Event 44). The occurrence of a zero Time Base 2 initiates the OMS-2 ignition sequence (Event 46). OMS cutoff (Event 48) and transition to MM 106 (Event 49) are similar to the MM 104 events (Figure 4.4-1).

4.4.1.3 Orbit Insertion Guidance Tasks and Time Line. The orbit insertion guidance principal function is composed of the following tasks for both MM's 104 and 105:

- CR89632
1. PFG input task (PFG INP TSK)
  2. Acceleration-mass update task (ACC-MASS UPD TSK)
  3. Thrust parameters task (THRST PRM TSK)
  4. OMS guidance task (OMS GUID TSK)
  5. Powered explicit guidance task (PEG TSK)
  6. Linear terminal velocity constraint task (LTVCON TSK)
  7. Commanded body attitude task (CMD BDY ATT TSK)

A typical time line of guidance-related events for either major mode is as follows:

1. AS MNVR DIP load solution
2. Maneuver to burn attitude.

3. Guidance calculations are initiated.
4. Engine ignition occurs and the transition DAP begins removing the attitude errors, using the guidance commands.
5. If an OMS engine failure occurs, guidance updates input parameters to achieve the same target.
6. Time of engine cutoff is computed for the OMS/RCS maneuver.
7. Engine cutoff occurs.
8. Velocity residuals are trimmed.
9. The current major mode is exited by crew action.

Figures 4.4-2, 4.4-3, and 4.4-4 illustrate the orbit insertion guidance task organization, functional flow, and data flow for MM's 104 and 105. The principal function interfaces are given in Section 4.4.4.



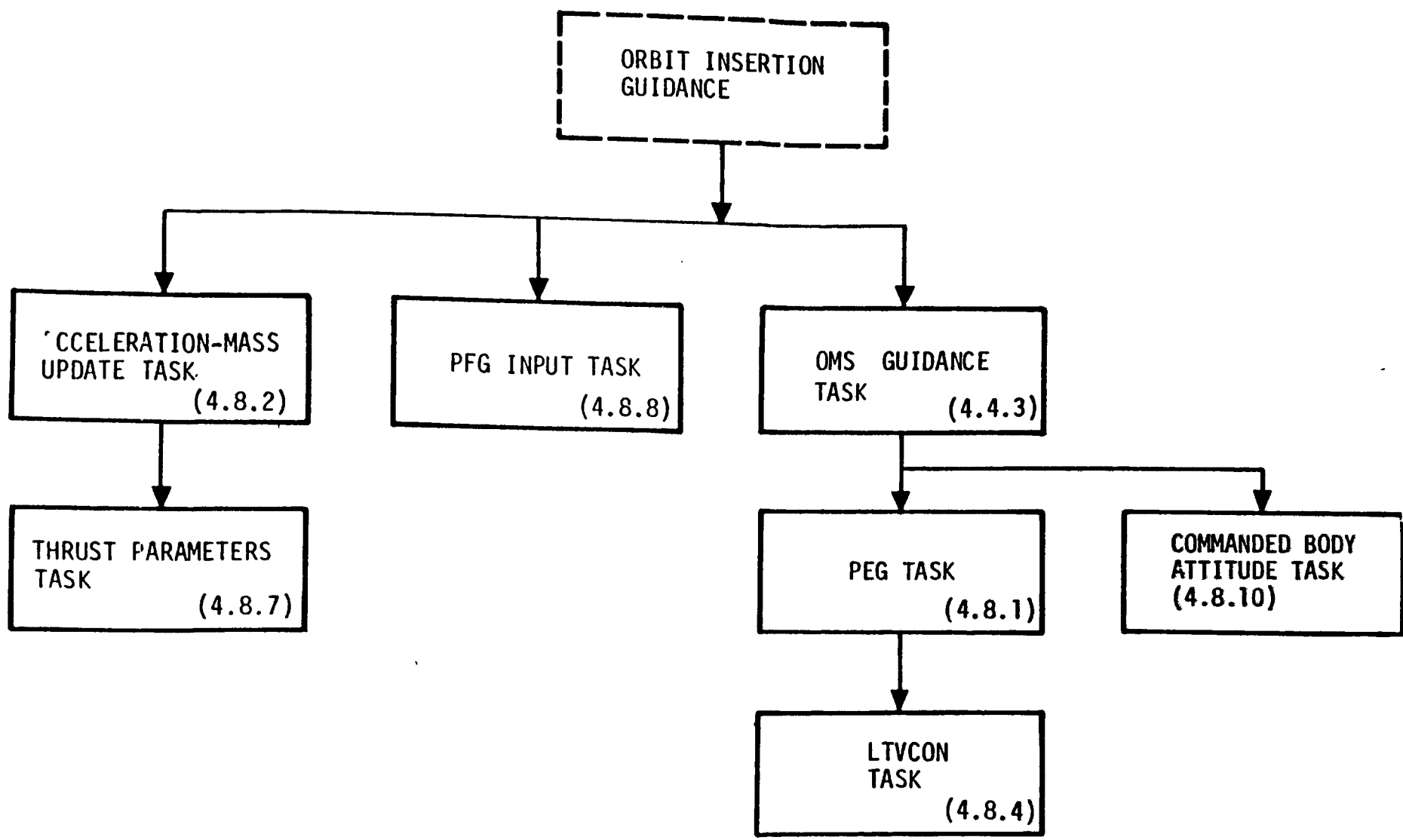


Figure 4.4-2. Orbit Insertion Guidance Principal Function Task Organization

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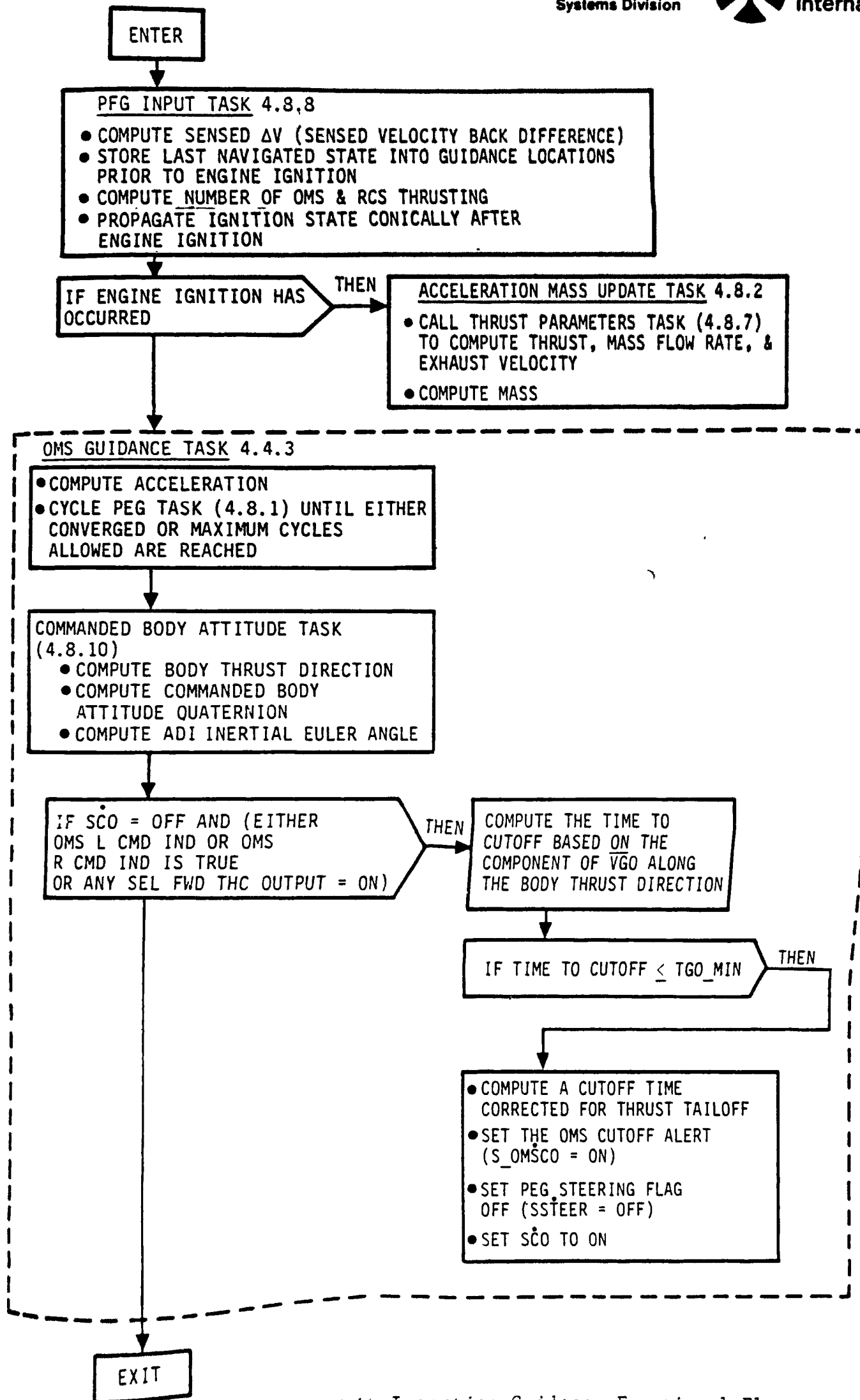


Figure 4.4-3. Orbit Insertion Guidance Functional Flow

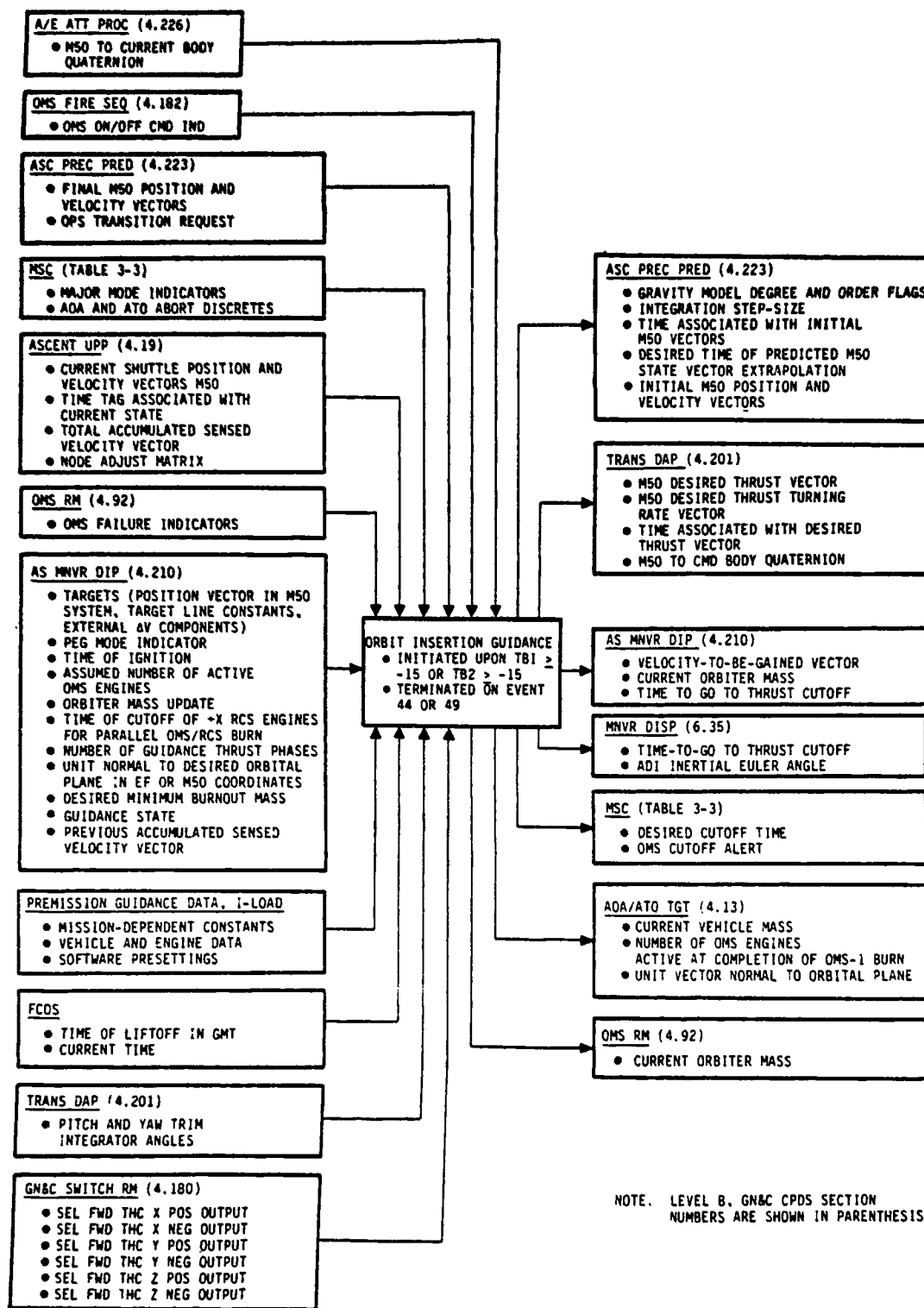


Figure 4.4-4. Orbit Insertion Guidance Data Flow

#### 4.4.2 Orbit Insertion Sequencing (ORB INS SEQ)

Several tasks that support the orbit insertion guidance principal function are initiated and terminated on specific events. (These events are identified in the CPDS, GN&C, Level B, Vol. 5, Book 1.) These tasks are:

1. PFG input task (PFG INP TSK)
2. Acceleration-mass update task (ACC-MASS UPD TSK)
3. OMS guidance task (OMS GUID TSK)

If an abort (AOA or ATO) is declared or "LOAD" becomes a dynamic flashing character set (LOAD\_FLASH = ON), subsequent to guidance initiation and prior to engine ignition authorization (BURN\_ENABLE = ON), then guidance must be terminated.

The orbit insertion guidance tasks must be sequenced in the following order:

1. The PFG input task (see Section 4.8.8) is performed repetitively every 0.96 second from the time that cyclic guidance is initiated until the major mode termination point (Event 44 or 49).
2. The acceleration-mass update task (see Section 4.8.2) is performed repetitively every 0.96 second from TIG until the major mode termination point (Event 44 or 49).
3. The OMS guidance task is performed repetitively every 0.96 second from TIG minus 15 seconds until the major mode termination point (Event 44 or 49).

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#### 4.4.3 OMS Guidance Task (OMS GUID TSK)

The OMS guidance task performs the following activities:

- Computes an estimated thrust acceleration (ATR) for PEG.
- Calls PEG to compute reference thrust orientation parameters and time-to-go (TGO) until engine cutoff.
- Calls CMD BDY ATT TSK to compute the M50 to commanded body attitude quaternion.
- Computes the engine cutoff time (T\_CUTOFF) and alerts the MSC to establish an engine cutoff timebase.

#### A. Detailed Requirements.

1. An estimate of the thrust acceleration is computed for PEG.

$$ATR = FT/M$$

2. The PEG task (PEG TSK, Section 4.8.1) is performed repetitively until PEG is either converged (SCONV=ON) or has been executed a maximum number (NMAX) of times. If PEG is executed NMAX times without obtaining convergence, the OMS GUID TSK is exited.
3. Set the time to compute the commanded body attitude quaternion (Q\_CB\_M50) equal to current time (T\_CA = T\_GMT) and perform the commanded body attitude task (CMD BDY ATT TSK, Section 4.8.10).
4. The following computations are executed if OMS  $\bar{L}$  ON\_CMD\_IND is ON or OMS  $\bar{R}$  ON\_CMD\_IND is ON or any SEL FWD THC (e.g.,  $\bar{THC\_NEG\_X\_CMD}$ ) output is ON and the cutoff flag (SCO) is OFF:
  - a. Compute the time to cutoff (TGO\_CUTOFF) by first transforming the thrust body vector computed in the commanded body attitude task from body to M50 coordinates using the  $\bar{Q\_B\_I}$  quaternion. TGO\_CUTOFF is then computed using the component of  $\bar{VGO}$  along this M50 thrust direction, TGO, and the magnitude of  $\bar{VGO}$ .

CALL QUAT\_XFORM

Inputs:  $-\bar{Q\_B\_I\_S}$ ,  $\bar{Q\_B\_I\_V}$ ,  $\bar{THRUST\_BODY}$

Outputs:  $\bar{THRUST\_M50}$

$$TGO\_CUTOFF = TGO (\bar{THRUST\_M50} \cdot \bar{VGO}) / ABVAL(\bar{VGO})$$

- b. If the time to cutoff (TGO\_CUTOFF) is less than or equal to TGO\_MIN, then a cutoff time corrected for thrust tailoff is computed, the OMS cutoff alert is set, the PEG steering flag is turned off, and the cutoff flag is set.



IF  $TCO\_CUTOFF \leq TCO\_MIN$ , then do the following

$T\_CUTOFF = TGD + TCO\_CUTOFF - TCO\_BIAS$

$S\_OMSCO = ON$

$SSTEER = OFF$

$SCO = ON$

B. Interface Requirements. The input and output parameters for the OMS guidance task are given in Tables 4.4.3-1 and 4.4.3-2.

C. Processing Requirements. Subtasks 1, 2, and 3 are performed every guidance cycle. Subtask 4 is performed only if the cutoff flag (SCO) is OFF and if either OMS\_L\_ON\_CMD\_IND or OMS\_R\_ON\_CMD\_IND is ON or any THC output is ON. The subtasks must be performed in the order shown.

D. Initialization Requirements. The following initialization is performed each time cyclic guidance is initialized.

$NMAX = N\_MAX$

$T\_CUTOFF = 0$

$S\_OMSCO = OFF$

$SSTEER = ON$

$SCO = OFF$

E. Supplemental Information. The PEG initialization is done by the AS MNVR DIP.

Table 4.4.3-1. OMS Guidance Task Inputs

Definition	Symbol	Source	Precision	Units
Time associated with RGD and VGD	TGD	PFG INP TSK	DP	sec
OMS/RCS ignition time	TIG	PRE MAN DISP SUPT TSK	DP	sec
Discrete indicating convergence	S $\bar{C}$ ONV	PEG TSK	D	N/A
Number of active OMS engines	N $\bar{O}$ MS	PFG INP TSK	I	N/A
Time-to-go to thrust cutoff	TGO	PEG TSK	SP	sec
Value of TGO_CUTOFF when steering output is inhibited during maneuvers	TGO_MIN	K-LOAD	SP	sec
Cutoff time bias	TCO_BIAS	I-LOAD	SP	sec
Maximum number of PEG iterations	N_MAX	I-LOAD	I	N/A
Total vehicle thrust force	FT	THRST PRM TSK	SP	lbf
Current vehicle mass	M	ACC-MASS UPD TSK, PRE-MAN DISP SUPT TSK	SP	slugs
Clock-computer (GMT)	T_GMT	FCOS	DP	sec
Left OMS ON indicator	OMS_L_ON_CMD_IND	OMS FIRE SEQ	D	N/A
Right OMS ON indicator	OMS_R_ON_CMD_IND	OMS FIRE SEQ	D	N/A
THC +X RCS command	THC_POS_X_CMD	GN&C SW RM	D	N/A
THC -X RCS command	THC_NEG_X_CMD	GN&C SW RM	D	N/A
THC +Y RCS command	THC_POS_Y_CMD	GN&C SW RM	D	N/A
THC -Y RCS command	THC_NEG_Y_CMD	GN&C SW RM	D	N/A
THC +Z RCS command	THC_POS_Z_CMD	GN&C SW RM	D	N/A
THC -Z RCS command	THC_NEG_Z_CMD	GN&C SW RM	D	N/A

Table 4.4.3-1. OMS Guidance Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
M50 to measured body quaternion	$Q_{BIS}$ , $Q_{BIV}$	A/E ATT PROC	SP	ND
Unit engine thrust direction in body coordinates	$\bar{T}HRUST_{BODY}$	CMD BDY ATT TSK	SP	ND
M50 velocity-to-be-gained vector	$V\bar{G}O$	PEG TSK	SP	fps
PEG steering enable flag	$S\dot{S}TEER$	PRE-MAN DISP SUPT TSK	D	N/A

Table 4.4.3-2. OMS Guidance Task Outputs

Definition	Symbol	Destination	Precision	Units
OMS/RCS maneuver cutoff time	$T_{CUTOFF}$	MSC	DP	sec
OMS cutoff alert discrete	$S_{\dot{O}MSCO}$	MSC, TLM	D	N/A
Thrust acceleration estimate	ATR	PEG TSK	SP	ft/sec <sup>2</sup>
Commanded body attitude time	$T_{CA}$	CMD BDY ATT TSK	DP	sec
PEG steering enable flag	$S\dot{S}TEER$	PEG TSK	D	N/A





#### 4.4.4 Parameter Tables for Orbit Insertion Guidance

The IDD inputs and outputs are listed in Table 4.4.4-1. Values for the I-loads are contained in the I-load requirements document (JSC-19350); however, I-load definitions applicable to this principal function are listed in Table 4.4.4-2. K-loads are listed in Table 4.4.4-3. Constants are listed in Table 4.4.4-4. The input variable cross-references are listed in Table 4.4.4-5.

Table 4.4.4 1. Orbit Insertion Guidance (G4.3) Input/Output Functional Parameters

DRIN D2B059 A PN: VP707100026P001 MAY 31, 1988  
 INPUT FUNCTIONAL PARAMETERS FOR ORBIT INSERTION GUIDANCE

ORB INS GUID G4.3 PAGE 3 OF 3

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE
CLOCK/CLOCKTIME	V91W5000C2	CLOCK COMPUTER(GMT)	FCOS	S	
C1	V94H3773CB	INTERCEPT OF TARGET LINE-GUID	ASC MNVR DIP	FT/S	
C2	V94H3774CB	SLOPE OF TARGET LINE-GUID	ASC MNVR DIP		
IYD(X)	V97U4413CA	UNIT VEC NORM TRAJ PLN X COMP	ASC MNVR DIP		
IYD(X)	V97U4413CB	UNIT VEC NORM TRAJ PLANE X COMP	UL		
IYD(Y)	V97U4414CA	UNIT VEC NORM TRAJ PLN Y COMP	ASC MNVR DIP		
IYD(Y)	V97U4414CB	UNIT VEC NORM TRAJ PLANE Y COMP	UL		
IYD(Z)	V97U4415CA	UNIT VEC NORM TRAJ PLN Z COMP	ASC MNVR DIP		
IYD(Z)	V97U4415CB	UNIT VEC NORM TRAJ PLANE Z COMP	UL		
M/CURR ORB MASS/WEIGHT	V90U1961CI	CURRENT VEHICLE MASS	ASC MNVR DIP	SLUGS	
M NODE_ADJ	V95U0512C	NODAL ADJUSTMENT MATRIX	ASC UPP		
MBO	V94U3838C	DESIRED MINIMUM BURNOUT MASS	ASC MNVR DIP	SLUGS	
MM CODE_104/MM_104	V90X8152X	MAJOR MODE 104 FLAG	HSC		
MM CODE_105/MM_105	V90X8623X	MAJOR MODE 105 FLAG	HSC		
MM CODE_106/MM_106	V90X8153X	MAJOR MODE 106 FLAG	HSC		
N	V94U3823C	NUMBER OF GUIDANCE THRUST PHASES	ASC MNVR DIP		
OMS_L ON CMD IND	V90X8271X	OMS-L ON CMD IND	OMS FIRE SEQ		
OMS PITCH TRIM	V93H6915CC	OMS PITCH TRIM	TRANS DAP	DEG	SP
OMS R ON CMD IND	V90X8272X	OMS-R ON CMD IND	OMS FIRE SEQ		
OMS_YAW TRIM(1)	V93H6916CC	OMS L YAW TRIM	TRANS DAP	DEG	SP
OMS_YAW TRIM(2)	V93H6918CC	OMS R YAW TRIM	TRANS DAP	DEG	SP
OPS TRANS REQUEST	V90X0892XB	OPS TRANSITION REQUEST FLAG	ASC PREC PRED		
PROP FLAG OFS	V94J3791CA	PRIME PROP SYS INDICATOR FLAG	ASC MNVR DIP		
Q BOD M50(1)/Q B_I(1)	V90U2240CA	M50 TO BODY QUAT MEASURED ELEM 1	A/E ATT PROC		
Q BOD M50(2)/Q B_I(2)	V90U2241CA	M50 TO BODY QUAT MEASURED ELEM 2	A/E ATT PROC		
Q BOD M50(3)/Q B_I(3)	V90U2242CA	M50 TO BODY QUAT MEASURED ELEM 3	A/E ATT PROC		
Q BOD M50(4)/Q B_I(4)	V90U2243CA	M50 TO BODY QUAT MEASURED ELEM 4	A/E ATT PROC		
R AVGG(1)	V95H0185CB	X-COMP OF CURRENT SHUTTLE POS VCTR	ASC UPP	FT	FT
R AVGG(2)	V95H0186CB	Y-COMP OF CURRENT SHUTTLE POS VCTR	ASC UPP	FT	FT
R AVGG(3)	V95H0187CB	Z-COMP OF CURRENT SHUTTLE POS VCTR	ASC UPP	FT	FT
R_FINAL(1)	V90H0881CB	X-COMP PREDICTED SHUTTLE POS VECTR	ASC PREC PRED	FT	FT
R_FINAL(2)	V90H0882CB	Y-COMP PREDICTED SHUTTLE POS VECTR	ASC PREC PRED	FT	FT
R_FINAL(3)	V90H0883CB	Z-COMP PREDICTED SHUTTLE POS VECTR	ASC PREC PRED	FT	FT
RGD(X)	V94H3930CA	X-COMP OF GUIDANCE POS VEC AT TGD	ASC MNVR DIP	FT	
RGD(Y)	V94H3931CA	Y-COMP OF GUIDANCE POS VEC AT TGD	ASC MNVR DIP	FT	
RGD(Z)	V94H3932CA	Z-COMP OF GUIDANCE POS VEC AT TGD	ASC MNVR DIP	FT	
RT(X)	V90H3781CA	X-M50 OF POSITION TARGET VECTOR	ASC MNVR DIP	FT	
RT(Y)	V90H3782CA	Y-M50 OF POSITION TARGET VECTOR	ASC MNVR DIP	FT	
RT(Z)	V90H3783CA	Z-M50 OF POSITION TARGET VECTOR	ASC MNVR DIP	FT	
S AOA	V90X8636X	AOA ABORT DECLARED	HSC		
S ATO	V90X8635X	ATO ABORT DECLARED	HSC		
S OMS1 FAIL	V90X7670X	LEFT OMS ENGINE SHUTDOWN FLAG	OMS RM		BD
S OMS2 FAIL	V90X7671X	RIGHT OMS ENGINE SHUTDOWN FLAG	OMS RM		BD
SMODE	V94J3779C	GUIDANCE MODE INDICATOR	ASC MNVR DIP		NXS
SOMS	V94U3820C	ASSUMED NUMBER OF ACTIVE OMS ENG	ASC MNVR DIP		
T GMTLO	V90W4380C	TIME OF LIFTOFF IN GMT	FCOS	S	
T RCS OFF	V94H3824C	TIME OF +X RCS CUTOFF FOR PRL BURN	ASC MNVR DIP		DPL
T STATE	V95W0200CD	TIME TAG ASSOC WITH CURRENT STATE	ASC UPP		
TGD	V94H3938CA	TIME ASSOCIATED WITH RGD,VGD	ASC MNVR DIP	S	
THC FSH(1)	V90X7694X	SEL FWD THC NEG X OUTPUT	CHIC SW RM		BD
THC FSH(2)	V90X7695X	SEL FWD THC NEG Y OUTPUT	CHIC SW RM		BD
THC FSH(3)	V90X7696X	SEL FWD THC NEG Z OUTPUT	CHIC SW RM		BD

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Table 4.4.4-1. Orbit Insertion Guidance (G4.3) Input/Output Functional Parameters (Cont)

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 INPUT FUNCTIONAL PARAMETERS FOR ORBIT INSERTION GUIDANCE

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FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE
THC_FSP(1)	V90X7697X	SEL FWD THC POS X OUTPUT	GN&C SW RM		BD
THC_FSP(2)	V90X7698X	SEL FWD THC POS Y OUTPUT	GN&C SW RM		BD
THC_FSP(3)	V90X7699X	SEL FWD THC POS Z OUTPUT	GN&C SW RM		BD
TIG	V94H3790CA	TIME OF IGNITION	ASC MNVR DIP	S	
V_AVGG(1)	V95L0190CB	X-COMP OF CURRENT SHUTTLE VEL VCTR	ASC UPP	FT/S	SPL
V_AVGG(2)	V95L0191CB	Y-COMP OF CURRENT SHUTTLE VEL VCTR	ASC UPP	FT/S	SPL
V_AVGG(3)	V95L0192CB	Z-COMP OF CURRENT SHUTTLE VEL VCTR	ASC UPP	FT/S	SPL
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_IMU_OLD(1)	V95L0210CB	X-COMP OF CURRENT ACCUM IMU VEL	ASC UPP	FT/S	
V_IMU_OLD(2)	V95L0211CB	Y-COMP OF CURRENT ACCUM IMU VEL	ASC UPP	FT/S	
V_IMU_OLD(3)	V95L0212CB	Z-COMP OF CURRENT ACCUM IMU VEL	ASC UPP	FT/S	
VGD(X)	V94H3935CA	X-COMP OF GUIDANCE VEL VEC AT TGD	ASC MNVR DIP	FT/S	
VGD(Y)	V94H3936CA	Y-COMP OF GUIDANCE VEL VEC AT TGD	ASC MNVR DIP	FT/S	
VGD(Z)	V94H3937CA	Z-COMP OF GUIDANCE VEL VEC AT TGD	ASC MNVR DIP	FT/S	
VGO(X)	V94L3804CA	X-EXTERNAL DEL V TARGET VECTOR	ASC MNVR DIP	FT/S	
VGO(Y)	V94L3805CA	Y-EXTERNAL DEL V TARGET VECTOR	ASC MNVR DIP	FT/S	
VGO(Z)	V94L3806CA	Z-EXTERNAL DEL V TARGET VECTOR	ASC MNVR DIP	FT/S	
VSP(X)	V94H3940CA	X-COMP OF PREV ACCUM IMU VEL	ASC MNVR DIP	FT/S	
VSP(Y)	V94H3941CA	Y-COMP OF PREV ACCUM IMU VEL	ASC MNVR DIP	FT/S	
VSP(Z)	V94H3942CA	Z-COMP OF PREV ACCUM IMU VEL	ASC MNVR DIP	FT/S	

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Table 4.4.4-1. Orbit Insertion Guidance (G4.3) Input/Output Functional Parameters (Cont)

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 OUTPUT FUNCTIONAL PARAMETERS FROM ORBIT INSERTION GUIDANCE

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FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	P R E C
DT MAX	V90U8500CB	MAX ALLOW TIME STEP SIZE	ASC PREC PRED		
GMD_PRED	V90U8501CB	GRAVITY MODEL DEGREE	ASC PREC PRED	S	
GMO_PRED	V90U8502CB	GRAVITY MODEL ORDER	ASC PREC PRED		
IY(X)	V90U1976CB	X-M50 UNIT VEC NORMAL TO ORB PLANE	AOA/ATO TGT, TLM		
IY(Y)	V90U1977CB	Y-M50 UNIT VEC NORMAL TO ORB PLANE	AOA/ATO TGT, TLM		
IY(Z)	V90U1978CB	Z-M50 UNIT VEC NORMAL TO ORB PLANE	AOA/ATO TGT, TLM		
LAMC(X)	V90U1954CC	X-COMP OF M50 REF THR VECTOR	TRANS DAP, TLM		
LAMC(Y)	V90U1955CC	Y-COMP OF M50 REF THR VECTOR	TRANS DAP, TLM		
LAMC(Z)	V90U1956CC	Z-COMP OF M50 REF THR VECTOR	TRANS DAP, TLM		
LAMDC(X)	V90U1957CC	X-M50 DESIRED THR TRNING RATE VCTR	TRANS DAP, TLM		
LAMDC(Y)	V90U1958CC	Y-M50 DESIRED THR TRNING RATE VCTR	TRANS DAP, TLM		
LAMDC(Z)	V90U1959CC	Z-M50 DESIRED THR TRNING RATE VCTR	TRANS DAP, TLM		
LAMDAG	V90U1968CB	MAGNITUDE OF LAMD	TLM		
M/CURR_ORB_MASS/WEIGHT	V90U1961CA	CURRENT VEHICLE MASS	AOA/ATO TGT, ASC MNVR DIP, OMS RM, TLM		
N_OMS	V90J2031CB	NUMBER OF ACTIVE OMS ENGINES	AOA/ATO TGT, TLM		
N_RCS	V90J1974CB	NUMBER OF ACTIVE RCS ENGINES	TLM		
N_RCS_NULL	V90J1975CB	NUMBER OF ACTIVE RCS NULL ENGINES	TLM		
PROP_FLAG_OPS	V94J3791CD	PRIME PROP SYS INDICATOR FLAG	TLM		
Q_CB_M50_S	V94U3980CC	M50 TO BODY QUAT ELEM 1	TRANS DAP, TLM		
Q_CB_M50_VI1	V94U3981CC	M50 TO BODY QUAT ELEM 2	TRANS DAP, TLM		
Q_CB_M50_VI2	V94U3982CC	M50 TO BODY QUAT ELEM 3	TRANS DAP, TLM		
Q_CB_M50_VI3	V94U3983CC	M50 TO BODY QUAT ELEM 4	TRANS DAP, TLM		
R_INIT(X)	V90H8508CB	X-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED		
R_INIT(Y)	V90H8509CB	Y-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED		
R_INIT(Z)	V90H8510CB	Z-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED		
S_OMSCO	V90X2035XA	OMS CUTOFF ALERT DISCRETE	MSC, TLM		
SCONV	V90X1971XB	PEG CONVERGENCE DISCRETE	TLM		
T_CUTOFF	V90W2034CA	DESIRED CUTOFF TIME	MSC, TLM		
T_FINAL	V90H8506CB	TIME AT WHICH STATE IS DESIRED	ASC PREC PRED		
T_INIT	V90H8512CB	TIME AT BEGINNING OF PRED	ASC PREC PRED		
TGD	V90H1994CC	GUIDANCE TIME TAG	TLM		
TGO	V90H1941CB	TIME TO GO TO ENGINE CUTOFF	6.35, ASC MNVR DIP, TLM		
TLAMC	V90H1953CC	TIME ASSOC W REF THR VECTOR	TRANS DAP, TLM		
TP	V90H1946CB	PREDICTED TIME OF THRUST C/O	TLM		
V_INIT(X)	V90L8513CB	X-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED		
V_INIT(Y)	V90L8514CB	Y-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED		
V_INIT(Z)	V90L8515CB	Z-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED		
VEH_PITCH	V93U6909CF	PITCH ANGLE IN ADI INERTIAL COORD	6.35, TLM		
VEH_ROLL	V93U6910CF	ROLL ANGLE IN ADI INERTIAL COORD	6.35, TLM		
VEH_YAW	V93U6911CF	YAW ANGLE IN ADI INERTIAL COORD	6.35, TLM		
VGO(X)	V90L2026C	X VEL TO BE GAINED VECTOR IN M50	ASC MNVR DIP		
VGO(Y)	V90L2027C	Y VEL TO BE GAINED VECTOR IN M50	ASC MNVR DIP		
VGO(Z)	V90L2028C	Z VEL TO BE GAINED VECTOR IN M50	ASC MNVR DIP		
VGOMAG	V90U1966CB	MAGNITUDE OF VGO VECTOR	TLM		

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Table 4.4.4-2. Orbit Insertion Guidance (G4.3) I-Loads Orbit Insertion Guidance

OI8B MISSIONS	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
EF_PLANE_SW	V99U7441C	ND	D	M	C		G4.2 G4.3 G4.19 G4.20 G4.226		A2N1
FT_OMS	V97U4390C	LBF	F	S	D	C	G4.210 G4.13 G4.4 G4.3 G4.2		ZF22
FT_RCS	V97U4391C	LBF	F	S	D	C	G4.2 G4.3 G4.210 G4.4		ZF22
IYD(1)	V97U4413C	ND	F	D	M	C	G4.226 G4.2 G4.3 G4.19 G4.20 G4.210		A2N1
IYD(2)	V97U4414C	ND	F	D	M	C	G4.226 G4.2 G4.3 G4.19 G4.20 G4.210		A2N1
IYD(3)	V97U4415C	ND	F	D	M	C	G4.226 G4.2 G4.3 G4.19 G4.20 G4.210		A2N1
KLAMDZX	V97U4423C	ND	F	S	D	C	G4.3 G4.209 G4.13 G4.210 G4.211		ZF12
KMISS	V97U4831C	ND	F	S	D	C	G4.209 G4.2 G4.3 G4.4 G4.210 G4.211		ZF12

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Table 4.4.4-2. Orbit Insertion Guidance (G4.3) I-Loads Orbit Insertion Guidance (Cont)

OI8B MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
MDOT_OMS	V97U4440C	SLUGS/SEC	F	S	D	C	G4.210 G4.13 G4.4 G4.3 G4.2	ZF22	
N_MAX	V97U4445C	ND	I	S	D	P	G4.2 G4.3 G4.4 G4.209	ZF12	
NSEG	V97U4447C	ND	I	S	D	P	G4.2 G4.3 G4.4 G4.209 G4.211	ZF12 ZF22	
ONE_ENG_OMS_PITCH_TRIM	V97U2367C	DEG	F	S	M	X	G4.201 G4.35 G4.7 G4.158 G4.3 G4.209 G4.210	OMT0 OMT0 OMT0 OMT0	
ONE_ENG_OMS_YAW_TRIM(1)	V97U2368C	DEG	F	S	M	C	G4.201 G4.35 G4.7 G4.158 G4.3 G4.209 G4.210	OMT0 OMT0 OMT0 OMT0	
ONE_ENG_OMS_YAW_TRIM(2)	V97U2369C	DEG	F	S	M	C	G4.201 G4.35 G4.7 G4.158 G4.3 G4.209 G4.210	OMT0 OMT0 OMT0 OMT0	
PHIDOT_MAX	V97U9003C	RAD/SEC	F	S	D	C	G4.3 G4.210 G4.2 G4.4	ZF12	
TCO_BIAS	V97U4662C	SEC	F	S	D	C	G4.209 G4.3 G4.7	ZF12	

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Table 4.4.4-2. Orbit Insertion Guidance (G4.3) I-Loads Orbit  
Insertion Guidance (Cont)

MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	THRUST_BODY_RCS_X(1)	V97U4812C	ND	F	S	D	C	G4.7		ZF12
								G4.209		
								G4.158		
								G4.3		
								G4.210		
								G4.211		
	THRUST_BODY_RCS_X(2)	V97U4813C	ND	F	S	D	C	G4.7		ZF12
								G4.209		
								G4.158		
								G4.3		
								G4.210		
								G4.211		
	THRUST_BODY_RCS_X(3)	V97U4814C	ND	F	S	D	C	G4.7		ZF12
								G4.209		
								G4.158		
								G4.3		
								G4.210		
								G4.211		

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Table 4.4.4-3. Orbit Insertion Guidance (G4.3) K-Loads Orbit Insertion Guidance

MISSIONS	FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT PR S PR FCTN	LAST CR EQTN MSID
CBETA_EPS		V97U5127C	+9.998480	E-01 ND	F S C G4.211 G4.210 G4.209 G4.158 G4.7 G4.3	89542A
DTP1X		V97U4369C	+1.00	E+20 SEC	F S C G4.209 G4.13 G4.4 G4.3 G4.2	89541
	MAX STEP SIZE, ASC PREC PRED					
DTHIN		V97U4370C	01 +2.0 02 +3.00 03 +2.0	E+00 SEC E+02 E+00	F S C G4.211 G4.210 G4.209 G4.158 G4.13 G4.4 G4.3 G4.2	29975A
EPSTGO		V97U4381C	+4.0	E-02 ND	F S C G4.2 G4.3 G4.4 G4.210	59955
	PEG INHIBIT STEERING OUTPUT					
MDOT_RCS		V97U4441C	+1.0655714	E-01 SLUGS/SEC	F S C G4.210 G4.2 G4.13 G4.4 G4.3	89661A
	NOMINAL RCS MASS FLOW RATE					
PITCH_BIAS		V97U4485C	+2.7605300	E-01 RAD	F S C G4.7 G4.3 G4.209 G4.210 G4.211 G4.158	59955
	CONST OMS ENG ELEC PITCH TRIM ANG					
Q M50_INRTL_ASCENT(1)		V97U2214CA	+1.0	E+00 ND	F S C G4.3 G4.210 G4.226	89688B
Q M50_INRTL_ASCENT(2)		V97U2215CA	+0.0	E+00 ND	F S C G4.3 G4.210 G4.226	89688B

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Table 4.4.4-3. Orbit Insertion Guidance (G4.3) K-Loads Orbit Insertion Guidance (Cont)

DI8B MISSIONS FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT PR S PR FCTN	LAST CR EQTN MSID
Q_M50_INRTL_ASCENT(3)	V97U2216CA	+0.0	E+00 ND	F S C G4.3 G4.210 G4.226	89688B
Q_M50_INRTL_ASCENT(4)	V97U2217CA	+0.0	E+00 ND	F S C G4.3 G4.210 G4.226	89688B
TGO_MIN MIN TIME-TO-GO THRUST TERMINATE	V97U4665C	+6.0000000	E+00 SEC	F S C G4.209 G4.3 G4.7	89542A
YAW_BIAS	V97U4829C	+1.134460	E-01 RAD	F S C G4.3 G4.7 G4.209 G4.210 G4.211 G4.158	89541
CNST OMS ENG ELEC YAW TRIM ANGLE					

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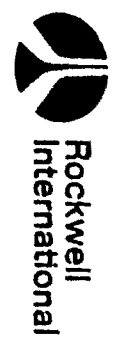


Table 4.4.4-4. Orbit Insertion Guidance (G4.3) Constants

NROKRM. FSSR2.DAT(X23 IBOOK2  
PFS CONSTANTS UPDATE B/L

FSSR NAME DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
EARTH MU EARTH'S GRAVITATIONAL CONSTANT	V97U4378C		1.40764487566 E+16	FT**3/ SEC**2	F	D	P			
MUP TH MINIMUM CHANGE IN MASS REQUIRED FOR MASS TO BE UPDATED			.3	SLUGS	F	S	P			
PI RATIO OF CIRCUMFERENCE TO DIAMETER	V98U8725C		3.1415926535897	ND	F	D	P			
RAD PER DEG DEGREE PER RADIAN CONVERSION	V97U0383C		.017453293	RAD/DEG	F	S	P			

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Space Transportation  
Systems Division



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4.5 AOA/ATO TARGETING REQUIREMENTS (MM's 103, 104, AND 105)

Table 4.4.4-5. ORB INS GUID Variable Cross-Reference

MSID	Local Name	Source Name
V95H0185CB, 6CB, 7CB	R_NAV	R_AVGG
V95W0200CD	T_NAV	T_STATE
V95L0190CB, 1CB, 2CB	V_NAV	V_AVGG
V95U0512C	M_NODE_ADJ	N_NODE_ADJ
V91W5000CZ	T_GMT	CLOCK
V90X8152X	MM104	MM_CODE_104
V90X8623X	MM105	MM_CODE_105
V90X8153X	MM106	MM_CODE_106



#### 4.5. AOA/ATO TARGETING REQUIREMENTS (MM's 103, 104, AND 105)

This section addresses the requirements for the principal function AOA/ATO TGT (CPDS, Level B, GN&C Section 4.13). Execution of this principal function requires the general guidance and targeting tasks Acceleration-Mass Update (Section 4.8.2), H- $\theta$ -to-M50 Target (Section 4.8.6), Powered Explicit Guidance (Section 4.8.1), Linear Terminal Velocity Constraint (Section 4.8.4), and Thrust Parameters (4.8.7).

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This principal function performs the targeting, both pre-MECO and post-MECO, required for AOA/ATO and sets flags that are used by the ABT CNTL SEQ principal function to control the pre-MECO OMS/RCS burns. This principal function will be performed if the crew has selected an AOA or ATO at any time up to crew proceed command for ignition of the OMS-2 burn. AOA/ATO TGT is common to several major modes (103, 104, 105) and performs appropriate tasks in each major mode as discussed in Section 4.5.1.

Continuous AOA and ATO capability exists from lift-off to a short time (mission dependent) before OMS-2 ignition for intact abort situations other than an SSME failure. For the failure of an SSME, AOA capability extends as late as possible (a short time before OMS-2 ignition) to support time-critical abort situations. ATO capability is desired as early as possible, since it is the preferred abort mode for all non-time-critical abort situations. Thus, the AOA/ATO TGT principal function must support an AOA or ATO request at any time up to the crew proceed command for OMS-2 ignition. However, for an abort situation other than an SSME failure, it is recommended that the crew not select an abort mode until the capability exists (based on velocity) to perform the abort with one SSME failed.

The pre-MECO AOA/ATO TGT logic is basically designed for the one-SSME failure abort situation, the most severe case designed for; but it readily handles other abort situations as well. To achieve AOA and ATO capability for early SSME failures, a more favorable MECO target may be used. Also, to achieve earliest abort capability, a variable IY mission option is available, which changes the orbital plane target (unit vector normal to the orbital plane,  $\overline{IY}$ ) at MECO from the nominal ascent value to a current, in-plane performance optimum value for an AOA or ATO. In addition, the available OMS propellant may be burned pre-MECO, leaving only enough propellant for on-orbit and deorbit usage. When possible, the ATO software conserves  $\Delta V$  to allow mission continuation from the ATO orbit. In the one-SSME failure ATO situation, this is achieved by reducing the pre-MECO OMS/RCS burn as performance improves with later abort initiations. For an AOA or ATO without an SSME failure, the pre-MECO OMS/RCS burn may be made to allow for aborts due to a partial SSME thrust loss.

The on-orbit objective for AOA targeting is to select stored targets that achieve a compatible set of acceptable entry interface (EI) conditions. The targets are premission-computed to minimize on-orbit  $\Delta V$  usage. This minimization of  $\Delta V$  results in the selection of a two-burn rather than a one-burn AOA sequence. The targets are stored on board in the form of earth-fixed, in-plane scalar parameters (altitude and downrange angle) and in terms of a



velocity-flight path angle relationship. However, if the variable IY targeting option is employed, the AOA OMS-2 targets must be a function of inclination in order to achieve the desired EI conditions. The software contains minimum  $\Delta V$  target sets for two EI target lines: a shallow and a nominal line. The shallow EI target set is used for early aborts where performance is critical, since it requires less on-orbit  $\Delta V$  to achieve. A nominal EI target set is selected as soon as adequate performance is available since it results in a nominal entry trajectory. A nominal entry trajectory is much more desirable for several reasons, including lower thermal protection system backface temperatures and less sensitivity to dispersions. If a nominal EI target set is selected and a subsequent MECO or OMS-1 burn dispersion results in inadequate performance, targets for shallow EI are selected in an effort to reduce the deorbit OMS  $\Delta V$  requirement to an acceptable level.

The on-orbit objective for ATO targeting is to retrieve stored targets that achieve an orbit from which a deorbit can be performed. The ATO targets are selected to minimize the total  $\Delta V$  required to perform the ATO and deorbit maneuvers.

The AOA/ATO OMS-1 and OMS-2 targeting is performed in OPS-1. The AOA OMS-1, ATO OMS-1, and ATO OMS-2 burns are executed during OPS-1; however, the AOA OMS-2 burn, a deorbit burn, is executed during OPS-3. Thus, a transfer from OPS-1 to OPS-3 is necessary prior to an AOA OMS-2 burn, and the AOA OMS-2 target parameters selected in OPS-1 must be part of the OPS-1 to OPS-3 data transfer.

All data sets transferred from the AOA/ATO TGT principal function to other principal functions (listed in Figure 4.5-2) are assumed to be time homogeneous.

If an AOA or ATO abort is selected, the automatically selected target set parameters and ID will be displayed to the crew upon entering MM 104 or MM 105. Any automatically selected target set may be overridden by the crew via an item number control (I\_TGT) execute display. This item entry control will also allow the crew to select an AOA or ATO abort and the respective target sets desired. I\_TGT is initially zero upon entering MM 104 and thereafter may be set equal to 1 through 12 by crew entry or automatically by AOA/ATO targeting when an abort is selected.

Tasks performed by the AOA/ATO TGT principal function include:

1. AOA/ATO MECO target selection task (AOA/ATO MECO TGT SEL TSK, 4.5.2)
2. AOA/ATO OMS/RCS pre-MECO burn determination task (AOA/ATO OMS/RCS PRE-MECO BRN DET TSK, 4.5.3)
3. AOA on-orbit target selection task (AOA ONORB TGT SEL TSK, 4.5.4)
4. ATO on-orbit target selection task (ATO ONORB TGT SEL TSK, 4.5.5)

In addition, five general guidance and targeting tasks are performed:

1. Ascent powered explicit guidance (4.8.1)
2. Linear terminal velocity constraint (4.8.4)
3. Acceleration-mass update (4.8.2)
4. Thrust parameters (4.8.7)
5. H- $\theta$ -to-M50 target (4.8.6)

Figure 4.5-1 presents a diagram of the task organization within the AOA/ATO TGT principal function.

An AOA/ATO targeting principal function task organization is shown in Figure 4.5-1, and a data flow diagram between other principal functions is shown in Figure 4.5-2. The input/output interfaces are listed in Section 4.5.6.

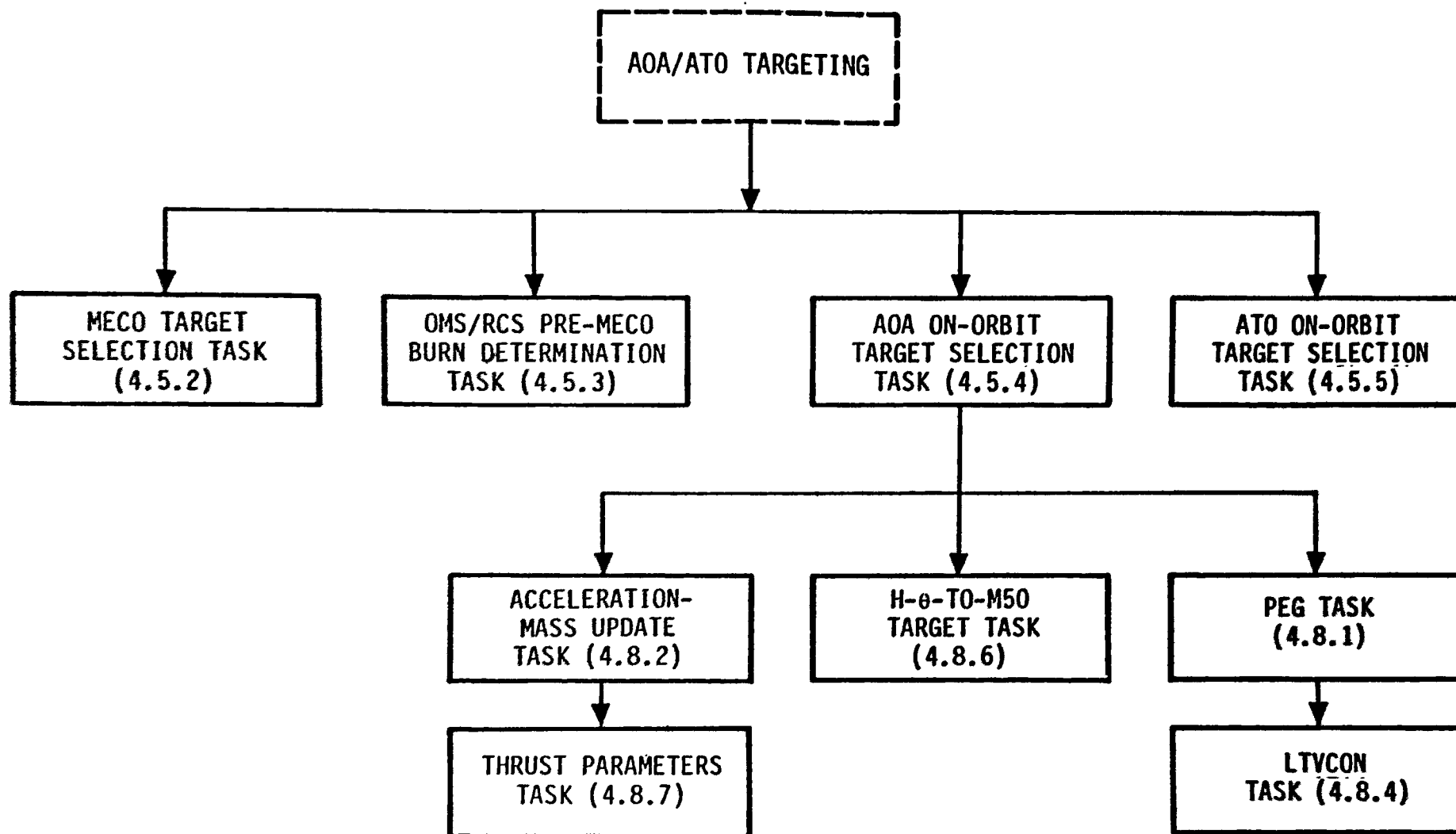


Figure 4.5-1. AOA/ATO Targeting Principal Function Task Organization

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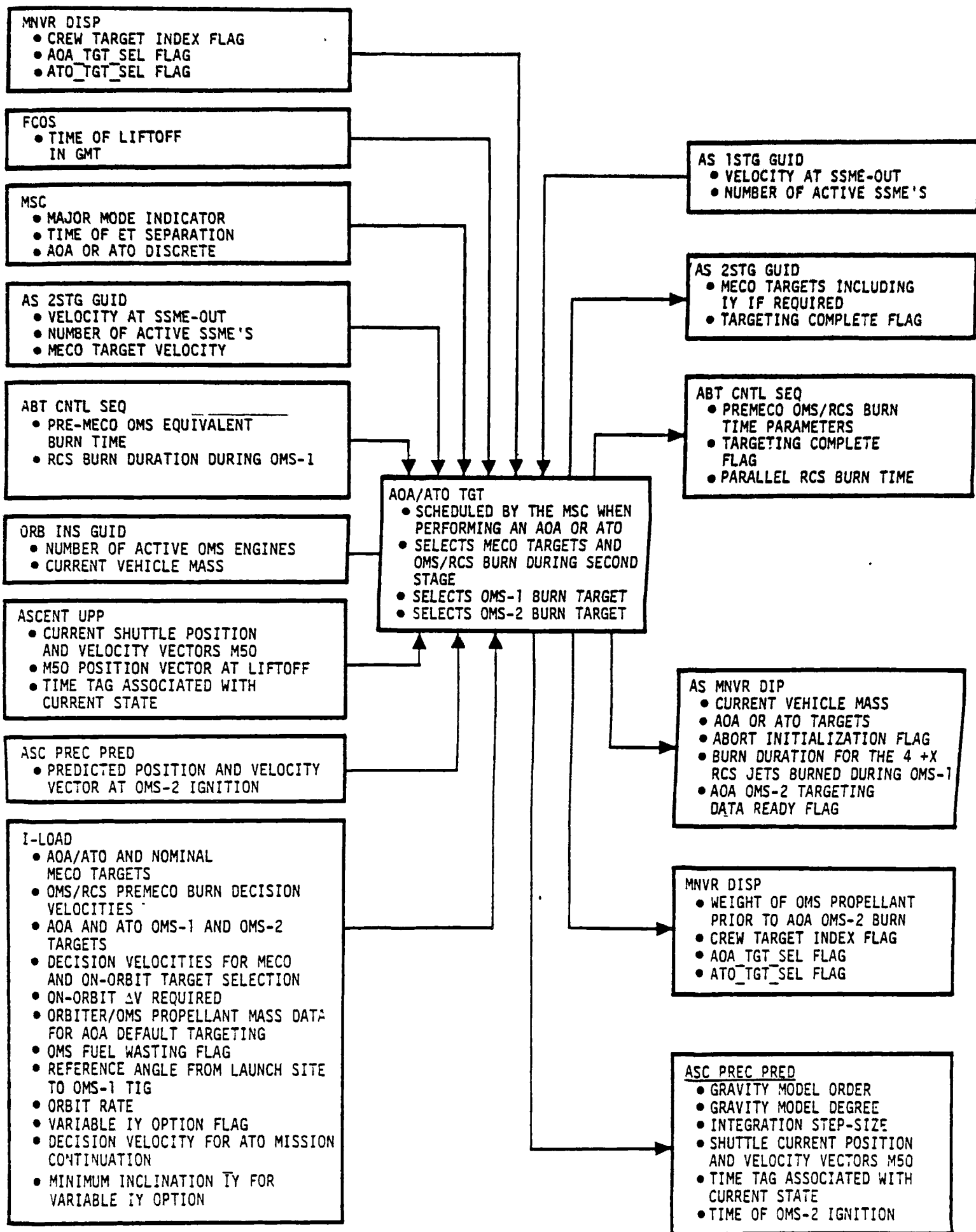


Figure 4.5-2. AOA/ATO Targeting Data Flow



#### 4.5.1 AOA/ATO Targeting Sequencing (AOA/ATO TGT SEQ)

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A. Scheduling of AOA/ATO TGT. The crew can request an AOA or ATO by (1) setting the abort-mode rotary switch to the AOA or ATO position and pressing the abort pushbutton indicator (PBI) or (2) by item entries on the override display or (3) by item entries on the ascent maneuver display. This crew action instructs the MSC to declare the appropriate abort and to schedule the AOA/ATO TGT principal function at the proper time. All Level B events that authorize the scheduling of AOA/ATO TGT are given in parenthesis in the appropriate places. The AOA/ATO TGT is scheduled (Event A5A) upon transition to ascent second stage (MM 103) if an AOA or ATO was selected during ascent first stage (MM 102), or is scheduled (Event A9.1) immediately if an ATO is selected during ascent second stage prior to FCD. Currently, an AOA cannot be requested during ascent second stage prior to MECO command (Event 32); instead during this time the AOA/TAL setting on the abort mode rotary switch or override display would request a TAL (Event A6.1). An AOA can be requested during second stage by the switch (or display) after MECO is commanded, but AOA/ATO TGT would not be scheduled until the transition to MM 104 (Event A13). If an SSME has failed prior to AOA or ATO selection, then  $V_{ME\_OUT}$  must be set equal to the earth relative velocity at SSME failure (within two seconds) before AOA/ATO TGT is executed. AOA/ATO TGT should only be executed once during MM 103 irrespective of the number of subsequent SSME failures. During ascent second stage, AOA/ATO TGT selects MECO targets and sets flags and scaling factors used by the ABT CNTL SEQ to control the pre-MECO OMS/RCS burn.

An AOA or ATO may be selected at any time up to a short time before ignition of the OMS-2 burn. If an AOA or ATO is in progress when transition to MM 104 occurs, AOA/ATO TGT is scheduled (Event A13) immediately to select the targets for the OMS-1 burn. If an AOA or ATO is selected after transition to MM 104, but before the OMS-1 proceed command, AOA/ATO TGT is scheduled (Events A16, A16A) immediately to select the targets for the OMS-1 burn. Then, upon transition to MM 105, AOA/ATO TGT is again scheduled (Events A17, A17A) immediately to select targets for the OMS-2 burn. If an AOA or ATO is selected after the OMS-1 proceed command, the nominal OMS-1 burn is performed and then upon transition to MM 105, AOA/ATO TGT is scheduled to select targets for the OMS-2 burn. If an AOA or ATO is selected during MM 105 before nominal OMS-2 proceed command, AOA/ATO TGT is scheduled (Events A19, A19A) immediately to select targets for the OMS-2 burn. Scheduling of the proper tasks is performed by sequencing logic within AOA/ATO TGT.

A downmode from ATO to AOA is possible in MM 104 prior to the OMS-1 proceed command. To perform this downmode the crew must set the abort rotary switch to the AOA position and press the PBI or select an AOA I\_TGT on the ascent maneuver display. When this occurs the MSC must reschedule (Event A16A) AOA/ATO TGT to select AOA OMS-1 burn targets. At the transition to MM 105, a normal scheduling of AOA/ATO TGT is made to select AOA OMS-2 burn targets.

If an AOA or ATO abort is selected, the automatically or manually selected target set and ID (I\_TGT) will be displayed to the crew during MM 104 or MM 105.

If the crew is not satisfied with the planned OMS burn targets based on their evaluation or on ground advice, then they can select another target from the stored matrix of targets in AOA/ATO TGT (Table 4.5.4-1). The crew makes this target selection by item entry of a target index (I\_TGT) through the maneuver display using a lap pad reference key that relates the target index flag to the particular target set. This target selection capability is available in MM 104 and MM 105 for OMS-1 and OMS-2 targeting, respectively. Upon crew selection of a target set in this manner, the AOA or ATO target select flag is set ON, which causes MSC to schedule (or reschedule) AOA/ATO TGT immediately. At this point, AOA/ATO TGT must lock out the automatic onboard target selection logic normally used and simply select the target set from the proper stored table based on the value of the target index flag. In the event of an OMS-1 target selection via item entry index by the crew, AOA/ATO TGT will automatically select the associated OMS-2 target when scheduled by the MSC at transition to MM 105. However, full capability exists for the crew to change this OMS-2 target through an item entry of a new target index value.

**B. Sequencing within AOA/ATO TGT.** Sequencing of tasks within AOA/ATO TGT is described in the AOA/ATO TGT functional flow, Figure 4.5.1-1. If AOA/ATO TGT is scheduled in MM 103, the AOA/ATO TGT sequencing executes the MECO target selection task and the OMS/RCS pre-MECO burn determination task. If AOA/ATO TGT is scheduled during MM 104, AOA/ATO TGT sequencing executes the AOA on-orbit target selection task or the ATO on-orbit target selection task to obtain OMS-1 burn target parameters. If AOA/ATO TGT is scheduled during MM 105, AOA/ATO TGT sequencing executes the AOA on-orbit target selection task or the ATO on-orbit target selection task to obtain OMS-2 burn target parameters.

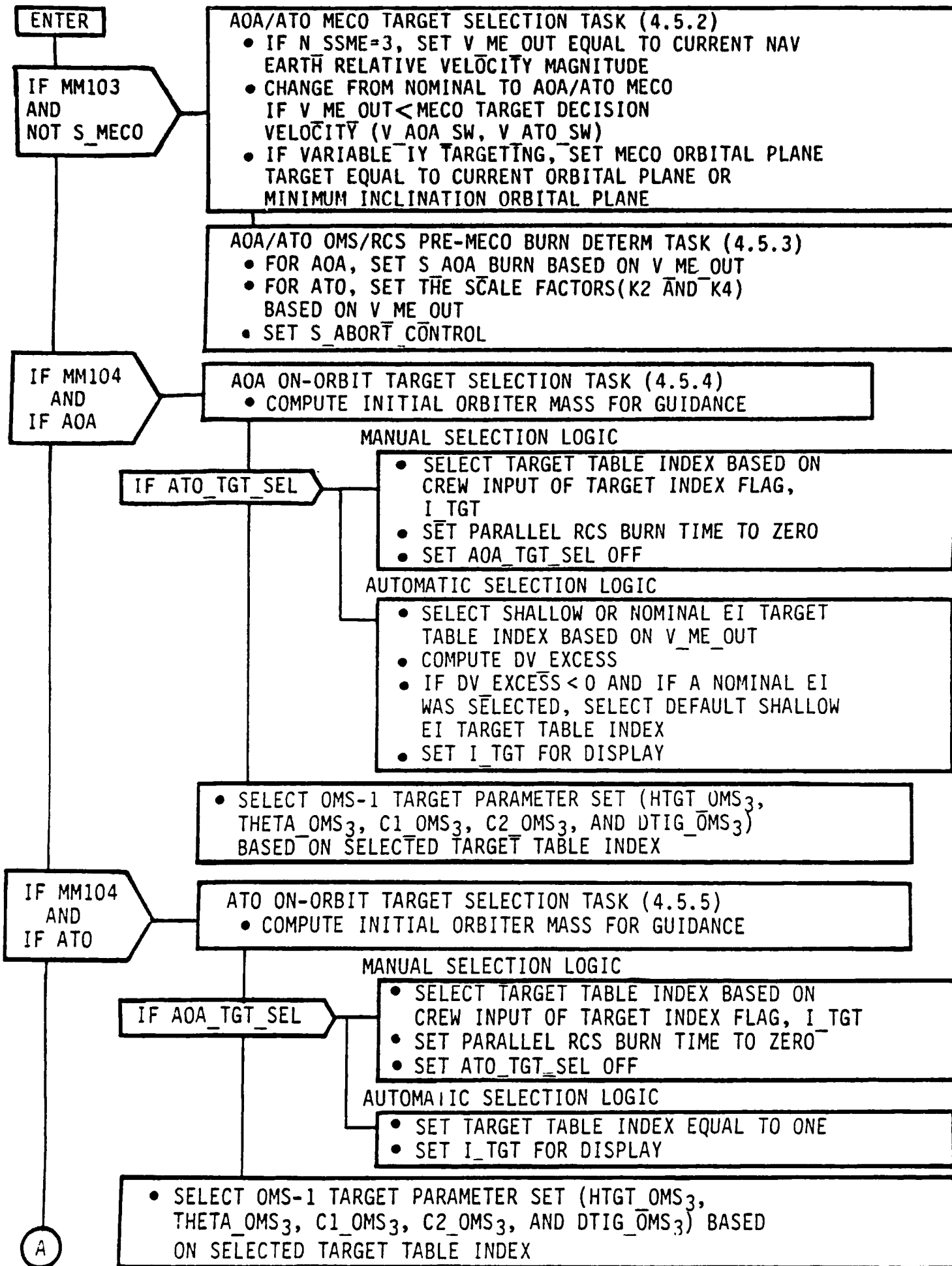


Figure 4.5.1-1. AOA/ATO Targeting Functional Flow (Sheet 1 of 2)

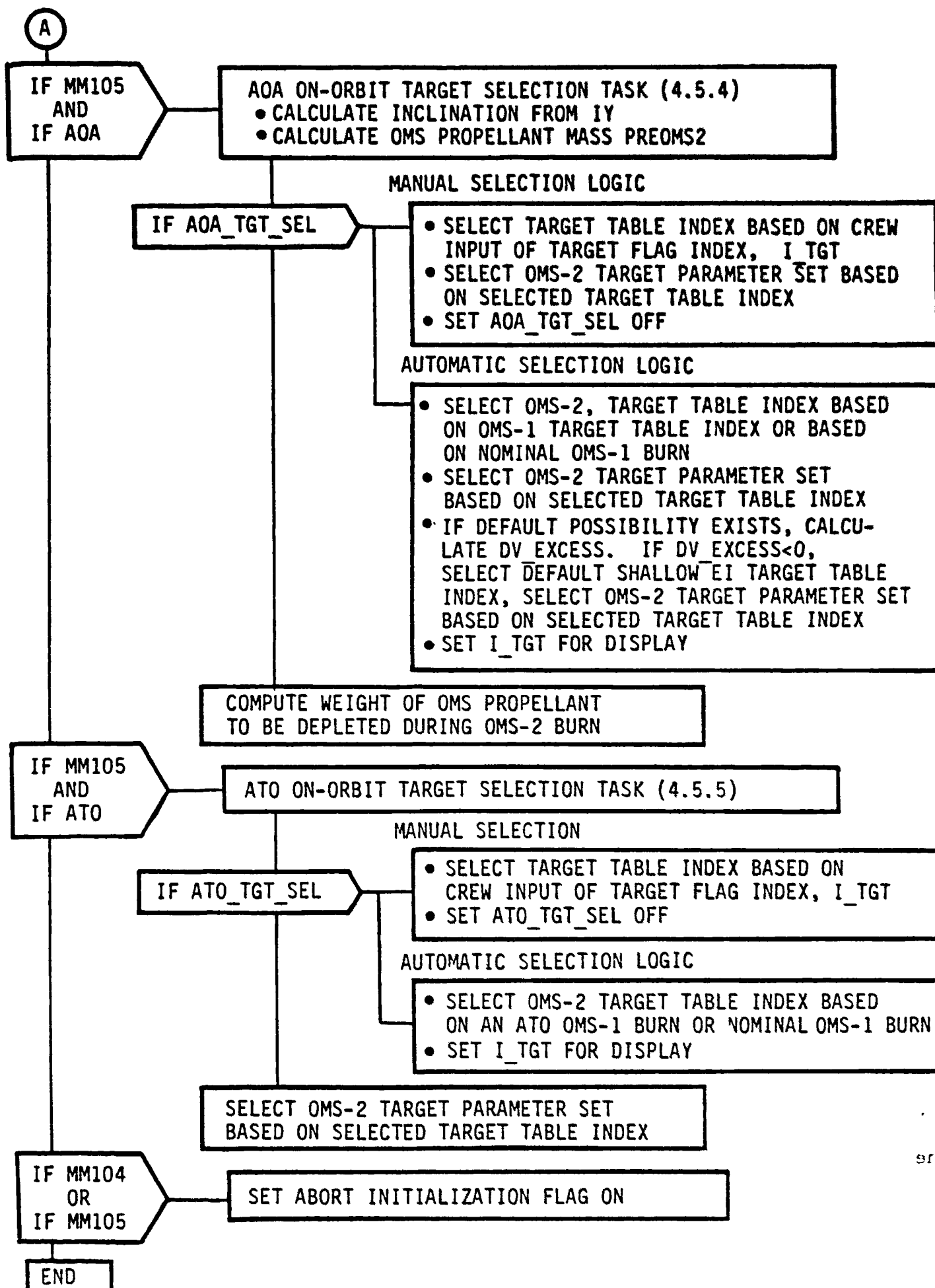


Figure 4.5.1-1. AOA/ATO Targeting Functional Flow (Sheet 2 of 2)

#### 4.5.2 AOA/ATO MECO Target Selection Task (AOA/ATO MECO TGT SEL TSK)

The AOA/ATO MECO target selection task determines whether the nominal or AOA/ATO MECO target will be used by the ascent second-stage guidance in the event of an AOA or ATO. Also, if the variable IY option has been selected premission, this task calculates the unit vector normal to the desired orbit plane at AOA/ATO MECO target set.

A. Detailed Requirements. An AOA/ATO MECO target set consisting of a velocity magnitude, radius magnitude, and flight path angle are premission loaded into this software. If an AOA or ATO has been requested, the software must decide whether the guidance should remain targeted for nominal MECO or be retargeted for the AOA/ATO MECO. This decision is based on the velocity at SSME-out; if  $V_{ME\_OUT}$  is less than the stored, premission computed switch velocity ( $V_{AOA\_SW}$  or  $V_{ATO\_SW}$  for an AOA or ATO, respectively), then the guidance will be targeted for the AOA/ATO MECO; e.g.,

$$VDMAG = VD\_AOA\_ATO$$

$$RDMAG = RD\_AOA\_ATO$$

$$GAMD = GAMD\_AOA\_ATO$$

The nominal MECO target is maintained if  $V_{ME\_OUT}$  is greater than or equal to the switch velocity; e.g.,  $VDMAG = VD\_NOM$ ,  $RDMAG = RD\_NOM$ ,  $GAMD = GAMD\_NOM$ . If an AOA or ATO is performed with no SSME failures (e.g., partial thrust loss of an SSME), then  $V_{ME\_OUT}$  is set to the current navigated relative velocity magnitude,  $V_{ME\_OUT} = \bar{V}_{RHO\_MAG}$ .

For an AOA or ATO with variable IY targetting option selected ( $S^*IY = ON$ ), the unit vector normal to the desired orbit plane used by AS 2STG GUID (IY) is calculated as follows:

$$\bar{IY} = \text{UNIT}(\bar{V}_{NAV} \times \bar{R}_{NAV})$$

However, if the orbit inclination associated with  $\bar{IY}$  is less than a minimum acceptable inclination defined premission, then  $\bar{IY}$  is set equal to the minimum  $\bar{IY}$ . This inclination test is made by comparing the Z components of the  $\bar{IY}$  vectors in the M50 coordinate system.  $\bar{IY}$  minimum in M50 is calculated by:

$$\bar{IY}_{MIN\_M50} = \overset{*}{EARTH\_FIXED\_TO\_M50\_COORD}(T\_GMTLO) \bar{IY}_{MIN\_EF}$$

If  $IY(3) < \bar{IY}_{MIN\_M50}(3)$ ,

then  $\bar{IY} = \bar{IY}_{MIN\_M50}$

where

$\bar{IY}_{MIN\_M50}$  = minimum inclination  $\bar{IY}$  in the M50 coordinate system

$\bar{IY}_{MIN\_EF}$  = premission stored minimum  $\bar{IY}$  in earth-fixed coordinates



$\bar{X}_{EARTH\_FIXED\_TO\_M30\_COORD}(t)$  = earth-fixed to M30 coordinate transformation of vector  $\bar{X}$  at time  $t$

$T_{CNTLO}$  = Greenwich mean time at lift-off

For an ATO when  $V_{ME\_OUT}$  is greater than or equal to a premission stored, mission continuation velocity criterion ( $V_{MSSN\_CNTN}$ ), the variable IY flag ( $S_{IY}$ ) is set to OFF so that nominal MECO IY target is maintained, allowing mission continuation. This task makes no change to IY when  $S_{IY} = OFF$ .

B. Interface Requirements. The AOA/ATO MECO target selection input and output parameters are given in Tables 4.5.2-1 and 4.5.2-2.

C. Processing Requirements. The AOA/ATO MECO target selection task is performed once if an AOA or ATO is initiated before FCD (Event 31).

D. Initialisation Requirements. None.



Table 4.5.2-1. AOA/ATO MECO Target Selection Task Inputs

Definition	Symbol	Source	Precision	Units
Discrete indicating AOA commanded	S_AOA	MSC	D	N/A
Time of lift-off in GMT	T_GMTLO	FCOS	DP	sec
Discrete indicating ATO commanded	S_ATO	MSC	D	N/A
Variable IY targeting option flag	S_IY	I-LOAD	D	N/A
Relative velocity magnitude at SSME failure time	V_ME_OUT	SSME-OUT SAF TSK	SP	fps
Earth-fixed unit vector normal to minimum inclination orbit plane	$\bar{I}Y_{MIN\_EF}$	I-LOAD	DP	ND
AOA/ATO MECO terminal radius constraint	RD_AOA_ATO	I-LOAD	DP	ft
AOA/ATO MECO terminal velocity constraint	VD_AOA_ATO	I-LOAD	SP	fps
AOA/ATO MECO terminal flightpath angle constraint	GAMD_AOA_ATO	I-LOAD	SP	rad
AOA velocity criterion for switching MECO/EI constraints	V_AOA_SW	I-LOAD	SP	fps
ATO mission continuation velocity criterion	V_MSSN_CNTN	I-LOAD	SP	fps
ATO velocity criterion for switching MECO/EI constraints	V_ATO_SW	I-LOAD	SP	fps
Current Shuttle position vector in M50	$\bar{R}_{NAV}$	ASC UPP	SP	ft
Current navigated earth relative velocity magnitude	V_RHO_MAG	ASC UPP	SP	fps
Current Shuttle velocity vector in M50	$\bar{V}_{NAV}$	ASC UPP	SP	fps
Number of active SSME's	N_SSME	1STG GUID INP TSK, PFG INP TSK	I	N/A
Nominal MECO terminal radius constraint	RD_NOM	I-LOAD	DP	ft



Table 4.5.2-1. AOA/ATO MECO Target Selection Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
Nominal MECO terminal velocity constraint	VD_NOM	I-LOAD	SP	fps
Nominal MECO terminal flightpath angle constraint	GAMD_NOM	I-LOAD	SP	rad

Table 4.5.2-2. AOA/ATO MECO Target Selection Task Outputs

Definition	Symbol	Destination	Precision	Units
MECO flight path angle	GAMD	PEG TSK	SP	rad
MECO radius	RDMAG	PEG TSK	DP	ft
MECO velocity	VDMAG	PEG TSK, AOA ONORB TGT SEL TSK	SP	fps
Unit vector normal to the desired orbit plane	$\bar{I}Y$	PEG TSK, AOA ONORB TGT SEL TSK	DP	ND



#### 4.5.3 AOA/ATO OMS/RCS Pre-MECO Burn Determination Task (AOA/ATO OMS/RCS PRE-MECO BRN DET TSK)

The AOA/ATO OMS/RCS pre-MECO burn determination task sets the burn time flags and scaling factors used by the ABT CNTL SEQ principal function to execute the pre-MECO OMS/RCS burn. Burn duration tables are premission loaded into the ABT CNTL SEQ. These tables include burn durations for OMS propellant through the OMS engines, RCS propellant through the 4 +X RCS jets, RCS propellant through 8 RCS null jets, and RCS propellant through the 4 +X RCS jets post-MECO. Since the philosophy for performing the burn differs slightly for AOA and ATO, the following two subtasks are required:

1. AOA OMS/RCS pre-MECO burn
2. ATO OMS/RCS pre-MECO burn

##### A. Detailed Requirements.

1. AOA OMS/RCS pre-MECO burn. This subtask sets the pre-MECO OMS/RCS burn duration flag ( $S_{AOA\_BURN}$ ) for an AOA. Separate values of  $S_{AOA\_BURN}$  exist for the shallow (OFF) and the nominal (ON) entry interface (EI) target lines. Selection of the proper value is made by comparing  $V_{ME\_OUT}$  with  $V_{AOA\_SW}$  (a premission-stored MECO/EI target line switch velocity). If  $V_{ME\_OUT}$  is less than  $V_{AOA\_SW}$  (which is the case for an early AOA), then  $S_{AOA\_BURN}$  is set OFF. Otherwise (for a late AOA), the flag  $S_{AOA\_BURN}$  is set ON. The  $S_{AOA\_BURN}$  flag is transmitted to the ABT CNTL SEQ, where it is used to select one of the two AOA premission-stored OMS burn time tables. Also, a discrete,  $S_{ABORT\_CONTROL}$ , is set to indicate that the pre-MECO OMS/RCS burn parameters have been set. This enables the ABT CNTL SEQ to start the burn. This flag is also output to second-stage guidance to indicate that AOA/ATO TGT has been executed.
2. ATO OMS/RCS pre-MECO burn. This subtask sets the necessary scaling factors ( $K_2$  and  $K_4$ ) used by the ABT CNTL SEQ to regulate the pre-MECO OMS burn durations for ATO, as shown in Figure 4.5.3-1. These scaling factors are applied to an ATO burn duration table, premission loaded into the ABT CNTL SEQ. Scaling factor  $K_2$  governs the OMS propellant burned through the OMS engines. Scaling factor  $K_4$  governs the RCS propellant burned pre-MECO through the 4 +X and 8 null RCS jets and post-MECO through the 4 +X jets. For early ATO's ( $V_{ME\_OUT}$  less than or equal to a premission-stored velocity,  $V_{LIN}$ ), a constant burn duration sequence is specified by setting  $K_2$  and  $K_4$  equal to unity. When  $V_{ME\_OUT}$  is greater than  $V_{LIN}$ , no RCS-propellant/RCS burns are made. This is accomplished by leaving  $K_4$  set at its initial value of zero. The OMS propellant burn (through both the OMS engines) is decreased linearly as  $V_{ME\_OUT}$  increases in an effort to conserve OMS propellant for on-orbit usage. This is achieved by decreasing the  $K_2$  scaling factor linearly as a function of  $V_{ME\_OUT}$  to a point ( $V_{ZERO}$ ) where  $K_2$  is decreased to zero

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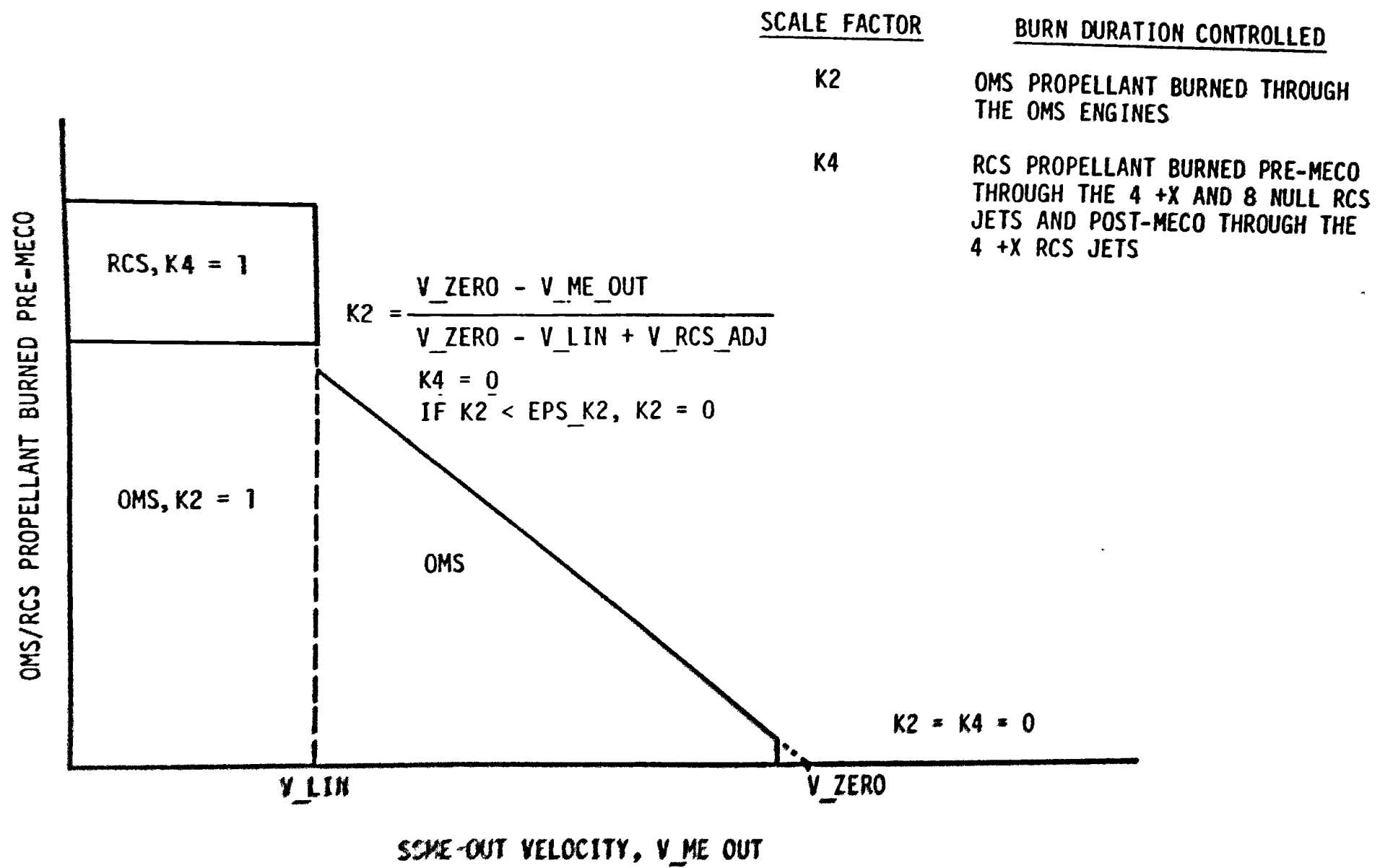


Figure 4.5.3 1. Pre MECO OMS/RCS Burn Duration Scaling Factors for ATO

$$K_2 = \frac{V\_ZERO - V\_ME\_OUT}{V\_ZERO - V\_LIN + V\_RCS\_ADJ}$$

The I-load  $V\_RCS\_ADJ$  reduces the pre-MECO OMS burn to save propellant for the OMS-1 burn to compensate for the performance loss from eliminating the parallel RCS burn ( $K_4 = 0$ ). Also,  $K_2$  is set to zero if it is less than a small value ( $EPS\_K2$ ) to preclude commanding a very short burn with insufficient time to perform the OMS/RCS interconnect.  $V\_MSSN\_CNTN$  described in Task 4.5.2 is always greater than  $V\_ZERO$  for a mission using variable  $IY$ , since a full mission continuation capability does not exist until the nominal mission orbit plane ( $IY$ ) can be achieved with zero pre-MECO OMS/RCS burn.

The discrete,  $S\_ABORT\_CONTROL$ , is set to indicate that the pre-MECO OMS/RCS burn parameters have been set. This enables the ABT CNTL SEQ to start the burn.

**B. Interface Requirements.** The AOA/ATO OMS/RCS pre-MECO burn determination input and output parameters are presented in Tables 4.5.3-1 and 4.5.3-2.

**C. Processing Requirements.** The AOA/ATO OMS pre-MECO burn determination task is performed once if an AOA or ATO is initiated before FCD (Event 31). The mutually exclusive flags,  $S\_AOA$  and  $S\_ATO$ , indicate which subtask to perform.

**D. Initialization Requirements.** Scale factors  $K_2$  and  $K_4$  must be set to zero initially.

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Table 4.5.3-1. AOA/ATO OMS/RCS Pre-MECO Burn Determination Task Inputs

Definition	Symbol	Source	Precision	Units
Discrete indicating AOA commanded	S_AOA	MSC	D	N/A
Discrete indicating ATO commanded	S_ATO	MSC	D	N/A
Relative velocity magnitude at SSME failure time	V_ME_OUT	SSME-OUT SAF TSK	SP	fps
AOA velocity criterion for switching MECO/EI constraints	V_AOA_SW	I-LOAD	SP	fps
ATO velocity criterion for defining pre- and post-MECO OMS and RCS burn requirements	V_LIN	I-LOAD	SP	fps
ATO velocity criterion for defining pre-MECO OMS and RCS burn requirements	V_ZERO	I-LOAD	SP	fps
Bias velocity for the pre-MECO OMS burn computation when the parallel RCS is not burned during OMS 1	V_RCS_ADJ	I-LOAD	SP	fps
Minimum tolerance value of K <sub>2</sub>	EPS_K2	I-LOAD	SP	ND

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Table 4.5.3-2. AOA/ATO OMS/RCS Pre-MECO Burn Determination Task Outputs

Definition	Symbol	Destination	Precision	Units
ATO pre-MECO burn time scaling factor for OMS propellant through OMS	K2	ABT CNTL SEQ	SP	ND
ATO pre- and post-MECO burn time scaling factor for RCS fuel through +X and null RCS jets	K4	ABT CNTL SEQ	I	N/A
AOA pre-MECO OMS/RCS burn table selection indicator	S_AOA_BURN	ABT CNTL SEQ, TLM	D	N/A
Discrete to indicate that pre-MECO AOA/ATO targeting is completed	S_ABORT CONTROL	ABT CNTL SEQ, 2STG SEQ	D	N/A



uts

Units

ND

N/A

N/A

N/A

4.5.4 AOA On-Orbit Target Selection Task (AOA ONORB TGT SEL TSK)

The AOA on-orbit target selection task selects an intermediate orbit in-plane apogee target for an OMS-1 burn or an entry interface target for an OMS-2 burn from a set of targets computed and stored on board premission. Target selection must be consistent with the MECO target and the entry interface target line selected earlier. If the variable IY option is being used, then the OMS-2 target must be considered with the orbit inclination. In addition, the excess OMS delta velocity (DV\_EXCESS) is calculated prior to the OMS-1 and OMS-2 burns. A negative value of DV\_EXCESS prior to either the OMS-1 or OMS-2 burn will result in a default to targets stored for the shallow entry interface target line. The automatic target selection logic can be overridden by crew item entry of the target index (I\_TGT) through the MANEUVER display, which sets AOA\_TGT\_SEL = ON. The following five subtasks are performed in the AOA on-orbit target selection task:

1. OMS-1 orbiter mass
2. Excess OMS-1 ΔV
3. AOA OMS-1 target
4. Excess OMS-2 ΔV
5. AOA OMS-2 target

A. Detailed Requirements.

1. OMS-1 Orbiter Mass. This subtask computes the initial orbiter mass to be used by ORB INS GUID for the OMS-1 burn. The orbiter mass is equal to the initial orbiter mass at lift-off (not including MPS propellant in the orbiter's lines) minus the OMS propellant burned pre-MECO. The required calculations are:

$$DM\_PREMECO = 2 \text{ MDOT\_OMS } T1$$

$$M = \text{MASS\_ORB} - DM\_PREMECO$$

where

DM\_PREMECO = mass of OMS propellant burned pre-MECO

MASS\_ORB = mass of orbiter at lift-off (should not include any SSME propellant or ET mass)

M = current orbiter mass

MDOT\_OMS = mass flow rate of an OMS engine

T1 = equivalent pre-MECO OMS burn time



Burn time T1 is supplied by the ABT CNTL SEQ principal function, and the orbiter mass at lift-off is I-loaded premission.

This OMS-1 orbiter mass calculation provides only an estimate of the actual mass since it does not account for smaller mass perturbances such as pre-MECO RCS propellant burned, APU vents, and main propulsion system dump.

2. Excess OMS-1 ΔV. This subtask computes the excess OMS ΔV prior to the OMS-1 burn and is used by the automatic target selection logic, AOA\_TGT\_SEL = OFF, in order to determine if the shallow EI default target set is required (see subtask 3). If AOA\_TGT\_SEL = ON, this subtask is not executed. The excess OMS ΔV requirement from the ΔV available pre-OMS-1 is obtained by subtracting the pre-MECO OMS burned and the OMS required for post-MECO c.g. control from the initial OMS loaded. Also, an OMS ΔV default tolerance is added into the excess OMS ΔV calculation to prevent a default for small ΔV deficiencies. The required computations are:

$$\text{MASS\_OMS\_PREOMS1} = \text{MASS\_OMS\_INIT} - \text{DM\_PREMECO} - \text{MASS\_CG\_CNTL}$$

$$\text{DV\_OMS} = \frac{\text{FT\_OMS}}{\text{MDOT\_OMS}} \text{ LOG} \left( \frac{\text{M}}{\text{M} - \text{MASS\_OMS\_PREOMS1}} \right)$$

$$\text{DV\_EXCESS} = \text{DV\_OMS} - \text{DV\_RQD} + \text{ABVAL}(\text{V\_NAV}) - \text{VDMAG} + \text{DV\_TOL}$$

where

DV\_EXCESS = excess OMS ΔV

DV\_OMS = remaining usable OMS ΔV

DV\_RQD = the sum of OMS-1 and OMS-2 ΔV required from the OMS engines

DV\_TOL = OMS ΔV default tolerance

FT\_OMS = nominal thrust of an OMS engine





MASS\_CG\_CNTL = mass of OMS propellant which must remain at EI  
for c.g. control

MASS\_OMS\_INIT = mass of usable OMS propellant loaded minus  
the OMS propellant set aside for DV\_TOL

MASS\_OMS\_PREOMS1 = mass of usable OMS propellant prior to  
OMS-1 burn

VDMAG = MECO target velocity magnitude

$\bar{V}_{NAV}$  = current navigated velocity

The MECO velocity dispersion is the difference between the current velocity and the MECO target velocity. The expected on-orbit delta velocity requirement, the initial usable OMS propellant mass, the OMS propellant mass needed for c.g. control, and the OMS  $\Delta V$  default tolerance are loaded premission. A separate value of the expected OMS on-orbit delta velocity required must be stored on board for the following two cases: nominal MECO, nominal EI target line, and nominal MECO, nominal EI target line with no parallel RCS burn during OMS-1. The mass of the orbiter prior to the OMS-1 burn (calculated above as M) is output to the ASC MNVR DIP for use in initializing the acceleration mass update task (4.8.2).

3. AOA OMS-1 Target. This subtask selects an intermediate orbit target set for the OMS-1 burn. The apogee altitude (HTGT) referenced to the earth equatorial radius, in-plane downrange angle from the launch site (THETA), velocity target parameters (C1 and C2), and a time of ignition after ET separation (DTIG) are the parameters that require computed values. These parameters are premission computed and I-loaded on board in the AOA OMS-1 target table containing three target sets. The HTGT and THETA target I-loads are designed to account for J2 and drag effects over the arc between OMS-1 ignition and the target apogee. (Note: OMS-1 targets are not a function of inclination for the variable IY targeting option.)

If automatic target selection is desired, AOA\_TGT\_SEL = OFF, then the following AOA target sets (HTGT, THETA, C1, C2, AND DTIG) are available as described by the following targeting situations: (1) AOA MECO target conditions, shallow entry interface (EI) target line (I\_TGT = 3); (2) nominal MECO target conditions, nominal EI target line (I\_TGT = 4); and (3) off-nominal MECO conditions, shallow EI target line (I\_TGT = 5). The AOA target set (1) will be selected automatically if AOA is declared pre-MECO and AOA MECO targets are chosen ( $V_{ME\_OUT} < V_{AOA\_SW}$ ). The AOA target set (2) will be selected automatically if AOA is declared pre-MECO and nominal MECO targets are chosen ( $V_{ME\_OUT} > V_{AOA\_SW}$ ), or if AOA is initiated after MECO but before the OMS-1 proceed command. The third AOA target set (3) will be automatically defaulted to if a delta velocity deficiency exists prior to OMS-1 ignition (negative excess delta V computed in the previous subtask). This default AOA target set reduces the delta V



required to perform the OMS-1 and OMS-2 burns as compared to the targets for the nominal EI target line which are normally selected.

In addition to the above target parameters, the 4 +X RCS jet burn duration during OMS-1 (TB RCS) is output to the PRE MAN DISP SUPT TSK and target index flag (I\_TGT) is set for the display.

In the event of a downmode from ATO to AOA, the AOA OMS-1 target set must be selected consistent with the MECO targets used by second-stage guidance following the initiation of ATO. The selection between the AOA/ATO MECO targets and the nominal MECO targets for ATO was based on the SSME failure velocity as described in Section 4.5.2.

If selection is manual, AOA\_TGT\_SEL = ON, meaning that the crew has selected a target set via item entry of the target index flag (I\_TGT), then the above automatic target selection logic is locked out, the previously selected OMS-1 targets are neglected, and a target set defined by the value of the index flag is selected from the I-loaded AOA OMS-1 target table. Since ATO targets are selected when I\_TGT = 1 or 2, the first AOA target set is selected from the AOA OMS-1 table when I\_TGT equals 3. If I\_TGT equals 4, then the second AOA target set is selected, etc. Refer to Table 4.5.4-1 for a definition of the relationship between the target index flag and the target table sets. The AOA\_TGT\_SEL flag is set to OFF to allow MSC to recognize a future target index item entry by the crew. Also, the 4 +X RCS parallel burn time (TB RCS) is set to zero and output to the AS MNVR DIP and the ABT CNTL SEQ to deschedule any automatically planned parallel RCS burn. If a parallel RCS burn is required, the crew must command it through the translational hand controller.

Every pass through this subtask, the abort initialization flag, ABORT\_INIT, is set to ON to indicate to the AS MNVR DIP that new targets have been selected.

4. Excess OMS-2 ΔV. This subtask computes the excess OMS ΔV prior to the OMS-2 burn and is used by the automatic target selection logic, AOA\_TGT\_SEL = OFF, in order to determine if the shallow EI default target set is required (see subtask 5). If target selection is manual, AOA\_TGT\_SEL = ON, then DV\_OMS, DV\_EXCESS, and the PEG call to obtain VGOMAG are not required. However, MASS\_OMS\_PREOMS2 and TIG\_OPS3 must still be calculated and H-θ-TO-M50 called to transform THETA. The excess OMS ΔV is obtained by computing the OMS propellant mass available prior to the OMS-2 burn, converting it to a ΔV, and then subtracting the projected OMS-2 ΔV required. An OMS ΔV default tolerance is added into the excess OMS delta velocity calculation to prevent a default for small ΔV deficiencies.

$$\text{MASS\_OMS\_PREOMS2} = \text{MASS\_OMS\_INIT} - \text{DM\_PREMECO} - \text{MASS\_CG\_CNTL} - \text{DM\_OMS1}$$

Table 4.5.4-1. Target Index Flag/Target Table Relationship

Target Index Flag, I_TGT	Table (Index)		Accessed by	
	OMS-1	OMS-2	Automatic Logic	Key-In of I_TGT*
1	ATO_OMS1(1)	ATO_OMS2(1)	yes	yes
2		ATO_OMS2(2)	yes	yes
3	AOA_OMS1(1)	AOA_OMS2(1)	yes	yes
4	AOA_OMS1(2)	AOA_OMS2(2)	yes	yes
5	AOA_OMS1(3)	AOA_OMS2(3)	yes	yes
6		AOA_OMS2(4)		yes
7		AOA_OMS2(5)		yes
8		AOA_OMS2(6)	yes	yes
9		AOA_OMS2(7)		yes
10		AOA_OMS2(8)		yes
11		AOA_OMS2(9)		yes
12		AOA_OMS2(10)	yes	yes

\*If the crew selects this OMS-1 target by key-in of the target index flag (I\_TGT), the associated OMS-2 target is automatically selected by the software upon transitioning to MM 105. The crew may override this automatic OMS-2 target selection by key-in of a new value for I\_TGT in MM 105 prior to the OMS-2 burn for ATO or prior to OPS-3 transition for AOA.

$$DV\_OMS = \left( \frac{FT\_OMS}{MDOT\_OMS} \right) \text{LOG} \left( \frac{M}{M - MASS\_OMS\_PREOMS2} \right)$$

$$DV\_EXCESS = DV\_OMS - VGOMAG + DV\_TOL$$

where

MASS\_OMS\_INIT = mass of usable OMS propellant loaded minus  
the OMS propellant set aside for DV\_TOL

DM\_OMS1 = OMS propellant burned during OMS-1 (see below)

MASS\_OMS\_PREOMS2 = OMS propellant mass remaining prior to  
the OMS-2 burn

DM\_PREMECO = mass of OMS propellant burned pre-MECO

M = current vehicle mass

MASS\_CG\_CNTL = mass of OMS propellant which must remain at  
EI for c.g. control

FT\_CMS = nominal thrust of an OMS engine

MDOT\_OMS = mass flow rate of an OMS engine

DV\_OMS = remaining OMS ΔV

VGOMAG = projected OMS-2 ΔV required

DV\_TOL = OMS ΔV default tolerance

DV\_EXCESS = excess OMS ΔV

The OMS propellant mass available prior to the OMS-2 burn is equal to the OMS propellant mass initially available minus the OMS propellant burned pre-MECO, the OMS propellant required for c.g. control, and the OMS propellant mass burned during OMS-1. The OMS propellant mass burned during OMS-1 is equal to the change in orbiter mass during OMS-1 adjusted for the parallel RCS burn.

$$MASS\_PREOMS1 = MASS\_ORB - DM\_PREMECO$$

$$DM\_OMS1 = MASS\_PREOMS1 - M - 4 TB\_RCS MDOT\_RCS$$

where

MASS\_PREOMS1 = mass of orbiter prior to OMS-1 burn

M = current vehicle mass

MASS\_ORB = mass of orbiter at lift-off (should not include  
any SSME propellant or ET structural mass)

TB\_RCS = RCS burn time duration during OMS-1

DM\_PREMECO = mass of OMS propellant burned pre-MECO

MDOT\_RCS = mass flow rate of an RCS jet

The mass of the orbiter prior to the OMS-1 burn is given by the mass of the orbiter at lift-off minus the OMS mass burned pre-MECO (zero for an AOA initiated post-MECO). The mass of the orbiter prior to the OMS-2 burn is saved by ORB INS GUID principal function at the end of the OMS-1 burn. (An adjustment for the SSME propellant dumped during OMS-1 is not necessary, since it is not accounted for in computing the mass burned during OMS-1 nor included in the mass of the orbiter prior to OMS-1.) The RCS burn duration is supplied by the ABT CNTL SEQ, and the mass flow rate is stored in this software premission.

The time of ignition of the OMS-2 burn is calculated by adding the stored delta TIG (selected below in Subtask 5) to the time of ET separation and subtracting an adjustment for MECO downrange dispersions:

$$TIG\_OPS3 = DTIG\_OMS + T\_ET\_SEP$$

where

$$DTIG\_OMS = DTIG - TIG\_ADJ,$$

$$TIG\_ADJ = (THETA\_LSS - THETA\_LS\_REF)/ORB\_RATE$$

The projected OMS-2 delta V is then computed by first propagating the current state ahead to TIG OPS3, with use of the ASC PREC PRED principal function. Inputs to ASC PREC PRED are:

- a.  $R\_NAV$ ,  $V\_NAV$ ,  $T\_NAV$ --the current state vector and time tag
- b. GMD and GMO--gravity degree (4) and order (4)

- c. DELTA\_T--integration step size (DELTA\_T = DT\_AOA\_PRED)
- d. T\_FINAL--the predicted state time (T\_FINAL = TIG\_OPS3)

Next, the H- $\theta$ -to-M50 task is called with arguments of the AOA OMS-2 target altitude (HTGT) (Subtask 5) and central angle (THETA), the OMS-2 TIG position vector (RGD), and an AOA OMS-2 burn discrete (S\_AOA\_OMS2 = ON). From these arguments the target position vector, RT, and the down-range angle from OMS-2 TIG to the target, THETA, are calculated. Then, if the default possibility exists (automatic selection logic in Subtask 5 selected I = 2 for the target table index), the ACC-MASS UPD TSK is called, which in turn calls THRST PRM TSK to furnish thrust (FT), mass (M), equivalent exhaust velocity (VEX), and mass flow rate (MDOT). Acceleration is calculated for PEG from FT and M, ATR = FT/M. Necessary inputs to ACC-MASS UPD TSK are number of active OMS engines (N\_OMS = 2) and number of RCS jets (N\_RCS = 0).

Finally, unless an OPS transition has been requested (OPS\_TRANS\_REQUEST = ON), PEG is called iteratively until convergence is achieved (SCONV = ON) or until the maximum number of calls (NMAX\_DIP) is exceeded to obtain the magnitude of the velocity to be gained, VGOMAG. Inputs to PEG are:

- a.  $\overline{RGD}$ ,  $\overline{VGD}$ , TGD--the guidance state (equal to TIG state)
- b.  $\overline{RT}$ --the target position vector
- c. C1, C2--the target line constants
- d. N--number of thrust phases (N=1)
- e. SINIT--PEG initialization switch (SINIT=ON)
- f. SMODE--PEG mode indicator (SMODE=4)
- g. ATR--thrust acceleration
- h. VEX--equivalent exhaust velocity
- i. MDOT--mass flow rate
- j. T\_RCS\_OFF--RCS burn time (T\_RCS\_OFF=0)
- k. Integration step size (DT\_LIMIT = DTMAX)

The projected OMS-2 delta V will be too small if both OMS are failed, but will be valid for a single OMS failure because the OMS-2 targets are designed for equal delta V for one or two OMS.



3. AOA OMS-2 Target. This subtask selects the desired set of entry interface target parameters for the OMS 2 burn. Target parameters are HTGT, THETA, C1, C2, and DTIG. These parameters are premission-computed and are I-loaded on board in the AOA OMS-2 target table containing ten target sets. The THETA and C1 I-loads are designed to account for the J2 effect over the arc between OMS-2 ignition and the entry interface. The altitude (HTGT) is referenced to the Fischer ellipsoid as required for an EI target and is set equal to a constant value, H\_EI, for all target sets. The downrange angle (THETA), I-loaded referenced to the launch site, must be converted to a downrange angle referenced to time of AOA OMS-2 ignition to be consistent with the OPS-3 target parameter format (THETA\_OMS<sub>3</sub> = THETA from H-θ-to-M50 task). This conversion of the downrange angle is performed in the H-θ-to-M50 target task. These target parameters (HTGT, THETA, C1, C2, and DTIG) are output to the AS MNVR DIP for conversion to display format and transferred to the OPS-3 maneuver display.

If selection is automatic, AOA TGT SEL = OFF, then five sets of OMS-2 burn target parameters are available for selection, three for shallow EI and two for nominal EI. The decision logic for OMS-2 target selection is the value of the target index (I) as follows, where  $I = I\_TGT - 2$ :

- a. Select shallow EI target set (I = 1) corresponding to AOA OMS-1 target set I\_TGT = 3.
- b. Select nominal EI target set (I = 2) if executing an AOA from nominal MECO to nominal EI and an AOA was initiated between MECO and the OMS-1 proceed command and if a default has not occurred (DV\_EXCESS > 0).
- c. Select shallow EI target set (I = 3) if default occurs prior to OMS-1 from the nominal MECO, nominal EI targeting situation.
- d. Select shallow EI target set (I = 6) if default occurs after OMS-1 (prior to OMS-2) from the nominal MECO, nominal EI targeting situation; that is, if the possibility exists for a default (I = 2) and DV\_EXCESS < 0, then set I = 6.
- e. Select nominal EI target set (I = 10) if the decision to perform an AOA was made after the crew proceed for the OMS-1 maneuver, i.e., nominal OMS-1 burn performed.

Note the target set (I = 3) built for AOA/ATO MECO conditions can no longer be accessed automatically prior to OMS-1 since an AOA abort cannot be selected pre-MECO.

For a default case (I = 6), the delta time and time of OMS-2 ignition must be recomputed

$$DTIG\_OMS_3 = DTIG - TIG\_ADJ$$

$$TIG\_OPS3 = DTIG\_OMS_3 + T\_ET\_SEP$$



ASC PREC PRED must be called once again to obtain the projected state vectors at TIG. Exit this task if an OPS transition has been requested (OPS\_TRANS\_REQUEST = ON); otherwise, the H-θ-to-M50 target task must be called once again to obtain THETA referenced to OMS-2 time of ignition (OPS-3 target format). For non-default cases, the TIG and THETA computed in the OMS-2 ΔV subtask are retained. The first three AOA OMS-2 target sets are compatible pairs with the three AOA OMS-1 target sets and are selected automatically based on OMS-1 target selection unless an OMS-2 default has occurred or a nominal OMS-1 burn has occurred. The target index flag, I\_TGT, is set for display.

If selection is manual, AOA\_TGT\_SEL = ON, the crew has item entered a target request and the target set defined by the value of the target index flag (I\_TGT) is selected from the I-loaded AOA OMS-2 target table. The manual target selection of ten OMS-2 target sets is available via the target index flag; five of the target sets are described above in the automatic OMS-2 target selection logic. The remaining five target sets can only be accessed by crew key-in of I\_TGT equal to 6, 7, 9, 10, or 11. (NOTE: I\_TGT = 1 or 2 selects ATO targets, so I\_TGT = 6, 7, 9, 10, or 11 results in selection of the fourth, fifth, seventh, eighth, or ninth sets from the AOA OMS-2 target table. See Table 4.5.4-1.) The AOA\_TGT\_SEL flag is set to OFF to allow MSC to recognize a future target index item entry by the crew.

If the variable IY option is requested, the OMS-2 target parameters THETA, C1, C2, and DTIG must be functions of the orbit inclination. The HTGT target parameter will remain a constant altitude, H\_EI, above the Fischer ellipsoid for all cases. The orbit inclination is calculated by

$$\text{INCL} = \text{ARCCOS}(-\text{IY}(3))$$

The functionalized target parameters are expressed as quadratic functions of inclination.

$$\text{THETA} = \text{THETA\_AOA\_OMS2}(I,1) + \text{THETA\_AOA\_OMS2}(I,2) \text{ INCL}$$

$$+ \text{THETA\_AOA\_OMS2}(I,3) \text{ INCL}^2$$

$$\text{C1} = \text{C1\_AOA\_OMS2}(I,1) + \text{C1\_AOA\_OMS2}(I,2) \text{ INCL}$$

$$+ \text{C1\_AOA\_OMS2}(I,3) \text{ INCL}^2$$

$$\text{C2} = \text{C2\_AOA\_OMS2}(I,1) + \text{C2\_AOA\_OMS2}(I,2) \text{ INCL}$$

$$+ \text{C2\_AOA\_OMS2}(I,3) \text{ INCL}^2$$

$$\text{DTIG} = \text{DTIG\_AOA\_OMS2}(I,1) + \text{DTIG\_AOA\_OMS2}(I,2) \text{ INCL}$$

$$+ \text{DTIG\_AOA\_OMS2}(I,3) \text{ INCL}^2$$



For target sets with indices 1 through 9, the parameters are functionalized; but for target set I = 10 (AOA after nominal OMS-1), the parameters are constants rather than functions of inclinations, since only the nominal mission inclination is possible.

If it is determined prelaunch that the variable IY option is not to be used, then all linear and quadratic terms are I-loaded to zero with only nonzero constant terms remaining.

The weight of the OMS propellant to be burned during OMS-2 (WT\_PROP\_DEP) is output to the maneuver display in OPS-3. Guidance will deplete this OMS propellant during the OMS-2 burn by thrusting out of plane. WT\_PROP\_DEP is prefixed by either a plus or minus to indicate right or left out-of-plane thrusting. A mission-dependent parameter (SFUELD) is premission-stored in AOA/ATO TGT to either +1 or -1 for this purpose. The necessary computation is

$$WT\_PROP\_DEP = SFUELD \ G\_2\_FPS2 \ MASS\_OMS\_PREOMS2$$

The MASS\_OMS\_PREOMS2 was computed above in the excess OMS-2 ΔV subtask. If MASS\_OMS\_PREOMS2 is negative, then WT\_PROP\_DEP is set to zero to avoid OMS propellant wasting. G\_2\_FPS2 is the gravitational constant.

Every pass through this subtask, the abort initialization flag, ABORT<sup>\*</sup> INIT, is set to ON to indicate to the AS MNVR DIP that new targets have been selected.

B. Interface Requirements. The input and output parameters for the AOA on-orbit target selection task are presented in Tables 4.5.4-2 and 4.5.4-3.

C. Processing Requirements. The excess OMS-1 ΔV and the AOA OMS-1 target subtasks are executed if the AOA/ATO TGT principal function is scheduled during MM 104 before the OMS-1 proceed command (BURN\_ENABLE). The excess OMS-2 ΔV and the AOA OMS-2 target subtasks are executed if AOA/ATO TGT is scheduled after transition to MM 105.

D. Initialization Requirements. None.

Table 4.5.4-2. AOA On-Orbit Target Selection Task Inputs

Definition	Symbol	Source	Precision	Units
Equivalent pre-MECO OMS burn time	T1	ABT CNTL SEQ	SP	sec
Mass of orbiter at lift-off (not to include MPS vent mass)	MASS_ORB	I-LOAD	SP	slug
Mass of usable OMS propellant loaded minus the OMS propellant set aside for DV_TOL	MASS_OMS_INIT	I-LOAD	SP	slug
Mass of OMS propellant to be reserved for c.g. control	MASS_CG_CNTL	I-LOAD	SP	slug
Sum of OMS-1 and OMS-2 $\Delta V$ expected (2)*	DV_RQD	I-LOAD	SP	fps
$\Delta V$ tolerance for OMS-1 and OMS-2 default targeting decision	DV_TOL	I-LOAD	SP	fps
Desired MECO velocity magnitude	VDMAG	GUID PRMT RINT TSK, I-LOAD, AOA/ATO MECO TGT SEL TSK	SP	fps
Target altitude referenced to earth equatorial radius for OMS-1 (3)*	HTGT_AOA_OMS1	I-LOAD	SP	ft
Target altitude referenced to Fischer ellipsoid for OMS-2 (1)*	H_EI	I-LOAD	SP	ft
Target in-plane downrange angle from launch site -OMS-1 (3)*	THETA_AOA_OMS1	I-LOAD	SP	rad
*Number of parameters				

Table 4.5.4-2. AOA On-Orbit Target Selection Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
Polynomial coefficients for target in-plane down-range angle from the launch site OMS-2				
Constant (10)*	THETA_AOA OMS2(I,1)	I-LOAD	SP	rad
Linear (9)*	THETA_AOA OMS2(I,2)	I-LOAD	SP	ND
Quadratic (9)*	THETA_AOA OMS2(I,3)	I-LOAD	SP	rad <sup>-1</sup>
Mass to weight conversion factor	G_2_FPS2	CONSTANT	SP	lb/ slug
Time tag associated with current state	T_NAV	ASCENT UPP	DP	sec
Target intercept of the vertical velocity vs. horizontal velocity relationship OMS-1 (3)*	C1_AOA_OMS1	I-LOAD	SP	fps
Polynomial coefficients for target intercept of the vertical velocity vs. horizontal velocity relationship OMS-2				
Constant (10)*	C1_AOA OMS2(I,1)	I-LOAD	SP	fps
Linear (9)*	C1_AOA OMS2(I,2)	I-LOAD	SP	fps/ rad
Quadratic (9)*	C1_AOA OMS2(I,3)	I-LOAD	SP	fps/ rad <sup>2</sup>
Target slope of the vertical velocity vs. horizontal velocity relationship OMS-1 (3)*	C2_AOA_OMS1	I-LOAD	SP	ND
Polynomial coefficients for target slope of the vertical velocity vs. horizontal velocity relationship OMS-2:				
Constant (10)*	C2_AOA OMS2(I,1)	I-LOAD	SP	ND
*Number of parameters				

Table 4.5.4-2. AOA On-Orbit Target Selection Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
Linear (9)*	$C2_{AOA_{OMS2(I,2)}}$	I-LOAD	SP	rad <sup>-1</sup>
Quadratic (9)*	$C2_{AOA_{OMS2(I,3)}}$	I-LOAD	SP	rad <sup>-2</sup>
Time of ignition referenced to ET separation OMS-1 (3)*	$DTIG_{AOA_{OMS1}}$	I-LOAD	SP	sec
Polynomial coefficient for time of ignition referenced to ET separation OMS-2:				
Constant (10)*	$DTIG_{AOA_{OMS2(I,1)}}$	I-LOAD	SP	sec
Linear (9)*	$DTIG_{AOA_{OMS2(I,2)}}$	I-LOAD	SP	sec/ rad
Quadratic (9)*	$DTIG_{AOA_{OMS2(I,3)}}$	I-LOAD	SP	sec/ rad <sup>2</sup>
Time of ET separation	$T_{ET\_SEP}$	FCOS	DP	sec
Magnitude of VGO vector	VGOMAG	PEG TSK	SP	fps
RCS burn time for AOA OMS-1 parallel (OMS/RCS) maneuver	TB_RCS	ABT CNTL SEQ	SP	sec
Assumed number of active OMS engines	N_OMS	PFG INP TSK	I	N/A
Position vector at OMS-2 time of ignition	$\bar{R}_{GD}$	A/E PREC PRED	DP	ft
Velocity vector at OMS-2 time of ignition	$\bar{V}_{GD}$	A/E PREC PRED	SP	fps
Current position vector	$\bar{R}_{NAV}$	ASCENT UP	DP	ft
Current velocity vector	$\bar{V}_{NAV}$	ASCENT UP	SP	fps
Current vehicle mass	M	ACC-MASS UPD TSK	SP	slug
Fuel wasting flag: 0- no fuel wasting ± left/right thrusting to use excess propellant	SFUELD	I-LOAD	I	N/A
*Number of parameters				

Table 4.5.4-2. AOA On-Orbit Target Selection Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
Nominal OMS thrust	FT_OMS	I-LOAD	SP	lb
Nominal OMS mass flow rate	MDOT_OMS	I-LOAD	SP	slug/ sec
Nominal RCS mass flow rate	MDOT_RCS	K-LOAD	SP	slug/ sec
Total vehicle thrust force	FT	THRST PRM TSK	SP	lb
Maximum PEG cycles	NMAX_DIP	K-LOAD	I	N/A
Discrete indicating convergence	SCONV	PEG TSK	D	N/A
Central angle between OMS-2 ignition and the target position vector at entry interface	THETA	H- $\theta$ -TO-M50 TSK	SP	rad
Desired A/E PREC PRED step size	DT_AOA_PRED	K-LOAD	SP	sec
Central angle between launch site reference and OMS-1 TIG	THETA_LSS	H- $\theta$ -TO-M50 TSK	SP	rad
Reference central angle between launch site reference and OMS-1 TIG	THETA_LS_REF	I-LOAD	SP	rad
Circular orbit rate	ORB_RATE	K-LOAD	SP	rad/ sec
Maximum integration step size	DTMAX	K-LOAD	SP	sec
Crew target index flag	I_TGT	MNVR DISP	I	N/A
AOA target selection	AOA_TGT_SEL	MNVR DISP	D	N/A
Abort initialization flag	ABORT_INIT	DISP INIT TSK	D	N/A
Unit vector normal to desired plane in M50 coordinates	I $\bar{Y}$	PEG TASK, AOA/ATO MECO TGT SEL, GUID PRMT RINT TSK	DP	ND
OPS transition request flag	OPS_TRANS_REQUEST	AS PREC PRED	D	N/A

Table 4.5.4-3. AOA On-Orbit Target Selection Task Outputs

Definition	Symbol	Destination	Precision	Units
Target altitude	HTGT_OMS <sub>3</sub>	DISP INIT TSK	SP	ft
	HTGT	H-θ-M50 TGT TSK	SP	ft
Target in-plane downrange angle (from launch site for OMS-1, from TIG for OMS-2)	THETA_OMS <sub>3</sub>	DISP INIT TSK	SP	rad
Angle from launch site to OMS-2 target position vector	THETA	H-θ-M50 TGT TSK	SP	rad
Target intercept of the vertical velocity vs. horizontal velocity relationship	C1_OMS <sub>3</sub>	DISP INIT TSK, TLM	SP	fps
	C1	PEG TSK	SP	fps
Target slope of the vertical velocity vs. horizontal velocity relationship	C2_OMS <sub>2</sub>	DISP INIT TSK, TLM	SP	ND
	C2	PEG TSK	SP	ND
Time of ignition referenced to ET separation	DTIG_OMS <sub>3</sub>	DISP INIT TSK	SP	sec
Time of ignition of the OMS-2 burn	T_FINAL	ASC PREC PRED	DP	sec
RCS cutoff time during AOA OMS-1 parallel OMS/RCS maneuver	T_RCS_OFF	PEG TSK	DP	sec
RCS burn duration during OMS-1	TB_RCS	PRE-MAN DISP SUPT TSK, TLM, ABT CNTL SEQ	SP	sec
PEG initialization discrete	SINIT	PEG TSK	D	N/A
Number of thrust phases	N	PEG TSK	I	N/A
AOA OMS-2 targeting data ready flag	S_AOA_OMS2	H-θ-TO-M50 TSK, DISP INIT TSK	D	N/A
Number of active OMS engines	N_OMS	THRST PRM TSK	I	N/A
Number of active RCS engines	N_RCS	THRST PRM TSK	I	N/A



Table 4.5.4-3. AOA On-Orbit Target Selection Task Outputs (Cont)

Definition	Symbol	Destination	Precision	Units
Weight of OMS propellant prior to the AOA OMS-2 burn	WT_PROP_DEP	MNVR DISP (OPS-3) <sup>1</sup>	SP	lb
Current position vector	$\bar{R}_{NAV}$	ASC PREC PRED	DP	ft
Current velocity vector	$\bar{V}_{NAV}$	ASC PREC PRED	SP	fps
Current vehicle mass	M	DISP INIT TSK	SP	slug
Time tag associated with current state	T_NAV	ASC PREC PRED	DP	sec
Gravity model degree	GMD_PRED	ASC PREC PRED	I	N/A
Gravity model order	GMO_PRED	ASC PREC PRED	I	N/A
Integration step size	DELTA_T	ASC PREC PRED	SP	sec
Vehicle position vector input to PEG	$\bar{R}_{GD}$	PEG TSK, H- $\theta$ -TO-M50 TSK	DP	ft
Vehicle velocity vector input to PEG	$\bar{V}_{GD}$	PEG TSK, H- $\theta$ -TO-M50 TSK	SP	fps
Time associated with $\bar{R}_{GD}$ and $\bar{V}_{GD}$	TGD	PEG TSK	DP	sec
Target position in inertial coordinates	$\bar{R}_T$	PEG TSK	DP	ft
Abort initialization flag	ABORT_INIT	DISP INIT TSK	D	N/A
Thrust acceleration estimate input to PEG	ATR	PEG TSK	SP	fps <sup>2</sup>
PEG mode indicator	SMODE	PEG TSK	I	N/A
Excess OMS delta V	DV_EXCESS	TLM	SP	ft/sec
Maximum integration step size for gravity prediction	DT_LIMIT	PEG TSK	SP	sec
Crew target index flag	I_TGT	MNVR DISP	I	N/A
AOA target selection	AOA_TGT_SEL	MNVR DISP	D	N/A

<sup>1</sup>Data transferred to OPS-3.

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#### 4.5.5 ATO On-Orbit Target Selection Task (ATO ONORB TGT SEL TSK)

The ATO on-orbit target selection task obtains the ATO OMS-1 and OMS-2 target parameters. The target parameters are computed and stored on board premission. The automatic target selection logic can be overridden by crew item entry of the target index flag (I\_TGT) through the maneuver display, which sets ATO\_TGT\_SEL = ON. Neither the OMS-1 nor OMS-2 ATO target is a function of the inclination for the variable IY targeting option. The following two subtasks are performed in the ATO on-orbit target selection task.

1. ATO OMS-1 target
2. ATO OMS-2 target

##### A. Detailed Requirements.

1. ATO OMS-1 Target. This subtask obtains the ATO OMS-1 apogee target parameters. These target parameters are a premission stored apogee altitude (HTGT) referenced to the earth equatorial radius, in-plane downrange angle from the launch site (THETA), velocity target parameters ( $C_1$  and  $C_2$ ), and a time of ignition referenced to ET separation (DTIG). The HTGT and THETA I-loads are designed to account for J2 and drag effects over the arc between OMS-1 ignition and the target apogee. Even though an ATO is performed from either the AOA/ATO or the nominal MECO, target parameters are a single HTGT, THETA,  $C_1$ ,  $C_2$ , DTIG set. The target index flag, I\_TGT, is set to 1.

If the crew has selected a target set via item entry of the target index flag (I\_TGT), then ATO\_TGT\_SEL is set ON and the above automatic target selection logic is locked out, the previously selected OMS-1 targets are neglected, and the target set defined by the value of the index flag is selected from the I-loaded ATO OMS-1 target table. One OMS-1 target set is available via the target index flag (I\_TGT), I\_TGT = 1. Table 4.5.4-1 shows the relationship between the target index flag and the ATO OMS-1 target table. The ATO\_TGT\_SEL flag is set to OFF to allow the MSC to recognize a future target index item entry by the crew. Also, the 4 +X RCS parallel burn time (TB RCS) is set to zero and output to the AS MNVR DIP (PRE-MAN DISP SUPT TSK) and the ABT CNTL SEQ to deschedule any automatically planned parallel RCS burn. If a parallel RCS burn is required, the crew must command it through the translational hand controller. Guidance will be less than optimum since it has not planned on this parallel burn.

Every pass through this subtask, the abort initialization flag, ABORT\_INIT, is set to ON to indicate to the AS MNVR DIP that new targets have been selected.



In addition to the above targets, the RCS burn duration (TB\_RCS) obtained from the ABT CNTL SEQ and the mass of the orbiter prior to the OMS-1 burn are output to the AS MNVR DIP for subsequent use in ORB INS GUID. The mass of the orbiter before the OMS-1 burn is computed by subtracting the pre-MECO OMS propellant burned from the initial orbiter mass.

$$DM\_PREMECO = 2 \text{ MDOT\_OMS } T1$$

$$M = \text{MASS\_ORB} - DM\_PREMECO$$

where

DM\_PREMECO = mass of OMS propellant burned pre-MECO

MDOT\_OMS = mass flow rate of an OMS engine

MASS\_ORB = mass of orbiter at lift-off

M = current vehicle mass

T1 = equivalent pre-MECO OMS burn time

The pre-MECO OMS propellant burn time parameter T1 is obtained from the ABT CNTL SEQ. Since ORB INS GUID required only an approximation of mass, an accounting of the RCS propellant burned pre-MECO is unnecessary.

2. ATO OMS-2 Target. This subtask obtains the ATO OMS-2 perigee target parameters. For most missions, this target will result in orbit circularization. The target parameters selected are an HTGT, THETA, C1, C2, DTIG set. Two ATO OMS-2 target parameter sets are required; one to be used if a nominal OMS-1 burn was performed, the other to be used if an ATO OMS-1 burn was performed. These target parameters are premission computed and I-loaded on-board and are offset for  $J_2$  in the same manner as the ATO OMS-1 target parameters. The target index flag, I\_TGT, is set to the selected target table index.

If the crew has item entered a target request (ATO\_TGT\_SEL=ON), the target set defined by the value of the target index flag (I\_TGT) is selected from the I-loaded ATO OMS-2 target table. The automatic target selection logic and any previously selected OMS-2 target must be ignored. Two OMS-2 target sets are available via the index flag;



the first one (I\_TGT = 1) is compatible with the OMS-1 target set. The second (I\_TGT = 2) target set is the one described above for use following a nominal OMS-1 burn. The ATO\_TGT\_SEL flag is set to OFF to allow the MSC to recognize a future target index item entry by the crew.

Every pass through this subtask, the abort initialization flag, ABORT\_INIT, is set to ON to indicate to the AS MNVR DIP that new targets have been selected.

B. Interface Requirements. The input and output parameters for the ATO on-orbit target selection task are given in Tables 4.5.5-1 and 4.5.5-2.

C. Processing Requirements. The ATO OMS-1 target subtask is executed if AOA/ATO TGT principal function is scheduled before OMS-1 proceed command (BURN\_ENABLE). The ATO OMS-2 target subtask is executed in MM 105 if AOA/ATO TGT is scheduled.

D. Initialization Requirements. None.

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Table 4.5.5-1. ATO On-Orbit Target Selection Task Inputs

Definition	Symbol	Source	Precision	Units
Target altitude referenced to earth equatorial radius (3)*				
- OMS-1 (1)*	HTGT_ATO_OMS1	I-LOAD	SP	ft
- OMS-2 (2)*	HTGT_ATO_OMS2	I-LOAD	SP	ft
Target inplane downrange angle from launch site:				
- OMS-1 (1)*	THETA_ATO_OMS1	I-LOAD	SP	rad
- OMS-2 (2)*	THETA_ATO_OMS2	I-LOAD	SP	rad
Time of ignition referenced to ET separation:				
- OMS-1 (1)*	DTIG_ATO_OMS1	I-LOAD	SP	sec
- OMS-2 (2)*	DTIG_ATO_OMS2	I-LOAD	SP	sec
RCS burn time duration during OMS-1	TB_RCS	ABT CNTL SEQ	SP	sec
Target intercept of the vertical velocity vs. horizontal velocity relationship:				
- OMS-1 (1)*	C1_ATO_OMS1	I-LOAD	SP	fps
- OMS-2 (2)*	C1_ATO_OMS2	I-LOAD	SP	fps
Target slope of the vertical velocity vs. horizontal velocity relationship:				
- OMS-1 (1)*	C2_ATO_OMS1	I-LOAD	SP	ND
- OMS-2 (2)*	C2_ATO_OMS2	I-LOAD	SP	ND
Equivalent pre-MECO OMS burn time	T1	ABT CNTL SEQ	SP	sec
Initial orbiter mass	MASS_ORB	I-LOAD	SP	slugs
OMS engine mass flow rate	MDOT_OMS	I-LOAD	SP	slug/sec
Crew target index flag	I_TGT	MNVR DISP	I	N/A
ATO target selection	ATO_TGT_SEL	MNVR DISP	D	N/A
Abort initialization flag	ABORT_INIT	DISP INIT TSK	D	N/A
*Number of parameters				

Table 4.5.5-2. ATO On-Orbit Target Selection Task Outputs

Definition	Symbol	Destination	Precision	Units
Target altitude	HTGT_OMS <sub>3</sub>	DISP INIT TSK	SP	ft
Target in-plane downrange angle from launch site	THETA_OMS <sub>3</sub>	DISP INIT TSK	SP	rad
Target intercept of the vertical velocity vs. horizontal velocity relationship	C1_OMS <sub>3</sub>	DISP INIT TSK, TLM	SP	fps
Target slope of the vertical velocity vs. horizontal velocity relationship	C2_OMS <sub>3</sub>	DISP INIT TSK, TLM	SP	ND
Time of ignition referenced to ET separation	DTIG_OMS <sub>3</sub>	DISP INIT TSK	SP	sec
RCS burn duration during OMS-1	TB_RCS	PRE-MAN DISP SUPT TSK, TLM, ABT CNTL SEQ	SP	sec
Current vehicle mass	M	DISP INIT TSK	SP	slug
Abort initialization flag	.ABORT_INIT	DISK INIT TSK	D	N/A
ATO target selection	ATO_TGT_SEL	MNVR DISP	D	N/A
Crew target index flag	I_TGT	MNVR DISP	I	N/A

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#### 4.5.6 Parameter Tables for AOA/ATO Targeting

The IDD inputs and outputs are listed in Table 4.5.6-1. Values for the I-loads are contained in the I-load requirements document (JSC-19350); however, I-load definitions applicable to this principal function are listed in Table 4.5.6-2. K-loads are listed in Table 4.5.6-3. Constants are listed in Table 4.5.6-4. The input variable cross-references are listed in Table 4.5.6-5.

Table 4.5.6-1. Abort-Once-Around/Abort-To-Orbit Targeting (G4.13)  
Input/Output Functional Parameters

DBFN: D2B039-A PN: VP707100026POOL MAY 31, 1988  
INPUT FUNCTIONAL PARAMETERS FOR ABORT-ONCE-AROUND/ABORT-TO-ORBIT TARGETING

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BOOK: 2

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE
ABORT_INIT	V90X8489XB	ABORT INITIALIZATION FLAG	ASC MNVR DIP		
AOA_TGT_SEL	V93X6963XA	AOA TARGET SELECTION	6.35		
ATO_TGT_SEL	V93X6964XA	ATO TARGET SELECTION	6.35		
I_TGT	V93J6962CA	CREW TARGET INDEX FLAG	6.35		
IY(X)	V90U1976CA	X-M50 UNIT VEC NORMAL TO ORB PLANE	ASC 2STG GUID		
IY(X)	V90U1976CB	X-M50 UNIT VEC NORMAL TO ORB PLANE	ORB INS GUID		
IY(Y)	V90U1977CA	Y-M50 UNIT VEC NORMAL TO ORB PLANE	ASC 2STG GUID		
IY(Y)	V90U1977CB	Y-M50 UNIT VEC NORMAL TO ORB PLANE	ORB INS GUID		
IY(Z)	V90U1978CA	Z-M50 UNIT VEC NORMAL TO ORB PLANE	ASC 2STG GUID		
IY(Z)	V90U1978CB	Z-M50 UNIT VEC NORMAL TO ORB PLANE	ORB INS GUID		
IY_MIN_EF(1)	V96U9388C	X-EF UN VEC NORM TO MIN INCL	UL		
IY_MIN_EF(2)	V96U9389C	Y-EF UN VEC NORM TO MIN INCL	UL		
IY_MIN_EF(3)	V96U9390C	Z-EF UN VEC NORM TO MIN INCL	UL		
M/CURR_ORB_MASS/WEIGHT	V90U1961CA	CURRENT VEHICLE MASS	ORB INS GUID	SLUGS	
MM_CODE_103/MM_103	V90X8156X	MAJOR MODE 103 FLAG	MSC		
MM_CODE_104/MM_104	V90X8152X	MAJOR MODE 104 FLAG	MSC		
MM_CODE_105/MM_105	V90X8623X	MAJOR MODE 105 FLAG	MSC		
N_OMS	V90J2031CB	NUMBER OF ACTIVE OMS ENGINES	ORB INS GUID		
N_SSME	V90U1962CA	NUMBER OF ACTIVE SSME'S	ASC 1STG GUID		
OPS_TRANS_REQUEST	V90X0892XB	OPS TRANSITION REQUEST FLAG	ASC PREC PRED		
R_AVGG(1)	V95H0185CB	X-COMP OF CURRENT SHUTTLE POS VCTR	ASC UPP	FT	DPL
R_AVGG(2)	V95H0186CB	Y-COMP OF CURRENT SHUTTLE POS VCTR	ASC UPP	FT	DPL
R_AVGG(3)	V95H0187CB	Z-COMP OF CURRENT SHUTTLE POS VCTR	ASC UPP	FT	DPL
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_M50_AT_LIFTOFF(1)	V95U0507C	X-M50 POS OF NB AT LIFTOFF	ASC UPP	FT	
R_M50_AT_LIFTOFF(2)	V95U0508C	Y-M50 POS OF NB AT LIFTOFF	ASC UPP	FT	
R_M50_AT_LIFTOFF(3)	V95U0509C	Z-M50 POS OF NB AT LIFTOFF	ASC UPP	FT	
REL_VEL_MAG	V95L0151CE	GND REL VEL MAGNITUDE IN M50 SYS	ASC UPP	FT/S	
S_AOA	V90X8636X	AOA ABORT DECLARED	MSC		
S_ATO	V90X8635X	ATO ABORT DECLARED	MSC		
T_ET_SEP	V90W8621C	TIME OF ET SEPARATION	MSC	S	
T_GMTLO	V90W4380C	TIME OF LIFTOFF IN GMT	FCOS	S	
T_STATE	V95W0200CD	TIME TAG ASSOC WITH CURRENT STATE	ASC UPP	S	
TB_RCS	V90W8298CB	POST MECO RCS +X DELTA T COMPUTED	ABT CNTL SEQ	S	
THETA_LSS	V94U3808C	LNCH SITE TO OMS1 TIG CNTRL ANGLE	ASC MNVR DIP	RAD	
T1	V90W8320C	OMS EQUIVALENT ON TIME	ABT CNTL SEQ	S	
V_AVGG(1)	V95L0190CB	X-COMP OF CURRENT SHUTTLE VEL VCTR	ASC UPP	FT/S	SPL
V_AVGG(2)	V95L0191CB	Y-COMP OF CURRENT SHUTTLE VEL VCTR	ASC UPP	FT/S	SPL
V_AVGG(3)	V95L0192CB	Z-COMP OF CURRENT SHUTTLE VEL VCTR	ASC UPP	FT/S	SPL
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_ME_OUT	V90L1947CA	SSME ENGINE-OUT VELOCITY	ASC 1STG GUID	FT/S	
V_ME_OUT	V90L1947CB	SSME ENGINE-OUT VELOCITY	ASC 2STG GUID	FT/S	
VDHAG	V90U8499CA	DESIRED MECO VELOCITY	ASC 2STG GUID	FT/S	

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Table 4.5.6-1. Abort-Once-Around/Abort-To-Orbit Targeting (G4.13)  
Input/Output Functional Parameters (Cont)

DBFN: D2B039-A PN: VP707100026P00L MAY 31, 1988 OI8B REV00 PAGE 210  
OUTPUT FUNCTIONAL PARAMETERS FROM ABORT-ONCE-AROUND/ABORT-TO-ORBIT TARGETING AOA/ATO TGT G4.13 BOOK: 2

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C
ABORT_INIT	V90X8489XA	ABORT INITIALIZATION FLAG	ASC MNVR DIP			
AOA_TGT_SEL	V93X6963XB	AOA TARGET SELECTION	6.35			
ATO_TGT_SEL	V93X6964XB	ATO TARGET SELECTION	6.35			
C1_OMS(3)	V90L8487C	INTERCEPT OF TARGET LINE-DIP	ASC MNVR DIP,TLM	FT/S		
C2_OMS(3)	V90U8488C	SLOPE OF TARGET LINE-DIP	ASC MNVR DIP,TLM			
DT_MAX	V90U8500CC	MAX ALLOW TIME STEP SIZE	ASC PREC PRED	S		
DTIG_OMS(3)	V90W8485C	TIME OF OMS 1/2 IGN AFTER ET SEP	ASC MNVR DIP,TLM	S		
DV_EXCESS	V90U8511C	EXCESS OMS DELTA V	TLM	FT/S		
GARD	V90U8497C	DESIRED MECO FLIGHT PATH ANGLE	ASC 2STG GUID	RAD		SPL
GMD_PRED	V90U8501CC	GRAVITY MODEL DEGREE	ASC PREC PRED			
GMO_PRED	V90U8502CC	GRAVITY MODEL ORDER	ASC PREC PRED			
HTGT_OMS(3)	V90H8481C	TGT ALTITUDE AT END OF COAST PHASE	ASC MNVR DIP,TLM	FT		
I_TGT	V93J6962CB	CREW TARGET INDEX FLAG	6.35,TLM			
IY(X)	V90U1976CD	X-M50 UNIT VEC NORMAL TO ORB PLANE	ASC 2STG GUID			
IY(Y)	V90U1977CD	Y-M50 UNIT VEC NORMAL TO ORB PLANE	ASC 2STG GUID			
IY(Z)	V90U1978CD	Z-M50 UNIT VEC NORMAL TO ORB PLANE	ASC 2STG GUID			
K2	V90J8517C	SCALE FACTOR 2	ABT CNTL SEQ			
K4	V90X8519X	SCALE FACTOR 4 FLAG	ABT CNTL SEQ			
M/CURR_ORB_MASS/HEIGHT	V90U1961CB	CURRENT VEHICLE MASS	ASC MNVR DIP,TLM	SLUGS		
R_INIT(X)	V90H8508CD	X-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT		
R_INIT(Y)	V90H8509CD	Y-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT		
R_INIT(Z)	V90H8510CD	Z-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT		
RDMAG	V90U8498C	DESIRED MECO RADIUS	ASC 2STG GUID	FT		
S_ABORT_CONTROL	V90X8504X	TGT COMPLETE FLAG	ABT CNTL SEQ,ASC 2STG GUID			
S_AOA_BURN	V90X8484X	PRE-MECO OMS/RCS BURN TABLE FLAG	ABT CNTL SEQ,TLM			BD
S_AOA_OMS2	V90X8486X	AOA OMS-2 TGT DATA READY FLAG	ASC MNVR DIP			
T_FINAL	V90W8506CD	TIME AT WHICH STATE IS DESIRED	ASC PREC PRED	S		
T_INIT	V90W8512CD	TIME AT BEGINNING OF PRED	ASC PREC PRED	S		
TB_RCS	V90W8298CA	POST MECO RCS +X DELTA T COMPUTED	ASC MNVR DIP,ABT CNTL SEQ,TLM	S		
THETA_OMS(3)	V90H8482C	TGT INPLN DNRNG ANG FROM LANH SITE	ASC MNVR DIP,TLM	RAD		
V_INIT(X)	V90L8513CD	X-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED	FT/S		
V_INIT(Y)	V90L8514CD	Y-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED	FT/S		
V_INIT(Z)	V90L8515CD	Z-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED	FT/S		
VDMAG	V90U8499CB	DESIRED MECO VELOCITY	ASC 2STG GUID	FT/S		
WT_PROP_DEP	V90U8491C	WT OF OMS PROP PRIOR AOA/OMS2 BURN	TLM	LBS		

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Table 4.5.6-2. AOA/ATO Targeting (G4.13) I-Loads Abort-Once-Around/  
Abort-to-Orbit Targeting

OIBB MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	C1_AOA_OMS1(1)	V97U4312C	FT/SEC	F	S	M	C	G4.13	ZF22	
	C1_AOA_OMS1(2)	V97U4313C	FT/SEC	F	S	M	C	G4.13	ZF22	
	C1_AOA_OMS1(3)	V97U4314C	FT/SEC	F	S	M	C	G4.13	ZF22	
	C1_AOA_OMS2(1,1)	V97U4316C	FT/SEC	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(1,2)	V96U9393C	(FT/SEC)/RAD	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(1,3)	V96U9397C	(FT/SEC)/RAD**2	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(10,1)	V96U9462C	FT/SEC	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(2,1)	V97U4317C	FT/SEC	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(2,2)	V96U9394C	(FT/SEC)/RAD	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(2,3)	V96U9398C	(FT/SEC)/RAD**2	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(3,1)	V97U4318C	FT/SEC	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(3,2)	V96U9395C	(FT/SEC)/RAD	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(3,3)	V96U9399C	(FT/SEC)/RAD**2	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(4,1)	V97U4319C	FT/SEC	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(4,2)	V96U9396C	(FT/SEC)/RAD	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(4,3)	V96U9400C	(FT/SEC)/RAD**2	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(5,1)	V97U4320C	FT/SEC	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(5,2)	V96U9463C	(FT/SEC)/RAD	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(5,3)	V96U9468C	(FT/SEC)/RAD**2	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(6,1)	V96U9458C	FT/SEC	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(6,2)	V96U9464C	(FT/SEC)/RAD	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(6,3)	V96U9469C	(FT/SEC)/RAD**2	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(7,1)	V96U9459C	FT/SEC	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(7,2)	V96U9465C	(FT/SEC)/RAD	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(7,3)	V96U9470C	(FT/SEC)/RAD**2	F	S	M	C	G4.13	A3A3	
	C1_AOA_OMS2(8,1)	V96U9460C	FT/SEC	F	S	M	C	G4.13	A3A3	

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Table 4.5.6-2. AOA/ATO Targeting (G4.13) I-Loads Abort-Once-Around/  
Abort-to-Orbit Targeting (Cont)

OI8B MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	C1_AOA_OMS2(8,2)	V96U9466C	(FT/SEC)/RAD	F	S	M	C	G4.13		A3A3
	C1_AOA_OMS2(8,3)	V96U9471C	(FT/SEC)/RAD**2	F	S	M	C	G4.13		A3A3
	C1_AOA_OMS2(9,1)	V96U9461C	FT/SEC	F	S	M	C	G4.13		A3A3
	C1_AOA_OMS2(9,2)	V96U9467C	(FT/SEC)/RAD	F	S	M	C	G4.13		A3A3
	C1_AOA_OMS2(9,3)	V96U9472C	(FT/SEC)/RAD**2	F	S	M	C	G4.13		A3A3
	C1_ATO_OMS1	V97U4323C	FT/SEC	F	S	M	C	G4.13		ZF22
	C1_ATO_OMS2(1)	V97U4324C	FT/SEC	F	S	M	C	G4.13		ZF22
	C1_ATO_OMS2(2)	V97U4325C	FT/SEC	F	S	M	C	G4.13		ZF22
	C2_AOA_OMS1(1)	V97U4328C	ND	F	S	M	C	G4.13		ZF22
	C2_AOA_OMS1(2)	V97U4329C	ND	F	S	M	C	G4.13		ZF22
	C2_AOA_OMS1(3)	V97U4330C	ND	F	S	M	C	G4.13		ZF22
	C2_AOA_OMS2(1,1)	V97U4332C	ND	F	S	M	C	G4.13		A3A3
	C2_AOA_OMS2(1,2)	V96U9401C	RAD**-1	F	S	M	C	G4.13		A3A3
	C2_AOA_OMS2(1,3)	V96U9405C	RAD**-2	F	S	M	C	G4.13		A3A3
	C2_AOA_OMS2(10,1)	V96U9477C	ND	F	S	M	C	G4.13		A3A3
	C2_AOA_OMS2(2,1)	V97U4333C	ND	F	S	M	C	G4.13		A3A3
	C2_AOA_OMS2(2,2)	V96U9402C	RAD**-1	F	S	M	C	G4.13		A3A3
	C2_AOA_OMS2(2,3)	V96U9406C	RAD**-2	F	S	M	C	G4.13		A3A3
	C2_AOA_OMS2(3,1)	V97U4334C	ND	F	S	M	C	G4.13		A3A3
	C2_AOA_OMS2(3,2)	V96U9403C	RAD**-1	F	S	M	C	G4.13		A3A3
	C2_AOA_OMS2(3,3)	V96U9407C	RAD**-2	F	S	M	C	G4.13		A3A3
	C2_AOA_OMS2(4,1)	V97U4335C	ND	F	S	M	C	G4.13		A3A3
	C2_AOA_OMS2(4,2)	V96U9404C	RAD**-1	F	S	M	C	G4.13		A3A3
	C2_AOA_OMS2(4,3)	V96U9408C	RAD**-2	F	S	M	C	G4.13		A3A3
	C2_AOA_OMS2(5,1)	V97U4336C	ND	F	S	M	C	G4.13		A3A3
	C2_AOA_OMS2(5,2)	V96U9478C	RAD**-1	F	S	M	C	G4.13		A3A3

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Table 4.5.6-2. AOA/ATO Targeting (G4.13) I-Loads Abort-Once-Around/  
Abort-to-Orbit Targeting (Cont)

MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	C2_AOA_OMS2(5,3)	V96U9483C	RAD**2	F	S	M	C	G4.13	A3A3	
	C2_AOA_OMS2(6,1)	V96U9473C	ND	F	S	M	C	G4.13	A3A3	
	C2_AOA_OMS2(6,2)	V96U9479C	RAD**1	F	S	M	C	G4.13	A3A3	
	C2_AOA_OMS2(6,3)	V96U9484C	RAD**2	F	S	M	C	G4.13	A3A3	
	C2_AOA_OMS2(7,1)	V96U9474C	ND	F	S	M	C	G4.13	A3A3	
	C2_AOA_OMS2(7,2)	V96U9480C	RAD**1	F	S	M	C	G4.13	A3A3	
	C2_AOA_OMS2(7,3)	V96U9485C	RAD**2	F	S	M	C	G4.13	A3A3	
	C2_AOA_OMS2(8,1)	V96U9475C	ND	F	S	M	C	G4.13	A3A3	
	C2_AOA_OMS2(8,2)	V96U9481C	RAD**1	F	S	M	C	G4.13	A3A3	
	C2_AOA_OMS2(8,3)	V96U9486C	RAD**2	F	S	M	C	G4.13	A3A3	
	C2_AOA_OMS2(9,1)	V96U9476C	ND	F	S	M	C	G4.13	A3A3	
	C2_AOA_OMS2(9,2)	V96U9482C	RAD**1	F	S	M	C	G4.13	A3A3	
	C2_AOA_OMS2(9,3)	V96U9487C	RAD**2	F	S	M	C	G4.13	A3A3	
	C2_ATO_OMS1	V97U4339C	ND	F	S	M	C	G4.13	ZF22	
	C2_ATO_OMS2(1)	V97U4340C	ND	F	S	M	C	G4.13	ZF22	
	C2_ATO_OMS2(2)	V97U4341C	ND	F	S	M	C	G4.13	ZF22	
	DTIG_AOA_OMS1(1)	V97U4356C	SEC	F	S	M	C	G4.13	A3A3	
	DTIG_AOA_OMS1(2)	V96U9488C	SEC	F	S	M	C	G4.13	A3A3	
	DTIG_AOA_OMS1(3)	V96U9489C	SEC	F	S	M	C	G4.13	A3A3	
	DTIG_AOA_OMS2(1,1)	V97U4357C	SEC	F	S	M	C	G4.13	A3A3	
	DTIG_AOA_OMS2(1,2)	V96U9409C	SEC/RAD	F	S	M	C	G4.13	A3A3	
	DTIG_AOA_OMS2(1,3)	V96U9413C	SEC/RAD**2	F	S	M	C	G4.13	A3A3	
	DTIG_AOA_OMS2(10,1)	V96U9447C	SEC	F	S	M	C	G4.13	A3A3	
	DTIG_AOA_OMS2(2,1)	V97U4358C	SEC	F	S	M	C	G4.13	A3A3	
	DTIG_AOA_OMS2(2,2)	V96U9410C	SEC/RAD	F	S	M	C	G4.13	A3A3	
	DTIG_AOA_OMS2(2,3)	V96U9414C	SEC/RAD**2	F	S	M	C	G4.13	A3A3	

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Table 4.5.6-2. AOA/ATO Targeting (G4.13) I-Loads Abort-Once-Around/  
Abort-to-Orbit Targeting (Cont)

MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	DTIG AOA OMS2(3,1)	V97U4359C	SEC	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(3,2)	V96U9411C	SEC/RAD	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(3,3)	V96U9415C	SEC/RAD**2	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(4,1)	V97U4360C	SEC	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(4,2)	V96U9412C	SEC/RAD	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(4,3)	V96U9416C	SEC/RAD**2	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(5,1)	V97U4361C	SEC	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(5,2)	V96U9448C	SEC/RAD	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(5,3)	V96U9453C	SEC/RAD**2	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(6,1)	V96U9443C	SEC	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(6,2)	V96U9449C	SEC/RAD	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(6,3)	V96U9454C	SEC/RAD**2	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(7,1)	V96U9444C	SEC	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(7,2)	V96U9450C	SEC/RAD	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(7,3)	V96U9455C	SEC/RAD**2	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(8,1)	V96U9445C	SEC	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(8,2)	V96U9451C	SEC/RAD	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(8,3)	V96U9456C	SEC/RAD**2	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(9,1)	V96U9446C	SEC	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(9,2)	V96U9452C	SEC/RAD	F	S	M	C	G4.13		A3A3
	DTIG_AOA_OMS2(9,3)	V96U9457C	SEC/RAD**2	F	S	M	C	G4.13		A3A3
	DTIG_ATO_OMS1	V97U4364C	SEC	F	S	M	C	G4.13		A3T3
	DTIG_ATO_OMS2(1)	V97U4365C	SEC	F	S	M	C	G4.13		A3T3
	DTIG_ATO_OMS2(2)	V97U4366C	SEC	F	S	M	C	G4.13		A3T3
	DV_RQD(1)	V97U4373C	FT/SEC	F	S	M	C	G4.13		ZF22
	DV_RQD(2)	V97U4374C	FT/SEC	F	S	M	C	G4.13		ZF22

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Table 4.5.6-2. AOA/ATO Targeting (G4.13) I-Loads Abort-Once-Around/  
Abort-to-Orbit Targeting (Cont)

MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	DV_TOL	V97U4377C	FT/SEC	F	S	M	C	G4.13		ZF22
	EPS_K2	V97U4837C	ND	F	S	M	C	G4.13		AAD0
	FT_OMS	V97U4390C	LBF	F	S	D	C	G4.210 G4.13 G4.4 G4.3 G4.2		ZF22
	GAMD_AOA_ATO	V97U4395C	RAD	F	S	M	C	G4.13		A2A1
	GAMD_NOM	V97U4396C	RAD	F	S	M	C	G4.2 G4.13		A2M1
	H_EI	V97U4401C	FT	F	S	D	C	G4.13		ZF22
	HTGT_AOA_OMS1(1)	V97U4397C	FT	F	S	M	C	G4.13		A3A3
	HTGT_AOA_OMS1(2)	V97U4398C	FT	F	S	M	C	G4.13		A3A3
	HTGT_AOA_OMS1(3)	V97U4399C	FT	F	S	M	C	G4.13		A3A3
	HTGT_ATO_OMS1	V97U4408C	FT	F	S	M	C	G4.13		A3T3
	HTGT_ATO_OMS2(1)	V97U4409C	FT	F	S	M	C	G4.13		A3T3
	HTGT_ATO_OMS2(2)	V97U4410C	FT	F	S	M	C	G4.13		A3T3
	IY_MIN_EF(1)	V96U9388C	ND	F	D	M	C	G4.13		A2N1
	IY_MIN_EF(2)	V96U9389C	ND	F	D	M	C	G4.13		A2N1
	IY_MIN_EF(3)	V96U9390C	ND	F	D	M	C	G4.13		A2N1
	KLAMDZX	V97U4423C	ND	F	S	D	C	G4.3 G4.209 G4.13 G4.210 G4.211		ZF12
	MASS_CG_CNTL	V97U4431C	SLUGS	F	S	M	C	G4.13		AMC2
	MASS_OMS_INIT	V97U4434C	SLUGS	F	S	M	C	G4.13		AMC2
	MASS_ORB	V97U4435C	SLUGS	F	S	M	C	G4.210 G4.13		AMC2

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Table 4.5.6-2. AOA/ATO Targeting (G4.13) I-Loads Abort-Once-Around/  
Abort-to-Orbit Targeting (Cont)

MISSIONS	FSSR NAME	NSID	ENG 'UNIT	DT	PR	D	S	PR	FCTN	CAT
	MDOT_OMS	V97U4440C	SLUGS/SEC	F	S	D	C	G4.210 G4.13 G4.4 G4.3 G4.2		ZF22
	RD_AOA_ATO	V97U4644C	FT	F	D	M	C	G4.13		A2A1
	RD_NOM	V97U4645C	FT	F	D	M	C	G4.2 G4.13		A2M1
	S_IY	V96U9391C	ND	D		M	C	G4.13		AVI0
	SFUELD	V97U4658C	ND	I	S	M	C	G4.13		A3A3
	THETA_AOA_OMS1(1)	V97U4787C	RAD	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS1(2)	V97U4788C	RAD	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS1(3)	V97U4789C	RAD	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(1,1)	V97U4791C	RAD	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(1,2)	V96U9417C	ND	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(1,3)	V96U9421C	RAD**-1	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(10,1)	V96U9432C	RAD	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(2,1)	V97U4792C	RAD	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(2,2)	V96U9418C	ND	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(2,3)	V96U9422C	RAD**-1	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(3,1)	V97U4793C	RAD	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(3,2)	V96U9419C	ND	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(3,3)	V96U9423C	RAD**-1	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(4,1)	V97U4794C	RAD	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(4,2)	V96U9420C	ND	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(4,3)	V96U9424C	RAD**-1	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(5,1)	V97U4795C	RAD	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(5,2)	V96U9433C	ND	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(5,3)	V96U9438C	RAD**-1	F	S	M	C	G4.13		A3A3

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Table 4.5.6-2. AOA/ATO Targeting (G4.13) I-Loads Abort-Once-Around/  
Abort-to-Orbit Targeting (Cont)

MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	THETA_AOA_OMS2(6,1)	V96U9428C	RAD	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(6,2)	V96U9434C	ND	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(6,3)	V96U9439C	RAD**~1	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(7,1)	V96U9429C	RAD	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(7,2)	V96U9435C	ND	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(7,3)	V96U9440C	RAD**~1	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(8,1)	V96U9430C	RAD	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(8,2)	V96U9436C	ND	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(8,3)	V96U9441C	RAD**~1	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(9,1)	V96U9431C	RAD	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(9,2)	V96U9437C	ND	F	S	M	C	G4.13		A3A3
	THETA_AOA_OMS2(9,3)	V96U9442C	RAD**~1	F	S	M	C	G4.13		A3A3
	THETA_ATO_OMS1	V97U4798C	RAD	F	S	M	C	G4.13		A3T3
	THETA_ATO_OMS2(1)	V97U4799C	RAD	F	S	M	C	G4.13		A3T3
	THETA_ATO_OMS2(2)	V97U4800C	RAD	F	S	M	C	G4.13		A3T3
	THETA_LS_REF	V97U4802C	RAD	F	S	M	C	G4.13		ZF22
	V_AOA_SH	V97U4815C	FT/SEC	F	S	M	C	G4.13		A2A1
	V_ATO_SH	V97U4816C	FT/SEC	F	S	M	C	G4.13		A2A1
	V_LIN	V97U4819C	FT/SEC	F	S	M	C	G4.13		AAD0
	V_MSSN_CNTN	V96U9392C	FT/SEC	F	S	M	C	G4.13		AVI0
	V_RCS_ADJ	V97U4822C	FT/SEC	F	S	D	C	G4.13		AAD0
	V_ZERO	V97U4825C	FT/SEC	F	S	M	C	G4.13		AAD0
	VD_AOA_ATO	V97U4826C	FT/SEC	F	S	M	C	G4.13		A2A1
	VD_NOM	V97U4827C	FT/SEC	F	S	M	C	G4.2 G4.13		A2M1

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Table 4.5.6-3. AOA/ATO Targeting (G4.13) K-Loads Abort-Once-Around/Abort-to-Orbit Targeting

OI8B MISSIONS							
FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT PR S PR FCTN	LAST CR EQTN	MSID	
DT_AOA_PRED	V97U4830C	+1.00	E+01 SEC	F S C G4.13	29602A		
DTMAX	V97U4369C	+1.00	E+20 SEC	F S C G4.209 G4.13 G4.4 G4.3 G4.2	89541		
MAX STEP SIZE, ASC PREC PRED							
DTMIN	V97U4370C	01 +2.0 02 +3.00 03 +2.0	E+00 SEC E+02 E+00	F S C G4.211 G4.210 G4.209 G4.158 G4.13 G4.4 G4.3 G4.2	29975A		
MDOT_RCS	V97U4441C	+1.0655714	E-01 SLUGS/SEC	F S C G4.210 G4.2 G4.13 G4.4 G4.3	89661A		
NOMINAL RCS MASS FLOW RATE							
NMAX_DIP	V97U4836C	+10	ND	I S C G4.211 G4.13 G4.210	59955		
MAXIMUM PEG CYCLE							
ORB_RATE	V97U4450C	+1.195301	E-03 RAD/SEC	F S C G4.13	39323		

DBFN:0534

DATE:07/14/88

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Table 4.5.6-4. AOA/ATO Targeting (G4.13) Constants

NROKRM1.FSSR2.DATA(X24)BOOK2  
PFS CONSTANTS UPDATE B/L

FSSR NAME DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
EARTH MU EARTH'S GRAVITATIONAL CONSTANT	V97U4378C		1.40764487566 E+16	FT**3/ SEC**2	F	D	P			
G_2 FPS2 MASS TO WEIGHT CONVERSION	V97U4393C		32.174049	LB/SLUG	F	S	P			
MUP TH MINIMUM CHANGE IN MASS REQUIRED FOR MASS TO BE UPDATED			.3	SLUGS	F	S	P			
PI RATIO OF CIRCUMFERENCE TO DIAMETER	V98U8725C		3.1415926535897	ND	F	D	P			
EARTH RADIUS EQUATOR EARTH EQUATORIAL RADIUS	V97U5324C		20925741. 4698163	FT	F	D	P			

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Systems Division



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Table 4.5.6-5. AOA/ATO TGT Input Variable Cross-Reference

MSID	Local Name	Source Name
V95H0185CB, 6CB, 7CB	$\bar{R}_{NAV}$	$\bar{R}_{AVGG}$
V95L0190CB, 1CB, 2CB	$\bar{V}_{NAV}$	$\bar{V}_{AVGG}$
V95L0151CE	V_RHO_MAG	REL_VEL_MAG
V95W0200CD	T_NAV	T_STATE

4.6 POWERED RTLS REQUIREMENTS (MM 601).

#### 4.6 POWERED RTLS REQUIREMENTS (MM 601)

Powered RTLS guidance is performed by the PW RTLS GUID principal function (CPDS, Level B, GN&C, Section 4.4). MM 601 extends from the RTLS abort initiation during second stage to the completion of the -Z translation. The general guidance and targeting tasks required for the powered RTLS principal function are PFG Input (Section 4.8.8), SSME-Out Safing (Section 4.8.9), G-Limiting (Section 4.8.3), MPS Guidance Cutoff (Section 4.8.5), PEG (Section 4.8.1), Acceleration-Mass Update (Section 4.8.2), Thrust Parameters (Section 4.8.7), and RTLS/TAL Target Selection (Section 4.8.11) tasks.

In second-stage flight the RTLS major mode is initiated by the crew setting the abort mode rotary switch to the RTLS position and pressing the abort button. If an RTLS is selected during first stage, the major mode begins at the SRB separation command. Termination occurs either as an automatic transition upon completion of the -Z translation maneuver (Event A39) or a crew-initiated transition (PRO) to MM 602. In the event of a second SSME failure (a contingency abort), PW RTLS GUID will set the ET low-level sensor arm command and a special contingency abort calculation will be performed by PW RTLS GUID to determine if glide RTLS guidance should be scheduled in MM 602. (Guidance is not normally scheduled in MM 602 for contingency aborts.)

The powered RTLS major mode is normally composed of three flight phases. The fuel dissipation phase continues the downrange flight at a fixed inertial thrust direction while cyclical computations are performed to determine the proper time to initiate the turnaround. This phase is not executed in aborts near the limit of the RTLS capability since the turnaround is begun immediately.

The flyback phase, which includes the turnaround, guides the vehicle to targets designated at the beginning of powered pitchdown (MECO minus 20 seconds). Throttling for fuel depletion control is also performed during the flyback phase.

The powered pitchdown phase serves two functions. Each cycle, it commands the orbiter/ET to the angle of attack required for separation and simultaneously computes the SSME cutoff time. The SSME thrust is then terminated at this time by the SSME OPS principal function.

The powered RTLS guidance principal function will be initiated and terminated at the same times as MM 601. The tasks to be performed by the powered RTLS (Figure 4.6-1) guidance principal function for MM 601 are as follows:

1. PFG input task (PFG INP TSK)
2. RTLS contingency abort task (RTLS CNTG ABT TSK)
3. Acceleration-mass update task (ACC-MASS UPD TSK)

4. ET low-level sensor arm command task (ET LLS ARM TSK)
5. TVC retrim task (TVC RT TSK)
6. G-limiting task (G-LIM TSK)
7. SSME-out safing task (SSME-OUT SAF TSK)
8. RTLS initialization task (RTLS INIT TSK)
9. RTLS/TAL target selection task (RTLS/TAL TGT SEL TSK)
10. Fuel dissipation task (FUL DISS TSK)
11. Flyback task (FLYBK TSK)
12. Powered pitchdown task (PPD TSK)
13. MPS guidance cutoff task (MPS GUID C/O TSK)
14. Pitch command task (PITCH CMD TSK)
15. MECO preparation task (MECO PREP TSK)

The PEG and thrust parameters general guidance tasks are called by the fuel dissipation and flyback tasks.

Figures 4.6-2, 4.6-3, and 4.6-4 illustrate the RTLS powered flight guidance task organization, functional flow, and data flow. The principal function interfaces are given in Section 4.6.8.

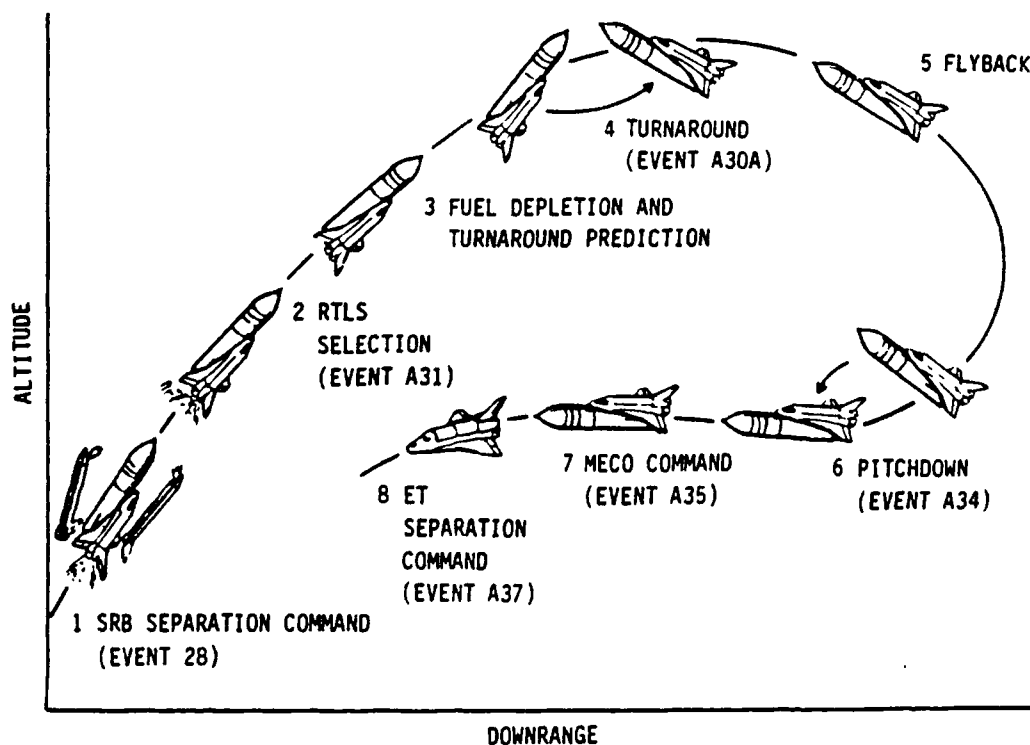
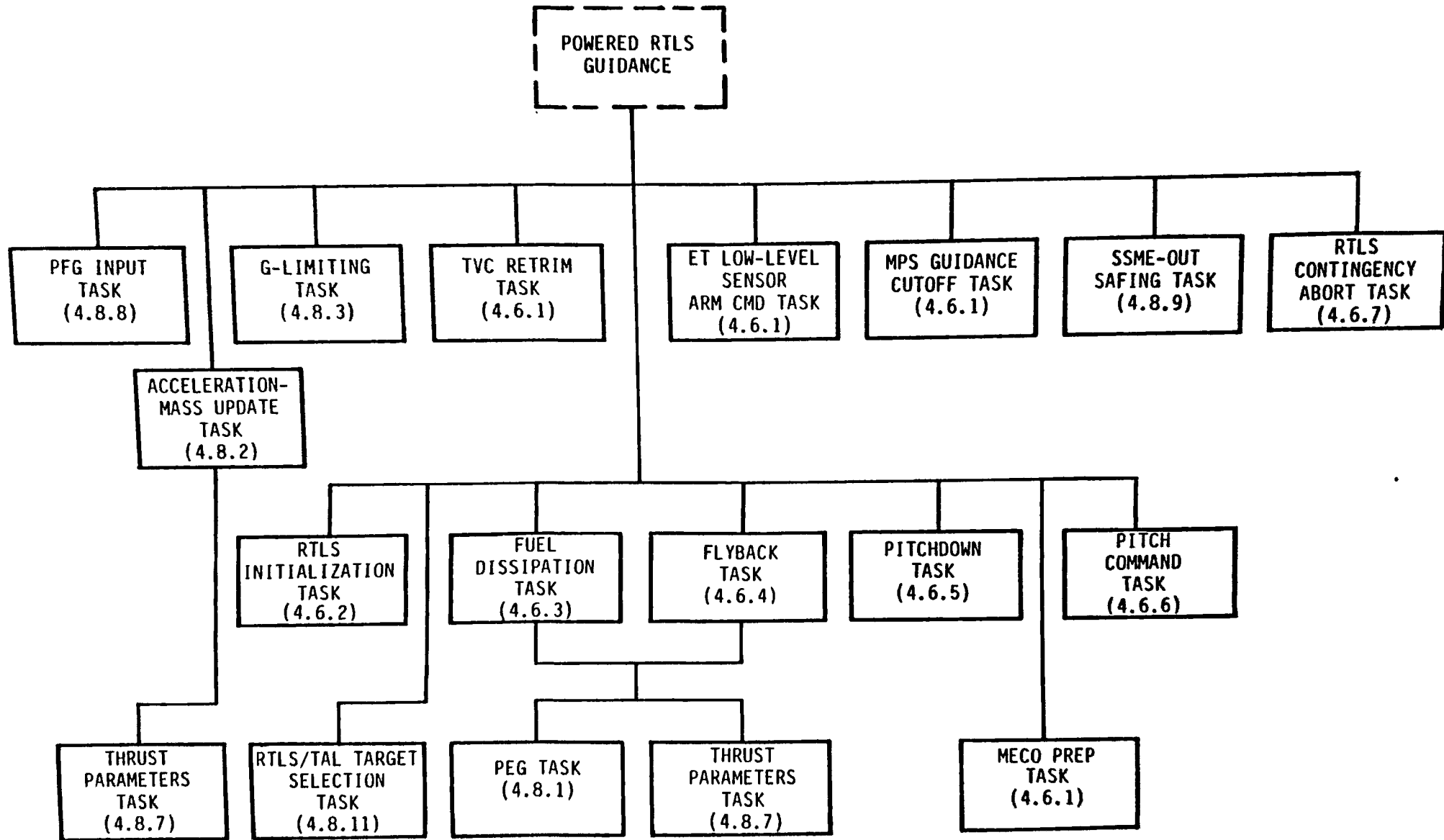


Figure 4.6-1. Typical PRTLS Sequence of Events

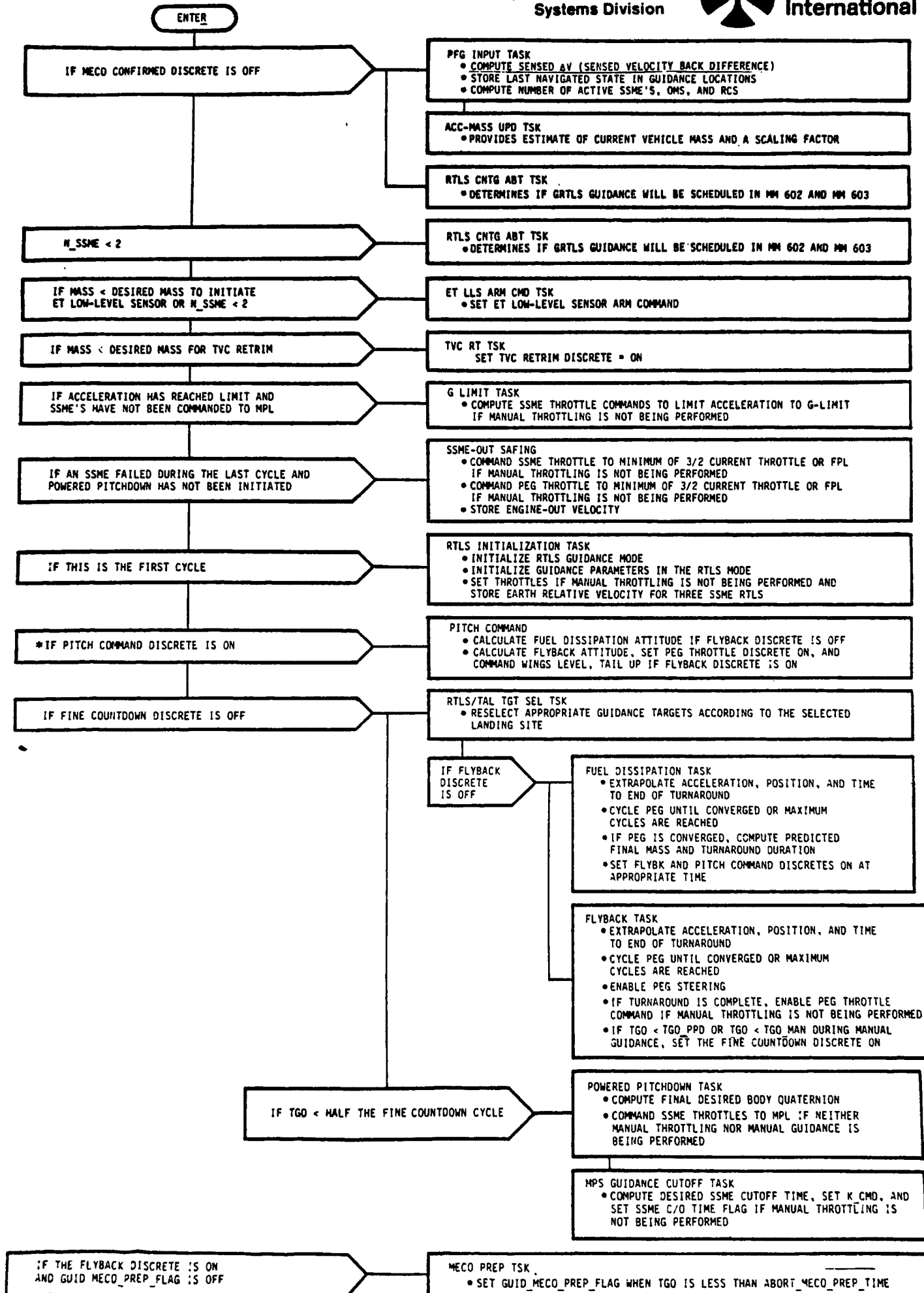


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Figure 4.6-2. PRTLS and Guidance Principal Function Task Organization





\*PITCH COMMAND TASK IS EXECUTED INDEPENDENT OF POWERED RTLS GUIDANCE

Figure 4.6-3. PRTL Guidance Functional Flow

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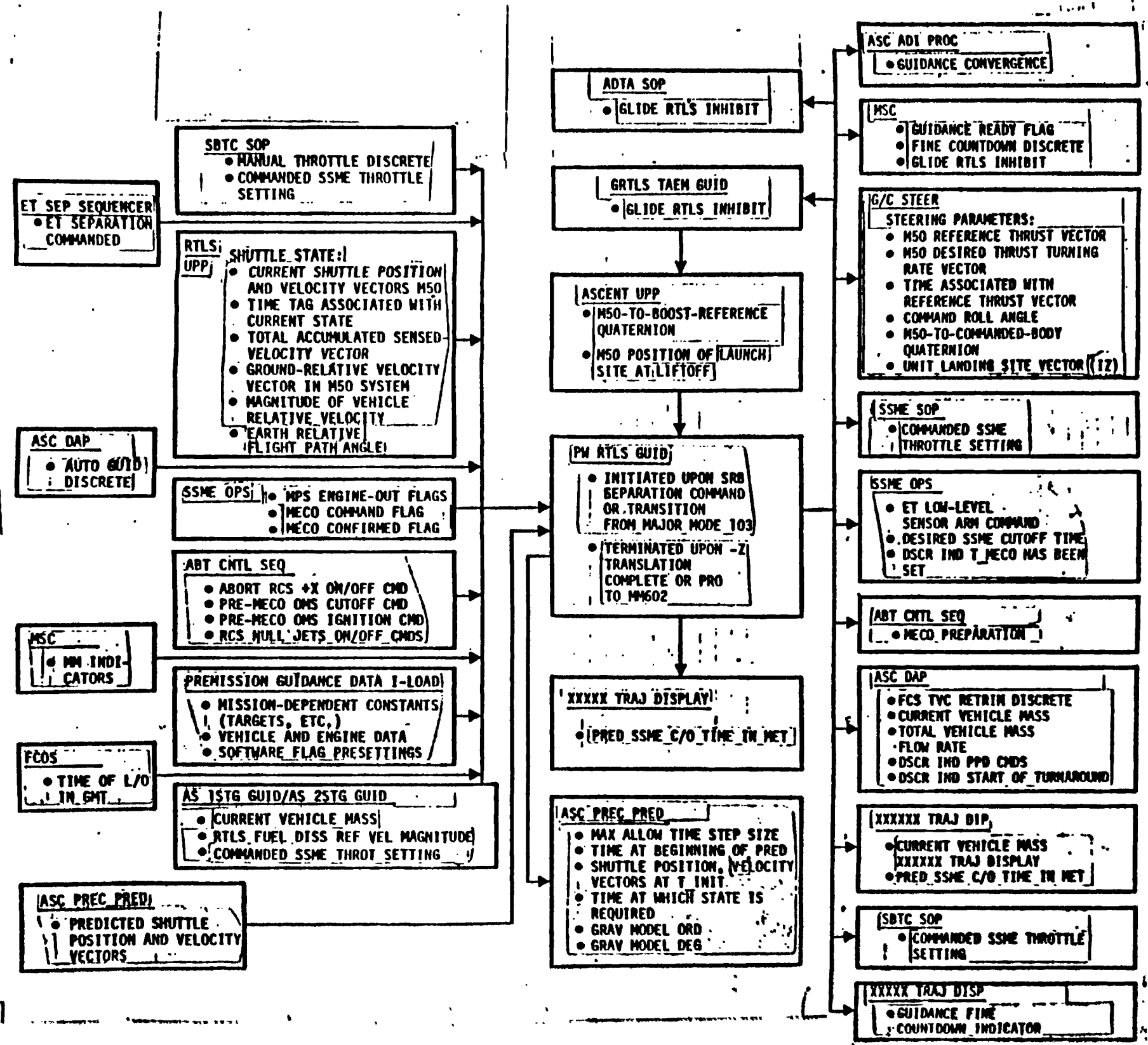


Figure 4-6-4 PBIT Guidance Algorithm Function (Major Mode 601) Data Flow

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#### 4.6.1 Powered RTLS Guidance Sequencing (PRTLS SEQ)

The tasks that support the RTLS second-stage guidance must be sequenced as follows:

1. The PFG input task (PFG INP TSK) must be performed on the first guidance pass after MM601 = ON until SSME cutoff confirmation (Event A36, MECO\_CONFIRM = ON). The detailed requirements for this task are given in Section 4.8.8.
2. The RTLS contingency abort task (RTLS CNTG ABT TSK) must be performed once when a second SSME has failed and once when the MECO confirmed flag is set to ON. When the RTLS CNTG ABT TSK is performed after a second SSME failure, the MPS low-level sensors are armed (see Task 4).
3. The acceleration-mass update task (Section 4.8.2) must be performed on the first guidance pass after MM601 = ON until SSME cutoff confirmation (Event A36).
4. The RTLS second-stage guidance principal function is also required to send a signal (S\_LOW\_LEVEL = ON) to the SSME operations principal function to activate the MPS low-level sensor. This will be done when current vehicle mass (M) becomes less than an I-load value (MASS\_LOW\_LEVEL), or after a second SSME failure.
5. The RTLS second-stage guidance principal function must send a signal (S\_SSME\_TRIM = ON) to the ASC DAP to retrim the TVC when M becomes less than an I-load value (MASS\_SSME\_TRIM).
6. The G-limiting task must be performed on the first guidance pass after MM601 = ON until the engines are commanded (S\_KCO = ON), to an I-load value KMIN, or during manual throttling until MECO confirmed, or until S\_TMECO is set to ON during manual guidance (AUTO = OFF). The detailed requirements for this task are given in Section 4.8.3.
7. The SSME-out safing task (Section 4.8.9) must be performed upon notification of an SSME failure from SRB separation or transition from MM 103 until the powered pitchdown discrete, S\_PPD\_QUAT, is set to ON.
8. The RTLS initialization task must be performed only once during the first cycle after MM601 = ON. Detailed requirements for this task are presented in Section 4.6.2.
9. The RTLS/TAL target selection task must be performed on the first guidance pass after MM601 equals ON and then repetitively until fine countdown (S\_MECO = ON). The detailed requirements for this task are presented in Section 4.8.11.

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10. The RTLS flyback and pitch command discret<sup>e</sup>s are set for immediate turnaround if the earth relative velocity is greater than an input value. This check must be made cyclically from RTLS select until S\_MECO is set ON. If S\_RTLS\_FB = OFF and V\_RHO\_MAG > V\_LATE\_RTLS, then S\_RTLS\_FB = ON and S\_PITCH\_CMD = ON.
11. The fuel dissipation task must be performed from the initiation of MM 601 until the discrete marking the beginning of the turnaround (S\_RTLS\_FB) is set to ON. If the velocity at SSME-out is near the boundary of RTLS opportunity, the S\_RTLS\_FB discrete is set to ON by PRTLS SEQ and the fuel dissipation task is not performed. The detailed requirements for this task are presented in Section 4.6.3.
12. The flyback task is performed from the time the flyback discrete is set to ON until the fine countdown discrete (S\_MECO) is set to ON. This includes the turnaround and flyback to the beginning of the fine countdown prior to the powered pitchdown. The detailed requirements for this task are presented in Section 4.6.4.
13. At the initiation of fine countdown (S\_MECO = ON), the powered RTLS sequencer will begin to compare the current time (T\_NAV) to the last computed MECO time (TP). On each guidance cycle prior to PPD, PRTLS sequencing will set S\_FCD to ON to cue the crew that fine countdown is in progress. When the value of TP - T\_NAV is less than one half of DT\_FCD, the flag S\_FCD is set to OFF.  
  
If the AUTO guidance discrete is OFF, then on each guidance cycle during fine countdown, PRTLS sequencing will set LAMC equal to the unit of the sensed M50 velocity increment (DVS\_RTLS), the time derivative of LAMC (LAMDC) and the associated time tag (TLAMC) equal to zero, and the guidance convergence indicator (S\_UNCONV) to OFF.
14. The powered pitchdown task must be performed when the difference between the PEG predicted time, TP, and navigation state time, T\_NAV, becomes less than half of DT\_FCD. The detailed requirements for this task are given in Section 4.6.5.
15. The MPS guidance cutoff task (Section 4.8.5) must be performed from the beginning of the powered pitchdown until the MECO discrete S\_MECO is set to ON or until MECO confirmed during manual throttling.
16. The MECO PREP TASK must be performed from the time the flyback discrete (S\_RTLS\_FB) is set ON until the discrete (GUID\_MECO\_PREP\_FLAG) is set. The detailed requirement for this task is to set the discrete (GUID\_MECO\_PREP\_FLAG) when the time to MECO is less than a K-loaded value ABORT\_MECO\_PREP\_TIME; that is:

If  $TMET\_MECO + T\_GMTLO - TGD < ABORT\_MECO\_PREP\_TIME$ , then:

GUID\_MECO\_PREP\_FLAG = ON

The RTLS pitch command task (PITCH CMD TSK) is performed within 160 milliseconds of the previous RTLS guidance cycle when the discrete S\_PITCH\_CMD is set to ON and MM = 601. The detailed requirements for this task are given in Section 4.6.6.

#### Manual Guidance Sequencing

1. Fuel Dissipation Phase: If manual guidance (AUTO = OFF) is selected in fuel dissipation and an early turnaround is initiated by the crew, then the flyback discrete (S\_RTLS\_FB) is set to ON, the pitch command discrete (S\_PITCH\_CMD) is set to ON, and the commanded throttle setting (K\_CMD) is set to the nearest integral value to the PEG throttle setting (K), provided that automatic throttling is selected (S\_MAN\_THROT = OFF).
2. Flyback Phase: If manual guidance is selected during the flyback phase, the throttling for fuel depletion is stopped and the PEG throttle is set to the engine commanded throttle setting (K\_CMD). The crew can return to auto guidance, but fuel depletion throttling is not resumed.
3. Powered Pitchdown Phase: If manual guidance is selected during the powered pitchdown, the powered pitchdown task and the MPS guidance cutoff task will be executed normally. Commanding the engines to KMIN will not be done if manual guidance is selected before the start of powered pitchdown and the crew does not return to auto guidance. PPD TSK will be executed cyclically after MECO confirmed is set ON.

If manual throttling is activated during flyback, the throttling for fuel depletion is terminated (S\_THROT = OFF) and the PEG throttle command, K, is set to the current commanded throttle setting, K\_CMD. Fuel depletion throttling cannot be resumed after this occurrence.

The input and output parameters for the PRTLS guidance sequencing are given in Tables 4.6.1-1 and 4.6.1-2.

The recommended execution rates for the tasks are as follows:

- |               |  |
|---------------|--|
| Tasks 1 and 3 | - 1.92 seconds from initiation until the fine countdown begins, then 0.16 second until MECO_CONFIRM = ON |
| Task 2        | - One time only when N_SSME < 2 and one time when MECO_CONFIRM = ON                                      |
| Task 4        | - One time only*   |
| Task 5        | - One time only*   |

\*The tests for performing these tasks should be made every guidance cycle until the tasks are executed.

- Task 6 - 1.92 seconds from initiation until the fine countdown begins, then 0.16 second until the task is terminated by PRTLS sequencing
- Task 7 - Each time an SSME has failed\*
- Task 8 - One time only\*
- Task 9 - 1.92 seconds from initiation until S\_MECO is set ON
- Task 10 - 1.92 seconds
- Task 11 - 1.92 seconds from initiation until S\_RTLS\_FB or S\_MECO is set ON
- Task 12 - 1.92 seconds from the time S\_RTLS\_FB is set ON until S\_MECO is set ON
- Task 13 - 0.16 second from the time S\_MECO is set ON until S\_FCD is set OFF
- Task 14 - 0.16 second from the time S\_FCD is set OFF until Event A39
- Task 15 - 0.16 second from the beginning of PPD until S\_TMECO is set ON
- Task 16 - 1.92 seconds from the time S\_RTLS\_FB is set on until GUID\_MECO\_PREP\_FLAG = ON

These tasks should be executed in the order listed.

\*The tests for performing these tasks should be made every guidance cycle until the tasks are executed.



Table 4.6.1-1. PRTLs Guidance Sequencing Inputs

Definition	Symbol	Source	Precision	Units
Number of active SSME's	N_SSME	PFG INP TSK	I	N/A
Planned guidance cycle time for fine countdown and powered pitchdown tasks	DT_FCD	K-LOAD	SP	sec
TGO for MECO preparation	ABORT_MECO_PREP_TIME	K-LOAD	SP	sec
Predicted time to achieve PEG targets	TP	PEG TSK	DP	sec
Value of mass for TVC retrim	MASS_SSME_TRIM	I-LOAD	SP	slugs
Value of mass in enabling MPS low-level sensing	MASS_LOW_LEVEL	I-LOAD	SP	slugs
Fine countdown discrete	S_MECO	FLYBK TSK	D	N/A
Flyback task discrete	S_RTLS_FB	FUL DISS TSK	D	N/A
MECO confirmation discrete	MECO_CONFIRM	SSME OPS	D	N/A
Time tag associated with current state	T_NAV	RTLS UPP	DP	sec
Current vehicle mass	M	ACC-MASS UPD TSK	SP	slugs
Discrete indicating powered pitchdown commands	S_PPD_QUAT	PPD TSK	D	N/A
AUTO guidance mode flag	AUTO	ASC DAP	D	N/A
Discrete indicating T_MECO has been set	S_TMECO	MPS GUID C/O TSK	D	N/A
Pitch command task discrete	S_PITCH_CMD	FUL DISS TSK, PITCH CMD TSK	D	N/A
Magnitude of vehicle relative velocity	V_RHO_MAG	RTLS UPP	SP	N/A
Relative velocity magnitude for latest RTLS	V_LATE_RTLS	I-LOAD	SP	fps



Table 4.6.1-1. PRTL Guidance Sequencing Inputs (Cont)

Definition	Symbol	Source	Precision	Units
GMT time of lift-off	T_GMTLO	FCOS	DP	sec
Predicted MECO time in MET seconds	TMET_MECO	FUL DISS TSK, FLYBK TSK	SP	sec
Current guidance time	TGD	PFG INP TSK	DP	sec
Change in sensed velocity	DVS_RTLS	PFG INP TSK	SP	fps
Discrete to indicate pre-MECO throttle down complete	S_RCO	MPS GUID C/O TSK	D	N/A
Manual throttle discrete	S_MAN_THROT	SBTC SOP	D	N/A

Table 4.6.1-2. PRTLS Guidance Sequencing Outputs

Definition	Symbol	Destination	Precision	Units
Discrete to activate MPS low-level sensor	S_LOW_LEVEL	SSME OPS	D	N/A
FCD TVC retrim discrete	S_SSME_TRIM	ASC DAP	D	N/A
MECO preparation discrete	GUID_MECO_PREP_FLAG	ABORT CNTL SEQ	D	N/A
Flyback discrete	S_RTLS_FB	PITCH CMD TASK	D	N/A
Guidance convergence status indicator	S_UNCONV	ASC ADI PROC	D	N/A
Fine countdown indicator	S_FCD	XXXXX TRAJ DIP	D	N/A
M50 desired thrust direction	LAMC	G/C STEER	SP	ND
M50 desired thrust turning rate vector	LAMDC	G/C STEER	SP	sec <sup>-1</sup>
GMT time associated with desired thrust direction	TLAMC	G/C STEER	DP	sec



4.6.2 RTLS Initialization Task (RTLS INIT TSK)

The subtasks to be performed for initializing the guidance and targets are as follows:

1. Reinitialize guidance parameters in the RTLS mode.
2. Set guidance parameters dependent on the number of active SSME's.

A.Detailed Requirements. The following subtasks must be performed to initialize the RTLS guidance and targets.

1. Set the correct guidance mode, number of phases, and initialization discrete. Set the discrete enabling guidance steering commands to OFF. Set the fine countdown indicator to OFF. Set the flyback discrete to OFF.

$$SMODE = 5$$

$$SINIT = ON$$

$$N = 2$$

$$SSTEER = OFF$$

$$S\_FCD = OFF$$

$$S\_RTLS\_FB = OFF$$

2. Determine if this is a three SSME RTLS case. If so ( $N\_SSME = 3$ ), set the values for the current and flyback throttles and store the present relative velocity and altitude rate:

$$K\_CMD = MAX(ROUND(2 KMAX/3), KMIN)$$

The current throttle value,  $K\_CMD$ , is set only if manual throttling is not being performed ( $S\_MAN\_THROT = OFF$ ).

$$K = K\_3ENG$$

$$V\_RTLS\_FD = V\_RHO\_MAG$$

$$H\_DOT\_FD = H\_DOT\_ELLIPSOID$$

Otherwise ( $N\_SSME < 3$ ), set the values for the flyback throttle.

$$K = K\_2ENG$$

Units

N A

N/A

N/A

N A

N A

N A

ND

sec<sup>-1</sup>

sec



B. Interface Requirements. The input and output parameters for the RTLs initialization task are given in Tables 4.6.2-1 and 4.6.2-2.

C. Processing Requirements. None.

D. Initialization Requirements. None.





Table 4.6.2-1. RTLS Initialization Task Inputs

Definition	Symbol	Source	Precision	Units
Minimum throttle setting	KMIN	I-LOAD	I	pct
Magnitude of vehicle relative velocity	V_RHO_MAG	RTLS UPP	SP	fps
Maximum throttle setting for SSME	KMAX	I-LOAD, ASC GUID TSK, 1STG GUID INP TSK	I	pct
Number of active SSME's	N_SSME	PFG INP TSK	I	N/A
Initial value of K for three-engine RTLS	K_3ENG	I-LOAD	SP	pct
Initial value of K for two-engine RTLS	K_2ENG	I-LOAD	SP	pct
Manual throttle discrete	S_MAN_THROT	SBTC SOP	D	N/A
Est attitude rate	H_DOT_ELLIPSOID	RTLS UPP	SP	fps



Table 4.6.2-2. RTLS Initialization Task Outputs

Definition	Symbol	Destination	Precision	Units
PEG maneuver mode flag	SMODE	PEG TSK	I	N/A
PEG initialization discrete	SINIT	PEG TSK	D	N/A
Number of thrust phases	N	PEG TSK	I	N/A
Commanded SSME throttle setting	K_CMD	SSME SOP, THRST PRM TSK, FLYBK TSK, FUL DISS TSK, G LIM TSK, SSME-OUT SAF TSK, SBTC SOP	I	pct
Desired throttle setting	K	PEG TSK, FUL DISS TSK, FLYBK TSK, TLM	SP	pct
Steering enable flag	SSTEER	PEG TSK	D	N/A
RTLS fuel dissipation reference velocity magnitude	V_RTLS_FD	PITCH CMD TSK	SP	fps
Guidance fine countdown indicator	S_FCD	XXXXXX TRAJ DIP	D	N/A
RTLS fuel dissipation ref HDOT	H_DOT_FD	PITCH CMD TSK	SP	fps
RTLS flyback discrete	S_RTLS_FB	PRTLS SEQ	D	N/A



#### 4.6.3 Fuel Dissipation Task (FUL DISS TSK)

The subtasks to be performed for fuel dissipation are as follows:

1. Set the flyback and pitch command discrettes on at the proper time.
2. Change the roll command at the proper time.
3. Calculate the turnaround time.
4. Calculate the predicted MECO time in MET.
5. If manual guidance is selected, set the guidance discrettes to their proper values.

##### A. Detailed Requirements.

1. On the first pass through the fuel dissipation task, the discrete  $S\_PITCH\_CMD$  is set to ON so that the pitch command task can calculate and issue the fuel dissipation thrust commands. The pitch command task then resets the discrete  $S\_PITCH\_CMD$  to OFF.
2. The fuel dissipation task must specify the commanded roll angle input to G/C STEER. When the relative velocity magnitude ( $V\_RHO\_MAG$ ) first exceeds  $V\_RHO\_PHI$ , the commanded roll angle is set as  $PHI\_CMD = PHI\_2STG$ .
3. The following calculations are cycled when the fuel dissipation task is active.

On the cycle that the maximum throttle level command is activated ( $MAX\_THROT\_CMD = ON$ ), the following must occur:

- (1)  $KMAX = KMAX\_SECONDARY$
- (2) In addition, if the number of thrusting SSME's is less than three ( $N\_SSME < 3$ ) and manual throttling is not being performed, ( $S\_MAN\_THROT = OFF$ ), the following must occur:

$$K\_CMD = KMAX\_SECONDARY$$

The acceleration is obtained by executing the THRST PRM TSK, followed by the equation  $AT\_EST = FT\_FACTOR FT/M$ .

Then the position, acceleration, and time are extrapolated to the estimated end of the turn, and the PEG task is called to obtain the magnitude of velocity to be gained by thrust to achieve the targets.



$\bar{R}_{GD} = \bar{R}_{NAV} + \bar{V}_{NAV} DT_{TURN}$   
 $\bar{V}_{EX} = \bar{V}_{EX} / (1 - N_{RCS\_NULL} MDOT_{RCS} / MDOT)$   
 $ATR = (\bar{V}_{EX} AT_{EST} / (\bar{V}_{EX} - DT_{TURN} AT_{EST})) K / K_{CMD}$   
 $TGD = T_{NAV} + DT_{TURN}$   
 Call PEG TSK (4.8.1)

If PEG is converged ( $S_{CONV} = ON$ ), then do the following:

- a. This velocity is summed with the estimated velocity gained during the turn by thrust and used in the ideal rocket equation to predict the final mass at the end of PEG guidance. This final mass is biased to prevent a late turnaround.

$$MF = M \exp(-(\bar{V}_{GOMAG} + AT_{EST} DT_{TURN}) / \bar{V}_{EX}) - M_{BIAS}$$

- b. The change in thrust direction desired during the turn is calculated from current and desired thrust direction at the beginning of the flyback. Based on this result, the time it takes to turn around is calculated by using the ideal rates and accelerations expected.

If PEG is converged ( $S_{CONV} = ON$ ), then:

$$\bar{U}_{F\_PEG} = \text{UNIT}(\bar{L}_{AM} + (TGD - TLAM) \bar{L}_{AMD})$$

$$\text{THETA} = \text{ARCCOS}(\text{UNIT}(\bar{D}_{VS\_RTLS}) \cdot \bar{U}_{F\_PEG})$$

$$DT_{TURN} = \text{THETA} / D\text{THETA\_LIM} + D\text{THETA\_LIM} / D\text{THETA\_RATE}$$

4. If PEG is converged, and the predicted final mass is less than or equal to the desired final mass and the desired flyback attitude satisfies initial flyback attitude constraints, then the turnaround is initiated by setting the flyback and pitch command discretetes to ON.

If  $S_{CONV} = ON$  and  $MF \leq MBO$  and

$$(\bar{U}_{F\_PEG} \cdot \bar{U}_{FZ} > \text{SQRT}(K\text{DELTA})) \text{ or}$$

$$\text{SIGN}(\bar{U}_{F\_PEG} \cdot (\bar{I}_X \times \bar{I}_Y_{TVR})) \text{THETA} > \text{PI}/2$$

then  $S_{RTLS\_FB} = ON$  AND  $S_{PITCH\_CMD} = ON$

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where KDELTA and  $\bar{U}FZ$  are defined by

$$KDELTA = \text{MAX}(0, (1 - (K/K\_CMD)^2))$$

$$\bar{U}FZ = \text{UNIT}(\bar{L}AMC \times \bar{I}Y\_TVR)$$

The unit vectors  $\bar{I}Y\_TVR$  and  $\bar{I}X$ , obtained from PEG, define the plane of thrust vector rotation and radial direction in that plane, respectively.

5. The predicted time of MECO in MET is calculated as  $TMET\_MECO = TP + DT\_PITCH - T\_GMTLO$ .
6. If an early turnaround is done by the crew in manual guidance, i.e., if  $(V\_RHO \cdot DVS\_RTLS) < 0$  and  $AUTO = OFF$ , then set  $S\_RTLS\_FB = ON$ ,  $S\_PITCH\_CMD = ON$ ; and if  $S\_MAN\_THROT = OFF$ ,  $K\_CMD = \text{ROUND}(K)$ .

B. Interface Requirements. The input and output parameters for the fuel dissipation task are listed in Tables 4.6.3-1 and 4.6.3-2.

C. Processing Requirements. None.

D. Initialization Requirements.  $STHROT = OFF$ .

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Table 4.6.3-1. RTLS Fuel Dissipation Task Inputs

Definition	Symbol	Source	Precision	Units
Desired roll command for second stage	PHI_2STG	I-LOAD	SP	rad
Switch velocity for roll command	V_RHO_PHI	I-LOAD	SP	fps
Magnitude of vehicle velocity	V_RHO_MAG	RTLS UPP	SP	fps
Current Shuttle position vector in M50	R_NAV	RTLS UPP	DP	ft
Current Shuttle velocity vector in M50	V_NAV	RTLS UPP	SP	fps
Time tag associated with current state	T_NAV	RTLS UPP	DP	sec
Length of turnaround	DT_TURN	I-LOAD	SP	sec
Total effective exhaust velocity	VEX	THRST PRM TSK	SP	fps
Ground relative velocity in M50	V_RHO	RTLS UPP	SP	fps
Thrust scaling factor	FT_FACTOR	ACC-MASS UPD TSK, SSME-OUT SAF TSK	SP	ND
Total vehicle thrust force	FT	THRST PRM TSK	SP	lb
Desired throttle setting	K	RTLS INIT TSK, SSME-OUT SAF TSK, PEG TSK	SP	pct
Commanded SSME throttle setting	K_CMD	RTLS INIT TSK, SSME-OUT SAF TSK, GUID PRMT RINT TSK, BST THROT TSK, SBTC SOP, ASC GUID TSK, LSTG GUID INP TSK	I	pct
Discrete indicating PEG convergence	S_CONV	PEG TSK	D	N/A
Unit normal to the plane of thrust vector rotation	Y_TVR	PEG TSK	SP	N/A
Guidance coordinate system X-axis in M50 coordinates	X	PEG TSK	DP	N/A
Predicted time to achieve PEG targets	TP	PEG TSK	DP	sec

Table 4.6.3-1. RTLS Fuel Dissipation Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
Magnitude of velocity to be gained	VGOMAG	PEG TSK	SP	fps
Current vehicle mass	M	ACC-MASS UPD TSK	SP	slugs
Time of lift-off in GMT	T_GMTLO	FCOS	DP	sec
Desired mass at end of flyback	MBO	PEG TSK	SP	slugs
Change in sensed velocity vector	DVS_RTLS	PFG INP TSK	SP	fps
Reference thrust direction vector	LAM	PEG TSK	SP	ND
Desired thrust turning rate vector	LAMD	PEG TSK	DP	sec <sup>-1</sup>
Time associated with reference thrust vector	TLAM	PEG TSK	DP	sec
ALTO guidance mode flag	AUTO	ASC DAP	D	N/A
Maximum angular velocity	DTHETA_LIM	I-LOAD	SP	rad/sec
Maximum angular acceleration	DTHETA_RATE	I-LOAD	SP	rad/sec <sup>2</sup>
Mass bias for turnaround	M_BIAS	I-LOAD	SP	slugs
Nominal time of powered pitchdown	DT_PITCH	I-LOAD	SP	sec
Manual throttle discrete	S_MAN_THROT	SBTC SOP	D	N/A
Maximum throttle level command	MAX_THROT_CMD	OVERRIDE DISPLAY	D	N/A
Secondary maximum throttle setting	KMAX_SECONDARY	I-LOAD	I	pct
M50 desired fuel dissipation thrust vector	LAMC	PITCH CMD TSK	SP	ND
No. of active null jets	N_RCS_NULL	PFG INP TSK	I	N/A
RCS mass flow rate	MDOT_RCS	K-LOAD	SP	slug/sec
Total mass flow rate	MDOT	THRUST PRM TSK	SP	slug/sec
Number of active SSME engines	N_SSME	PFG INP TSK	I	N/A



Table 4.6.3-2. RTLS Fuel Dissipation Task Outputs

Definition	Symbol	Destination	Precision	Units
Command roll angle	PHI_CMD	G/C STEER	SP	rad
Flyback task discrete	S_RTLS_FB	PRTLS SEQ, PITCH CMD TSK	D	N/A
Vehicle position vector input to PEG	RGD	PEG TSK	DP	ft
Thrust acceleration estimate input to PEG	ATR	PEG TSK	SP	fps <sup>2</sup>
Time associated with RGD and VGD	TGD	PEG TSK	DP	sec
Pitch command discrete	S_PITCH_CMD	PRTLS SEQ	D	N/A
Predicted SSME C/O time in MET	TMET_MECO	XXXXX TRAJ TLM, PRTLS SEQ	SP	sec
Fuel depletion throttling discrete	STHROT	PEG TSK	D	N/A
Length of turnaround	DT_TURN	FLYBK TSK, TLM	SP	sec
Predicted final mass	MF	TLM	SP	slugs
Maximum throttle setting for SSME	KMAX	RTLS INIT TSK, PEG TSK, G-LIM TSK, SSME-OUT, SAF TSK, SBTC SOP, PPD TSK	I	pct
Commanded SSME throttle setting	K_CMD	SSME SOP, THRST PRM TSK, FLYBK TSK, GT-LIM TSK, SSME-OUT SAF TSK, SBTC SOP	I	pct
Equivalent exhaust velocity	VEX	PEG TSK	SP	fps

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#### 4.6.4 RTLS Flyback Task (FLYBK TSK)

The following subtasks are necessary to support the flyback task:

1. Obtain an estimate of filtered acceleration, exhaust velocity, and mass.
2. Extrapolate acceleration, position, and time to the end of the turn until the end of the turn is reached.
3. Execute the powered explicit guidance (PEG) calculations and maintain convergence.
4. Calculate the estimated time of MECO in MET.
5. Issue throttle commands.
6. Set fine countdown discrete on when  $TGO \leq TGO\_PPD$ .
7. If manual guidance is selected, set the throttle and guidance discrettes to their proper values.

##### A. Detailed Requirements.

1. The RTLS flyback task must obtain an estimate of acceleration, exhaust velocity, and mass. The acceleration is calculated by executing the THRUST PRM TSK followed by the equation

$$AT\_EST = FT\_FACTOR FT/M$$

2. The PEG steering discrete is set to ON, and the time to turnaround is decremented by the guidance cycle. The position, acceleration, and time are then extrapolated through the turn until the end of the turn is reached.

$$SSTEER = ON$$

$$DT\_TURN = DT\_TURN - DTGD$$

$$\text{If } DT\_TURN < 0, \text{ then } DT\_TURN = 0$$

$$RGD = R\_NAV + V\_NAV DT\_TURN$$

$$VEX = VEX / (1 - N\_RCS\_NULL MDOT\_RCS / MDOT)$$

$$ATR = (VEX AT\_EST / (VEX - DT\_TURN AT\_EST)) K / K\_CMD$$

$$TGD = T\_NAV + DT\_TURN$$



- 2a. If the maximum throttle level command is activated (MAX\_THROT\_CMD = ON), the following must occur:

$$K_{MAX} = K_{MAX\_SECONDARY}$$

3. The flyback task is required to execute the PEG calculations and maintain a solution by cycling PEG until it is converged or until the maximum number of cycles is reached. The convergence criterion is determined internal to the PEG task. Once PEG is converged in the turnaround, the calculated values of LAMC, LAMDC, and TLAMC will be used by the steering interface for the flyback rather than the LAMC calculated by the pitch command task. Prior to each PEG call, ATR is recomputed by the above equation.
4. The estimated time of MECO is then calculated as

$$T_{MET\_MECO} = T_P - T_{GMTLO} + DT\_PITCH$$

5. When the end of the turn has been reached, the guidance has converged, and the difference between the current throttle setting and the PEG throttle setting is greater than an K-load value and neither manual guidance nor manual throttling is being performed, then the SSME throttle commands for fuel depletion are issued.

If  $DT\_TURN = 0$ , and  $S_{CONV} = ON$ ,  $AUTO = ON$ ,  $S_{MAN\_THROT} = OFF$ , and  $ABS(K\_CMD - K) > DK\_ROUND$ , then  $K\_CMD = ROUND(K)$ .

6. When TGO to start of powered pitchdown becomes less than TGO\_PPD and the AUTO guidance discrete is on or TGO becomes less than TGO\_MAN and the AUTO guidance discrete is off, the fine countdown discrete S\_MECO is set to ON and the flyback task is no longer executed.
7. If manual guidance or manual throttling is selected in the flyback phase, the fuel depletion throttling is stopped (S\_THROT set OFF), and the PEG throttle is set to and maintained at the current commanded engine throttle, ( $K = K\_CMD$ ).

B. Interface Requirements. The input and output parameters for the flyback task are given in Tables 4.6.4-1 and 4.6.4-2.

C. Processing Requirements. None.

D. Initialization Requirements. None.

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Table 4.6.4-1. RTLS Flyback Task Inputs

Definition	Symbol	Source	Precision	Units
Length of turnaround	DT_TURN	I-LOAD, FUL DISS TSK	SP	sec
Time tag associated with current state	T_NAV	RTLS UPP	DP	sec
Current Shuttle position vector in M50	R_NAV	RTLS UPP	DP	fps
Current Shuttle velocity vector in M50	V_NAV	RTLS UPP	SP	fps
Total effective exhaust velocity	VEX	THRST PRM TSK	SP	fps
Desired throttle setting	K	PEG TSK, RTLS INIT TSK, SSME-OUT SAF TSK, G-LIM TSK	SP	pct
Commanded SSME throttle setting	K_CMD	RTLS INIT TSK, SSME-OUT SAF TSK, G-LIM TSK, SBTC SOP, ASC GUID TSK, 1STG GUID INP TSK	I	pct
Discrete indicating convergence	SCONV	PEG TSK	D	N/A
Time to go	TGO	PEG TSK	SP	sec
Predicted time to achieve PEG targets	TP	PEG TSK	DP	sec
Thrust scaling factor	FT_FACTOR	ACC-MASS UPD TSK, SSME-OUT SAF TSK	SP	none
Total vehicle thrust force	FT	THRST PRM TSK	SP	lb
TGO to initiate fine count-down for manual guidance	TGO_MAN	I-LOAD	SP	sec
TGO to initiate fine countdown	TGO_PPD	K-LOAD	SP	sec
Time of lift-off in GMT	T_GMTLO	FCOS	DP	sec
Difference between current and previous values of TGD	DTGD	PFG INP TSK	SP	sec
Current vehicle mass	M	ACC-MASS UPD TSK	SP	slugs
Auto guidance mode flag	AUTO	ASC DAP	D	N/A

Table 4.6.4-1. RTLS Flyback Task Inputs (Cont)

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Definition	Symbol	Source	Precision	Units
Difference needed to update SSME throttle command	DK_ROUND	K-LOAD	SP	pct
Nominal time of powered pitchdown	DT_PITCH	I-LOAD	SP	sec
Manual throttle discrete	S_MAN_THROT	SBTC SOP	D	N/A
Maximum number of PEG iterations	N_MAX	I-LOAD	I	N/A
No. of active null jets	N_RCS_NULL	PFG INP TSK	I	N/A
RCS mass flow rate	MDOT_RCS	K-LOAD	SP	slugs/sec
Total mass flow rate	MDOT	THRUST PRM TSK	SP	slugs/sec
Maximum throttle level command	MAX_THROT_CMD	OVERRIDE DISPLAY	D	N/A
Secondary maximum throttle setting	KMAX_SECONDARY	I-LOAD	I	pct

Table 4.6.4-2. RTLS Flyback Task Outputs

Definition	Symbol	Destination	Precision	Units
Vehicle position vector input to PEG	$\overline{RGD}$	PEG TSK	DP	ft
Thrust acceleration estimate input to PEG	ATR	PEG TSK	SP	fps <sup>2</sup>
Time associated with RGD and VGD	TGD	PEG TSK	DP	sec
Steering enable flag	SSTEER	PEG TSK	D	N/A
Throttling discrete	STHROT	PEG TSK	D	N/A
Fine countdown discrete	S_MECO	RTLS UPP SEQ, ACC-MASS UPD TSK, TLM, MSC, PRTLS SEQ	D	N/A
Commanded SSME throttle setting	K_CMD	SSME SOP, SSME-OUT SAF TSK, THRST PRM TSK, PEG TSK, SBTC SOP	I	pct
Predicted SSME C/O time in MET	TMET_MECO	XXXXXX TRAJ, TLM, PRTLS SEQ	SP	sec
Exhaust velocity	VEX	PEG TSK	SP	fps
Maximum throttle setting for SSME	KMAX	PEG TSK, G-LIM TSK, SSME-OUT SAF TSK, SBTC SOP, PPD TSK	I	pct
M50 desired thrust direction	$\overline{LAMC}$	G/C STEER, TLM	SP	N/A
M50 desired thrust turning rate vector	$\overline{LAMDC}$	G/C STEER, TLM	SP	sec <sup>-1</sup>
Time associated with desired thrust vector	TLAMC	G/C STEER, TLM	DP	sec
Desired throttle setting	K	PEG TSK	SP	pct

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#### 4.6.5 Powered Pitchdown Task (PPD TSK)

The following subtasks are necessary to support the powered pitchdown calculations:

1. Compute the M50-to-commanded body quaternion for the powered pitchdown, mated coast, and -Z translation.
2. Command the SSME throttles to KMIN.
3. Set the powered pitchdown discrete to ON.

#### A. Detailed Requirements.

1. The M50-to-commanded body quaternion is computed in the following manner:
  - a. The quaternion  $Q_{M50\_VR}^+$  is found by using the function RV\_TO\_QLVLH. Define a coordinate system by setting the  $\bar{Z}$  axis equal to the unit negative of the first input vector, the Y axis equal to the unit vector of the second input vector crossed into the first input vector, and the  $\bar{X}$  axis equal to  $\bar{Y} \times \bar{Z}$ . The quaternion representing the transformation from this coordinate system, called the VR coordinate system, to the M50 coordinate system is computed as follows:

$$Q_{M50\_VR}^+ = RV\_TO\_QLVLH(V\_RHO, -R\_NAV)$$

- b. Prior to ET separation, the rotation angle needed to align the +X (body) axis with respect to the velocity vector is calculated as  $ALPHA\_Q = (PI/2 + ALPHA\_PPD)/2$ . After ET separation ( $ET\_SEP\_CMD = ON$ ), the angle is computed as  $ALPHA\_Q = (PI/2 + ALPHA\_Z)/2$ .
- c. The rotation quaternion  $Q_{CB\_VR}^+$  from the VR to the commanded body system is computed with the scalar element  $COS(ALPHA\_Q)$  and the vector part  $(0, -SIN(ALPHA\_Q), 0)$ .
- d. The M50-to-commanded body quaternion,  $Q_{CB\_M50}^+$ , is then computed by forming the conjugate of the quaternion  $Q_{M50\_VR}^+$  and premultiplying it by the rotation quaternion ( $Q_{CB\_VR}^+$ ) computed in paragraph c:

$$Q_{CB\_M50}^+ = QUAT\_MULT(Q_{CB\_VR}^+, Q_{VR\_M50}^+)$$

2. The engines are commanded to minimum power ( $K\_CMD = KMIN$ ) only if neither manual throttling nor manual guidance is being performed and  $N\_SSME > 1$ . The engines are commanded to maximum power ( $K\_CMD = KMAX$ ) only if  $N\_SSME$  is less than 2 and the manual throttling discrete is OFF.
3. The power pitchdown discrete is set to ON to reconfigure the steering interface for quaternion inputs:  $S\_PPD\_QUAT = ON$ .



B. Interface Requirements. The input and output parameters for the powered pitchdown task are given in Tables 4.6.5-1 and 4.6.5-2.

C. Processing Requirements.  $Q_{CB\_VR}^+$  needs to be calculated once prior to and once after ET separation.

D. Initialization Requirements. None.

E. Supplemental Information. The outputs  $Q_{CB\_M50}^+$  and  $S_{PPD\_QUAT}$  are a time-homogeneous set.

Table 4.6.5-1. Powered Pitchdown Task Inputs

Definition	Symbol	Source	Precision	Units
Current Shuttle position vector in M50 coordinates	R_NAV	RTLS UPP	DP	ft
Earth relative velocity vector in M50	V_RHO	RTLS UPP	SP	fps
Desired angle of attack at end of PPD	ALPHA_PPD	I-LOAD	SP	rad
Minimum throttle setting of SSME	KMIN	I-LOAD	I	pct
Manual throttle discrete	S_MAN_THROT	SBTC SOP	D	N/A
Auto guidance mode flag	AUTO	ASC DAP	D	N/A
Desired angle of attack at end of -Z translation	ALPHA_Z	I-LOAD	SP	rad
ET separation commanded discrete	ET_SEP_CMD	ET SEP SEQ	D	N/A
Number of active SSME's	N_SSME	PFG INP TSK	I	N/A
Maximum throttle setting for SSME	KMAX	I-LOAD, ASC GUID TSK, 1ST GUID INP TSK, FUL DISS TSK, FLYBK TSK	I	pct

Table 4.6.5-2. Powered Pitchdown Task Outputs

Definition	Symbol	Destination	Precision	Units
M50-to-commanded body quaternion	+ Q_CB_M50	G/C STEER	SP	ND
Commanded SSME throttle setting	K_CMD	SSME SOP, SBTC SOP	I	pct
Discrete indicating powered pitchdown commands	S_PPĐ_QUAT	ASC DAP, PRTLS SEQ	D	N A



#### 4.6.6 Pitch Command Task (PITCH CMD TSK)

The pitch command task computes a desired thrust direction for the fuel dissipation phase and a desired flyback thrust direction to begin the RTLS turnaround and flyback. It also notifies the steering interface of the beginning of the turnaround.

##### A. Detailed Requirements.

1. If the flyback discrete,  $S_{RTLS\_FB}$ , is OFF, the fuel dissipation thrust angle is calculated as a linear function of  $V_{RTLS\_FD}$ , and the guidance ready flag ( $S_{GDRDY}$ ) is set to ON: If  $V_{RTLS\_FD} < V_{SWITCH}$ , then

$$THETA\_C = THETA\_0 + (THETA\_1) V_{RTLS\_FD} + (THETA\_4) H\_DOT\_FD$$

Otherwise,  $THETA\_C = THETA\_2 + (THETA\_3) V_{RTLS\_FD}$

In all cases,  $THETA\_C = MIDVAL(THETA\_MAX, THETA\_C, THETA\_MIN)$   
 $S_{GDRDY} = ON$

2. If the flyback discrete,  $S_{RTLS\_FB}$ , is ON, the initial flyback thrust angle is set to an I-load value, the turnaround and throttle discretions are set, and the vehicle is commanded to wings level, tail up. The I-load DTTHROT controls whether or not fuel depletion throttling will be performed during flyback.

$$THETA\_C = THETA\_FB$$

If  $DTTHROT < 1000$ ,  $STHROT = ON$ ; otherwise,  $STHROT = OFF$

$$S_{RTLS\_TURN} = ON$$

$$PHI\_CMD = 0$$

3. The RTLS azimuth is computed by transforming the vehicle's earth relative velocity vector,  $\bar{V}_{RHO}$ , from M50 to the boost reference system, and obtaining the angle AZ.

$$\bar{V}_{RHO\_BR} = QUAT\_XFORM(Q_{BR\_M50}, \bar{V}_{RHO})$$

$$AZ = ARCTAN2(V_{RHO\_BR}(2), V_{RHO\_BR}(1))$$

If AZ is negative, then  $AZ = AZ + 2 \text{ PI}$ .

4. The desired thrust direction is then computed by changing the desired thrust angle to a vector along the RTLS azimuth in the boost reference system and transforming the vector by quaternion multiplication to the M50 system, using the QUAT\_XFORM function and the conjugate of  $Q_{BR\_M50}$ .

$$\underline{L}_{AMC} = QUAT\_XFORM\{Q_{M50\_BR}, [\cos(AZ) \cos(THETA\_C), \sin(AZ) \cos(THETA\_C), -\sin(THETA\_C)]\}$$



5. The time derivative of  $\overline{L\dot{A}M\dot{C}}$  and the time tag of  $\overline{L\dot{A}M\dot{C}}$  are set to zero to ensure a constant thrust attitude:

$$\overline{L\dot{A}M\dot{D}C} = 0$$

$$\overline{TL\dot{A}M\dot{C}} = 0$$

6. The pitch command discrete is set to OFF at the end of the task:

$$S\_PITCH\_CMD = OFF$$

B. Interface Requirements. The input and output parameters for the pitch command task are given in Tables 4.6.6-1 and 4.6.6-2.

C. Processing Requirements. Since the pitch command can be time-critical in late aborts, the pitch command task should be executed within 160 milliseconds of the previous RTLS guidance cycle. This task is executed whenever  $S\_PITCH\_CMD = ON$  and  $MM = 601$ .

D. Initialization Requirements. None.

E. Supplemental Information. Before turnaround,  $\overline{L\dot{A}M\dot{C}}$ ,  $\overline{L\dot{A}M\dot{D}C}$ ,  $\overline{TL\dot{A}M\dot{C}}$ , and  $S\_GDRDY$  are a time-homogeneous set; and at turnaround,  $\overline{L\dot{A}M\dot{C}}$ ,  $\overline{L\dot{A}M\dot{D}C}$ ,  $\overline{TL\dot{A}M\dot{C}}$ ,  $\overline{PHI\_CMD}$ , and  $S\_RTLS\_TURN$  are a time-homogeneous set. The discrete  $S\_PITCH\_CMD$  is set to  $\overline{ON}$  in the fuel dissipation task and PRTLS sequencing.



Table 4.6.6-1. Pitch Command Task Inputs

Definition	Symbol	Source	Precision	Units
M50-to-boost reference quaternion	$\bar{Q}_{BR\_M50}$	ASC UPP	SP	ND
RLTS fuel dissipation reference velocity magnitude	$V_{RTLS\_FD}$	SSME-OUT SAF TSK, RTLS INIT TSK, 1STG GUID INP TSK	SP	fps
Burn time left to stop throttling	DTTHROT	I-LOAD	SP	sec
Coefficients for calculating fuel dissipation thrust attitude	THETA_0, THETA_1, THETA_2, THETA_3, THETA_4	I-LOAD	SP	rad, rad/fps, rad, rad/fps, rad/fps
Flyback thrust direction	THETA_FB	I-LOAD	SP	rad
Flyback task discrete	$S_{RTLS\_FB}$	PRTLS SEQ, FUL DISS TSK	D	N/A
Fuel dissipation thrust attitude switch velocity	$V_{SWITCH}$	I-LOAD	SP	fps
RLTS H_DOT reference	$H\_DOT\_FD$	SSME-OUT SAF TSK, 1STG GUID INP TSK, RTLS INIT TSK	SP	fps
Upper fuel dissipation attitude limit	THETA_MAX	I-LOAD	SP	rad
Lower fuel dissipation attitude limit	THETA_MIN	I-LOAD	SP	rad
Earth relative velocity vector in M50	$\bar{V}_{RHO}$	RTLS UPP	SP	fps

Table 4.6.6-2. Pitch Command Task Outputs

Definition	Symbol	Destination	Precision	Units
Time associated with desired thrust vector	TLAMC	G/C STEER, TLM	DP	sec
Commanded roll angle	PHI_CMD	G/C STEER	SP	rad
Pitch command task discrete	S_PITCH_CMD	PRTLS SEQ	D	N/A
Throttling discrete	STHROT	PEG TSK	D	N/A
Guidance ready flag	S_GDRDY	MSC	D	N/A
Discrete indicating start of turn	S_RTLS_TURN	ASC DAP, TLM	D	N/A
M50 desired thrust vector	LAMC	G/C STEER, TLM, FUL DISS TSK	SP	ND
M50 desired thrust turning rate vector	LAMDC	G/C STEER, TLM	SP	sec <sup>-1</sup>



#### 4.6.7 RTLS Contingency Abort Task (RTLS CNTG ABT TSK)

This task determines whether a contingency or intact abort is being attempted. The following tests are required to determine if the orbiter is flying back toward the launch site. If all of these tests are passed, a flag is set to OFF to indicate an intact abort. If any of these tests are failed, the flag is set ON to indicate a contingency abort.

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##### A. Detailed Requirements.

1. If the magnitude of the current navigated velocity ( $ABVAL(\bar{V}_{NAV})$ ) is greater than a premission stored decision velocity ( $V_{RTLS\_CNTG}$ ), then continue with Step 2. Otherwise, set the RTLS contingency flag ( $GLIDE\_RTLS\_INHIBIT$ ) ON and exit this task.
2. A launch site heading vector ( $\bar{R}_{CNTG\_TGT}$ ) is calculated by subtracting the current position vector ( $\bar{R}_{NAV}$ ) from the launch site vector ( $\bar{R}_{LS\_M50}$ ):

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$$\bar{R}_{CNTG\_TGT} = \bar{R}_{LS\_M50} - \bar{R}_{NAV}$$

To determine if the orbiter is heading back toward the launch site, rather than downrange, a dot product of  $\bar{R}_{CNTG\_TGT}$  and the current navigated velocity vector  $\bar{V}_{NAV}$  is computed. If this dot product is positive, then set  $GLIDE\_RTLS\_INHIBIT$  to OFF; if negative, set  $GLIDE\_RTLS\_INHIBIT$  flag to ON.

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B. Interface Requirements. The input and output parameters for the RTLS contingency abort task are given in Tables 4.6.7-1 and 4.6.7-2.

C. Processing Requirements. This task is executed once when two or more SSME's have failed ( $N_{SSME} < 2$ ); if the SSME checkout timing request flag,  $S_{IMECO}$ , has not been set; and once when  $MÉCO\_CONFIRM$  has occurred.

D. Initialization Requirements. None.



Table 4.6.7-1. RTLS Contingency Abort Task Inputs

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Definition	Symbol	Source	Precision	Units
M50 position vector of launch site at liftoff	$\underline{R}_{LS\_M50}$	ASC UPF	DP	ft
Current Shuttle position vector in M50	$\underline{R}_{NAV}$	RTLS UPF	DP	ft
Current Shuttle velocity vector in M50	$\underline{V}_{NAV}$	RTLS UPF	SP	fps
RTLS contingency decision velocity	$\underline{V}_{RTLS\_CNTG}$	I-LOAD	SP	fps

Table 4.6.7-2. RTLS Contingency Abort Task Outputs

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Definition	Symbol	Destination	Precision	Units
RTLS contingency flag	$\underline{GLIDE\_RTLS\_INHIBIT}$	MSC, ADTA SOP, GRTLS TAEM GUID	D	N/A

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4.6.8 Parameter Tables for Powered RTLS Guidance

The IDD inputs and outputs are listed in Table 4.6.8-1. Values for the I-loads are contained in the I-load requirements document (JSC-19350); however, I-load definitions applicable to this principal function are listed in Table 4.6.8-2. K-loads are listed in Table 4.6.8-3. Constants are listed in Table 4.6.8-4. The input variable cross-references are listed in Table 4.6.8-5.

Ion	Units
	ft
	ft
	ft/s
	ft/s

ion	Units
	N/A

NASA

Table 4.6.8-1. Powered RTLS Guidance (G4.4) Input/Output Functional Parameters

DBFN: D2B039-A PN: VP707100026POOL MAY 31, 1988  
 INPUT FUNCTIONAL PARAMETERS FOR POWERED RETURN TO LAUNCH SITE GUIDANCE

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FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE
AREA SEL	V93J4392CB	SELECTED AREA	ASC SITE LOOKUP		
AUTO	V90X1710X	AUTO GUIDANCE MODE FLAG	ASC DAP		BD
D ARC	V95H0477C	ARC LENGTH AROUND HAC(WPI TO NEP)	RTLS UPP		
EVENT A37	V90X8250X	ET SEPARATION CMD FLAG	ET SEP SEQ		BD
FLT PATH ANG/GAMMA	V95H0261CC	GROUND-REL FLT PATH ANGLE	RTLS UPP	RAD	
FLT PATH ANG TIME	V95H0464C	TIME OF COMPUTING FLT PATH ANG	RTLS UPP		
H DOT ELLIPSOID/H_DOT	V95L0265CA	EST ALTITUDE RATE	RTLS UPP	FT/S	
H DOT_FD	V90R2098CA	RTLS FUEL DISSP REF HDOT	ASC 1STG GUID	FT/S	
H DOT_FD	V90R2098CB	RTLS FUEL DISSP REF HDOT	ASC 2STG GUID	FT/S	
K_CMD	V90U1948CA	COMMANDED SSME THROTTLE SETTING	ASC 2STG GUID	PCT	
K_CMD	V90U1948CB	COMMANDED SSME THROTTLE SETTING	ASC 1STG GUID	PCT	
K_CMD	V90U1948CE	COMMANDED SSME THROTTLE SETTING	SBTC SOP	PCT	
K_MAX	V97U4424CA	MAXIMUM THROTTLE SETTING OF SSME	ASC 1STG GUID	PCT	
K_MAX	V97U4424CB	MAXIMUM THROTTLE SETTING OF SSME	ASC 2STG GUID	PCT	
LL	V90J2007CA	RTLS FLIGHT PATH ANG TARGET INDEX	ASC 1STG GUID		
LL	V90J2007CB	RTLS FLIGHT PATH ANG TARGET INDEX	ASC 2STG GUID		
M/CURR ORB_MASS/WEIGHT	V90U1961CF	CURRENT VEHICLE MASS	ASC 1STG GUID	SLUGS	
M/CURR ORB_MASS/WEIGHT	V90U1961CG	CURRENT VEHICLE MASS	ASC 2STG GUID	SLUGS	
MAX THROT_CMD	V93X5349X	MAXIMUM THROTTLE LEVEL COMMAND	6.47		BD
MECO_CONFIRM	V90X8561X	MECO CONFIRMED FLAG	SSME OPS		BD
ME1_FAIL_SHUTDOWN	V95X1207X	MPS E1 FAIL FLAG	SSME OPS		BD
ME2_FAIL_SHUTDOWN	V95X1208X	MPS E2 FAIL FLAG	SSME OPS		BD
ME3_FAIL_SHUTDOWN	V95X1209X	MPS E3 FAIL FLAG	SSME OPS		BD
MM_CODE_103/MM_103	V90X8156X	MAJOR MODE 103 FLAG	MSC		
MM_CODE_601/MM_601	V90X8194X	MAJOR MODE 601 FLAG	MSC		
Q M50TOBR(1)	V95U0503C	M50-TO BOOST REF QUATERNION ELE 1	ASC UPP		
Q M50TOBR(2)	V95U0504C	M50-TO BOOST REF QUATERNION ELE 2	ASC UPP		
Q M50TOBR(3)	V95U0505C	M50-TO BOOST REF QUATERNION ELE 3	ASC UPP		
Q M50TOBR(4)	V95U0506C	M50-TO BOOST REF QUATERNION ELE 4	ASC UPP		
R_AVGG(1)	V95H0185CA	X-COMP OF CURRENT SHUTTLE POS VCTR	RTLS UPP	FT	DPL
R_AVGG(2)	V95H0186CA	Y-COMP OF CURRENT SHUTTLE POS VCTR	RTLS UPP	FT	DPL
R_AVGG(3)	V95H0187CA	Z-COMP OF CURRENT SHUTTLE POS VCTR	RTLS UPP	FT	DPL
R_CC_EF(1)	V95H0478C	HAC X POSITION EF(TOD)	RTLS UPP		
R_CC_EF(2)	V95H0479C	HAC Y POSITION EF(TOD)	RTLS UPP		
R_CC_EF(3)	V95H0480C	HAC Z POSITION EF(TOD)	RTLS UPP		
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 M50_AT_LIFTOFF(1)	V95U0507C	X-M50 POS OF NB AT LIFTOFF	ASC UPP	FT	
R M50_AT_LIFTOFF(2)	V95U0508C	Y-M50 POS OF NB AT LIFTOFF	ASC UPP	FT	
R M50_AT_LIFTOFF(3)	V95U0509C	Z-M50 POS OF NB AT LIFTOFF	ASC UPP	FT	
REL VEL MAG/V	V95L0151CA	GND REL VEL MAGNITUDE IN M50 SYS	RTLS UPP	FT/S	
S MAN_THROT	V96X0006X	MANUAL THROTTLE DISCRETE	SBTC SOP		BD
S OMS_CUTOFF	V90X8318XA	OMS CUTOFF CMD	ABT CNTL SEQ		
S OMS_IGN	V90X8319X	ABORT OMS IGNITION CMD	ABT CNTL SEQ		
S OMS1_FAIL	V90X7670X	LEFT OMS ENGINE SHUTDOWN FLAG	OMS RM		BD
S OMS2_FAIL	V90X7671X	RIGHT OMS ENGINE SHUTDOWN FLAG	OMS RM		BD
S RCS_IGN	V90X8314X	ABORT RCS +X ON CMD	ABT CNTL SEQ		BD
S RCS_NULL14	V90X8316X	14 RCS NULL JETS ON CMD	ABT CNTL SEQ		BD
S RCS_NULL20	V90X8317X	20 RCS NULL JETS ON CMD	ABT CNTL SEQ		BD
S RCS_NULL8	V90X8315X	8 RCS NULL JETS ON CMD	ABT CNTL SEQ		BD
T GMTLO	V90W4380C	TIME OF LIFTOFF IN GMT	FCOS	S	

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Table 4.6.8-1. Powered RTLS Guidance (G4.4) Input/Output  
Functional Parameters (Cont)

DBFN: D2B039-A PN: VP707100026POOL MAY 31, 1988  
INPUT FUNCTIONAL PARAMETERS FOR POWERED RETURN TO LAUNCH SITE GUIDANCE

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FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE
T_STATE	V95W0200CC	TIME TAG ASSOC WITH CURRENT STATE	RTLS UPP	S	
V_AVGG(1)	V95L0190CA	X-COMP OF CURRENT SHUTTLE VEL VCTR	RTLS UPP	FT/S	SPL
V_AVGG(2)	V95L0191CA	Y-COMP OF CURRENT SHUTTLE VEL VCTR	RTLS UPP	FT/S	SPL
V_AVGG(3)	V95L0192CA	Z-COMP OF CURRENT SHUTTLE VEL VCTR	RTLS UPP	FT/S	SPL
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_IMU_OLD(1)	V95L0210CA	X-COMP OF CURRENT ACCUM IMU VEL	RTLS UPP	FT/S	
V_IMU_OLD(2)	V95L0211CA	Y-COMP OF CURRENT ACCUM IMU VEL	RTLS UPP	FT/S	
V_IMU_OLD(3)	V95L0212CA	Z-COMP OF CURRENT ACCUM IMU VEL	RTLS UPP	FT/S	
V_RHO(1)	V95L0215CA	X-COMP OF RELATIVE VEL IN M50	RTLS UPP		
V_RHO(2)	V95L0216CA	Y-COMP OF RELATIVE VEL IN M50	RTLS UPP		
V_RHO(3)	V95L0217CA	Z-COMP OF RELATIVE VEL IN M50	RTLS UPP		
V_RTLS_FD	V90U1967CA	RTLS FUEL DISSIPATION REF VEL MAG	ASC 1STG GUID	FT/S	
V_RTLS_FD	V90U1967CB	RTLS FUEL DISSIPATION REF VEL MAG	ASC 2STG GUID	FT/S	
YSGNP/YSGN	V95J0153CC	R/L CONE IND PRI RW	RTLS UPP		

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Table 4.6.8-1. Powered RTLS Guidance (G4.4) Input/Output Functional Parameters (Cont)

DBFN: D2B039-A PN: VP707100026P00L MAY 31, 1988  
 OUTPUT FUNCTIONAL PARAMETERS FROM POWERED RETURN TO LAUNCH SITE GUIDANCE

PM RTLS GUID OI8B REV00 G4.4

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FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE
AD	V90A1973CB	DESIRED THRUST ACCELERATION	TLM		
DT_MAX	V90U8500CG	MAX ALLOW TIME STEP SIZE	ASC PREC PRED	FT/S2	
DT_TURN	V90U2092C	LENGTH OF TURNAROUND	TLM	S	
FT_FACTOR	V90U1979CB	THRUST SCALING FACTOR	TLM		SPL
GLIDE RTLS_INHIBIT	V90X2090XA	RTLS CONTINGENCY FLAG	ADTA SOP, MSC		
GMD_PRED	V90U8501CH	GRAVITY MODEL DEGREE	ASC PREC PRED		
GMO-PRED	V90U8502CH	GRAVITY MODEL ORDER	ASC PREC PRED		
GUID MECO_PREP_FLAG	V90X1989XB	MECO PREPARATION DISCRETE	ABT CNTL SEQ		
IY(X)	V90U1976CC	X-M50 UNIT VEC NORMAL TO ORB PLANE	TLM		
IY(Y)	V90U1977CC	Y-M50 UNIT VEC NORMAL TO ORB PLANE	TLM		
IY(Z)	V90U1978CC	Z-M50 UNIT VEC NORMAL TO ORB PLANE	TLM		
IZ(X)	V90U2095CB	X-UNIT VECTOR TO LANDING SITE	G/C STEER		
IZ(Y)	V90U2096CB	Y-UNIT VECTOR TO LANDING SITE	G/C STEER		
IZ(Z)	V90U2097CB	Z-UNIT VECTOR TO LANDING SITE	G/C STEER		
K	V90J2091C	DESIRED THROTTLE SETTING	TLM		
K_CMD	V90U1948CC	COMMANDED SSME THROTTLE SETTING	SSME SOP, SBTC SOP, TLM	PCT	SPL
K_MAX	V97U4424CC	MAXIMUM THROTTLE SETTING OF SSME	SBTC SOP	PCT	
LAMC(X)	V90U1954CB	X-COMP OF M50 REF THR VECTOR	G/C STEER, TLM		
LAMC(Y)	V90U1955CB	Y-COMP OF M50 REF THR VECTOR	G/C STEER, TLM		
LAMC(Z)	V90U1956CB	Z-COMP OF M50 REF THR VECTOR	G/C STEER, TLM		
LAMDC(X)	V90U1957CB	X-M50 DESIRED THR TRNING RATE VCTR	G/C STEER, TLM	RAD/S	
LAMDC(Y)	V90U1958CB	Y-M50 DESIRED THR TRNING RATE VCTR	G/C STEER, TLM	RAD/S	
LAMDC(Z)	V90U1959CB	Z-M50 DESIRED THR TRNING RATE VCTR	G/C STEER, TLM	RAD/S	
LAMDAG	V90U1968CC	MAGNITUDE OF LAMD	TLM	SLUGS	
M/CURR ORB_MASS/WEIGHT	V90U1961CH	CURRENT VEHICLE MASS	ASC DAP, XXXXXX TRAJ DIP, TLM	SLUGS/S	
MDOT	V90R1993CB	TOTAL VEHICLE MASS FLOW RATE	ASC DAP, TLM	SLUGS	SPL
MF	V90U2093C	PREDICTED FINAL MASS	TLM		
N OMS	V90J2031CC	NUMBER OF ACTIVE OMS ENGINES	TLM		
N RCS	V90J1974CC	NUMBER OF ACTIVE RCS ENGINES	TLM		
N RCS NULL	V90J1975CC	NUMBER OF ACTIVE RCS NULL ENGINES	TLM		
N SSME	V90U1962CB	NUMBER OF ACTIVE SSME'S	TLM		
PHI_CMD	V90H1969CB	COMMANDED ROLL ANGLE	G/C STEER	RAD	
Q CB M50(1)/Q_GCB_1	V90U1949CB	M50-TO-CMD BODY QUATERNION ELE 1	G/C STEER		
Q CB M50(2)/Q_GCB_2	V90U1950CB	M50-TO-CMD BODY QUATERNION ELE 2	G/C STEER		
Q CB M50(3)/Q_GCB_3	V90U1951CB	M50-TO-CMD BODY QUATERNION ELE 3	G/C STEER		
Q CB M50(4)/Q_GCB_4	V90U1952CB	M50-TO-CMD BODY QUATERNION ELE 4	G/C STEER		
R_INIT(X)	V90H8508CC	X-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT	
R_INIT(Y)	V90H8509CC	Y-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT	
R_INIT(Z)	V90H8510CC	Z-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT	
S_FCD	V90X2086X	FINE COUNTDOWN IND	6.22		BD
S_GDRDY	V90X1965XB	GUIDANCE READY FLAG	MSC, TLM		
S_LOW_LEVEL	V90X1942XB	ET LEVEL SENSOR ARM CMD	SSME OPS, TLM		
S_MECO	V90X1963XA	FINE COUNTDOWN DISCRETE	MSC, RTLS UPP SEQ, TLM		
S_PPD_QUAT	V90X2087X	DISCRETE INDICATING PPD CMDS	ASC DAP, TLM		BD
S_RTLS_TURN	V90X2089X	DSCR IND START OF TURN AROUND	ASC DAP, TLM		BD
S_SSME_TRIM	V90X1960XB	FCS TVC RETRIM DISCRETE	ASC DAP, TLM		
S_TMECO	V90X1944XB	SSME C/O TIMING REQUEST FLAG	SSME OPS		
S_UNCONV	V90X2084XB	PEG UNCONVERGED DSCR IND	ASC ADI PROC		
S_CONV	V90X1971XD	PEG CONVERGENCE DISCRETE	TLM		
T_FINAL	V90H8506CG	TIME AT WHICH STATE IS DESIRED	ASC PRFC PRED	S	
T_INIT	V90H8512CG	TIME AT BEGINNING OF PRED	ASC PREC PRED		
T_MECO	V90H1945CB	DESIRED SSME C/O TIME	SSME OPS		

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Table 4.6.8-1. Powered RTLS Guidance (G4.4) Input/Output  
Functional Parameters (Cont)

DBFN: D2B039-A PN: VP707100026P00L MAY 31, 1988  
 OUTPUT FUNCTIONAL PARAMETERS FROM POWERED RETURN TO LAUNCH SITE GUIDANCE PW RTLS GUID OI8B REV00 G4.4

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FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS
TGD	V90H1994CD	GUIDANCE TIME TAG	TLM	S
TGO	V90H1941CC	TIME TO GO TO ENGINE CUTOFF	TLM	S
TLAMC	V90H1953CB	TIME ASSOC W REF THR VECTOR	G/C STEER,TLM	S
TMET_MECO	V90H1970CB	PREDICTED SSME C/O TIME IN MET	6.22,TLM	S
TP	V90H1946CC	PREDICTED TIME OF THRUST C/O	TLM	FT/S
V_INIT(X)	V90L8513CC	X-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED	FT/S
V_INIT(Y)	V90L8514CC	Y-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED	FT/S
V_INIT(Z)	V90L8515CC	Z-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED	FT/S
V_ME_OUT	V90L1947CC	SSME ENGINE-OUT VELOCITY	TLM	FT/S
VDMAG	V90U8499CC	DESIRED MECO VELOCITY	TLM	FT/S
VGOMAG	V90U1966CC	MAGNITUDE OF VGO VECTOR	TLM	FT/S

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Table 4.6.8-2. Powered RTLS Guidance (G4.4) I-Loads Powered RTLS Guidance

MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	AD_INIT	V97U4306C	FT/SEC**2	F	S	D	C	G4.4 G4.2		ZF12
	AL	V97U4307C	FT/SEC**2	F	S	D	C	G4.2 G4.4		ZF12
	ALIM_1	V97U4308C	FT/SEC**2	F	S	D	C	G4.4 G4.2		ZF12
	ALIM_2	V97U4309C	FT/SEC**2	F	S	D	C	G4.4 G4.2		ZF12
	ALPHA_PPD	V97U4310C	RAD	F	S	D	C	G4.4		ZF12
	ALPHA_Z	V97U1332C	RAD	F	S	D	C	G4.4		ZF12
	DT_PITCH	V97U4351C	SEC	F	S	D	C	G4.4		ZF12
	DT_TAILOFF(1)	V96U8335C	SEC	F	S	D	C	G4.2 G4.4		ZF12
	DT_TAILOFF(2)	V96U8334C	SEC	F	S	D	C	G4.2 G4.4		ZF12
	DT_TURN	V97U4353C	SEC	F	S	D	C	G4.4		ZF12
	DTHETA_LIM	V97U4354C	RAD/SEC	F	S	D	C	G4.4		ZF12
	DTHETA_RATE	V97U4355C	RAD/SEC**2	F	S	D	C	G4.4		ZF12
	DTRD	V97U4371C	SEC	F	S	D	C	G4.2 G4.4		ZF12
	DTTHROT	V97U4372C	SEC	F	S	D	C	G4.4		ZF12
	FT_FACTOR	V97U4389C	ND	F	S	D	C	G4.2 G4.4		ZF12
	FT_OMS	V97U4390C	LBF	F	S	D	C	G4.210 G4.13 G4.4 G4.3 G4.2		ZF22
	FT_RCS	V97U4391C	LBF	F	S	D	C	G4.2 G4.3 G4.210 G4.4		ZF22
	FT_SSME	V97U4392C	LBF	F	S	D	C	G4.2 G4.4		ZF12

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Table 4.6.8-2. Powered RTLS Guidance (G4.4) I-Loads Powered RTLS Guidance (Cont)

OI8B MISSIONS FSSR NAME	MSID	ENG UNIT	DT PR D S PR FCTN	CAT
K_2ENG	V97U4854C	PCT	F S M C G4.4	A2P1
K_3ENG	V97U4421C	PCT	F S D C G4.4	A2P1
KMAX	V97U4424C	PCT	I S M C G4.1 G4.2 G4.4 G4.55	A2P1,
KMAX_SECONDARY	V99U7107C	PCT	I S M C G4.1 G4.2 G4.4	A2P1
KMIN	V97U4425C	PCT	I S D C G4.1 G4.2 G4.4 G4.55	A2P1
KMISS	V97U4831C	ND	F S D C G4.209 G4.2 G4.3 G4.4 G4.210 G4.211	ZF12
M_BIAS	V97U4430C	SLUGS	F S D C G4.4	ZF12
MASS_LOW_LEVEL	V97U4432C	SLUGS	F S M C G4.4 G4.2	AMC2
MASS_SSME_TRIM	V97U4436C	SLUGS	F S M C G4.2 G4.4	AMC2
MBOD(1)	V97U4438C	SLUGS	F S M C G4.4	AMC2
MBOD(2)	V97U4439C	SLUGS	F S M C G4.4	AMC2
MDOT_OMS	V97U4440C	SLUGS/SEC	F S D C G4.210 G4.13 G4.4 G4.3 G4.2	ZF22
MDOT_SSME	V97U4442C	SLUGS/SEC	F S D C G4.1 G4.2 G4.4	ZF12
N_MAX	V97U4445C	ND	I S D P G4.2 G4.3 G4.4 G4.209	ZF12

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Table 4.6.8-2. Powered RTLS Guidance (G4.4) I-Loads Powered  
RTLS Guidance (Cont)

MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	NMAX_CYCLES_UNCONV	V96U7796C	ND	I	S	D	P	G4.2 G4.4		ZF12
	NSEG	V97U4447C	ND	I	S	D	P	G4.2 G4.3 G4.4 G4.209 G4.211		ZF12 ZF22
	PHI_2STG	V97U4482C	RAD	F	S	D	C	G4.2 G4.4		ZF12
	PHIDOT_MAX	V97U9003C	RAD/SEC	F	S	D	C	G4.3 G4.210 G4.2 G4.4		ZF12
	RADIUS_NEP	V97U5458C	FT	F	S	D	C	G4.19 G4.20 G4.4		ZFV2
	RNG_TURN_PRED	V98U7972C	FT	F	S	D	C	G4.4		ZF12
	RTLS_PRIME_AREA	V99U8961C	ND	I	S	M	C	G4.2 G4.4 G4.238		AAPO
	TAL_PRIME_AREA	V99U8962C	ND	I	S	M	C	G4.2 G4.4 G6.21		AAPO
	TARGET1(1)	V99U8901C	ND	I	S	M	C	G4.2 G4.4 G5.7		AA10
	TARGET1(2)	V99U8913C	ND	I	S	M	C	G4.2 G4.4 G5.7		AA20
	TARGET1(3)	V99U8925C	ND	I	S	M	C	G4.2 G4.4 G5.7		AA30
	TARGET1(4)	V99U8937C	ND	I	S	M	C	G4.2 G4.4 G5.7		AA40
	TARGET1(5)	V99U8949C	ND	I	S	M	C	G4.2 G4.4 G5.7		AA50

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Table 4.6.8-2. Powered RTLS Guidance (G4.4) I-Loads Powered  
RTLS Guidance (Cont)

OI88 MISSIONS

FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
TARGET10(1)	V99U8910C	ND	F	S	M	C	G4.2 G4.4		AA10
TARGET10(2)	V99U8922C	ND	F	S	M	C	G4.2 G4.4		AA20
TARGET10(3)	V99U8934C	ND	F	S	M	C	G4.2 G4.4		AA30
TARGET10(4)	V99U8946C	ND	F	S	M	C	G4.2 G4.4		AA40
TARGET10(5)	V99U8958C	ND	F	S	M	C	G4.2 G4.4		AA50
TARGET11(1)	V99U8911C	ND	F	S	M	C	G4.2 G4.4		AA10
TARGET11(2)	V99U8923C	ND	F	S	M	C	G4.2 G4.4		AA20
TARGET11(3)	V99U8935C	ND	F	S	M	C	G4.2 G4.4		AA30
TARGET11(4)	V99U8947C	ND	F	S	M	C	G4.2 G4.4		AA40
TARGET11(5)	V99U8959C	ND	F	S	M	C	G4.2 G4.4		AA50
TARGET12(1)	V99U8912C	ND	F	S	M	C	G4.2 G4.4		AA10
TARGET12(2)	V99U8924C	ND	F	S	M	C	G4.2 G4.4		AA20
TARGET12(3)	V99U8936C	ND	F	S	M	C	G4.2 G4.4		AA30
TARGET12(4)	V99U8948C	ND	F	S	M	C	G4.2 G4.4		AA40
TARGET12(5)	V99U8960C	ND	F	S	M	C	G4.2 G4.4		AA50
TARGET13(1)	V99U8963C	ND	F	S	M	C	G4.2 G4.4		AA10
TARGET13(2)	V99U8964C	ND	F	S	M	C	G4.2 G4.4		AA20

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Table 4.6.8-2. Powered RTLS Guidance (G4.4) I-Loads Powered  
RTLS Guidance (Cont)

OIBB MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	TARGET13(3)	V99U8965C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET13(4)	V99U8966C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET13(5)	V99U8967C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET2(1)	V99U8902C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET2(2)	V99U8914C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET2(3)	V99U8926C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET2(4)	V99U8938C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET2(5)	V99U8950C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET3(1)	V99U8903C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET3(2)	V99U8915C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET3(3)	V99U8927C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET3(4)	V99U8939C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET3(5)	V99U8951C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET4(1)	V99U8904C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET4(2)	V99U8916C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET4(3)	V99U8928C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET4(4)	V99U8940C	ND	F	S	M	C	G4.2 G4.4		AA40

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Table 4.6.8-2. Powered RTLS Guidance (G4.4) I-Loads Powered RTLS Guidance (Cont)

OI8B MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	TARGET4(5)	V99U8952C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET5(1)	V99U8905C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET5(2)	V99U8917C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET5(3)	V99U8929C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET5(4)	V99U8941C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET5(5)	V99U8953C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET6(1)	V99U8906C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET6(2)	V99U8918C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET6(3)	V99U8930C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET6(4)	V99U8942C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET6(5)	V99U8954C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET7(1)	V99U8907C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET7(2)	V99U8919C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET7(3)	V99U8931C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET7(4)	V99U8943C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET7(5)	V99U8955C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET8(1)	V99U8908C	ND	F	S	M	C	G4.2 G4.4		AA10

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Table 4.6.8-2. Powered RTLS Guidance (G4.4) I-Loads Powered  
RTLS Guidance (Cont)

MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	TARGET8(2)	V99U8920C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET8(3)	V99U8932C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET8(4)	V99U8944C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET8(5)	V99U8956C	ND	F	S	M	C	G4.2 G4.4		AA50
	TARGET9(1)	V99U8909C	ND	F	S	M	C	G4.2 G4.4		AA10
	TARGET9(2)	V99U8921C	ND	F	S	M	C	G4.2 G4.4		AA20
	TARGET9(3)	V99U8933C	ND	F	S	M	C	G4.2 G4.4		AA30
	TARGET9(4)	V99U8945C	ND	F	S	M	C	G4.2 G4.4		AA40
	TARGET9(5)	V99U8957C	ND	F	S	M	C	G4.2 G4.4		AA50
	TGO_MAN	V97U9002C	SEC	F	S	D	P	G4.2 G4.4		ZF12
	THETA_FB	V97U4801C	RAD	F	S	D	C	G4.4		ZF12
	THETA_MAX	V99U7323C	RAD	F	S	D	C	G4.4		ZF12
	THETA_MIN	V99U7324C	RAD	F	S	D	C	G4.4		ZF12
	THETA_0	V97U4805C	RAD	F	S	M	C	G4.4		AFD0
	THETA_1	V97U4806C	RAD*SEC/FT	F	S	M	C	G4.4		AFD0
	THETA_2	V97U4807C	RAD	F	S	M	C	G4.4		AFD0
	THETA_3	V97U8366C	RAD*SEC/FT	F	S	M	C	G4.4		AFD0
	THETA_4	V99U7322C	RAD*SEC/FT	F	S	M	C	G4.4		AFD0
	V_LATE_RTLS	V97U4818C	FT/SEC	F	S	M	C	G4.4		A2R4
	V_RHO_PHI	V97U4823C	FT/SEC	F	S	D	C	G4.4 G4.2		ZF12
	V_RTLS_CNTG	V98U7974C	FT/SEC	F	S	D	P	G4.4		ZF12

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Table 4.6.8-2. Powered RTLS Guidance (G4.4) I-Loads Powered RTLS Guidance (Cont)

OI8B MISSIONS FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
V_SWTCH	V97U8368C	FT/SEC	F	S	M	C	G4.4		AFD0
X_NEP	V97U5575C	FT	F	S	M	X	G4.4 G4.19 G4.20 G5.7		XS60 XS60

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Table 4.6.8-3. Powered RTLS Guidance (G4.4) K-Loads  
Powered RTLS Guidance

OI8B MISSIONS FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT PR S PR FCTN	LAST CR EQTN MSID
ABORT_MECO_PREP_TIME	V98U7961C	01 +1.0	E+01 SEC	F S C G4.2 G4.4	59955
DK_ROUND	V97U4345C	+7.5	E-01 PCT	F S C G4.4	29602A
DT_FCD	V97U4347C	+3.200	E-01 SEC	F S C G4.4 G4.2	89541
DTMAX	V97U4369C	+1.00	E+20 SEC	F S C G4.209 G4.13 G4.4 G4.3 G4.2	89541
MAX STEP SIZE, ASC PREC PRED					
DTMIN	V97U4370C	01 +2.0 02 +3.00 03 +2.0	E+00 SEC E+02 E+00	F S C G4.211 G4.210 G4.209 G4.158 G4.13 G4.4 G4.3 G4.2	29975A
EPS-X	V97U4380C	+2.0	E-02 ND	F S C G4.2 G4.4	59955
CRIT REJ THRUST SCALING FACTOR					
EPSTGO	V97U4381C	+4.0	E-02 ND	F S C G4.2 G4.3 G4.4 G4.210	59955
PEG INHIBIT STEERING OUTPUT					
ETB	V97U4382C	+5.000000	E+00 SEC	F S C G4.2 G4.4	59955
MIN TBN-1 COMPUTATION OF TGO					
FTF_MIN	V97U4838C	+6.5	E-01 ND	F S C G4.2 G4.4	29602A
K_INT	V97U4418C	+1.0	E-02 SEC**-2	F S C G4.4 G4.2	59955
G-LIMITING INTEGRAL GAIN					
K_PROP	V97U4419C	+1.5	E-01 SEC**-1	F S C G4.4 G4.2	59955
PROPORTIONAL GAIN					

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Table 4.6.8-3. Powered RTLS Guidance (G4.4) K-Loads  
 Powered RTLS Guidance (Cont)

MISSIONS	MSID	MC KLOAD VALUE	ENG UNIT	DT PR S PR FCTN	LAST CR EQTN MSID
MDOT_RCS	V97U4441C	+1.0655714	E-01 SLUGS/SEC	F S C G4.210 G4.2 G4.13 G4.4 G4.3	89661A
NOMINAL RCS MASS FLOW RATE					
TGO IA MIN TGO SEL RTLS CONSTRAINT	V97U4664C	+6.0000000	E+01 SEC	F S C G4.4	59955
TGO PPD TIME TO GO TO POWERED PITCHDOWN	V97U4666C	+6.0000000	E+00 SEC	F S C G4.4	59955
TLAG THROTTLE LAG TIME	V97U4834C	+5.0000000	E-01 SEC	F S C G4.2 G4.4	59955

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Table 4.6.8-4. Powered RTLS Guidance (G4.4) Constants

NROKRM.FSSR2.DATA(X25)BOOK2  
PFS CONSTANTS UPDATE B/L

FSSR NAME DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
EARTH POLE(1) UNIT POLE VECTOR IN M50, X-COMP	V98U8460C		.28322844 E-02	ND	F	D	P			
EARTH POLE(2) UNIT POLE VECTOR IN M50, Y-COMP	V98U8461C		-.5027996 E-04	ND	F	D	P			
EARTH POLE(3) UNIT POLE VECTOR IN M50, Z-COMP	V98U8462C		.9999959841	ND	F	D	P			
EARTH MU EARTH'S GRAVITATIONAL CONSTANT	V97U4378C		1.40764487566 E+16	FT**3/ SEC**2	F	D	P			
EARTH RATE EARTH ROTATIONAL RATE	V97U4379C		7.29211514646 E-5	RAD/SEC	F	D	P			
MUP TH MINIMUM CHANGE IN MASS REQUIRED FOR MASS TO BE UPDATED			.3	SLUGS	F	S	P			
PI RATIO OF CIRCUMFERENCE TO DIAMETER	V98U8725C		3.1415926535897	ND	F	D	P			

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Table 4.6.8-5. Powered RTLS Input Variable Cross-Reference

MSID	Local Name	Source Name
V95H0185CA, 6CA, 7CA	$\bar{R}_{NAV}$	$\bar{R}_{AVGG}$
V95L0190CA, 1CA, 2CA	$\bar{V}_{NAV}$	$\bar{V}_{AVGG}$
V95W0200CC	T_NAV	T_STATE
V95L0210CA, 1CA, 2CA	$\bar{V}_S$	$\bar{V}_{IMU\_OLD}$
V95L0151CA	V_RHO_MAG	REL_VEL_MAG
V95U0503C, 4C, 5C, 6C	$Q_{BR^+M50}$	Q_M50TOBR
V95U0507C, 8C, 9C	$\bar{R}_{LS\_M50}$	$\bar{R}_{M50\_AT\_LIFTOFF}$
V90X8250X	$E\dot{T}_{SEP\_CMD}$	EVENT_A37
V90X8156X	MM103	MM_CODE_103
V90X8194X	MM601	MM_CODE_601
V95X1207X	S_ÉO_E1	ME1_FAIL_SHUTDOWN
V95X1208X	S_ÉO_E2	ME2_FAIL_SHUTDOWN
V95X1209X	S_ÉO_E3	ME3_FAIL_SHUTDOWN

4.7 ASCENT XXXXX MANEUVER YYYYY DISPLAY INTERFACE  
PROCESSING REQUIREMENTS (MM's 104, 105, AND 106)





#### 4.7 ASCENT XXXXX MANEUVER YYYYY DISPLAY INTERFACE PROCESSING REQUIREMENTS (MM's 104, 105, AND 106)

The ascent XXXXX maneuver YYYYY display interface processing principal function (AS MNVR DIP, CPDS, Level B GN&C, Section 4.210) provides software required to support the XXXXX MNVR YYYYY display (MNVR DISP). The MNVR DISP provides the crew capability to set up maneuvers, adjust target values, monitor maneuvers, and trim burn residuals when required.

The general guidance and targeting tasks required for the AS MNVR DIP principal function and not documented in Section 4.7 are powered explicit guidance (Section 4.8.1), thrust parameters (Section 4.8.7), and H- $\theta$ -to-M50 target (Section 4.8.6), and the Commanded Body Attitude task (Section 4.8.10). In addition, the ascent precise predictor principal function (ASC PREC PRED, CPDS, Level B GN&C, Section 4.236) documented in the Ascent/RTLS Navigation FSSR is required.

Since the AS MNVR DIP provides supportive software for the MNVR DISP, an understanding of the display is essential to comprehending the details of this section. It is recommended that the Display and Controls, Display Formats, Level C, FSSR document be reviewed prior to reading this section. The display format is shown for information only in Figure 4.7-1.

##### 4.7.1 Overview

The AS MNVR DIP is active during MM's 104, 105, and 106 and supports OMS-1 and OMS-2 insertion maneuvers for nominal missions, AOA, and ATO. For an AOA OMS-2 maneuver, the only function of the AS MNVR DIP is to prepare targeting data for display and transfer to the OPS-3 MNVR DISP; the maneuver is performed in OPS-3 and supported by the DEORB MNVR DIP. The AS MNVR DIP specific requirements vary slightly as a function of the major mode. Therefore, for clarity, the following is a description of the AS MNVR DIP interactions with the crew and other software functions in each of the major modes.

For an OMS-1 (MM 104) nominal maneuver, the AS MNVR DIP principal function is initiated by the MSC when MM 104 is entered upon completion of the -Z RCS translational maneuver for orbiter/ET separation or by crew action. Upon initialization, the I-load OMS-1 guidance targets of altitude, earth central angle from the launch site to the target position, and the terminal velocity constraint slope and intercept constants are displayed. The I-load value of delta time of ignition referenced to actual time of orbiter/ET separation is used to calculate a time of ignition and this parameter is displayed. Also displayed is the I-load value of the planned propulsion system (left OMS, right OMS, both OMS, or +X RCS). Entry into MM 104 also initiates cyclic computation of the current apogee and perigee altitudes and time to the next apsis.

A second group of calculations is initiated or performed automatically as part of the MM 104 AS MNVR DIP initialization, but these calculations may be repeated at a later time by crew entry of the LOAD item entry (display Item 22). The display parameters supported by this group of calculations are:

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51

1	XXXX / XXX / XXX	XXXXX	MNVR	XXXXX	XX	X	DDD / HH : MM : SS
2	OMS BOTH 1X						DDD / HH : MM : SS
3	L 2XS		BURN ATT				XXXX
4	R 3XS		24 R XXX			ΔVTOT	XXXX.X
5	RCS SEL 4X		25 P XXX			TGO	XX:XX
6	5 TV ROLL XXX		26 Y XXX				
7	TRIM LOAD		MNVR 27X			VGO X ±XXXX.XX	
8	6 P [ ]X.X					Y ±XXX.XX	
9	7 LY [ ]X.X		REI XXXX			Z ±XXX.XX	
10	8 RY [ ]X.X		TXX XX:XX				
11	9 WT XXXXXX		GMBL			HA HP	
12	10 TIG		L R			TGT XXX ±XXX	
13	XXX / XX : XX : XX . X		P ±X.XS ±X.XS			CUR XXX ±XXX	
14	TGT PEG 4		Y ±X.XS ±X.XS				
15	14 C1 XXXXX						
16	15 C2 [ ]XXXX		PRI 28X 29X			35 ABORT TGT XX	
17	16 HT XXX.XXX		SEC 30X 31X				
18	17 θT XXX.XXX		OFF 32X 33X			FWD RCS	
19	18 PRPLT [ ]XXXX					ARM 36X	
20	TGT PEG 7		GMBL CK 34X			DUMP 37X	
21	19 ΔVX [ ]XXXX.X					OFF 38X	
22	20 ΔVY [ ]XXXX.X		XXXXXXXXX			SURF DRIVE	
23	21 ΔVZ [ ]XXXX.X					ON 39X	
24	XXXX 22 / TIMER 23					OFF 40X	

NOTE: THIS PAGE IS FOR INFORMATION ONLY AND IS NOT A REQUIREMENT. FOR MORE INFORMATION SEE DOCUMENT STS 83-0020B

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41  
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66 75  
85 94  
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123 132  
142 151  
161 170  
180 189  
199 208  
218 227  
237 246  
256 265  
275 284  
294 303  
313 322  
332 341  
351 360  
370 379  
389 398  
408 417  
427 436  
446 455  
465 474  
484 493  
503 512  
522 531  
541 550  
560 569  
579 588  
598 607  
617 626  
636 645  
655 664  
674 683  
693 702  
712 721  
731 740  
750 759  
769 778  
788 797  
807 816  
826 835  
845 854  
864 873  
883 892  
902 911  
921 930  
940 949  
959 968  
978 987  
997

Figure 4.7-1. XXXXX MNVR YYYYY Display Format

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1. Desired ignition attitude (pitch, yaw, and roll angles in ADI inertial coordinate frame)
2. Velocity-to-go in current body axis coordinates
3. Total delta velocity required
4. Targeted apogee and perigee altitudes
5. Time-based time (initiates MSC calculations; additional crew action is required for this parameter to be displayed).
6. PEG 4 velocity-to-go components in an LVLH coordinate system at TIG

Concurrent with the calculation of the above display parameters, the target setup data currently displayed are transferred as a group to orbit insertion guidance and other software principal functions. Other functions performed in this group are defined in the premaneuver display support task (Subsection 4.7.8).

The crew must perform two actions to enable OMS ignition. The first action is to arm the OMS engines via the cockpit hardware switches. This action is independent of the AS MNVR DIP requirements. The second action is a crew-entered software engine ignition proceed to AS MNVR DIP, which is achieved by depressing the EXEC button on the keyboard. Depressing the EXEC button subsequent to time of planned ignition minus 15 seconds is recognized by the AS MNVR DIP as one of two required conditions that allows OMS ignition. The other required condition is that the currently displayed data be consistent with the software recognized data. If these two conditions are satisfied, an indicator is set to authorize the MSC to allow OMS ignition; i.e., initiate the OMS FIRE SEQ principal function. Maneuvers with the RCS propulsive system assume manual engine ignition and cutoff via the THC; therefore, the above actions and conditions do not apply.

Maneuver parameters monitored on the MNVR DISP and calculated by the AS MNVR DIP are the velocity-to-go components in current orbiter body axis coordinates, the velocity-to-go magnitude, PEG 4 velocity-to-go components in LVLH coordinates, current burn attitude in ADI inertial coordinates, the orbiter weight, the current apogee and perigee altitudes, and the time to next apsis. The AS MNVR DIP also monitors the status of the active OMS actuator system and sets a flag to indicate any failure condition. Time-to-go values are calculated by the ORB INS GUID principal function and current values for the OMS gimbal angles are supplied by the OMS TVC FB SOP principal function. These two parameter sets are supplied directly to the MNVR DISP.

MNVR DISP capabilities not supported by the AS MNVR DIP principal function are (for information only):

- |  |                                   |
|--|-----------------------------------|
| 1. GMBL CK (Item 34)                       | OMS gimbal drive check initiator  |
| 2. GMBL SEL (Items 28, 29, 30, 31, 32, 33) | OMS gimbal drive system selection |



3. FWD RCS DUMP (Items 36, 37, 38) Forward RCS dump
4. SURF DRIVE (Items 39, 40) Aerosurface drive
5. ABORT TGT (Item 35) AOA/ATO abort and target selection

When an AOA or an ATO abort is commanded prior to MNVR DISP initialization entry into MM 104, AS MNVR DIP activities are similar to the nominal ascent OMS-1 described above except that the orbit insertion guidance targets displayed and transferred to orbit insertion guidance are provided by the AOA/ATO targeting principal function. Additional input parameters are also required. These additional input parameters are the +X RCS engines burn time for a parallel OMS and +X RCS maneuver and a new orbiter initial mass estimate to compensate for any OMS propellant burned prior to MECO. If an AOA or ATO abort is initiated subsequent to MNVR DISP initialization, and prior to crew software enablement of OMS ignition, the abort targets replace the stored I-load values on the MNVR DISP and are assumed by orbit insertion guidance. Declaration of an abort condition subsequent to crew software enablement of OMS ignition will result in a nominal OMS-1 maneuver with abort targets for the OMS-2 maneuver being selected and displayed upon proceeding into MM 105.

The AS MNVR DIP principal function software requirements for the OMS-2 maneuver are identical to the software requirements for the OMS-1 maneuver except that the activities nominally associated with "LOAD" item entry are not performed automatically when the OMS-2 insertion maneuver major mode (105) is entered. If an AOA or ATO abort is initiated subsequent to MNVR DISP initialization upon entry into MM 105 and prior to crew software enablement of OMS ignition, the abort targets selected will be put onto the MNVR DISP, but the "LOAD" item entry is required to transfer these abort targets to the software. Declaration of an abort condition subsequent to crew software enablement of OMS ignition will result in a nominal OMS-2 maneuver. A crew activity is that the manual maneuver to the ignition vehicle attitude is performed. Additionally, a preburn commanded body quaternion is computed and transmitted to the TRANS DAP for subsequent calculation of attitude errors (A/E ATTITUDE PROCESSING principal function) for display on the ADI.

Upon entry into MM 106, the dynamic variables of the maneuver execute major modes are blanked except for the current apogee and perigee altitudes and time to next apsis. These orbital parameters are updated cyclically throughout MM 106.

The functional task organization, logic flow, and data flow for AS MNVR DIP principal function are shown in Figures 4.7-2, 4.7-3, and 4.7-4. AS MNVR DIP inputs and outputs are given in the Section 4.7.10.

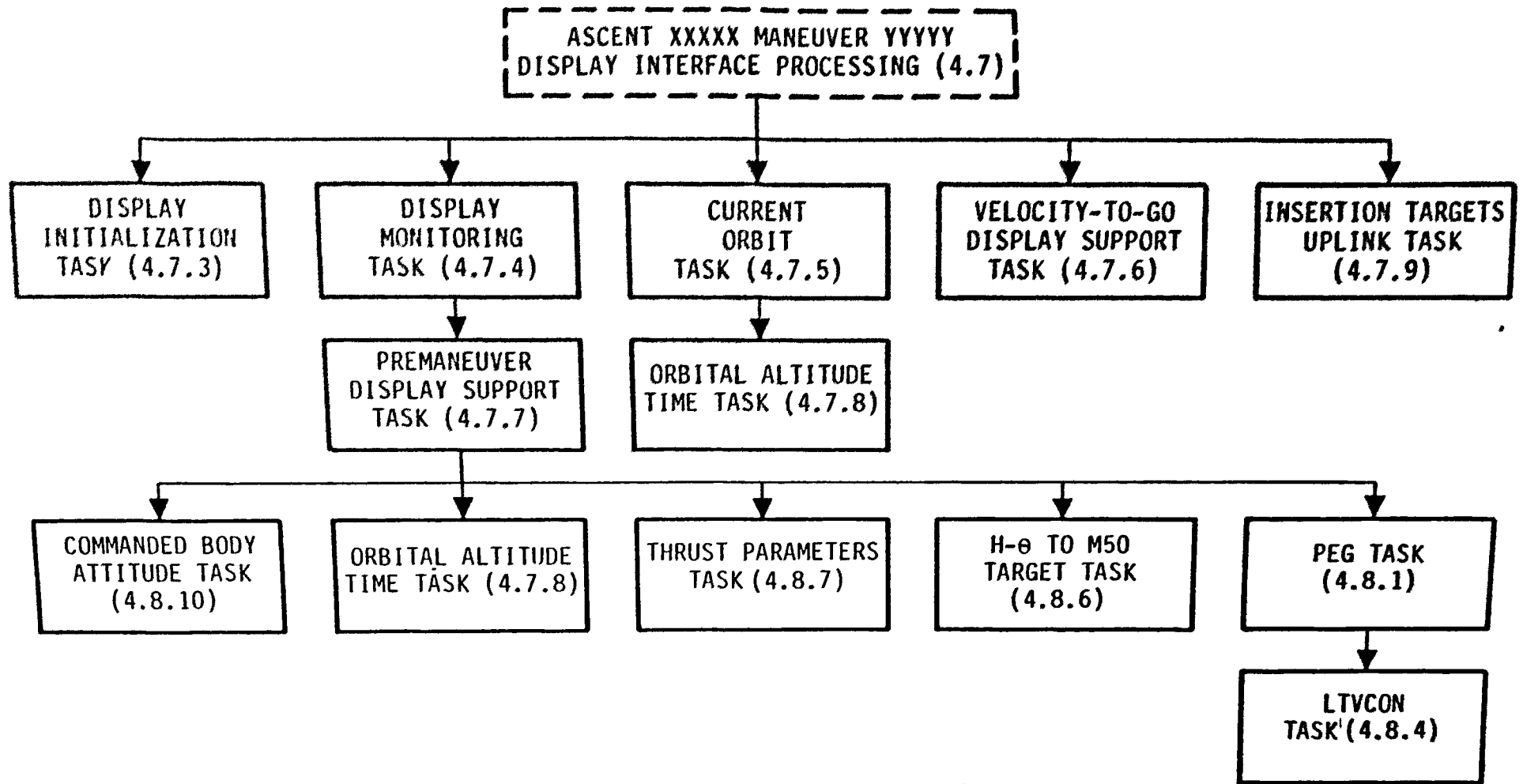


Figure 4.7-2. Ascent XXXXX Maneuver YYYYY Display Interface Processing  
Principal Function Task Organization

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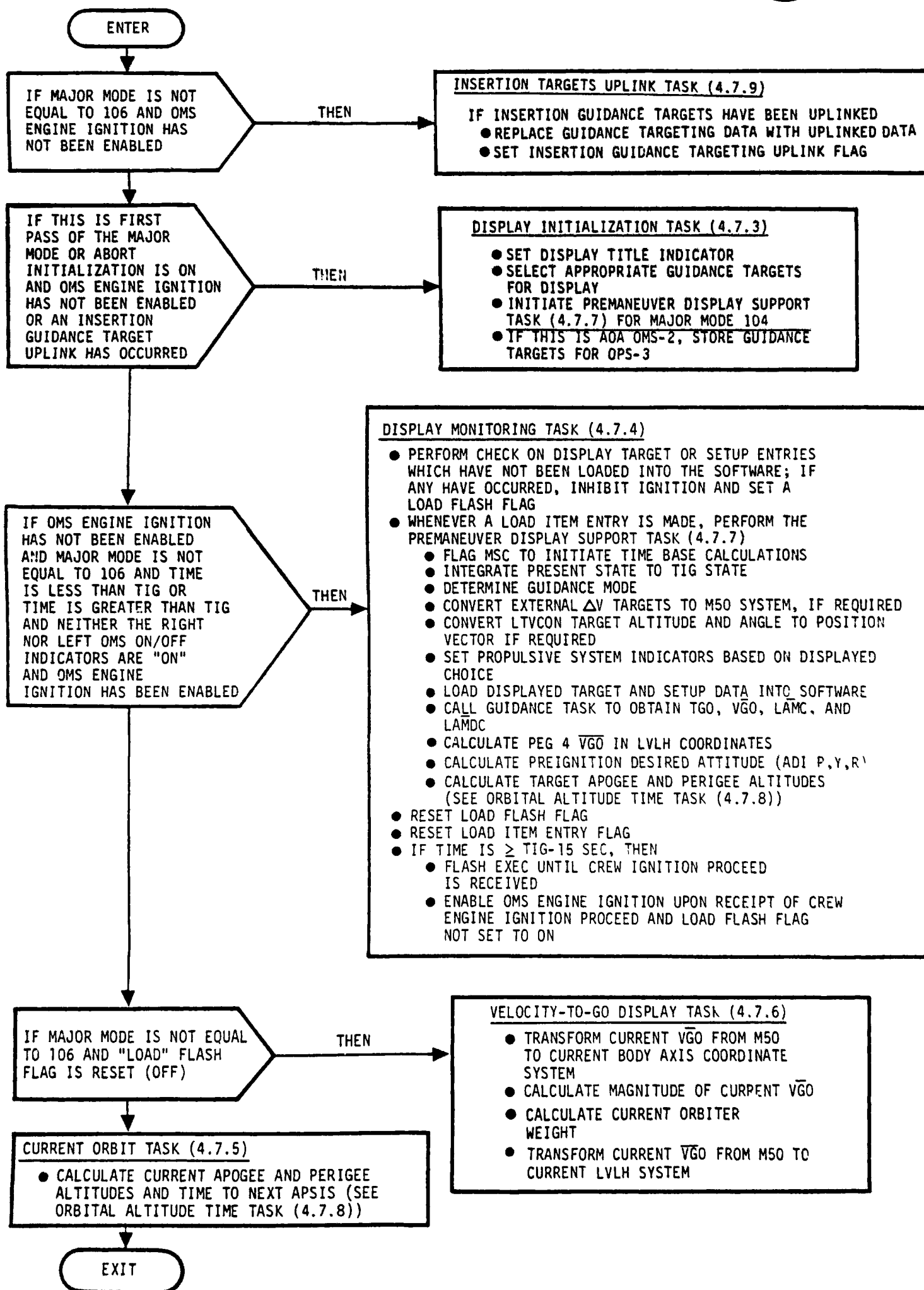


Figure 4.7-3. Ascent XXXXX Maneuver YYYYY Display Interface Processing Functional Flow

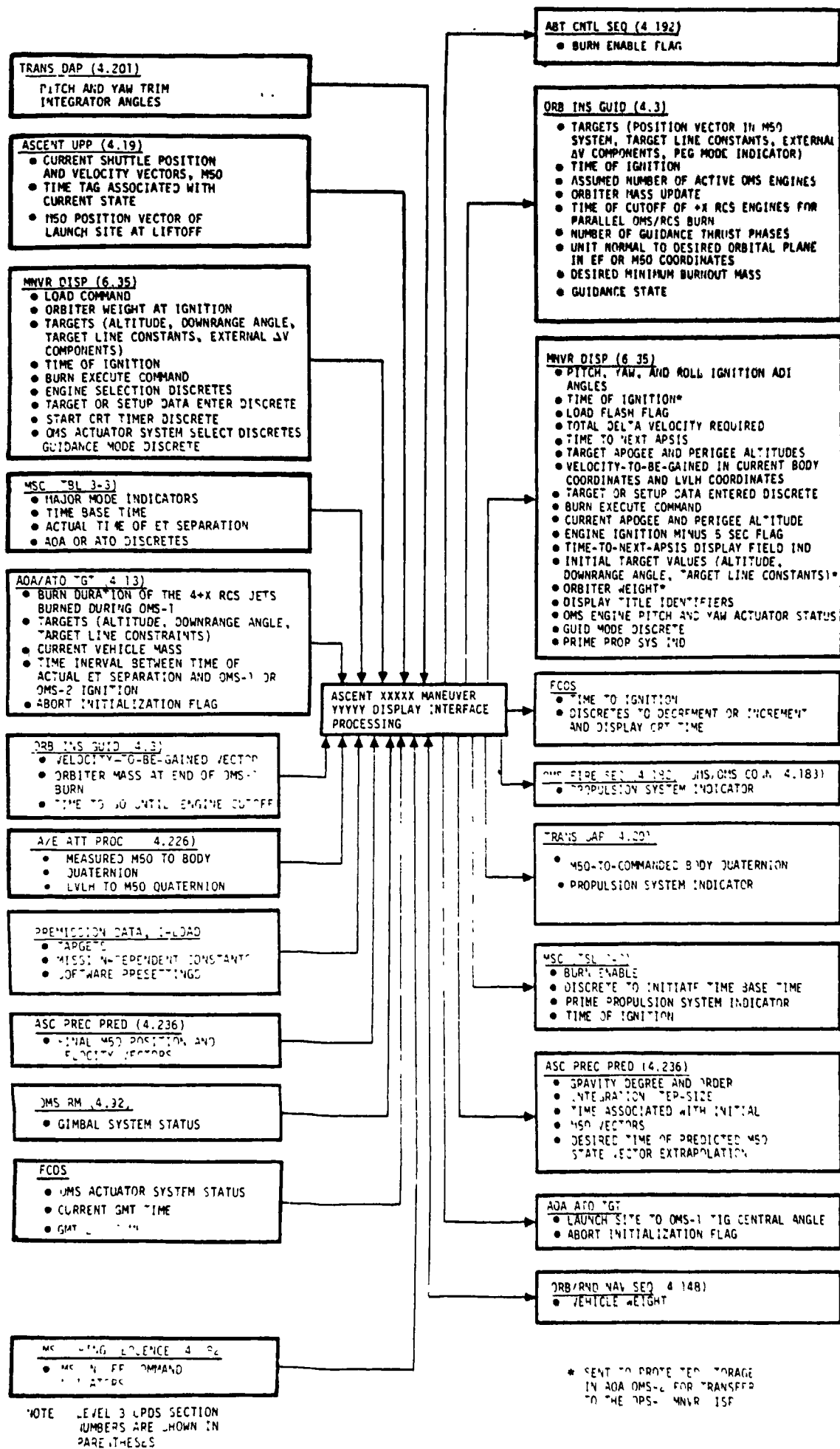


Figure 4.7-4. Ascent XXXXX Maneuver YYYYY Display Interface Processing Data Flow



#### 4.7.2 Ascent XXXXX Maneuver YYYYYY Display Interface Processing Sequencing

The correct sequencing of some of the tasks defined in the ascent XXXXX maneuver YYYYYY display interface processing principal function is dependent on the concurrence of specific events. These events are identified in CPDS, Level B, Volume 5, Book 1.

The tasks to be sequenced are:

1. Insertion targets uplink task (INS TGT UL TSK)
2. Display initialization task (DISP INIT TSK)
3. Display monitoring task (DISP MONIT TSK)
4. Velocity-to-go display task (VGO DISP TSK)
5. Current orbit task (CUR ORBIT TSK)

Two additional tasks are defined to reflect a large related group of requirements or a group of requirements that is performed more than once within the other tasks. These two additional tasks are:

1. Premaneuver display support task (PRE MAN DISP SUPT TSK)
2. Orbital altitude time task (ORB ALT TIME TSK)

The first group of tasks must be sequenced as follows and is presented in the correct order of solution.

1. The INS TGT UL TSK is performed repetitively beginning with transition into MM 104 (Event 36) or 105 (Event 44) and ending when either MM 104 is exited (Event 44), MM 105 is exited (Event 49), or OMS engine ignition has been enabled (BURN\_ENABLE = ON) for an OMS-1 or OMS-2 maneuver.
2. The DISP INIT TSK is performed once upon entry into MM's 104 (Event 36), 105 (Event 44), or 106 (Event 49). This task is also performed once if either (a) an insertion guidance target uplink has occurred (TBD = ON) or (b) an AOA or ATO abort has been initiated and the AOA/ATO TGT principal function has been executed, subsequent to entry into MM 104 or 105 but prior to OMS engine ignition enablement. The abort initialization flag (ABORT\_INIT) is set ON by AOA/ATO TGT following a crew selection of ATO, AOA, or a downmode from ATO to AOA, or a crew item entry request for a target set.
3. The DISP MONIT TSK is performed repetitively beginning each time any of the following conditions occur:
  - a. Transition into MM 104.



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t on
- b. Transition into MM 105
  - c. OMS engine ignition criteria have been met (BURN\_ENABLE = ON) and current time (T\_GMT) is greater than or equal to the time of ignition (TIG) and neither the left nor the right OMS ON/OFF command indicators (OMS\_L\_ON\_CMD\_IND, OMS\_R\_ON\_CMD\_IND) are set to "ON" by the OMS firing sequencer principal function.

Cyclic processing of the DISP MONIT TSK is terminated each time any of the following conditions occur.

- a. MM 104 is exited.
  - b. MM 105 is exited.
  - c. Engine ignition has been enable (BURN\_ENABLE = ON) and T\_GMT < TIG.
- 4. The VGO DISP TSK is performed only in MM's 104 and 105 when the "LOAD" flash flag is reset (OFF).
  - 5. The CUR ORBIT TSK is performed repetitively beginning with transition into MM 104 (Event 36) and ending with transition out of operational sequence 1 (Events 59, 60, or A20).

The recommended execution rate for Tasks 1, 3, and 4 is once every 0.96 second. The recommended execution rate for Task 5 is once every 1.92 seconds.

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### 4.7.3 Display Initialization Task (DISP INIT TSK)

This task generates a display title indicator for the variable portion of the display title (XXXXX and YYYYY of the XXXXX MNVR YYYYY) and determines the proper set of orbit insertion guidance targets (OMS-1, OMS-2, or abort) to be displayed and utilized by the software. In addition, it performs supportive calculations for uplink.

A. Detailed Requirements. The display initialization task performs the following activities as a function of the major mode and abort condition indicators and initialization condition (uplink support or other initialization condition). If this task is performed to support uplink, then Items 7, 8, 9, 11, and 12 must be performed. Otherwise, Items 1 through 10 and 12 must be performed.

1. The default value of the guidance mode discrete (PEG\_MODE\_4) is set to ON to be consistent with the I-load nominal or AOA/ATO TGT selected abort target set. Also, the abort initialization discrete (ABORT\_INIT) is set to OFF to avoid recycling this subtask unless another abort target has been selected via keyboard (denoted by ABORT\_INIT = ON).
2. A display title indicator (MNVR\_TITLE\_IND) is generated for the variable portion of the display title (XXXXX and YYYYY of the XXXXX MNVR YYYYY) based on the value of the MM indicators (MM104, MM105, MM106) and abort discrettes (S\_AOA and S\_ATO). The value of the MNVR\_TITLE\_IND variable and the resulting display title, as well as the required conditions for setting the MNVR\_TITLE\_IND value, are as follows:

Major Mode	S_AOA Value	S_ATO Value	MNVR_TITLE_IND	Display
104	OFF	OFF	1	OMS-1 MNVR EXEC
104	OFF	ON	2	ATO-1 MNVR EXEC
104	ON	OFF	3	AOA-1 MNVR EXEC
105	OFF	OFF	4	OMS-2 MNVR EXEC
105	OFF	ON	5	ATO-2 MNVR EXEC
105	ON	OFF	6	AOA MNVR TRANS
106	OFF	OFF	7	OMS-2 MNVR COAST
106	OFF	ON	8	ATO-2 MNVR COAST

3. For MM's 104 and 105, the proper set of orbit insertion guidance targets must be selected as a function of whether the current maneuver is a nominal OMS-1, OMS-2, or an abort OMS maneuver. If an abort condition does not exist (S\_AOA = OFF and S\_ATO = OFF), then the nominal orbit insertion guidance targets must be used to initialize the display. (The current display values are transferred to orbit insertion guidance in the premaneuver display support task.)



The I-load set of targets selected is a function of the OMS maneuver target index (I): I = 1 for an OMS-1 maneuver and I = 2 for an OMS-2 maneuver. If an abort condition does exist (S\_AOA = ON or S\_ATO = ON), the orbit insertion guidance targets selected by the AOA/ATO TGT principal function must be used to initialize the display: I = 3 for an AOA or ATO abort. The nominal OMS-1, nominal OMS-2, or AOA/ATO abort target values selected are then used to initialize the display as follows:

HTGT\_DISP = HTGT\_OMS\_I /  
NM\_PER\_FT:

Target altitude magnitude above a spherical earth that is biased to account for noncentral body forces from planned engine ignition to the target position.

THETA\_DISP = THETA\_OMS\_I /  
RAD\_PER\_DEG:

Target earth central angle from the launch site that is biased to account for noncentral body forces from planned engine ignition to the target position.

C1\_DISP = C1\_OMS\_I:

Intercept of the vertical velocity versus the horizontal velocity target line that is biased to account for noncentral body forces from planned engine ignition to target position.

C2\_DISP = C2\_OMS\_I:

Slope of the vertical velocity versus horizontal velocity target line.

TIG = T\_ET\_SEP + DTIG\_OMS\_I:

Time of ignition. (The variable T\_ET\_SEP is the actual GMT time of external tank separation and DTIG\_OMS\_I is the delta time of ignition from this reference time.)

- The unit vector normal to the desired orbital plane ( $\bar{IYD}$ ) is selected from I-load vectors which are functions of the OMS maneuver. If the major mode is 104 and I (Item 3) is equal to 1 or the major mode is 105 and I is equal to 2, then

$$\bar{IYD} = IYD\_OMS(3 \ I-2)$$

- For MM 104 (MM104 = ON), if either S\_ATO = ON or S\_AOA = ON, then initial orbiter mass is equivalenced to the orbiter mass prior to the OMS-1 burn computed by the AOA/ATO TGT principal function. If an AOA or ATO condition does not exist, the initial orbiter mass (M) is an I-load (MASS\_ORB):

If S\_ATO = OFF and S\_AOA = OFF, then M = MASS\_ORB.

For MM 105 (MM105 = ON), the current vehicle mass (M), as computed by ORB INS GUID at the end of the OMS-1 maneuver, is used.

The selected orbiter mass estimated must then be converted to a weight for display:

$$WT\_DISP = M G\_2\_FPS2$$

The variable G\_2\_FPS2 is a constant to transform mass to weight.

6. For MM's 104 and 105, the desired minimum burnout mass (MBO), to be used by PEG (Section 4.8.1) to limit the out-of-plane component of the velocity-to-be-gained vector, must be selected. If either S\_AOA = ON or S\_ATO = ON, then there is to be no out-of-plane thrusting and MBO is set equal to M. Otherwise MBO is set to an I-load MBO\_MIN which is a function of the OMS maneuver.

If S\_AOA = ON or S\_ATO = ON, then MBO = M; otherwise MBO = MBO\_MIN\_I.

7. If the major mode is 104 and an uplink has occurred or the major mode is 105, then the target set is not accepted by guidance until positive action is taken by the crew. This function is accomplished by setting the LOAD\_FLASH discrete (see Section 4.7.4) to ON.

If the major mode is 104 (MM104 = ON) and a TAL abort has not been declared (TAL\_ABORT\_DECLARED=OFF), then the LOAD\_CMD discrete must be set to ON to initiate the processing contained in the PRE-MAN DISP SUPT TSK (Section 4.7.4).

8. The TIG value calculated in Item 3 must be converted to the proper display units (DAYS, HRS, MIN, SEC) in mission elapsed time for display.

$$TIG = TIG - T\_GMTLO$$

$$TIG\_DAY = TRUNCATE(TIG/86400)$$

$$TIG = MOD(TIG, 86400)$$

$$TIG\_HR = TRUNCATE(TIG/3600)$$

$$TIG\_MIN = TRUNCATE((TIG - 3600 TIG\_HR)/60)$$

$$TIG\_SEC = TIG - 3600 TIG\_HR - 60 TIG\_MIN$$

9. If the maneuver is an AOA OMS-2 burn, and the AOA OMS-2 targeting data ready flag (S\_AOA\_OMS2) is ON, then the display targeting parameters HTGT\_DISP, THETA\_DISP, C1\_DISP, C2\_DISP, TIG\_DAY, TIG\_HR, TIG\_MIN, TIG\_SEC, and WT\_DISP are loaded into protective storage for the OPS-3 maneuver display and the AOA OMS-2 targeting complete flag (S\_OPS3\_TGT\_RDY) is set to ON.

10. For MM 106, all parameters are assumed to retain the value they had in MM 105. The following parameters must be blanked upon entry into MM 106:
- a. DV\_TOT            Magnitude of velocity-to-go
  - b.  $\bar{VGO\_DISP}$        Velocity-to-go in current body coordinates
  - c. TGT\_HA           Target apogee altitude
  - d. TGT\_HP           Target perigee altitude
  - e. TGO               Time-to-go
  - f. VEH\_PITCH        Vehicle pitch angle
  - g. VEH\_YAW          Vehicle yaw angle
  - h. VEH\_ROLL         Vehicle roll angle
  - i.  $\bar{VGO\_LVLH}$        Velocity-to-go in LVLH coordinates
11. An uplinked target set must be identified as to guidance type (linear terminal velocity constraint or external delta-V). If the OPS code contained in the uplink word is 0101101, then linear terminal velocity constraint guidance is assumed and PEG\_MODE\_4 = ON.
12. Set guidance targeting update discrete (TBD) OFF.

B. Interface Requirements. The input and output parameters for the display initialization task are given in Tables 4.7.3-1 and 4.7.3-2.

During OPS-1 and OPS-9 the following I-load parameters can be updated via uplink as part of the OMS targeting data set (OP CODE 0011001) TVR\_ROLL HTGT\_OMS<sub>1</sub>, IYD\_OMS<sub>1-3</sub>, THETA\_OMS<sub>1</sub>, DTIG\_OMS<sub>1</sub>, C1\_OMS<sub>1</sub>, C2\_OMS<sub>1</sub>, HTGT\_OMS<sub>2</sub>, IYD\_OMS<sub>4-6</sub>, THETA\_OMS<sub>2</sub>, DTIG\_OMS<sub>2</sub>, C1\_OMS<sub>2</sub>, and C2\_OMS<sub>2</sub>. Replacement of the original I-load data with uplinked data will be transparent to the flight software.

C. Processing Requirements. The display initialization task is performed once upon entry into MM's 104, 105, or 106 and once after execution of the AOA/ATO TGT principal function for an abort selection via the abort rotary switch or crew item entry of the target index flag (ABORT\_INIT = ON), occurring subsequent to entry into MM's 104 or 105 but prior to setting the burn enable discrete. This task is also performed after an uplink of guidance targets (TBD criteria).

D. Initialization Requirements. PEG\_MODE\_4 = ON.

E. Supplemental Information. None.

Table 4.7.3-1. Display Initialization Task Inputs

Definition	Symbol	Source	Precision	Units
Discrete indicating AOA abort commanded	S_Δ <sub>AOA</sub>	MSC	D	N/A
Discrete indicating ATO abort commanded	S_Δ <sub>ATO</sub>	MSC	D	N/A
Major mode indicators	MM104, MM105, MM106	MSC	D	N/A
Target altitude magnitude (I=1-3)	HTGT_OMS <sub>I</sub>	I-LOAD, AOA ONORB TGT SEL TSK, ATO ONORB TGT SEL TSK	SP	ft
Target earth central angle from the launch site (I=1-3)	THETA_OMS <sub>I</sub>	I-LOAD, AOA ONORB TGT SEL TSK, ATO ONORB TGT SEL TSK	SP	rad
Intercept of target line (I=1-3)	C1_OMS <sub>I</sub>	I-LOAD, AOA ONORB TGT SEL TSK, ATO ONORB TGT SEL TSK	SP	fps
Slope of target line (I=1-3)	C2_OMS <sub>I</sub>	I-LOAD, AOA ONORB TGT SEL TSK, ATO ONORB TGT SEL TSK	SP	ND
Actual GMT time of external tank separation	T_ET_SEP	MSC	DP	sec
Time interval between time of actual external tank separation and OMS-1 or OMS-2 ignition (I=1-3)	DTIG_OMS <sub>I</sub>	I-LOAD, AOA ONORB TGT SEL TSK, ATO ONORB TGT SEL TSK	SP	sec
Current vehicle mass	M	AOA ONORB TGT SEL TSK, ATO ONORB TGT SEL TSK, ACC-MASS UPD TSK	SP	slugs
Initial orbiter-alone mass	MASS_ORB	I-LOAD	SP	slugs
Conversion factor for feet to nautical miles	NM_PER_FT	CONSTANT	SP	nmi/ft
Conversion factor for degrees to radians	RAD_PER_DEG	CONSTANT	SP	rad/deg
GMT time of lift-off	T_GMTLO	FCOS	DP	sec
Conversion factor for slugs to pounds	G_2_FPS2	CONSTANT	SP	lb/slug



Table 4.7.3-1. Display Initialization Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
AOA OMS-2 targeting data read flag	$S_{\dot{A}OA\_OMS2}$	AOA/ATO TGT	D	N/A
Discrete indicating a guidance target update via uplink	TBD	INS TGT UL TSK	D	N/A
Unit vector normal to desired orbital plane (I=1,6)	$\bar{I}YD\_OMS_I$	I-LOAD	DP	ND
Desired minimum burnout mass (I=1,2)	MBO_MIN <sub>I</sub>	I-LOAD	SP	slugs
Abort initialization flag	ABORT_INIT	AOA ONORB TGT SEL TSK, ATO ONORB TGT SEL TSK	D	N/A
Discrete indicating a TAL abort is in progress	TAL_ABORT_ DECLARED	MSC	D	N/A

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Table 4.7.3-2. Display Initialization Task Outputs

Definition	Symbol	Destination	Precision	Units
Initial value of orbiter weight	WT_DISP	MNVR DISP,* ORB/RND NAV SEQ	SP	lb
Display title indicator	MNVR_TITLE_IND	MNVR DISP	I	N/A
Target altitude magnitude above a spherical earth <sup>1</sup>	HTGT_DISP	MNVR DISP,* TLM	SP	deg
Target earth central angle from the launch site <sup>1</sup>	THETA_DISP	MNVR DISP,* TLM	SP	deg
Intercept of vertical velocity versus horizontal target line <sup>1</sup>	C1_DISP	MNVR DISP,* TLM	SP	fps
Slope of vertical velocity versus horizontal target line	C2_DISP	MNVR DISP,* TLM	SP	ND
AOA OMS-2 targeting complete flag	S_OPS3_TGT_RDY	MNVR DISP	D	N/A
Time of ignition	TIG_DAY, TIG_HR, TIG_MIN, TIG_SEC	MNVR DISP*	SP	day hr, min, sec
Unit vector normal to desired plane in earth-fixed system	IYD	PEG TSK	DP	ND
Desired minimum burnout mass	MBO	PEG TSK	SP	slugs
Guidance mode discrete	PEG_MODE_4	MNVR DISP, PRE-MAN DISP SUPT TSK, VGO DISP TSK	D	N/A
Abort initialization flag	ABORT_INIT	AOA ONORB TGT SEL TSK, ATO ONORB TGT SEL TSK	D	N/A
Load Command	LOAD_CMD	DISP MONIT TSK, MNVR DISP	D	N/A
Load flash flag	LOAD_FLASH	DISP MONIT TSK	D	N/A

<sup>1</sup>Biased for noncentral body forces from the time of planned ignition to the time of achieving the target position.

\*Sent to protective storage in AOA OMS-2 for transfer to OPS-3.





#### 4.7.4 Display Monitoring Task (DISP MONIT TSK)

This task performs a series of monitoring activities for the MNVR DISP described as follows:

1. Monitors for a "LOAD" item entry and initiates the required processing upon receipt of this entry.
2. Provides visual cues (display character flash indicators) to the crew if the displayed and software-loaded data are inconsistent or if an "EXEC" keyboard entry is required to enable ignition.
3. Sets an OMS engine ignition proceed discrete to ON if the following conditions are satisfied:
  - a. An "EXEC" keyboard entry has been made subsequent to the planned time of engine ignition minus 15 seconds.
  - b. The displayed target and setup data are consistent with the software-loaded target and setup data, signified by LOAD\_FLASH = OFF.
4. Monitors for a START CRT TIMER item entry and initiates the required processing upon receipt of this entry.

A. Detailed Requirements. The display monitoring task performs the following activities each time it is called:

1. If LOAD\_CMD = ON, then the following activities are performed once:
  - a. The premaneuver display support task (PRE-MAN DISP SUPT TSK, Section 4.7.7) is performed.

CALL PRE-MAN DISP SUPT TSK
  - b. The LOAD\_FLASH discrete is set to OFF.
  - c. The LOAD\_CMD discrete is set to OFF to preclude the above activities from being performed except as required upon keyboard entry.
  - d. The DATA\_ENTER discrete is set to OFF.
2. The following monitoring activities must be performed. To ensure a consistent set of target and setup data and consistency between displayed and software-recognized target and setup data, OMS engine ignition is precluded (BURN\_ENABLE is not set to ON) and the "LOAD" becomes a flashing character set (LOAD\_FLASH = ON) for the following condition: Any of the display item entries identified as target and setup data are changed (DATA\_ENTER = ON) and a subsequent "LOAD" item



entry is not made. The target and setup data group consists of all numbered entries on the MNVR DISP (Figure 4.7-1) except the following:

- a. OMS gimbal drive selection and check (Items 28, 29, 30, 31, 32, 33, and 34)
- b. Burn attitude and maneuver to burn attitude (Items 24, 25, 26, and 27)
- c. Surf drive (Items 39 and 40)
- d. Forward RCS dump (Items 36, 37, and 38)
- e. LOAD (Item 22)
- f. Start CRT timer (Item 23)

If DATA ENTER is set to ON (indicating an entry), the LOAD FLASH discrete must be set to ON. The LOAD FLASH = ON condition indicates that "LOAD" is to become a dynamic flashing character set and precludes setting the burn enable discrete to ON to allow OMS ignition.

3. If LOAD FLASH = ON (indicating "LOAD" is a dynamic flashing character set), the discrete for FCOS to display time to ignition on the CRT (CRT\_TIMER\_START) must be set to OFF.
4. Positive crew action (pushing the keyboard EXEC button, which sets EXEC\_CMD to ON, subsequent to planned OMS ignition time minus 15 seconds, that is, when  $T_{GMT} - TIG \geq BURN\_ENABLE\_WINDOW$ ) is required to enable OMS engine ignition ( $BURN\_ENABLE = ON$ ). Until the EXEC button is pushed, the EXEC character set is flashing ( $TIG\_MINUS5\_FLAG = ON$ ). An additional requirement for enabling engine ignition is  $LOAD\_FLASH = OFF$ . These requirements are depicted in the following logic:
  - a. If  $TB\_TIME \geq -BURN\_ENABLE\_WINDOW$  and the  $LOAD\_FLASH$  flag is OFF (indicating a consistent target and setup data group), then proceed to step b. Otherwise the  $EXEC\_CMD$  and  $TIG\_MINUS5\_FLAG$  must be set to OFF to nullify any previous crew action for enabling OMS ignition and stop the EXEC dynamic characters from flashing, respectively, and proceed to Item 5.
  - b. If the  $EXEC\_CMD$  flag is ON (indicating crew authorization of OMS ignition), then set the  $BURN\_ENABLE$  flag to ON (necessary condition for the MSC to allow OMS ignition) and set the  $TIG\_MINUS5\_FLAG$  to OFF (stop the EXEC dynamic characters from flashing). Otherwise the  $TIG\_MINUS5\_FLAG$  must be set to ON (initiate the EXEC dynamic characters flash).

- c. The flags EXEC\_CMD and BURN\_ENABLE should be reset to OFF anytime the OMS firing sequencer is called to initiate OMS ignition. This will allow proper sequencing if OMS ignition does not occur and the ignition task is reattempted.
5. If the ST\_CRT\_TIMER = ON, the following activities are performed once:
- a. Calculate the delta time to ignition in seconds to establish a display time base:

$$\text{CRT\_SEC} = \text{TIG-T\_GMT}$$

- b. If CRT\_SEC is positive, set the discrete indicating that FCOS should decrement CRT time:

$$\text{COUNTDOWN} = \text{ON}$$

- c. If CRT\_SEC is not positive, set the discrete such that FCOS increments CRT time and set CRT\_SEC positive:

$$\text{COUNTDOWN} = \text{OFF}$$

$$\text{CRT\_SEC} = -\text{CRT\_SEC}$$

- d. Set the discrettes for FCOS to display the time relative to ignition:

$$\text{CRT\_TIMER\_START} = \text{ON}$$

- e. Reset the start CRT timer discrete to allow reinitiation of this activity:

$$\text{ST\_CRT\_TIMER} = \text{OFF}$$

B. Interface Requirements. The input and output parameters for the display monitoring task are presented in Tables 4.7.4-1 and 4.7.4-2.

C. Processing Requirements. The display monitoring task is performed every 0.96 second. The beginning conditions for cyclic processing are defined in Step 3 of sequencing (Section 4.7.2).

D. Initialization Requirements. Initialization is performed on the first pass each time cyclic processing begins.

For each beginning, the following initiation occurs:

DATA\_ENTER = OFF

Discrete to indicate that a target or setup data value has been crew-entered is initially set to indicate no crew entry.



BURN\_ENABLE = OFF

Discrete to allow OMS engine ignition is initially set to disallow OMS engine ignition.

TIG\_MINUSS\_FLAG = OFF

Discrete to indicate that the EXEC character set is to be flashed to prompt crew for an engine ignition proceed is initially set to a nonflash condition.



Table 4.7.4-1. Display Monitoring Task Inputs

Definition	Symbol	Source	Precision	Units
Discrete indicating target or setup data entries have been made	DATA_ENTER	MNVR DISP	D	N/A
Load command	LOAD_CMD	MNVR DISP, DISP INIT TSK	D	N/A
Current GMT computer time	T_GMT	FCOS	DP	sec
Start CRT timer flag	ST_CRT_TIMER	MNVR DISP	D	N/A
Time of ignition	TIG	PRE-MAN DISP SUPT TSK	DP	sec
Time base time (TB1 or TB2)	TB_TIME	MSC	DP	sec
Burn execute command	EXEC_CMD	UI	D	N/A
Load flash flag	LOAD_FLASH	DISP INIT TSK	D	N/A
Burn enable window	BURN_ENABLE_WINDOW	K-LOAD	SP	sec



Table 4.7.4-2. Display Monitoring Task Outputs

Definition	Symbol	Destination	Precision	Units
Load flash flag	LOAD_FLASH	MNVR DISP, TLM	D	N/A
Seconds to ignition	CRT_SEC	FCOS	DP	sec
CRT timer start flag	CRT_TIMER_START	FCOS	D	N/A
CRT timer flag to indicate countdown mode is desired	COUNTDOWN	FCOS	D	N/A
Discrete indicating target or setup data entries have been made	DATA_ENTER	TLM, MNVR DISP	D	N/A
Engine ignition minus (15) second flag	TIG_MINUS5_FLAG	MNVR DISP	D	N/A
Burn enable	BURN_ENABLE	MSC, TLM	D	N/A
Burn execute command	EXEC_CMD	VI	D	N/A
Start CRT timer flag	ST_CRT_TIMER	MNVR DISP	D	N/A

#### 4.7.5 Current Orbit Task (CUR ORBIT TSK)

The current orbit task cyclically computes the current orbit apogee and perigee altitudes and the time to next apsis (apogee or perigee).

A. Detailed Requirements. The value of current apogee and perigee altitude and time to next apsis (measured from current time) is calculated by calling the orbital altitude time task (ORB ALT TIME TSK, Subsection 4.7.8). Inputs to this task are the current navigation state ( $\bar{R}_{NAV}$  and  $\bar{V}_{NAV}$ ) which must be assigned to  $\bar{R}$  and  $\bar{V}$  respectively.

CALL ORB ALT TIME TSK

Outputs are the apogee altitude (HA), perigee altitude (HP), time to next apsis (TT\_X), and an indicator for next apsis point and label field (TXX\_FLAG). These outputs (HA, HP, and TXX\_FLAG) must be assigned to CUR\_HA, CUR\_HP, and TXX\_FLAG\_DISP, respectively.

The MNVR DISP background field corresponding to the TXX\_FLAG\_DISP value is defined below.

TXX_FLAG_DISP	Label Field Displayed	Next Apsis
1	TTA	Apogee
2	TTP	Perigee
3	TTC	Near Circular

B. Interface Requirements. The input and output parameters for the current orbit task are given in Tables 4.7.5-1 and 4.7.5-2.

C. Processing Requirements. The current orbit task is performed repetitively during MM's 104, 105, and 106.

D. Initialization Requirements. None.

Table 4.7.5-1. Current Orbit Task Inputs

Definition	Symbol	Source	Precision	Units
Apogee altitude	HA	ORB ALT TIME TSK	SP	nmi
Perigee altitude	HP	ORB ALT TIME TSK	SP	nmi
Indicator for next apsis point and label field (= 1, TTA (apogee); = 2, TTP (perigee); = 3, TTC (circular))	TXX_FLAG	ORB ALT TIME TSK	I	N/A
Time to next apsis (apogee or perigee)	TT_X	ORB ALT TIME TSK	SP	sec
Current Shuttle position vector	R_NAV	ASCENT UPP	DP	ft
Current Shuttle velocity vector	V_NAV	ASCENT UPP	SP	fps



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Table 4.7.5-2. Current Orbit Task Outputs

Definition	Symbol	Destination	Precision	Units
Position vector	$\bar{R}$	ORB ALT TIME TSK	DP	ft
Velocity vector	$\bar{V}$	ORB ALT TIME TSK	SP	fps
Current apogee altitude	CUR_HA	MNVR DISP	SP	nmi
Current perigee altitude	CUR_HP	MNVR DISP	SP	nmi
Indicator for next apsis point and label field (= 1, TTA (apogee); = 2, TTP (perigee); = 3, TTC (circular))	TXX_FLAG_DISP	MNVR DISP	I	N/A
Time to next apsis (apogee or perigee)	TT_X	MNVR DISP	SP	sec



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#### 4.7.6 Velocity-To-Go Display Task (VGO DISP TSK)

This task transforms the velocity-to-go vector from mean-of-1950 coordinates into current LVLH coordinates, if guidance mode is PEG 4 and if current time is greater than time of ignition, and into current orbiter body axis coordinates (Section 5.1, Figures 5.1-1 and 5.1-4) and computes the magnitude of the current velocity-to-go (DV\_TOT) and orbiter weight (WT\_DISP).

##### A. Detailed Requirements.

1. The guidance computed velocity-to-go in mean-of-1950 coordinates ( $\vec{VGO}$ ) is transformed to velocity-to-go in current body axis coordinates ( $\vec{VGO\_DISP}$ ) for display. This transformation is accomplished by the use of a quaternion transformation module (QUAT\_XFORM), which is defined in the Control Level C FSSR document, and repeated (for information only) in Part E of Section 4.7.7:

CALL QUAT\_XFORM

Inputs:  $Q\_B\_I\_S$ ,  $Q\_B\_I\_V$ ,  $\vec{VGO}$

Outputs:  $\vec{VGO\_DISP}$

The variables  $Q\_B\_I\_S$  and  $Q\_B\_I\_V$  are the scalar and vector quaternion elements defining the transformation from mean-of-1950 coordinates to current body axis coordinates as computed by the A.E ATT PROC principal function.

2. The current magnitude of velocity-to-go is calculated.

$DV\_TOT = ABVAL(\vec{VGO})$

3. The current orbiter estimated mass is converted to weight for display:

$WT\_DISP = M\_G\_2\_FPS2$

4. The PEG guidance computed velocity-to-go in mean-of-1950 coordinates ( $\vec{VGO}$ ) is transformed to current LVLH coordinates ( $\vec{VGO\_LVLH}$ ) for display. This transformation is accomplished by the use of a quaternion transformation module (QUAT\_XFORM). The LVLH to mean-of-1950 quaternion from the A.E ATT PROC principal function is conjugated prior to calling QUAT\_XFORM. The velocity-to-go in LVLH ( $\vec{VGO\_LVLH}$ ) is displayed in the PEG 7 target section of the maneuver execute display. For a PEG 4 target load,  $\vec{VGO\_LVLH}$  is computed by the premaneuver display support task with respect to an LVLH coordinate system at the planned time of ignition (TIG). After the planned TIG,  $\vec{VGO\_LVLH}$  is computed for display with respect to the current LVLH coordinate system.



If the guidance mode is PEG 4 and current time is greater than or equal to TIG.

Call QUAT\_XFORM

Inputs:  $\bar{Q}_{M50\_LVLH\_S}$ ,  $Q_{M50\_LVLH\_V}$ ,  
 $\bar{VGO}$

Output:  $\bar{VGO\_LVLH}$

B. Interface Requirements. The input and output parameters for the velocity-to-go display task are given in Tables 4.7.6-1 and 4.7.6-2.

C. Processing Requirements. The velocity-to-go display task is performed at 1.04 Hz only in MM's 104 and 105 when the "LOAD" flash flag is reset (OFF). Steps 2 and 3 are performed on alternate passes of the VGO DISP TSK.

D. Initialization Requirements. None.



Table 4.7.6-1. Velocity-To-Go Display Task Inputs

Definition	Symbol	Source	Precision	Units
Quaternion to transform from mean-of-1950 coordinates to current vehicle body axis coordinates	Q_B_I_S, Q_B_I_V	A/E ATT PROC	SP	ND
Velocity-to-be gained vector in mean 1950 coordinates	VGO	PEG TSK	SP	fps
Current vehicle mass	M	ACC-MASS UPD TSK	SP	slugs
Quaternion to transform from LVLH coordinates to mean 1950 coordinates	Q_M50_LVLH_S Q_M50_LVLH_V	A/E ATT PROC	SP	ND
Guidance mode discrete	PEG_MODE_4	DISP INIT TSK, MNVR DISP	ND	None
Time of ignition	TIG	PRE-MAN DISP SUPT TSK	DP	sec
Conversion factor for slugs to pounds	G_2_FPS2	CONSTANT	SP	lb/slug
Current GMT computer time	T_GMT	FCOS	DP	sec

Table 4.7.6-2. Velocity-To-Go Display Task Outputs

Definition	Symbol	Destination	Precision	Units
Maneuver velocity to be gained in current body axis coordinates	$\bar{VGO\_DISP}$	MNVR DISP	SP	fps
Total delta velocity required for the maneuver	DV_TOT	MNVR DISP	SP	fps
Velocity-to-be-gained vector in mean of 1950 coordinates	$\bar{VGO}$	TLM	SP	fps
Orbiter weight	WT_DISP	MNVR DISP	SP	lb
PEG 4 velocity to be gained in LVLH coordinates	$\bar{VGO\_LVLH}$	MNVR DISP	SP	fps

Units  
ND  
fps  
slugs  
ND  
None  
sec  
lb/slug  
sec

#### 4.7.7 Premaneuver Display Support Task (PRE-MAN DISP SUPT TSK)

This task provides software that computes parameters required for premaneuver evaluation of the maneuver setup and target information. In addition, the current display values for the target and setup data are transferred to orbit insertion guidance and other software functions by this task.

A. Detailed Requirements. The premaneuver display support task performs the following activities each time it is called:

1. The currently displayed value of mission elapsed time (MET) of ignition in days, hours, minutes, and seconds must be transformed to a GMT time in seconds.

$$\text{TIG} = \text{TIG\_SEC} + \text{TIG\_MIN} \ 60 + \text{TIG\_HR} \ 3600 \\ + \text{TIG\_DAY} \ 86400 + \text{T\_GMTLO}$$

Limit the evaluation of OMS burns to 12 hours in the future and 5 minutes in the past.

If  $-300 > (\text{TIG} - \text{T\_GMT})$  or  $(\text{TIG} - \text{T\_GMT}) > 43200$ , write "illegal entry" on the maneuver execute CRT display message line and return control to the display monitoring task.

2. A switch (TB\_ENABLE) is set indicating to the MSC that a new time base should be established consistent with the current value of TIG and maintained.

$$\text{TB\_ENABLE} = \text{ON}$$

3. Before the display parameters required to evaluate a maneuver can be computed, a state vector at ignition must be obtained. This is accomplished by utilizing a navigation precision state predictor principal function (ASC PREC PRED), which propagates the current state (R\_NAV, V\_NAV, T\_NAV) to the time of ignition (TIG) and outputs the propagated ignition state (R\_GD, V\_GD). Other inputs required by the ASC PREC PRED principal function are the maximum time interval step size (DT\_MAX = DTMIN) and integers (GMD\_PRED, GMO\_PRED) that determine the gravity degree (4) and order (4) models to be assumed:

CALL ASC PREC PRED

Inputs: R\_NAV, V\_NAV, T\_NAV, TIG, DT\_MAX, GMD\_PRED, GMO\_PRED

Outputs: R\_GD, V\_GD



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4. The guidance mode flag value is determined by testing the current value of the guidance mode discrete (PEG\_MODE\_4). If PEG\_MODE\_4 = ON, then linear terminal velocity constraint guidance is assumed. Otherwise external delta-V guidance is assumed.

If PEG\_MODE\_4 = ON, then SMODE = 4; otherwise, SMODE = 7.

If external delta-V guidance is desired (SMODE = 7), then the velocity targets are transformed to M50 inertial coordinates from the ignition state local vertical, local horizontal (LVLH) coordinates for input to orbit insertion guidance. Software modules documented in the Flight Control Level C FSSR are used to perform this transformation. The RV\_TO\_QLVLH module accepts an input state (ignition position and velocity in this case) and outputs the scalar and vector components of the quaternion to transform from the ignition state local vertical, local horizontal coordinate system to the mean of 1950 coordinate system (Q\_I\_LVLH\_S and Q\_I\_LVLH\_V). This quaternion is an input to the QUAT\_XFORM module, which transforms the input EXT\_DV\_LVLH vector to the VGO vector in M50 coordinates required for orbit insertion guidance. A description of the RV\_TO\_QLVLH and QUAT\_XFORM modules is presented, for information only, in Part E of this task.

CALL RV\_TO\_QLVLH

Inputs: RGD, VGD

Outputs: Q\_I\_LVLH\_S, Q\_I\_LVLH\_V

CALL QUAT\_XFORM

Inputs: Q\_I\_LVLH\_S, Q\_I\_LVLH\_V, EXT\_DV\_LVLH

Outputs: VGO

If linear terminal velocity constraint guidance is assumed (SMODE = 4), then the orbit insertion guidance targets are set equal to the currently displayed values, and the target values of altitude (HTGT\_DISP) and in-plane angle (THETA\_DISP) from the launch site position to target position are transformed into an inertial position target vector (RT) in the M50 coordinate system.

- |  |   |
|--|---|
| a. THETA = THETA_DISP RAD_PER_DEG        | Target earth central angle from the launch site                           |
| b. HTGT = HTGT_DISP NM_PER_FT            | Target altitude magnitude   |
| c. C <sub>1</sub> = C <sub>1</sub> _DISP | Intercept of the vertical velocity versus horizontal velocity target line |



d.  $C_2 = C2\_DISP$

Slope of the vertical  
velocity versus horizontal  
velocity target line

The altitude and the downrange angle are transformed to the mean-of-1950 position vector ( $\bar{RT}$ ) by calling the H- $\theta$ -M50 TGT TSK (Section 4.8.6).

CALL H- $\theta$ -M50 TGT TSK

5. Current orbiter weight is transformed to mass for input to orbit insertion guidance.

$M = WT\_DISP/G\_2\_FPS2$

6. The orbit insertion guidance principal function requires an input of the number of assumed OMS (SOMS) and RCS (SRCS) engines to form an assumed acceleration quantity. In addition, the OMS FIRE SEQ, MSC, MNVR DISP, and TRANS DAP require a prime propulsion system indicator (PROP\_FLAG\_OFS). Based on the discrete settings input from the maneuver execute display, these quantities are set as follows:

If BOTH\_OMS = ON, then

SOMS = 2

SRCS = 0

PROP\_FLAG\_OFS = 1

If LEFT\_OMS = ON, then

SOMS = 1

SRCS = 0

PROP\_FLAG\_OFS = 2

If RIGHT\_OMS = ON, then

SOMS = 1

SRCS = 0

PROP\_FLAG\_OFS = 3

If PLUS\_X\_RCS = ON, then

SOMS = 0

SRCS = 4

PROP\_FLAG\_OFS = 4





For each of the above conditions, the previous value of the prime propulsion system indicator must be set equal to zero:

PROP\_FLAG\_OFS\_P = 0

In addition to the display input discrete settings, the AOA/ATO targeting principal function may specify a parallel OMS and RCS burn for the OMS-1 insertion maneuver. If a parallel burn is specified by AOA/ATO targeting, the RCS burn duration parameter (TB\_RCS) will have a non-zero value and if MM104 is also set to ON, the following activities must be performed.

- a. N = 2 Set the number of orbit insertion guidance thrust phases equal to 2.
- b. SRCS = 4 Set the number of assumed RCS engines to 4.
- c. T\_RCS\_OFF = TIG+TB\_RCS Calculate the RCS engine cutoff time.

If TB\_RCS is not greater than zero or MM105 = ON, then the number of guidance thrust phases is set equal to one (N=1).

7. The current guidance target values are evaluated by calculating for display the velocity-to-go ( $\bar{VGO}$ ) and time-to-go (TGO) resulting from these target values. The powered explicit guidance task (Subsection 4.8.1) is called iteratively until convergence is obtained ( $S_{CONV} = ON$ ) and the steering parameters are ready ( $S_{GDRDY} = ON$ ) or the maximum number of calls ( $N_{MAX\_DIP}$ ) is exceeded to calculate these parameters. If the maximum number of calls is exceeded without convergence being obtained, the premaneuver display support task is exited. Additional outputs from the powered explicit guidance task are the desired thrust orientation parameters (LAMC, LAMDC, TLAMC) required to calculate the desired ignition attitude and the desired burnout state ( $\bar{VD}$ ,  $\bar{RD}$ ) for calculating target apsis values. Before the powered explicit guidance task is called, the discrete to initiate PEG initialization (SIINIT) must be set to ON, and the thrust parameter task (THRST PRM TSK, Subsection 4.8.7) must be called to form the thrust and exhaust velocity parameters required by the powered explicit guidance task. Inputs to the THRST PRM TSK are the number of OMS ( $N_{OMS} = SOMS$ ), number of translational RCS ( $N_{RCS} = SRCS$ ), number of null RCS ( $N_{RCS\_NULL} = 0$ ), and number of main engines ( $N_{SSME} = 0$ ).

CALL THRST PRM TSK

Inputs to the powered explicit guidance task from the AS MNVR DIP principal function are:

- a. Ignition state values ( $\bar{RGD}$ ,  $\bar{VGD}$ ,  $TGD = TIG$ )



- b. Linear terminal velocity constraint guidance targets ( $\bar{R}_T$ ,  $C_1$ , and  $C_2$ ) or external delta-V guidance targets (VGO)
- c. Estimated initial acceleration (ATR = FT/M)
- d. PEG initialization discrete (SINIT = ON)
- e. Guidance mode flag (SMODE)
- f. Cutoff time for RCS engines (OMS/RCS parallel burn) (T\_RCS\_OFF)
- g. Number of guidance thrust phases (N)
- h. Number of OMS (N\_OMS)
- i. Integration step size (DT\_LIMIT = DTMIN)
- j. Guidance ready flag (S\_GDRDY = OFF)
- k. Steering flag (S\_STEER = ON)

CALL PEG TSK

Outputs from powered explicit guidance task to be used by the AS MNVR DIP principal function are:

- a. Velocity-to-go ( $\bar{V}_GO$ ) and time-to-go (TGO)
  - b. Commanded reference thrust orientation parameters (LAMC, LAMDC, TLAMC)
  - c. Desired burnout state ( $\bar{R}_D$ ,  $\bar{V}_D$ ) (linear terminal velocity constraint guidance only)
  - d. Initial and final offset coasting trajectory states from the PEG gravity computations ( $R_{INIT}$ ,  $V_{INIT}$ ,  $R_{FINAL}$ ,  $V_{FINAL}$ ) (linear terminal velocity constraint guidance only)
8. If guidance mode is PEG 4, compute the PEG 4 velocity-to-be gained in LVLH coordinates at TIG using the guidance state vector at TIG determined in step 3.

Call RV\_TO\_QLVLH

Inputs:  $\bar{R}_D$ ,  $\bar{V}_D$

Outputs:  $Q_I_{LVLH_S}$ ,  $Q_I_{LVLH_V}$



Call QUAT\_XFORM

Inputs: -  $Q_I\_LVLH\_S$ ,  $Q_I\_LVLH\_V$ ,  $VGO$

Outputs:  $VGO\_LVLH$

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9. The desired vehicle attitude at ignition (pitch, yaw, and roll gimbal angles based upon the current ADI inertial attitude reference) is calculated for display as follows.
  - a. Set time to compute commanded body attitude ( $T\_CA = TIG$ )
  - b. Perform the commanded body attitude task (Section 4.8.10)
10. Calculation of target apogee and perigee altitudes (Item 11) requires a predicted burnout state. For linear terminal velocity constraint guidance ( $S\_MODE = 4$ ), the predicted burnout state must be corrected as in a. below. For external delta-V guidance ( $S\_MODE = 7$ ), the burnout state must be calculated as in b. below.
  - a. The desired burnout state ( $R\bar{D}$ ,  $V\bar{D}$ ) obtained from PEG (see Item 7) does not contain J2 gravity acceleration during the powered flight. To compensate for this acceleration, the ASC PREC PRED principal function is used to propagate the initial state obtained from PEG through the time interval TGO with the J2 forces modeled ( $GMO\_PRED = 0$ ,  $GMD\_PRED = 2$ ).

$DT\_MAX = DTMIN$

CALL ASC PREC PRED

Inputs:  $R\_INIT$ ,  $V\_INIT$ , TIG, TIG + TGO, DT\_MAX,

GMD\_PRED, GMO\_PRED

Outputs:  $RC3$ ,  $VC3$

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To obtain the delta position and velocity ( $R\bar{J}2$ ,  $V\bar{J}2$ ), the output state containing the J2 gravity effects ( $RC3$ ,  $VC3$ ) is differenced with the PEG-derived state with only central body gravity forces ( $R\_FINAL$ ,  $V\_FINAL$ ):

$$V\bar{J}2 = VC3 - V\_FINAL$$

$$R\bar{J}2 = RC3 - R\_FINAL$$

The desired burnout state is then corrected as follows:

$$R\bar{D} = R\bar{D} + R\bar{J}2$$

$$V\bar{D} = V\bar{D} + V\bar{J}2$$



- b. The desired guidance cutoff orbit is computed by defining an initial coasting trajectory ( $\bar{V}_D$ ,  $\bar{R}_D$ ) that when coasted through the burn time will approximate the powered-flight burnout trajectory (SMODE = 7).

$$\bar{V}_D = \bar{V}_{GD} + \bar{V}_{GO}$$

$$\bar{R}_D = \bar{R}_{GD} - 0.5 T_{GO} \bar{V}_{GO}$$

where:

$\bar{R}_{GD}$  is the predicted position vector at TIG

$\bar{V}_{GD}$  is the predicted velocity vector at TIG

$\bar{V}_{GO}$  is the external delta-V guidance velocity vector

11. The target apogee (TGT\_HA) and perigee (TGT\_HP) altitudes are next computed for display with use of the orbital altitude time task (ORB ALT TIME TSK, Subsection 4.7.8).

The orbital altitude time task is called with the state computed in Item 10 ( $\bar{V}_D$ ,  $\bar{R}_D$ ) input as  $\bar{V}$  and  $\bar{R}$ , respectively, and outputs the resulting apogee altitude (HA) and perigee altitude (HP), which are then assigned to the target apogee altitude (TGT\_HA) and target perigee altitude (TGT\_HP).

CALL ORB ALT TIME TSK

12. If current time ( $T_{NAV}$ ) exceeds the time of ignition (TIG), a state associated with  $T_{NAV}$  must be computed to reinitialize the state (central-body) maintained by orbit insertion guidance after TIG. This is accomplished by utilizing the navigation principal function ASC PREC PRED, which propagates the ignition state ( $\bar{R}_{GD}$ ,  $\bar{V}_{GD}$ ) computed in Item 3, in a central-body field to  $T_{NAV}$  and outputs the propagated state ( $\bar{R}_{GD}$ ,  $\bar{V}_{GD}$ ). Other inputs are the maximum time interval step size (DTMIN) and integers (GMD\_PRED, GMO\_PRED) that determine the gravity degree (0) and order (0) models to be used.

Before calling the predictor, the time (TGD) associated with  $\bar{R}_{GD}$ ,  $\bar{V}_{GD}$ , and the previous value of accumulated sensed velocity ( $\bar{V}_{SP}$ ) must be set to ensure that the guidance principal function is consistent with this propagation.

$$TGD = T_{NAV}$$

$$\bar{V}_{SP} = \bar{V}_S$$

$$DT_{MAX} = DTMIN$$



CALL ASC PREC PRED

Inputs:  $\bar{R}GD$ ,  $\bar{V}GD$ , TIG, T\_NAV, DT\_MAX, GMD\_PRED, GMD\_PRED

Outputs:  $\bar{R}GD$ ,  $\bar{V}GD$

If T\_NAV is less than or equal to TIG, then the initial guidance state has already been calculated in Item 3 and is equal to the TIC state.

B. Interface Requirements. The input and output parameters for the premaneuver display support task are given in Tables 4.7.7-1 and 4.7.7-2.

C. Processing Requirements. The premaneuver display support task is performed once when the LOAD\_CMD is set to ON by either keyboard input, entry into Major Mode 104, or the recognition of an abort condition subsequent to display initialization, but prior to burn enablement.

D. Initialization Requirements. None.

E. Supplemental Information. The (1) QUAT\_XFORM and (2) RV\_TO\_QLVLH modules referenced in this task and formally documented in the Flight Control Level C FSSR are presented here for information only.

1. QUAT\_XFORM

$$QTMP_S = -Q_{\bar{B}_I_V} \cdot \bar{V}GO$$

$$QTMP_V = Q_{\bar{B}_I_S} \bar{V}GO + \bar{Q}_{\bar{B}_I_V} \times \bar{V}GO$$

$$\bar{V}GO_{DISP} = -QTMP_S Q_{\bar{B}_I_V} + Q_{\bar{B}_I_S} QTMP_V - QTMP_V \times Q_{\bar{B}_I_V}$$

2. RV\_TO\_QLVLH

$$\bar{X}Z = \text{UNIT}(-\bar{R}GD)$$

$$\bar{X}Y = \text{UNIT}(\bar{V}GD \times \bar{R}GD)$$

$$\bar{X}X = \text{UNIT}(\bar{X}Y \times \bar{X}Z)$$

$$\bar{X}M = (\text{MATRIX}(\bar{X}X, \bar{X}Y, \bar{X}Z))^T$$

The output quaternion is formed from  $\bar{X}M$  by invoking the MAT\_TO\_QUAT module.

Table 4.7.7-1. Premaneuver Display Support Task Inputs

Definition	Symbol	Source	Precision	Units
Time of ignition	TIG_SEC, TIG_MIN, TIG_HR, TIG_DAY	MNVR DISP	SP	sec,min, hr,days
Current Shuttle position vector in M50 coordinates	$\vec{R}_{NAV}$	ASC UPP	DP	ft
Current Shuttle velocity vector in M50 coordinates	$\vec{V}_{NAV}$	ASC UPP	SP	fps
Time associated with current Shuttle state	T_NAV	ASC UPP	DP	sec
External delta-V velocity- to-be-gained vector in local vertical, local horizontal coordinates	$\vec{EXT\_DV\_LVLH}$	MNVR DISP	SP	fps
Orbiter weight	WT_DISP	MNVR DISP	SP	lb
Target altitude magnitude	HTGT_DISP	MNVR DISP	SP	nmi
Target earth central angle from launch site	THETA_DISP	MNVR DISP	SP	deg
Intercept of target line	C1_DISP	MNVR DISP	SP	fps
Slope of target line	C2_DISP	MNVR DISP	SP	ND
Left OMS engine select discrete	LEFT_OMS	MNVR DISP	D	N/A
Right OMS engine select discrete	RIGHT_OMS	MNVR DISP	D	N/A
Both OMS engine select discrete	BOTH_OMS	MNVR DISP	D	N/A
RCS engine select discrete	PLUS_X_RCS	MNVR DISP	D	N/A
Burn duration of the 4 +X RCS jets during OMS-1 for AOA or ATO	TB_RCS	AOA ONORB TGT SEL TSK, ATO ONORB TGT SEL TSK	SP	sec
Discrete indicating guidance convergence	S_CONV	PEG TSK	D	N/A
Desired burnout position, vector in M50 coordinates	$\vec{RD}$	PEG TSK	DP	ft
Desired burnout velocity vector in M50 coordinates	$\vec{VD}$	PEG TSK	SP	fps

Table 4.7.7-1. Premaneuver Display Support Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
Predicted position vector at TGD in M50 coordinates	$\bar{R}_{GD}$	ASC PREC PRED	DP	ft
Predicted velocity vector at TGD in M50 coordinates	$\bar{V}_{GD}$	ASC PREC PRED	SP	fps
Apogee altitude	HA	ORB ALT TIME TSK	SP	nmi
Perigee altitude	HP	ORB ALT TIME TSK	SP	nmi
Velocity-to-be-gained vector in M50 coordinates	$\bar{V}_{GO}$	PEG TSK	SP	fps
Time-to-go to thrust cutoff	TGO	PEG TSK	SP	sec
Accumulated sensed velocity vector	$\bar{V}_S$	ASCENT UPP	DP	fps
Current GMT computer time	T_GMT	FCOS	DP	sec
Unit desired thrust direction vector in M50 coordinates	$\bar{L}_{AMC}$	PEG TSK	SP	none
Desired thrust direction turning rate in M50 coordinates	$\bar{L}_{AMDC}$	PEG TSK	SP	sec <sup>-1</sup>
Time associated with reference thrust vectors LAMC and LAMDC	TLAMC	PEG TSK	DP	sec
Mass-to-weight conversion factor	G_2_FPS2	CONSTANT	SP	lb/slug
Time interval step-size to be used by ASC PREC PRED function to predict current state to ignition state	DTMIN	K-LOADS	SP	sec
Degrees-to-radians conversion factor	RAD_PER_DEG	CONSTANT	SP	rad/deg
Target position in mean-of-1950 coordinates	$\bar{RT}$	H-θ-M50 TGT TSK	DP	ft

Table 4.7.7-1. Premaneuver Display Support Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
Maximum number of PEG iterations	NMAX_DIP	K-LOAD	I	N/A
MM104 indicator	MM104	MSC	D	N/A
MM105 indicator	MM105	MSC	D	N/A
Total vehicle thrust force	FT	THRST PRM TSK	SP	LbF
Initial coasting trajectory position vector for linear terminal velocity constraint guidance	$\bar{R}_{INIT}$	PEG TSK	DP	ft
Initial coasting trajectory velocity vector for linear terminal velocity constraint guidance	$\bar{V}_{INIT}$	PEG TSK	SP	ft/s
Guidance ready flag	S_GDRDY	PEG TSK	D	N/A
Final coasting trajectory position vector excluding J2 gravity effects	$\bar{R}_{FINAL}$	PEG TSK	DP	ft
Final coasting trajectory velocity vector excluding J2 gravity effects	$\bar{V}_{FINAL}$	PEG TSK	SP	ft/s
Final coasting trajectory position vector including J2 gravity effects	$\bar{RC3}$	ASC PREC PRED	DP	ft
Final coasting trajectory velocity vector including J2 gravity effects	$\bar{VC3}$	ASC PREC PRED	SP	ft/s
Feet to nautical miles conversion factor	NM PER FT	CONSTANT	SP	ft
Guidance mode discrete	PEG MODF 4	DISP INIT TSK, MNVR DISP	D	N/A
Time of lift-off to GMT	T_GMTIO	FCOS	DP	sec
OMS pitch trim angle	OMS PITCH TRIM	TRANS DAP	SP	deg
Left OMS yaw trim angle	OMS YAW TRIM <sub>1</sub>	TRANS DAP	SP	deg
Right OMS yaw trim angle	OMS YAW TRIM <sub>2</sub>	TRANS DAP	SP	deg



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ational

Table 4.7.7-2. Premaneuver Display Support Task Outputs

Definition	Symbol	Destination	Precision	Units
Time of ignition	TIG	MSC, ASC PREC PRED, DISP MONIT TSK, PFG INP TSK, TLM, CMD BDY ATT TSK, OMS GUID TSK, VGO DISP TSK	DP	sec
Discrete to initiate time base calculations	TB_ENABLE	MSC	D	N/A
PEG maneuver mode indicator	SMODE	PEG TSK, TLM	I	N/A
Guidance position vector	$\overline{RGD}$	PEG TSK, PFG-INP TSK, H- $\theta$ -M50 TGT TSK, ASC PREC PRED	DP	ft
Guidance velocity vector	$\overline{VGD}$	PEG TSK, PFG INP TSK, H- $\theta$ -M50 TGT TSK, ASC PREC PRED	SP	fps
Time associated with $\overline{RGD}$ , $\overline{VGD}$	TGD	PEG TSK, PFG INP TSK	DP	sec
Target earth central angle from the launch site	THETA	H- $\theta$ -M50 TGT TSK	SP	rad
Target altitude magnitude	HTGT	H- $\theta$ -M50 TGT TSK	SP	ft
Target position vector in M50 coordinates	$\overline{RT}$	PEG TSK	DP	ft
Intercept of target line	$C_1$	LTVCON TSK	SP	fps
Slope of target line	$C_2$	LTVCON TSK	SP	ND
Current vehicle mass	M	ACC-MASS UPD TSK, OMS GUID TSK	SP	slugs
Number of main engines operating	N_SSME	ACC-MASS UPD TSK, PEG TSK, THRST PRM TSK	I	N/A
Assumed number of active OMS engines	SOMS	PFG INP TSK	I	N/A
Prime propulsive system flag	PROP_FLAG_OFS	CMD BDY ATT TSK, OMS FIRE SEQ, MSC, TRANS DAP, MNVR DISP, TLM, OMS RM, ASC NAV SEQ	I	N/A
PEG 4 velocity-to-go in LVLH coordinates	$\overline{VGO\_LVLH}$	MNVR DISP	SP	fps

Units  
N/A  
N/A  
N A  
lbf  
ft  
fps  
N/A  
ft  
fps  
ft  
fps  
nmi ft  
N A  
sec  
deg  
deg  
deg



Table 4.7.7-2. Premaneuver Display Support Task Outputs (Cont)

Definition	Symbol	Destination	Precision	Units
Number of guidance thrust phases	N	PEG TSK	I	N/A
Time of cutoff for the +X RCS engines for a parallel OMS/RCS burn	T_RCS_OFF	PFG INP TSK, PEG TSK, TLM	DP	sec
Number of active OMS engines	N_OMS	THRST PRM TSK, PEG TSK	I	N/A
Number of active RCS engines	N_RCS	THRST PRM TSK, CMD BDY ATT TSK	I	N/A
Target apogee altitude	TGT_HA	MNVR DISP	SP	nmi
Target perigee altitude	TGT_HP	MNVR DISP	SP	nmi
External delta-V target velocity-to-go vector	V $\bar{G}$ O	PEG TSK, TLM	SP	fps
Previous value of prime propulsion system flag	PROP_FLAG_OFS_P	CMD BDY ATT TSK	I	N/A
GMT to compute commanded body attitude	T_CA	CMD BDY ATT TSK	SP	sec
Previous value of accumulated sensed velocity vector	V $\bar{S}$ P	PFG INP TSK	DP	fps
Position vector	R $\bar{}$	ORB ALT TIME TSK	DP	ft
Velocity vector	V $\bar{}$	ORB ALT TIME TSK	SP	fps
Gravity model order and degree flags	GMO_PRED, GMD_PRED	ASC PREC PRED	I	N/A
Maximum integration step interval	DT_MAX	ASC PREC PRED	SP	sec
Current Shuttle position vector	R $\bar{}$ _NAV	ASC PREC PRED	DP	ft
Current Shuttle velocity vector	V $\bar{}$ _NAV	ASC PREC PRED	SP	fps
Time associated with current Shuttle state	T_NAV	ASC PREC PRED	DP	sec

Table 4.7.7-2. Premaneuver Display Support Task Outputs (Cont)

Definition	Symbol	Destination	Precision	Units
Discrete indicating whether initialization (ON) or update (OFF) is to be performed	S <sub>INIT</sub>	PEG TSK	D	N/A
Nominal acceleration	ATR	PEG TSK	SP	ft/sec <sup>2</sup>
Number of active RCS null engines	N_RCS_NULL	THRST PRM TSK	I	N/A
Initial coasting trajectory position vector for linear terminal velocity constraint guidance	R <sub>INIT</sub>	ASC PREC PRED	DP	ft
Initial coasting trajectory velocity vector for linear terminal velocity constraint guidance	V <sub>INIT</sub>	ASC PREC PRED	SP	fps
Time of thrust cutoff	TIG + TGO	ASC PREC PRED	DP	sec
Maximum integration step size for gravity prediction	DT_LIMIT	PEG TSK	SP	sec
PEG steering enable flag	S <sub>STEER</sub>	PEG TSK	D	N/A
Guidance ready flag	S <sub>GDRDY</sub>	PEG TSK	D	N/A



#### 4.7.8 Orbital Altitude Time Task (ORB ALT TIME TSK)

The orbital altitude time task provides software to compute apogee and perigee altitude above a spherical earth and the time to next apsis based on an input state ( $\bar{R}$ ,  $\bar{V}$ ). This procedure may be done in single precision.

##### A. Detailed Requirements.

1. Calculate the magnitude of the radius vector (RMAG), the vertical velocity magnitude (RDOT), and the unit radius vector ( $\bar{R}_{UNIT}$ ):

$$RMAG = ABVAL(\bar{R})$$

$$\bar{R}_{UNIT} = \bar{R}/RMAG$$

$$RDOT = \bar{V} \cdot \bar{R}_{UNIT}$$

2. Calculate the two Keplerian elements, the semimajor axis (AM), and the semilatus rectum (P):

$$AM = EARTH\_MU \cdot RMAG / (2 \cdot EARTH\_MU - RMAG (\bar{V} \cdot \bar{V}))$$

$$P = RMAG (2 - (RMAG/AM) - RMAG RDOT^2 / EARTH\_MU)$$

The constant EARTH\_MU is the earth's gravitational constant.

3. Compute a term to be used repeatedly in subsequent calculations:

$$K = J2\_GRAV \cdot RE^2 / (4 \cdot P)$$

where J2\_GRAV is the second gravitational constant ( $J_2$ ) for the earth and RE is the reference radius of the earth.

4. Compute three quantities to be used in later computations--the product of the sine of the inclination and the sine of the argument of latitude (MM), the product of the sine of the inclination and the cosine of the argument of latitude (NN), and the square of the sine of the inclination (S\_INC)--as follows:

$$MM = \bar{EARTH\_POLE} \cdot \bar{R}_{UNIT}$$

$$NN = UNIT(\bar{V} - RDOT \bar{R}_{UNIT}) \cdot \bar{EARTH\_POLE}$$

$$S\_INC = MM^2 + NN^2$$

where  $\bar{EARTH\_POLE}$  is the current M50 unit angular momentum vector of the earth, which is a premission-determined value.

5. Compute the mean semimajor axis (AM) and the inverse of the mean orbital rate (NU):

$$AM = AM - (J2\_GRAV RE^2 AM^2/RMAG^3) (1 - 3MM^2)$$

$$NU = AM \text{ SQRT}(AM/EARTH\_MU)$$

6. Compute the adjusted elements: radius (RMAG), vertical velocity (RDOT), semimajor axis (AM):

$$RMAG = RMAG + K (MM^2 - NN^2)$$

$$RDOT = RDOT + 4 K MM NN/NU$$

$$AM = AM - K (2 - 3 (S\_INC))$$

7. Compute two quantities to be used in later computations--the product of the eccentricity and the sine of the eccentric anomaly (M) and the product of the eccentricity and the cosine of the eccentric anomaly (N)--as follows:

$$M = RMAG RDOT/SQRT(EARTH\_MU AM)$$

$$N = 1 - RMAG/AM$$

8. Compute the eccentricity (E):

$$E = \text{SQRT}(M^2 + N^2)$$

9. Compute a term (DELTA) to be applied to correct the apogee and perigee altitudes:

$$\text{DELTA} = K (NN^2 - MM^2)$$

10. Check the difference in apogee and perigee radii (2 AM E) to determine if the orbit is near circular, (2 AM E < DELT\_H\_CIRC).

If it is not a circular orbit, proceed to Step 11. For a circular orbit, set the flag (TXX\_FLAG) to indicate a circular orbit, and the time to next apsis (TT\_X) to zero.

$$\text{TXX\_FLAG} = 3$$

$$\text{TT\_X} = 0$$

Then proceed to Step 16.



11. For an elliptical orbit ( $2 AM E \geq DELT\_H\_CIRC$ ), compute the time to next apsis ( $TT\_X$ ) and compute the sine of the true anomaly ( $M$ ) and the cosine of the true anomaly ( $N$ ):

$$SW = SIGN(RDOT)$$

$$TT\_X = ((1 + SW) PI/2 + M-ARCTAN2(M, N)) NU$$

$$M = SQRT(1-E^2) M/(E (1-N))$$

$$N = (N-E^2)/(E (1-N))$$

12. Test the sign of RDOT to determine if the next apsis is apogee ( $TXX\_FLAG = 1$ ) or perigee ( $TXX\_FLAG = 2$ ) and set  $TXX\_FLAG$  to the proper value:

If ( $RDOT \geq 0$ ) then  $TXX\_FLAG = 1$

else  $TXX\_FLAG = 2$

13. Recompute the correction to apogee and perigee ( $DELTA$ ) to include a true anomaly factor:

$$DELTA = DELTA (N^2 - M^2) + 4 M MM N NN K$$

14. Compute a term ( $KK$ ) to correct the time-to-next-apsis ( $TT\_X$ ):

$$KK = (AM^2 E)/(4 P)$$

15. To prevent numerical problems in applying this correction term ( $KK$ ), a check is performed to ensure that it is in the allowable range:

If  $KK > K S\_INC$

If it is not in this range, proceed to Step 16. For an allowable value, compute a quantity proportional to the sine of twice the argument of perigee ( $DELTB$ ) and check to ensure that it has a non-zero value:

$$DELTB = 2 K (M N (MM^2 - NN^2) - MM NN (M^2 - N^2))$$

If  $DELTB = 0$ , then proceed to Step 16. For a non-zero value of  $DELTB$ , compute the time correction term ( $KK$ ) and the time-to-next-apsis ( $TT\_X$ ):

$$KK = -(SW KK + DELTA)/DELTB$$

$$TT\_X = TT\_X + (1 + 2 SW E) NU/(KK + SIGN(KK) SQRT(KK^2 + 2))$$

If the time-to-next-apsis (TT\_X) is negative, add half the period to this time and update the TXX\_FLAG:

$$TT\_X = TT\_X + PI \text{ NU}$$

$$TXX\_FLAG = 1 + MOD (TXX\_FLAG, 2)$$

16. Compute the altitudes of apogee (HA) and perigee (HP) above a spherical earth:

$$HA = (AM (1 + E) + DELTA - RE) NM\_PER\_FT$$

$$HP = (AM (1 - E) + DELTA - RE) NM\_PER\_FT$$

The variable NM\_PER\_FT is the conversion factor from feet to nautical miles.

B. Interface Requirements. The input and output parameters for the orbital altitude time task are given in Tables 4.7.8-1 and 4.7.8-2.

C. Processing Requirements. This task is performed once when called.

D. Initialization Requirements. None.



Table 4.7.8-1. Orbital Altitude Time Task Inputs

Definition	Symbol	Source	Precision	Units
Position vector	$\bar{R}$	CUR ORBIT TSK, PRE-MAN DISP SUPT TSK	DP	ft
Velocity vector	$\bar{V}$	CUR ORBIT TSK, PRE-MAN DISP SUPT TSK	SP	fps
Earth gravitational constant	EARTH_MU	CONSTANT	DP	ft <sup>3</sup> /sec <sup>2</sup>
Earth's second gravitational constant (J <sub>2</sub> )	J2_GRAV	CONSTANT	SP	ND
Earth radius	RE	CONSTANT	DP	ft
M50 unit vector normal to equator pointing north	$\bar{EARTH\_POLE}$	CONSTANT	DP	ND
Maximum difference between apogee and perigee for orbit to be considered circular	DELT_H_CIRC	K_LOAD	SP	nmi
Feet to nautical mile conversion factor	NM_PER_FT	CONSTANT	SP	nmi/ft
Ratio of the circumference of a circle to the diameter	PI	CONSTANT	SP	ND

Table 4.7.8-2. Orbital Altitude Time Task Outputs

Definition	Symbol	Destination	Precision	Units
Apogee altitude	HA	CUR ORBIT TSK, PRE-MAN DISP TSK	SP	nmi
Perigee altitude	HP	CUR ORBIT TSK, PRE-MAN DISP TSK	SP	nmi
Time to next apsis	TT_X	CUR ORBIT TSK, PRE-MAN DISP TSK	SP	sec
Indicator for next apsis and label field  (= 1, TTA (Apogee), = 2, TPP (Perigee), = 3, TTC (Circular))	TXX_FLAG	CUR ORBIT TSK	I	N/A



4.7.9 Insertion Targets Uplink Task (INS TGT UL TSK)

This task determines if insertion guidance targets have been uplinked and, if so, moves the targeting data from the uplink buffer into the correct storage locations.

A. Detailed Requirements. On the first execution of this task following an uplink of new insertion guidance targeting data, the following checks are made:

1. OP code = 0101101.
2. A previously uplinked or crew input target set is not being processed.
3. A burn is not in progress.

If any of these conditions are not met, the uplinked target data are rejected. If all conditions are met, the targeting values in memory are replaced with the values in the uplink buffer, and the guidance targeting update discrete is set to ON (TBD = ON).

B. Interface Requirements. Table 4.7.9-1 lists the insertion targeting uplink parameters and their destinations and the uplink discrete set by the task.

C. Processing Requirements. This task is performed whenever an uplink of new insertion targeting data is received.

D. Initialization Requirements. None.

Units
ft
fps
ft <sup>3</sup> /sec <sup>2</sup>
ND
ft
ND
nmi
nmi ft
ND

Units
nmi
nmi
sec
N A



Table 4.7.9-1. Insertion Targets Uplink Task Inputs and Outputs

Definition	Symbol	Source	Destination	Precision	Units
Time of ignition	TIG	UL	AS MNVR DIP	DP	sec
OMS pitch trim angle	OMS_PITCH_TRIM	UL	MNVR DISP	SP	deg
OMS left yaw trim angle	OMS_YAW_TRIM(1)	UL	MNVR DISP	SP	deg
OMS right yaw trim angle	OMS_YAW_TRIM(2)	UL	MNVR DISP	SP	deg
Thrust vector roll angle	TVR_ROLL	UL	MNVR DISP	SP	deg
Vehicle weight	WT_DISP	UL	MNVR DISP	SP	lb
Intercept of target line	C1_DISP	UL	MNVR DISP	SP	fps
Slope of target line	C2_DISP	UL	MNVR DISP	SP	ND
Target altitude magnitude	HTGT_DISP	UL	MNVR DISP	SP	nmi
Target in-plane downrange angle from launch	THETA_DISP	UL	MNVR DISP	SP	deg
Both OMS engine select	BOTH_OMS	UL	MNVR DISP	D	N/A
Left OMS engine select	LEFT_OMS	UL	MNVR DISP	D	N/A
Right OMS engine select	RIGHT_OMS	UL	MNVR DISP	D	N/A
RCS engine select cmd	PLUS_X_RCS	UL	MNVR DISP	D	N/A
Guidance targetting update discrete	TBD	-	DISP INIT TSK	D	N/A



4.7.10 Parameter Tables for Ascent Maneuver Display Interface Processing

The IDD inputs and outputs are listed in Table 4.7.10-1. Values for the I-loads are contained in the I-load requirements document (JSC-19350); however, I-load definitions applicable to this principal function are listed in Table 4.7.10-2. K-loads are listed in Table 4.7.10-3. Constants are listed in Table 4.7.10-4. The input variable cross-references are listed in Table 4.7.10-5.

Input	Units
	sec
	deg
	deg
	deg
	deg
	lb
	fps
	RD
	mm
	deg
	N A
	N A
	N A
	N A
	N A

Table 4.7.10-1. Ascent Maneuver Display Processing (G4.210) Input/Output Functional Parameters

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FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE
ABORT INIT	V90X8489XA	ABORT INITIALIZATION FLAG	AOA/ATO TGT		
BOTH OMS	V93X6922XA	BOTH OMS ENG SEL	6.35		
BOTH OMS	V93X6922XB	BOTH OMS ENG SEL	UL		
CLOCK/CLOCKTIME	V91W5000C1	CLOCK-COMPUTER(IGMT)	FCOS	S	
C1 DISP	V93U6966CA	INTERCEPT OF TARGET LINE	6.35	FT/S	
C1 DISP	V93U6966CD	INTERCEPT OF TARGET LINE	UL	FT/S	
C1_OMS(1)	V97U4326C	OMS-1 TGT LINE INTERCEPT	UL		
C1_OMS(2)	V97U4327C	OMS-2 TGT LINE INTERCEPT	UL		
C1_OMS(3)	V90L8487C	INTERCEPT OF TARGET LINE-DIP	AOA/ATO TGT	FT/S	
C2 DISP	V93U6967CA	SLOPE OF TARGET LINE	6.35		
C2_DISP	V93U6967CD	SLOPE OF TARGET LINE	UL		
C2_OMS(1)	V97U4342C	OMS-1 TGT LINE SLOPE	UL		
C2_OMS(2)	V97U4343C	OMS-2 TGT LINE SLOPE	UL		
C2_OMS(3)	V90U8488C	SLOPE OF TARGET LINE-DIP	AOA/ATO TGT		
DATA ENTER	V93X6973X	TGT/SETUP DATA ENTERED FLAG	6.35		
DTIG_OMS(1)	V97U4367C	TIME OF OMS-1 IGN AFTER ET SEP	UL		
DTIG_OMS(2)	V97U4368C	TIME OF OMS-2 IGN AFTER ET SEP	UL		
DTIG_OMS(3)	V90W8485C	TIME OF OMS 1/2 IGN AFTER ET SEP	AOA/ATO TGT	S	
EXEC_CMD	V93X1050XA	BURN EXECUTE CMD	6.35		
EXEC_CMD	V93X1050XC	BURN EXECUTE CMD	UI		
EXT_DV_LVLH(1)	V93L6950CA	EXT DELTA V X-COMP	6.35	FT/S	
EXT_DV_LVLH(2)	V93L6951CA	EXT DELTA V Y-COMP	6.35	FT/S	
EXT_DV_LVLH(3)	V93L6952CA	EXT DELTA V Z-COMP	6.35	FT/S	
HTGT_DISP	V93U6968CA	TGT ALTITUDE MAGNITUDE	6.35	NM	
HTGT_DISP	V93U6968CD	TGT ALTITUDE MAGNITUDE	UL	NM	
HTGT_OMS(1)	V97U4411C	OMS-1 TGT ALT	UL		
HTGT_OMS(2)	V97U4412C	OMS-2 TGT ALT	UL		
HTGT_OMS(3)	V90H8481C	TGT ALTITUDE AT END OF COAST PHASE	AOA/ATO TGT	FT	
IYD_OMS1(1)	V97U4855C	X-M50/EF UN NORM TO ORB PLN OMS 1	UL		
IYD_OMS1(2)	V97U4856C	Y-M50/EF UN NORM TO ORB PLN OMS 1	UL		
IYD_OMS1(3)	V97U4857C	Z-M50/EF UN NORM TO ORB PLN OMS 1	UL		
IYD_OMS2(1)	V97U4858C	X-M50/EF UN NORM TO ORB PLN OMS 2	UL		
IYD_OMS2(2)	V97U4859C	Y-M50/EF UN NORM TO ORB PLN OMS 2	UL		
IYD_OMS2(3)	V97U4860C	Z-M50/EF UN NORM TO ORB PLN OMS 2	UL		
LEFT_OMS	V93X6925XA	L OMS ENG SEL	6.35		
LEFT_OMS	V93X6925XB	L OMS ENG SEL	UL		
LOAD_CMD	V93X6956X	LOAD COMMAND	6.35		BD
M/CURR_ORB_MASS/WEIGHT	V90U1961CA	CURRENT VEHICLE MASS	ORB INS GUID	SLUGS	
M/CURR_ORB_MASS/WEIGHT	V90U1961CB	CURRENT VEHICLE MASS	AOA/ATO TGT	SLUGS	
MM_CODE_104/MM_104	V90X8152X	MAJOR MODE 104 FLAG	MSC		
MM_CODE_105/MM_105	V90X8623X	MAJOR MODE 105 FLAG	MSC		
MM_CODE_106/MM_106	V90X8153X	MAJOR MODE 106 FLAG	MSC		
OMS L ON CMD IND	V90X8271X	OMS-L ON CMD IND	OMS FIRE SEQ		
OMS PITCH TRIM	V93H6915CC	OMS PITCH TRIM	TRANS DAP	DEG	SPL
OMS PITCH TRIM	V93H6915CD	OMS PITCH TRIM	UL	DEG	SPL
OMS R ON CMD IND	V90X8272X	OMS-R ON CMD IND	OMS FIRE SEQ		
OMS_YAW_TRIM(1)	V93H6916CC	OMS L YAW TRIM	TRANS DAP	DEG	SPL
OMS_YAW_TRIM(1)	V93H6916CD	OMS L YAW TRIM	UL	DEG	SPL
OMS_YAW_TRIM(2)	V93H6918CC	OMS R YAW TRIM	TRANS DAP	DEG	SPL
OMS_YAW_TRIM(2)	V93H6918CD	OMS R YAW TRIM	UL	DEG	SPL
OP_CODE	V96J3524C	OP CODE TO DEFINE CMD LOAD	UL		
OPS_TRANS_REQUEST	V90X0892XB	OPS TRANSITION REQUEST FLAG	ASC PREC PRED		

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Table 4.7.10-1. Ascent Maneuver Display Processing (G4.210) Input/Output Functional Parameters (Cont)

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FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE
PEG_MODE_4	V93X6976XA	PEG4/PEG7 TGT DATA ENTERED	6.35		
PEG_MODE_4	V93X6976XD	PEG4/PEG 7 TGT DATA ENTERED	UL		
PLUS_X_RCS	V93X6929XA	RCS ENG SEL CMD	6.35		
PLUS_X_RCS	V93X6929XB	RCS ENG SEL CMD	UL		
PROP_DEP	V93U6970CA	OUT OF PLANE PRPLT WASTE	6.35	LB	
PROP_DEP	V93U6970CD	OUT OF PLANE PRPLT WASTE	UL		
Q_BOD_M50(1)/Q_B_I(1)	V90U2240CA	M50 TO BODY QUAT MEASURED ELEM 1	A/E ATT PROC		
Q_BOD_M50(2)/Q_B_I(2)	V90U2241CA	M50 TO BODY QUAT MEASURED ELEM 2	A/E ATT PROC		
Q_BOD_M50(3)/Q_B_I(3)	V90U2242CA	M50 TO BODY QUAT MEASURED ELEM 3	A/E ATT PROC		
Q_BOD_M50(4)/Q_B_I(4)	V90U2243CA	M50 TO BODY QUAT MEASURED ELEM 4	A/E ATT PROC		
Q_M50_LVLH(1)	V90U2641CB	M50 WRT LVLH QUAT 1	A/E ATT PROC		
Q_M50_LVLH(2)	V90U2642CB	M50 WRT LVLH QUAT 2	A/E ATT PROC		
Q_M50_LVLH(3)	V90U2643CB	M50 WRT LVLH QUAT 3	A/E ATT PROC		
Q_M50_LVLH(4)	V90U2644CB	M50 WRT LVLH QUAT 4	A/E ATT PROC		
R_AVGG(1)	V95H0185CB	X-COMP OF CURRENT SHUTTLE POS VCTR	ASC UPP	FT	DPL
R_AVGG(2)	V95H0186CB	Y-COMP OF CURRENT SHUTTLE POS VCTR	ASC UPP	FT	DPL
R_AVGG(3)	V95H0187CB	Z-COMP OF CURRENT SHUTTLE POS VCTR	ASC UPP	FT	DPL
R_FINAL(1)	V90H0881CB	X-COMP PREDICTED SHUTTLE POS VCTR	ASC PREC PRED	FT	
R_FINAL(2)	V90H0882CB	Y-COMP PREDICTED SHUTTLE POS VCTR	ASC PREC PRED	FT	
R_FINAL(3)	V90H0883CB	Z-COMP PREDICTED SHUTTLE POS VCTR	ASC PREC PRED	FT	
R_M50_AT_LIFTOFF(1)	V95U0507C	X-M50 POS OF NB AT LIFTOFF	ASC UPP	FT	
R_M50_AT_LIFTOFF(2)	V95U0508C	Y-M50 POS OF NB AT LIFTOFF	ASC UPP	FT	
R_M50_AT_LIFTOFF(3)	V95U0509C	Z-M50 POS OF NB AT LIFTOFF	ASC UPP	FT	
RIGHT_OMS	V93X6926XA	R OMS ENG SEL	6.35		
RIGHT_OMS	V93X6926XB	R OMS ENG SEL	UL		
S_AOA	V90X8636X	AOA ABORT DECLARED	MSC		
S_AOA_OMS2	V90X8486X	AOA OMS-2 TGT DATA READY FLAG	AOA/ATO TGT		
S_ATO	V90X8635X	ATO ABORT DECLARED	MSC		
ST CRT TIMER	V93X6553X	START CRT TIMER CMD	6.35		BD
T_ET_SEP	V90W8621C	TIME OF ET SEPARATION	MSC	S	
T_GMTLO	V90W4380C	TIME OF LIFTOFF IN GMT	FCOS	S	
T_STATE	V95W0200CD	TIME TAG ASSOC WITH CURRENT STATE	ASC UPP	S	
TAL_ABORT_DECLARED	V90X8658X	TAL ABORT DECLARED	MSC		
TB_RCS	V90W8298CA	POST MECO RCS +X DELTA T COMPUTED	AOA/ATO TGT	S	
TB_TIME	V90W8625C	ENGINE IGNITION TIME BASE TIME	MSC	S	
TGO	V90W1941CB	TIME TO GO TO ENGINE CUTOFF	ORB INS GUID	S	
THETA_DISP	V93U6969CA	TGT INPLN DNRNG ANG FROM LANH	6.35	DEG	
THETA_DISP	V93U6969CD	TGT INPLN DNRNG ANG FROM LANH	UL	RAD	
THETA_OMS(1)	V97U4803C	OMS-1 TGT DNRNG ANG FROM LANH	UL		
THETA_OMS(2)	V97U4804C	OMS-2 TGT DNRNG ANG FROM LANH	UL		
THETA_OMS(3)	V90H8482C	TGT INPLN DNRNG ANG FROM LANH SITE	AOA/ATO TGT	RAD	
TIG	V94W3790CD	TIME OF IGNITION	UL	S	
TIG_DAY	V93W6947CA	TIG(DAYS)	6.35	DAYS	
TIG_HR	V93W6944CA	TIG(HOURS)	6.35	HRS	
TIG_MIN	V93W6945CA	TIG(MIN)	6.35	MIN	
TIG_SEC	V93W6946CA	TIG(SEC)	6.35	S	
TVR_ROLL	V93H6936CD	ROLL ANGLE	UL	DEG	
V_AVGG(1)	V95L0190CB	X-COMP OF CURRENT SHUTTLE VEL VCTR	ASC UPP	FT/S	SPL
V_AVGG(2)	V95L0191CB	Y-COMP OF CURRENT SHUTTLE VEL VCTR	ASC UPP	FT/S	SPL
V_AVGG(3)	V95L0192CB	Z-COMP OF CURRENT SHUTTLE VEL VCTR	ASC UPP	FT/S	SPL
V_FINAL(1)	V90L0885CB	X-COMP PREDICTED SHUTTLE VEL VCTR	ASC PREC PRED	FT/S	
V_FINAL(2)	V90L0886CB	Y-COMP PREDICTED SHUTTLE VEL VCTR	ASC PREC PRED	FT/S	
V_FINAL(3)	V90L0887CB	Z-COMP PREDICTED SHUTTLE VEL VCTR	ASC PREC PRED	FT/S	

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Table 4.7.10-1. Ascent Maneuver Display Processing (G4.210) Input/Output Functional Parameters (Cont)

DBFN: D2B039-A PN: VP707100026P00L MAY 31, 1988  
 INPUT FUNCTIONAL PARAMETERS FOR ASCENT MANEUVER DISPLAY PROCESSING

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FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE
V_IMJ_OLD(1)	V95L0210CB	X-COMP OF CURRENT ACCUM IMJ VEL	ASC UPP	FT/S	
V_IMJ_OLD(2)	V95L0211CB	Y-COMP OF CURRENT ACCUM IMJ VEL	ASC UPP	FT/S	
V_IMJ_OLD(3)	V95L0212CB	Z-COMP OF CURRENT ACCUM IMJ VEL	ASC UPP	FT/S	
VGO(X)	V90L2026C	X VEL TO BE GAINED VECTOR IN M50	ORB INS GUID	FT/S	
VGO(Y)	V90L2027C	Y VEL TO BE GAINED VECTOR IN M50	ORB INS GUID	FT/S	
VGO(Z)	V90L2028C	Z VEL TO BE GAINED VECTOR IN M50	ORB INS GUID	FT/S	
WT_DISP	V93G6940CA	VEHICLE WEIGHT	6.35	LB	
WT_DISP	V93G6940CD	VEHICLE WEIGHT	UL	LBS	

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Table 4.7.10-1. Ascent Maneuver Display Processing (G4.210) Input/Output Functional Parameters (Cont)

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 OUTPUT FUNCTIONAL PARAMETERS FROM ASCENT MANEUVER DISPLAY PROCESSING

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FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE
ABORT INIT	V90X8489XB	ABORT INITIALIZATION FLAG	AOA/ATO TGT		
BURN ENABLE	V94X3815XA	BURN ENABLE	MSC,ABT CNTL SEQ,TLM		
COUNTDOWN	V94X4064XB	CRT TIMER COUNTDOWN FLAG	FCOS		
CRT_SEC	V94H4053CB	SECONDS TO IGNITION	FCOS	S	
CRT_TIMER_START	V94X4063XB	CRT TIMER START FLAG	FCOS		
CUR_HA	V94H3810CA	CURRENT APOGEE ALTITUDE	6.35,TLM	NM	
CUR_HP	V94H3811CA	CURRENT PERIGEE ALTITUDE	6.35,TLM	NM	
C1	V94H3773CB	INTERCEPT OF TARGET LINE-GUID	ORB INS GUID	FT/S	
C1 DISP	V93U6966CC	INTERCEPT OF TARGET LINE	6.35,TLM	FT/S	
C2	V94H3774CB	SLOPE OF TARGET LINE-GUID	ORB INS GUID	FT/S	
C2 DISP	V93U6967CC	SLOPE OF TARGET LINE	6.35,TLM	FT/S	
DT_MAX	V90U8500CE	MAX ALLOW TIME STEP SIZE	ASC PREC PRED	S	
DV TOT	V94L3795CA	TOTAL DELTA V REQD FOR MANEUVER	6.35,TLM	FT/S	
EXEC_CMD	V93X1050XB	BURN EXECUTE CMD	6.35		
EXT_DV_LVLH(1)	V93L6950CD	EXT DELTA V X-COMP	6.35	FT/S	
EXT_DV_LVLH(2)	V93L6951CD	EXT DELTA V Y-COMP	6.35	FT/S	
EXT_DV_LVLH(3)	V93L6952CD	EXT DELTA V Z-COMP	6.35	FT/S	
GMO_PRED	V90U8501CE	GRAVITY MODEL DEGREE	ASC PREC PRED		
GMO_PRED	V90U8502CE	GRAVITY MODEL ORDER	ASC PREC PRED		
HTGT_DISP	V93U6968CC	TGT ALTITUDE MAGNITUDE	6.35,TLM	FT	
IYD(X)	V97U4413CA	UNIT VEC NORM TRAJ PLN X COMP	ORB INS GUID		
IYD(Y)	V97U4414CA	UNIT VEC NORM TRAJ PLN Y COMP	ORB INS GUID		
IYD(Z)	V97U4415CA	UNIT VEC NORM TRAJ PLN Z COMP	ORB INS GUID		
LOAD_FLASH	V94X3814XA	LOAD FLASH FLAG	6.35,TLM		
M/CURR_ORB_MASS/WEIGHT	V90U1961CI	CURRENT VEHICLE MASS	ORB INS GUID,TLM	SLUGS	
MBO	V94U3838C	DESIRED MINIMUM BURNOUT MASS	ORB INS GUID	SLUGS	
MNVR_TITLE_IND	V94U4096CB	DISPLAY TITLE ID	6.35		
N	V94U3823C	NUMBER OF GUIDANCE THRUST PHASES	ORB INS GUID		
OMSL_ACT_SEL	V93J6904CB	L P/S/OFF GMBL ACTR SEL	OMS RM		
OMSR_ACT_SEL	V93J6906CB	R P/S/OFF GMBL ACTR SEL	OMS RM		
PEG_MODE_4	V93X6976XC	PEG4/PEG7 TGT DATA ENTERED	6.35,TLM		
PROP_DEP	V93U6970CC	OUT OF PLANE PRPLT WASTE	6.35,TLM	LB	
PROP_FLAG_OFS	V94J3791CA	PRIME PROP SYS INDICATOR FLAG	OMS FIRE SEQ,TRANS DAP,MSC, OMS RM,ASC NAV SEQ, ORB INS GUID,TLM		
Q CB_M50_S	V94U3980CE	M50 TO BODY QUAT ELEM 1	TRANS DAP		
Q CB_M50_V(1)	V94U3981CE	M50 TO BODY QUAT ELEM 2	TRANS DAP		
Q CB_M50_V(2)	V94U3982CE	M50 TO BODY QUAT ELEM 3	TRANS DAP		
Q CB_M50_V(3)	V94U3983CE	M50 TO BODY QUAT ELEM 4	TRANS DAP		
R_INT(X),RGD(X)	V90H8508CE	X-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT	
R_INT(Y),RGD(Y)	V90H8509CE	Y-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT	
R_INT(Z),RGD(Z)	V90H8510CE	Z-COMP SHUTTLE POS VECTR AT T_INIT	ASC PREC PRED	FT	
RGD(X)	V94H3930CA	X-COMP OF GUIDANCE POS VEC AT TGD	ORB INS GUID	FT	
RGD(Y)	V94H3931CA	Y-COMP OF GUIDANCE POS VEC AT TGD	ORB INS GUID	FT	
RGD(Z)	V94H3932CA	Z-COMP OF GUIDANCE POS VEC AT TGD	ORB INS GUID	FT	
RT(X)	V90H3781CA	X-M50 OF POSITION TARGET VECTOR	ORB INS GUID,TLM	FT	
RT(Y)	V90H3782CA	Y-M50 OF POSITION TARGET VECTOR	ORB INS GUID,TLM	FT	
RT(Z)	V90H3783CA	Z-M50 OF POSITION TARGET VECTOR	ORB INS GUID,TLM	FT	
S_OPS3_TGT_ROY	V94X3911X	AOA OMS-2 TARGETING COMPLETE FLAG	6.35		
SMODE	V94J3779C	GUIDANCE MODE INDICATOR	ORB INS GUID,TLM		
SOMS	V94U3820C	ASSUMED NUMBER OF ACTIVE OMS ENG	ORB INS GUID		
T_INIT/T_NAV,TGD	V90W8512CE	TIME AT BEGINNING OF PRED	ASC PREC PRED	S	

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Table 4.7.10-1. Ascent Maneuver Display Processing (G4.210) Input/Output Functional Parameters (Cont)

DBFN: D2B039-A PN: VP707100026P00L MAY 31, 1988  
 OUTPUT FUNCTIONAL PARAMETERS FROM ASCENT MANEUVER DISPLAY PROCESSING

ASC MNVR DIP 0188 REV00 G4.210

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FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	PREC
T RCS OFF	V94M3824C	TIME OF +X RCS CUTOFF FOR PRL BURN	ORB INS GUID, TLM	S	DPL	
TB ENABLE	V94X3826XA	TIME BASE TIME INITIATOR FLAG	MSC			
TGD	V94M3938CA	TIME ASSOCIATED WITH RGD, VGD	ORB INS GUID	S		
TGT HA	V94H3798CA	TARGET APOGEE ALTITUDE	6.35, TLM	NM		
TGT HP	V94H3799CA	TARGET PERIGEE ALTITUDE	6.35, TLM	NM		
THETA_DISP	V93U6969CC	TGT INPLN DNRNG ANG FROM LANH	6.35, TLM	DEG		
THETA_LSS	V94U3808C	LNCH SITE TO OMSI TIG CNTRL ANGLE	AOA/ATO TGT	RAD		
TIG	V94M3790CA	TIME OF IGNITION	ORB INS GUID, MSC, TLM	S		
TIG, TGO, TNAV	V90M8506CE	TIME AT WHICH STATE IS DESIRED	ASC PREC PRED	S		
TIG DAY	V93H6947CD	TIG(DAYS)	6.35	DAYS		
TIG HR	V93H6944CD	TIG(HOURS)	6.35	HRS		
TIG MIN	V93H6945CD	TIG(MIN)	6.35	MIN		
TIG MINUS5_FLAG	V94X3813XA	ENGINE IGNITION MINUS 5 SEC FLAG	6.35			
TIG_SEC	V93H6946CD	TIG(SEC)	6.35	S		
TT_X_DISP	V94M3796CA	TIME TO NEXT APSIS/FREE FALL	6.35, TLM	S		
TTX_FLAG_DISP	V94J4098CA	TIME TO XXXXX DISPLAY FIELD IND	6.35			
TVR_ROLL	V93H6936CE	ROLL ANGLE	6.35	DEG		
V_INIT(X), VGD(X)	V90L8513CE	X-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED	FT/S		
V_INIT(Y), VGD(Y)	V90L8514CE	Y-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED	FT/S		
V_INIT(Z), VGD(Z)	V90L8515CE	Z-COMP SHUTTLE VEL VECTR AT T_INIT	ASC PREC PRED	FT/S		
VEH PITCH	V93U6909CC	PITCH ANGLE IN ADI INERTIAL COORD	6.35, TLM	DEG		
VEH_ROLL	V93U6910CC	ROLL ANGLE IN ADI INERTIAL COORD	6.35, TLM	DEG		
VEH_YAW	V93U6911CC	YAW ANGLE IN ADI INERTIAL COORD	6.35, TLM	DEG		
VGD(X)	V94H3935CA	X-COMP OF GUIDANCE VEL VEC AT TGD	ORB INS GUID	FT/S		
VGD(Y)	V94H3936CA	Y-COMP OF GUIDANCE VEL VEC AT TGD	ORB INS GUID	FT/S		
VGD(Z)	V94H3937CA	Z-COMP OF GUIDANCE VEL VEC AT TGD	ORB INS GUID	FT/S		
VGO(X)	V94L3804CA	X-EXTERNAL DEL V TARGET VECTOR	ORB INS GUID, TLM	FT/S		
VGO(Y)	V94L3805CA	Y-EXTERNAL DEL V TARGET VECTOR	ORB INS GUID, TLM	FT/S		
VGO(Z)	V94L3806CA	Z-EXTERNAL DEL V TARGET VECTOR	ORB INS GUID, TLM	FT/S		
VGO_DISP(X)	V94U3800CA	X-COMP OF VGO OF MNVR-BODY COORD	6.35, TLM	FT/S		
VGO_DISP(Y)	V94U3801CA	Y-COMP OF VGO OF MNVR-BODY COORD	6.35, TLM	FT/S		
VGO_DISP(Z)	V94U3802CA	Z-COMP OF VGO OF MNVR-BODY COORD	6.35, TLM	FT/S		
VGO_LVLH(X)	V94L3945CA	PEG 4 LVLH X-COMP OF VGO	6.35, TLM	FT/S		
VGO_LVLH(Y)	V94L3946CA	PEG 4 LVLH Y-COMP OF VGO	6.35, TLM	FT/S		
VGO_LVLH(Z)	V94L3947CA	PEG 4 LVLH Z-COMP OF VGO	6.35, TLM	FT/S		
VSP(X)	V94H3940CA	X-COMP OF PREV ACCUM IMU VEL	ORB INS GUID	FT/S		
VSP(Y)	V94H3941CA	Y-COMP OF PREV ACCUM IMU VEL	ORB INS GUID	FT/S		
VSP(Z)	V94H3942CA	Z-COMP OF PREV ACCUM IMU VEL	ORB INS GUID	FT/S		
WT_DISP	V93G6940CB	VEHICLE WEIGHT	ORB/RND NAV SEQ. 6.35	LBS		
	V94M3816C	INITIALIZE TIME BASE TIME	MSC, TLM	S		

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Table 4.7.10-2. I-Loads (G4.210 Ascent Manuever Display Interface Processing)

OI8B MISSIONS FSSR NAME	MSID	ENG UNIT	DT PR D S PR FCTN	CAT
C1_OMS(1)	V97U4326C	FT/SEC	F S M C G4.210	ZF22
C1_OMS(2)	V97U4327C	FT/SEC	F S M C G4.210	ZF22
C2_OMS(1)	V97U4342C	ND	F S M C G4.210	ZF22
C2_OMS(2)	V97U4343C	ND	F S M C G4.210	ZF22
DTIG_OMS(1)	V97U4367C	SEC	F S M C G4.210	A3N2
DTIG_OMS(2)	V97U4368C	SEC	F S M C G4.210	A3N2
FT_OMS	V97U4390C	LBF	F S D C G4.210 G4.13 G4.4 G4.3 G4.2	ZF22
FT_RCS	V97U4391C	LBF	F S D C G4.2 G4.3 G4.210 G4.4	ZF22
HTGT_OMS(1)	V97U4411C	FT	F S M C G4.210	A3N2
HTGT_OMS(2)	V97U4412C	FT	F S M C G4.210	A3N2
IYD(1)	V97U4413C	ND	F D M C G4.226 G4.2 G4.3 G4.19 G4.20 G4.210	A2N1
IYD(2)	V97U4414C	ND	F D M C G4.226 G4.2 G4.3 G4.19 G4.20 G4.210	A2N1
IYD(3)	V97U4415C	ND	F D M C G4.226 G4.2 G4.3 G4.19 G4.20 G4.210	A2N1
IYD_OMS(1)	V97U4855C	ND	F D M C G4.210	A2N1
IYD_OMS(2)	V97U4856C	ND	F D M C G4.210	A2N1

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Table 4.7.10-2. I-Loads (G4.210) Ascent Maneuver  
Display Interface Processing (Cont)

OI8B MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	ONE_ENG_OMS_YAW_TRIM(2)	V97U2369C	DEG	F	S	M	C	G4.201 G4.35 G4.7 G4.158 G4.3 G4.209 G4.210		OMT0 OMT0 OMT0 OMT0
	PHIDOT_MAX	V97U9003C	RAD/SEC	F	S	D	C	G4.3 G4.210 G4.2 G4.4		ZF12
	THETA_OMS(1)	V97U4803C	RAD	F	S	M	C	G4.210		A3N2
	THETA_OMS(2)	V97U4804C	RAD	F	S	M	C	G4.210		A3N2
	THRUST_BODY_RCS_X(1)	V97U4812C	ND	F	S	D	C	G4.7 G4.209 G4.158 G4.3 G4.210 G4.211		ZF12
	THRUST_BODY_RCS_X(2)	V97U4813C	ND	F	S	D	C	G4.7 G4.209 G4.158 G4.3 G4.210 G4.211		ZF12
	THRUST_BODY_RCS_X(3)	V97U4814C	ND	F	S	D	C	G4.7 G4.209 G4.158 G4.3 G4.210 G4.211		ZF12
	TVR_ROLL	V93H6936C	DEG	F	S	D	C	G4.7 G4.158 G4.209 G4.210 G4.211		ZF22

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Table 4.7.10-2. I-Loads (G4.210) Ascent Maneuver  
Display Interface Processing (Cont)

OI8B MISSIONS	FSSR NAME	MSID	ENG UNIT	DT	PR	D	S	PR	FCTN	CAT
	IYD_OMS(3)	V97U4857C	ND	F	D	M	C	G4.210		A2N1
	IYD_OMS(4)	V97U4858C	ND	F	D	M	C	G4.210		A2N1
	IYD_OMS(5)	V97U4859C	ND	F	D	M	C	G4.210		A2N1
	IYD_OMS(6)	V97U4860C	ND	F	D	M	C	G4.210		A2N1
	KLAMDXZ	V97U4423C	ND	F	S	D	C	G4.3 G4.209 G4.13 G4.210 G4.211		ZF12
	KMISS	V97U4831C	ND	F	S	D	C	G4.209 G4.2 G4.3 G4.4 G4.210 G4.211		ZF12
	MASS_ORB	V97U4435C	SLUGS	F	S	M	C	G4.210 G4.13		AMC2
	MBO_MIN(1)	V97U4861C	SLUGS	F	S	M	C	G4.210		AMC2
	MBO_MIN(2)	V97U4862C	SLUGS	F	S	M	C	G4.210		AMC2
	MDOT_OMS	V97U4440C	SLUGS/SEC	F	S	D	C	G4.210 G4.13 G4.4 G4.3 G4.2		ZF22
	ONE_ENG_OMS_PITCH_TRIM	V97U2367C	DEG	F	S	M	X	G4.201 G4.35 G4.7 G4.158 G4.3 G4.209 G4.210		OMTO OMTO OMTO OMTO
	ONE_ENG_OMS_YAW_TRIM(1)	V97U2368C	DEG	F	S	M	C	G4.201 G4.35 G4.7 G4.158 G4.3 G4.209 G4.210		OMTO OMTO OMTO OMTO

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Table 4.7.10-2. I-Loads (G4.210) Ascent Maneuver  
Display, Interface Processing (Cont)

MISSIONS	MSID	MC KLOAD VALUE	ENG UNIT	DT PR S PR FCTN	LAST CR EQTN	MSID
BURN_ENABLE_WINDOW	V97U5181C	-1.5	E+01 SEC	F D X G4.7 G4.158 G4.210 G4.211	89662B	V96U9498C
BURN ENABLE WINDOW						
CBETA_EPS	V97U5127C	+9.998480	E-01 ND	F S C G4.211 G4.210 G4.209 G4.158 G4.7 G4.3	89542A	
DELT_H_CIRC	V97U4832C	+5.0	E+00 NMI	F S A G4.158 G4.210 G4.211	39534	V97U4832C
DTMIN	V97U4370C	01 +2.0 02 +3.00 03 +2.0	E+00 SEC E+02 E+00	F S C G4.211 G4.210 G4.209 G4.158 G4.13 G4.4 G4.3 G4.2	29975A	
EPSTGO	V97U4381C	+4.0	E-02 ND	F S C G4.2 G4.3 G4.4 G4.210	59955	
PEG INHIBIT STEERING OUTPUT						
MDOT_RCS	V97U4441C	+1.0655714	E-01 SLUGS/SEC	F S C G4.210 G4.2 G4.13 G4.4 G4.3	89661A	
NOMINAL RCS MASS FLOW RATE						
NMAX_DIP	V97U4836C	+10	ND	I S C G4.211 G4.13 G4.210	59955	
MAXIMUM PEG CYCLE						
PITCH_BIAS	V97U4485C	+2.7605300	E-01 RAD	F S C G4.7 G4.3 G4.209 G4.210 G4.211 G4.158	59955	

CONST OMS ENG ELEC PITCH TRIM ANG

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Table 4.7.10-3. Ascent Maneuver Display Processing (G4.210)  
 K-Loads Ascent Maneuver Display Processing (Cont)

OI8B MISSIONS								
FSSR NAME DESCRIPTION	MSID	MC KLOAD VALUE	ENG UNIT	DT	PR	S	PR FCTN	LAST CR EQTN MSID
Q_M50_INRTL_ASCENT(1)	V97U2214CA	+1.0	E+00 ND	F	S	C	G4.3 G4.210 G4.226	896888
Q_M50_INRTL_ASCENT(2)	V97U2215CA	+0.0	E+00 ND	F	S	C	G4.3 G4.210 G4.226	896888
Q_M50_INRTL_ASCENT(3)	V97U2216CA	+0.0	E+00 ND	F	S	C	G4.3 G4.210 G4.226	896888
Q_M50_INRTL_ASCENT(4)	V97U2217CA	+0.0	E+00 ND	F	S	C	G4.3 G4.210 G4.226	896888
YAH_BIAS	V97U4829C	+1.134460	E-01 RAD	F	S	C	G4.3 G4.7 G4.209 G4.210 G4.211 G4.158	89541
CNST OMS ENG ELEC YAH TRIM ANGLE								

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Table 4.7.10-4. Ascent Maneuver Display Interface Processing  
(G4.210) Constants

NROKRMM.FSSR2.DATA(X26)BOOK2  
PFS CONSTANTS UPDATE B/L

FSSR NAME DESCRIPTION	MSID	MC	VALUE	UNITS	DT	PR	S	PF REF	LAST CR	EQTN MSID
EARTH MU EARTH'S GRAVITATIONAL CONSTANT	V97U4378C		1.40764487566 E+116	FT3/SEC2	F	D	P			
EARTH POLE(1) UNIT POLE VECTOR IN M50	V9848460C		.28322844 E-02	ND	F	D	P			
EARTH POLE(2) UNIT POLE VECTOR IN M50	V98U8461C		-.5027996 E-04	ND	F	D	P			
EARTH POLE(3) UNIT POLE VECTOR IN M50	V98U8462C		.9999959841	ND	F	D	P			
G_2 FPS2 MASS TO WEIGHT CONVERSION	V97U4393C		32.174049	LB/SLUG	F	S	P			
J2 GRAV EARTH SECOND GRAVITY CONSTANT, J2	V97U4416C		1.0826271 E-3	ND	F	S	P			
NAUTMI PER FT FEET TO NAUTICAL MILE CONVERSION	V97U5423C		1.6457884 E-04	NM/FT	F	S	P			
PI RATIO OF CIRCUMFERENCE TO DIAMETER	V98U8725C		3.1415926535897	ND	F	D	P			
RAD PER DEG DEGREE PER RADIAN CONVERSION	V97U0383C		.017453293	RAD/DEG	F	S	P			
RE EARTH EQUATORIAL RADIUS	V97U5324C		20925741. 4698163	FT	F	D	P			

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Table 4.7.10-5. Ascent Maneuver Display Interface Processing  
Input Variable Cross-Reference

Local Name	Source Name	MSID
T_GMT	CLOCK	V91W5000C1
R_NAV	R_AVGG	V95H0185CB, 86CB, 87CB
V_NAV	V_AVGG	V95L0190CB, 91CB, 92CB
T_NAV	T_STATE	V95W0200CD
RGD, RC3	R_FINAL	V90H0881CB, 2CB, 3CB
VGD, VC3	V_FINAL	V90L0885CB, 6CB, 7CB
IYD_OMS(1)	IYD_OMS1(1)	V97U4855C
IYD_OMS(2)	IYD_OMS1(2)	V97U4856C
IYD_OMS(3)	IYD_OMS1(3)	V97U4857C
IYD_OMS(4)	IYD_OMS2(1)	V97U4858C
IYD_OMS(5)	IYD_OMS2(2)	V97U4859C
IYD_OMS(6)	IYD_OMS2(3)	V97U4860C
R_LS_M50	R_M50_AT_LIFTOFF	V95U0507C, 8C, 9C

#### 4.8 GENERAL GUIDANCE AND TARGETING TASKS



#### 4.8 GENERAL GUIDANCE AND TARGETING TASKS

This section describes the detailed requirements for several general guidance and targeting tasks which may be used to support more than one guidance and targeting function. These tasks, and the principal functions which they support, are as follows:

1. PEG task (PEG TSK): AS 2STG GUID, ORB INS GUID, AOA/ATO TGT, AS MNVR DIP, PW RTLS GUID
2. Acceleration-mass update task (ACC-MASS UPD TSK): AS 2STG GUID, ORB INS GUID, AOA/ATO TGT, PW RTLS GUID
3. G-limiting task (G-LIM TSK): AS 2STG GUID, PW RTLS GUID
4. Linear terminal velocity constraint task (LTVCON TSK): ORB INS GUID, AOA/ATO TGT, AS MNVR DIP
5. MPS guidance cutoff task (MPS GUID C/O TSK): AS 2STG GUID, PW RTLS GUID
6. H- $\theta$ -to-M50 target task (H- $\theta$ -M50 TGT TSK): AOA/ATO TGT, AS MNVR DIP
7. Thrust parameters task (THRST PRM TSK): AS 2STG GUID, PW RTLS GUID, ORB INS GUID, AOA/ATO TGT, AS MNVR DIP
8. PFG input task (PFG INP TSK): AS 2STG GUID, ORB INS GUID, PW RTLS GUID
9. SSME-out safing task (SSME-OUT SAF TSK): AS 1STG GUID, AS 2STG GUID, PW RTLS GUID
10. Commanded body attitude task (CMD BDY ATT TSK): ORB INS GUID, AS MNVR DIP
11. RTLS/TAL target selection task (RTLS/TAL TGT SEL TSK): AS 2STG GUID, PW RTLS GUID



#### 4.8.1 PEG Task (PEG TSK)

PEG is a general-purpose guidance task which computes the reference thrust vector, desired thrust turning rate vector, reference thrust vector time, and time-to-go (TGO) to thrust termination for all explicitly guided Shuttle exoatmospheric maneuvers. It is used by several guidance principal functions which control the proper inputs and interfaces to meet maneuver objectives.

The ascent PEG task consists of a set of guidance modes which are designed to satisfy all currently defined ascent Shuttle powered flight maneuver guidance requirements. These modes are defined as follows:

1. Standard Ascent. This mode is intended for use during the second-stage ascent phase. The target conditions are specified preflight and defined by a desired terminal velocity, flightpath angle, radius, inclination, and ascending node. The inclination and node constraints are implicitly specified by a unit vector normal to the desired orbital plane. Thus, all components of the terminal state are specified except the downrange component of position which is computed so that the velocity-to-be-gained (VGO), or equivalently propellant usage, is minimized.

2. Linear Terminal Velocity Constraint. This mode is intended for use in maneuvers in which the cutoff velocity is constrained so that the subsequent coasting trajectory passes through a specified target position vector with a specified linear relationship between the vertical and horizontal components of velocity at the target. The target conditions are the end-of-coast target position vector and the intercept and slope constants defining the target velocity constraint line. This mode is applicable to the nominal orbit insertion maneuvers, the AOA OMS maneuvers, and the ATO OMS maneuvers. Note that since the target position vectors for the nominal orbit insertion, AOA OMS-1, and ATO OMS maneuvers are normally desired apsis vectors, the intercept and slope constants for these maneuvers are normally input as zero.

3. External Delta-V. This mode is designed to guide the vehicle through a constant inertial thrust attitude maneuver that achieves a specified velocity change. The targeting for this mode is performed externally. The guidance input is a desired inertial velocity-to-be-gained (VGO) vector. This mode will normally be used for on-orbit maneuvers or when accuracy in achieving terminal conditions is not of prime concern. No corrections are made for misses in desired terminal conditions.

4. Return-to-Launch-Site. This mode is intended for use during the ascent if it has been determined that the abort mode region is an RTLS and an abort is required for various reasons; e.g., SSME failure. The target conditions are:

- a. A preflight specified radius
- b. A desired terminal velocity that is a function of range
- c. A desired terminal flight path angle that is a function of the terminal vertical altitude

- d. A desired terminal mass
- e. A burnout flight heading such that the aim point vector is contained in the burnout plane. The burnout heading is specified by a unit vector normal to the plane defined by the burnout position vector and aim point vector.

Shuttle ascent and descent abort mission design constraints, as well as Shuttle vehicle constraints, impact the design of the ascent PEG task. In particular, these constraints are the SSME G-limiting constraints, the continuous intact-abort constraint, the AOA-preferred abort mode constraint, and the RTLS final mass constraint.

The G-limiting constraint implies that all nominal SSME burns must have at least two thrust phases--one constant thrust and one constant acceleration. This adds complexity to the time-to-go (TGO) and thrust integral calculations to account for the two phases.

To satisfy the continuous intact-abort constraint, the abort-critical missions require two constant SSME thrust phases prior to the G-limiting (constant acceleration) phase. For the first phase three SSME's are assumed and for the second phase only two are assumed. This adds complexity to the TGO calculations to account for the additional constant thrust phase.

The AOA-preferred abort mode constraint impacts the ascent PEG design since, for some pre-MECO aborts, the post-MECO OMS-1 maneuver is required to burn RCS translation jets to assist the OMS. That the RCS translation may be terminated prior to OMS cutoff requires two separate constant thrust phases--one in which both OMS and RCS thrust is considered and the other in which only the OMS thrust is considered. This constraint, when combined with those previously discussed, requires that a distinction be made between SSME phases, OMS phases, and combined OMS and RCS phases.

The RTLS final mass constraint requires that propellants remaining in the ET at RTLS MECO be minimal.

The subtasks necessary to perform the ascent PEG guidance modes consist of a related group of calculations which may be unique to a particular guidance mode or may be required by two or more of the guidance modes. Therefore, the detailed requirements (Part A) describe each subtask independently of the applicability and order in which these subtasks are used to perform a guidance mode. The processing requirements (Part C) supply information regarding the necessary subtasks required for particular guidance modes in the correct order of solution. The functional flow for the PEG task is shown in Figure 4.3.1-1.

#### A. Detailed Requirements.

1. Position Magnitude Subtask. The magnitude of the current position vector is calculated to be used later in the PEG calculations.

$$RMAG = ABVAL(\overline{RCD})$$



- 2a. RTLS PPD Targets Subtask. The desired mass and flightpath angle at the start of PPD are selected as functions of the active SSME configuration on the first RTLS pass, or when an SSME shutdown has occurred since the last guidance cycle and  $TGO > TGO_{IA}$ . The desired mass is set as  $MBO = MBOD_{N\_SSME-1}$ , and the desired flightpath angle is  $GAMD = GAM_{LL}$ .
- 2b. VGO-Desired Subtask. The velocity to be gained for RTLS must be constrained to be consistent with the desired terminal mass, MBO. The magnitude of the desired VGO is  $VGOD = VEX \text{ LOG}(M/MBO)$ , where M is current mass and VEX is the equivalent exhaust velocity.
3. VGO Update Subtask. The purpose of this subtask is to update the velocity-to-be-gained, VGO, as well as the phase counter, KPHASE, and the associated variables required by the TGO and thrust integral calculations.

First, the  $\bar{VGO}$  is updated by decrementing it by the sensed velocity change that has occurred since the last update calculation. This is accomplished by the following equation:

$$\bar{VGO} = \bar{VGO} - \bar{DVS}$$

$$\bar{DVS} = \bar{0}$$

where  $\bar{DVS}$  is the current sensed velocity change, and  $\bar{VGO}$  is the current estimate of velocity-to-be-gained.

Next, if the burn time of the current guidance phase has elapsed, that is, if  $TB_{KPHASE} - (TGD - TPRIME) \leq 0$  and if KPHASE is less than N, then the guidance phase counter, KPHASE, must be incremented. Also, the current guidance phase burn time,  $TB_{KPHASE}$ , and the accumulated burn time for this guidance phase,  $TGOA_{KPHASE}$ , must be reset to zero as follows:

$$TB_{KPHASE} = 0$$

$$TGOA_{KPHASE} = 0$$

$$KPHASE = KPHASE + 1$$

Lastly, the value of current time, TGD, must be saved for the next pass through this subtask as follows:

$$TPRIME = TGD$$

4. TGO subtask. The purpose of this subtask is to calculate the total time-to-go until the end of the maneuver TGO, and the intermediate time-to-go for each guidance phase for use in the thrust integrals. The TGO until the end of the maneuver is obtained by computing the burn time (TB) for each remaining guidance phase and then adding these computed times. For each guidance phase, TB is

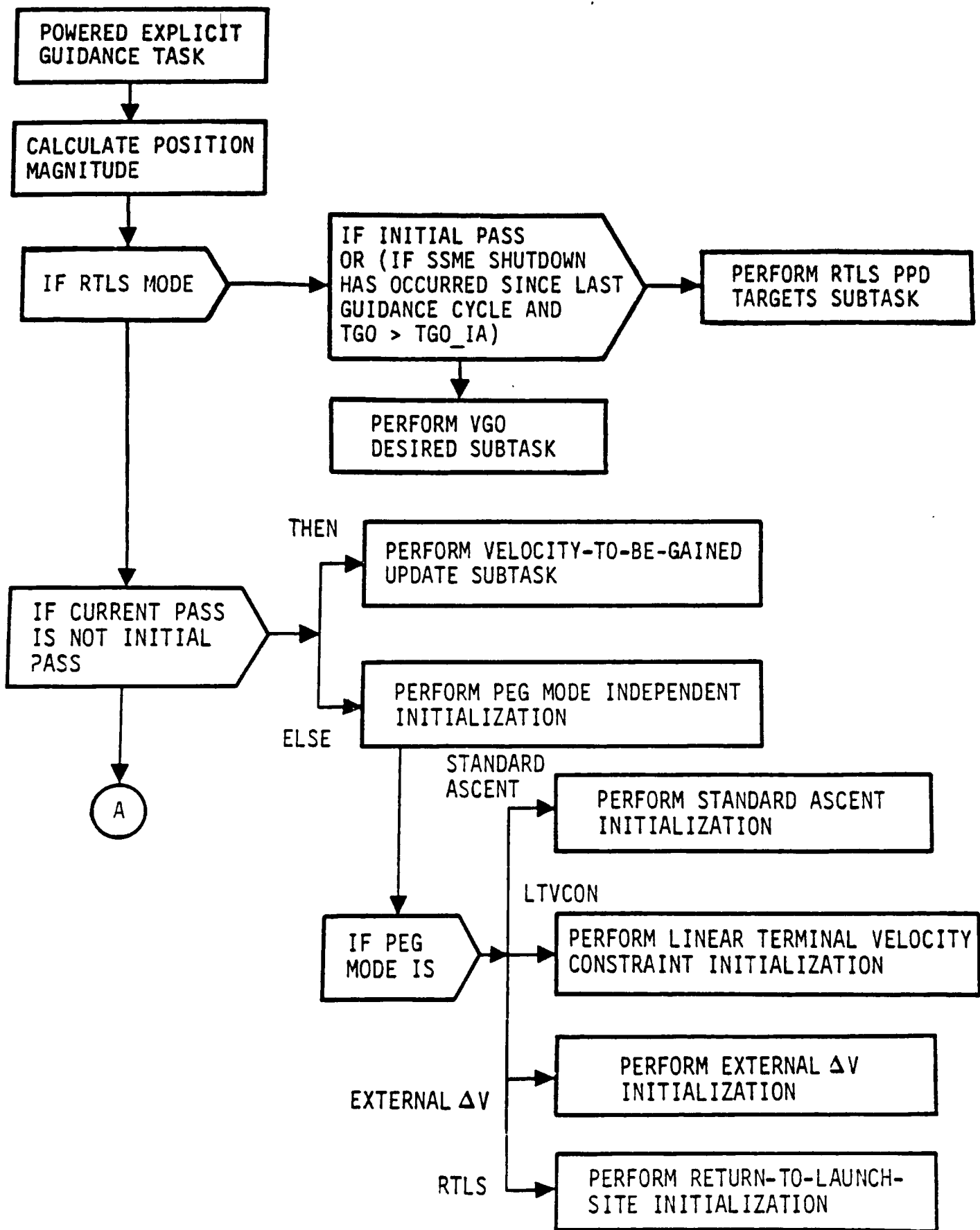


Figure 4.8.1-1. Powered Explicit Guidance Task Functional Flow (Sheet 1 of 5)

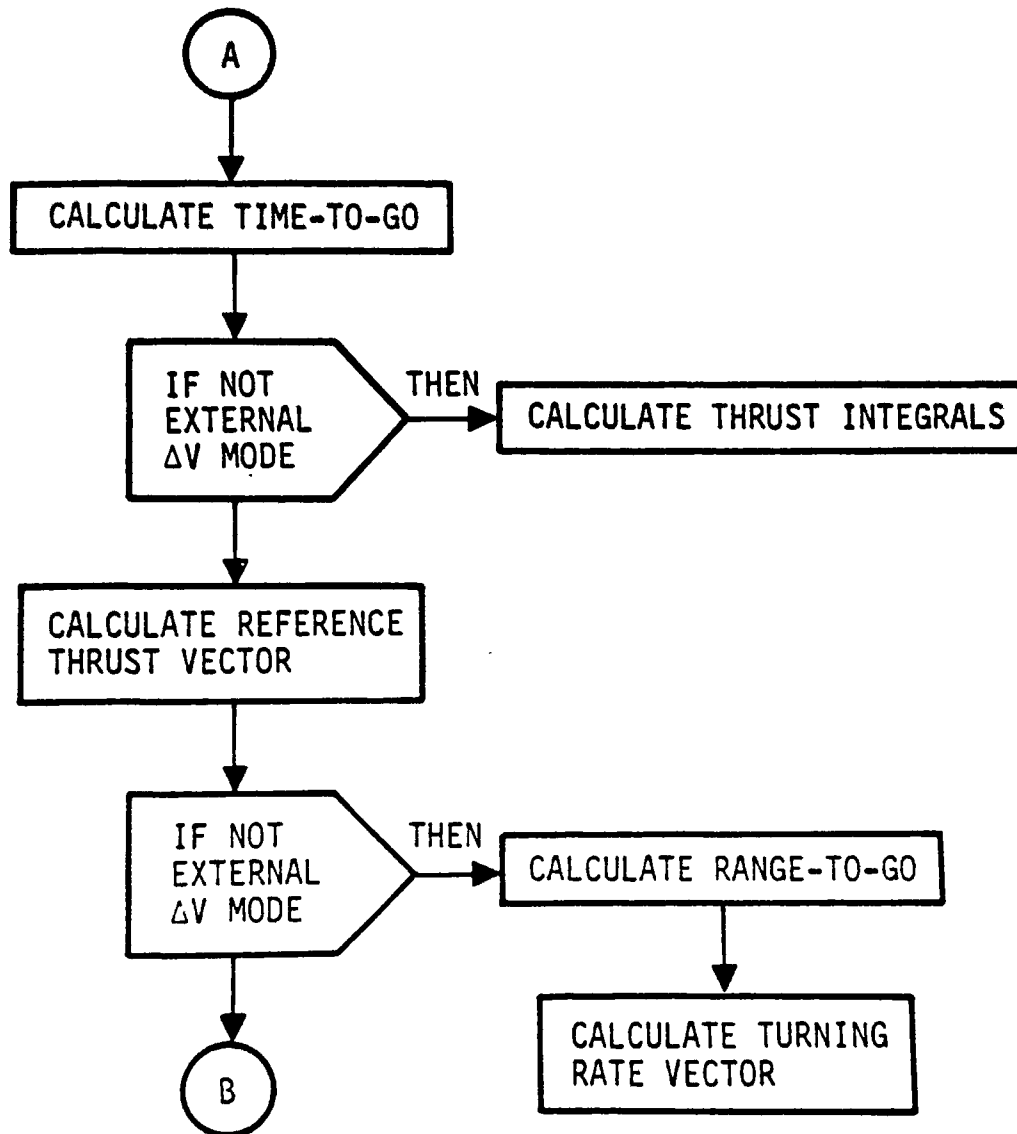


Figure 4.8.1-1. Powered Explicit Guidance Task Functional Flow (Sheet 2 of 5)

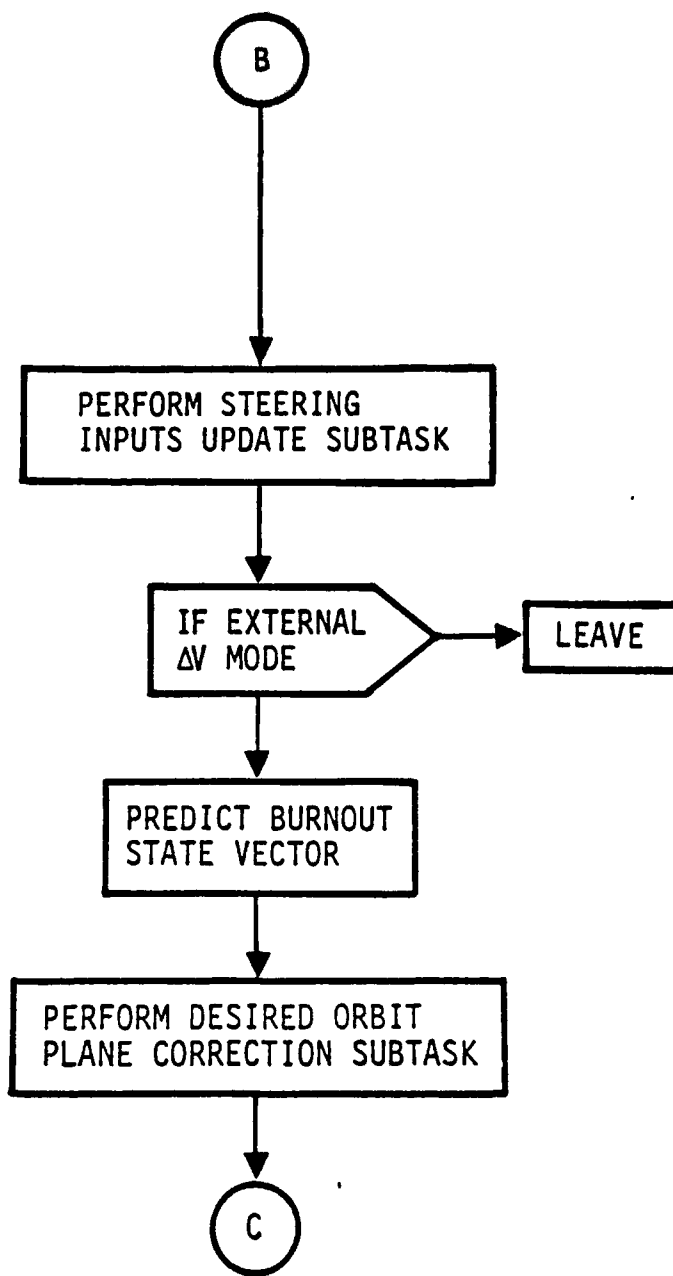


Figure 4.8.1-1. Powered Explicit Guidance Task Functional Flow (Sheet 3 of 5)

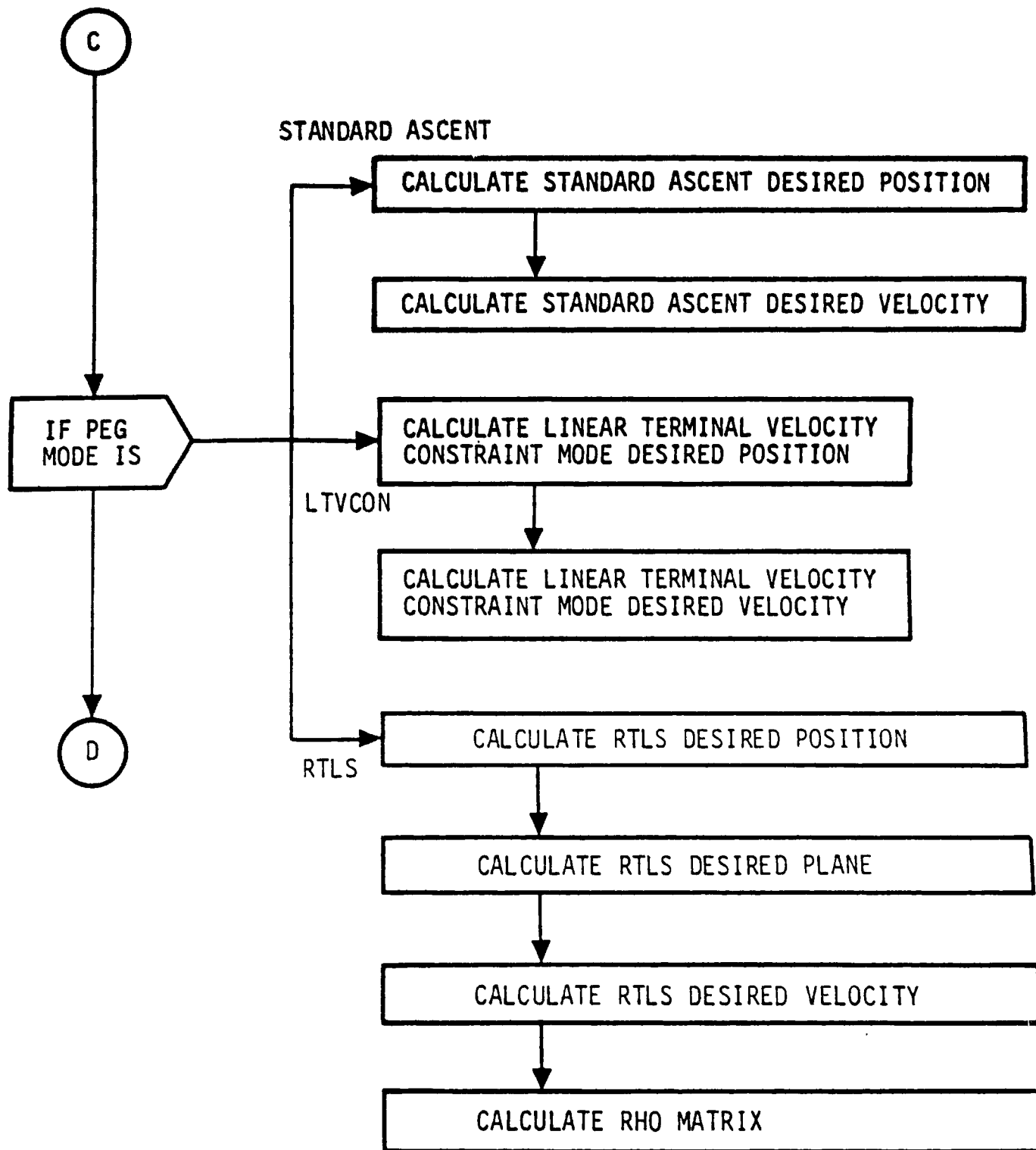


Figure 4.8.1-1. Powered Explicit Guidance Task Functional Flow (Sheet 4 of 5)



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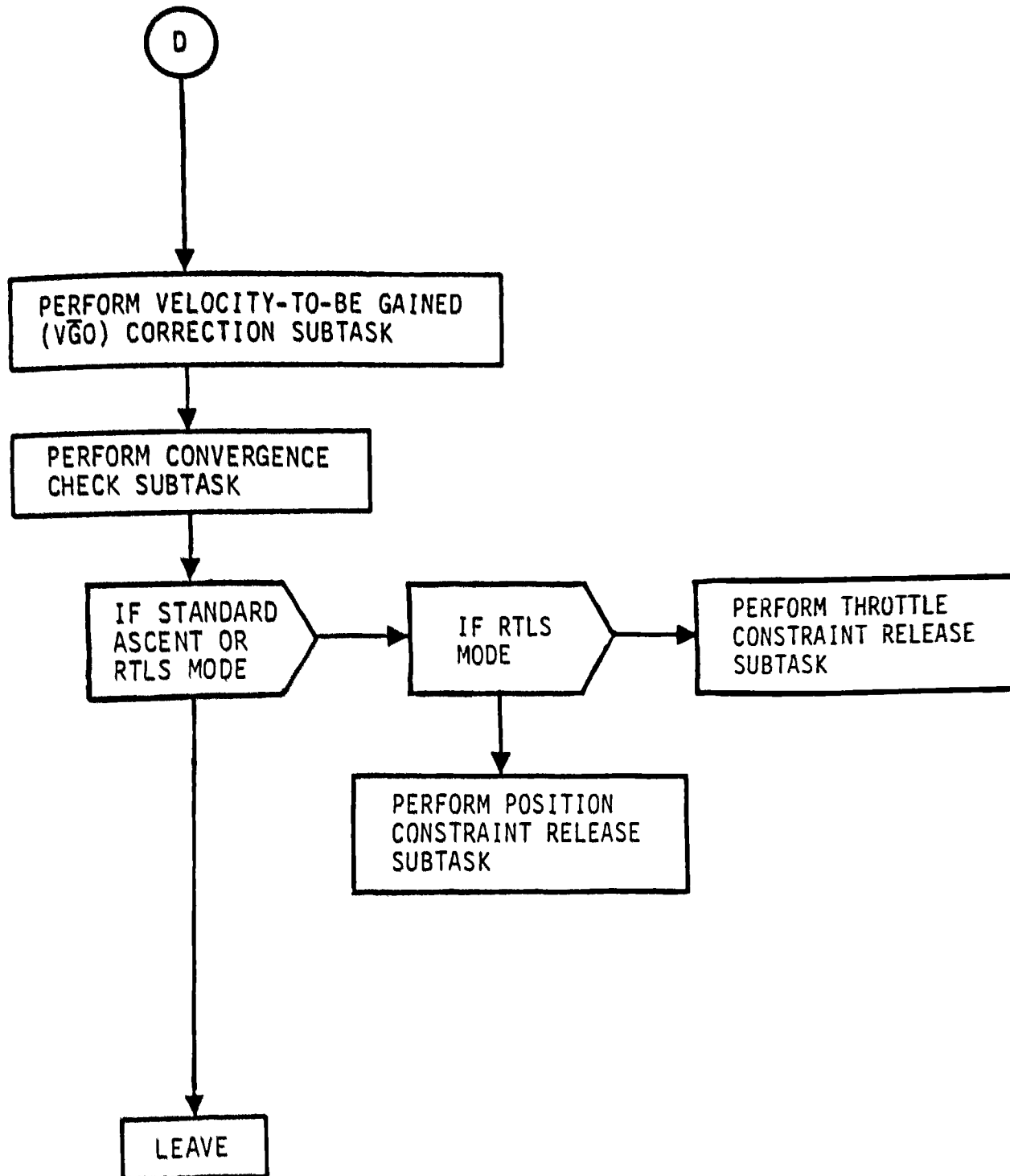


Figure 4.8.1-1. Powered Explicit Guidance Task Functional Flow (Sheet 5 of 5)

of 5)



either computed as the time remaining until a specified time, such as TFAIL; or until constant acceleration, AL, is achieved; or as a function of the computed first integral of thrust acceleration for that guidance phase, LA. In guidance phases where TB is a function of LA, LA is expressed as a function of the remaining VGO. Therefore, it is necessary to compute LA for each guidance phase to determine the remaining VGO for succeeding guidance phases.

The TGO parameter is a function of the current VGO, the equivalent exhaust velocity of the thrusting engines (VEX), and the current estimated acceleration (ATR). The first calculations for TGO are as follows:

- a. The calculation of the magnitude of the VGO vector:

$$VGOMAG = ABVAL(VGO)$$

- b. The calculation of the mass-to-mass flow rate ratio for the current phase:

$$TAU_{KPHASE} = VEX \cdot ATR$$

- c. The first element of the equivalent exhaust velocity array is set:

$$VEX_{KPHASE} = VEX$$

The elements of this equivalent exhaust velocity array are required by the thrust integrals subtask. If the TGO is being computed for an SSME maneuver, which may be distinguished by N\_SSME not equal to zero, then Subtasks 1 and 3 must be performed; otherwise, Subtasks 2 and 3 must be performed.

- (1) For an SSME maneuver, the last guidance phase is assumed to be constant acceleration and the other guidance phases are constant thrust.

If the current guidance phase is the first of two successive constant thrust phases (KPHASE = 1 and N = 3), the burn time of the first guidance phase is determined as the time remaining until TFAIL

$$TB_1 = TFAIL - TGD$$

where TGD is the current guidance time.

The next calculation required is for the thrust integral, LA, for this guidance phase.

$$LA_1 = -VEX (\text{LOG}(1 - TB_1 / TAU_1))$$



where LOG is a functional representation of the natural logarithm of the expression within the inner parentheses.

In addition to  $TB_1$  and  $LA_1$ , the initial mass-to-mass flow rate ratio for the second constant thrust guidance phase,  $TAU_2$ , is required. Assuming that the three SSME's are thrusting prior to the time TFAIL and that one SSME will fail at TFAIL, the mass-to-mass flow rate ratio for the second constant thrust guidance phase is:

$$TAU_2 = (K\_CMD/KMAX) (N\_SSME/2) (TAU_1 - TB_1)$$

Also, the second element of the equivalent exhaust velocity array is required:

$$VEXA_2 = VEX$$

Although a constant acceleration is assumed for the third thrust phase, it is sometimes possible to achieve the maneuver completion before the G-limiting (constant acceleration) constraint is encountered. Therefore, to ensure that TGO and, hence, guidance prediction are compatible with the actual vehicle performance, it is necessary to provide logic to account for this possibility. This is done by introducing a parameter, LREM, which is the sum of the thrust integrals  $LA_{N-1}$  and  $LA_N$  for the last two guidance phases. Specifically, whenever  $KPHASE = 1$  and  $N = 3$ , the remaining VGO is computed as follows:

$$LREM = VGOMAG - LA_1$$

Otherwise:

$$LREM = VGOMAG$$

For the next to last guidance phase,  $TB$  is a function of when the constant acceleration,  $AL$ , for G-limiting will be reached. This  $TB$  is computed by using the following equation:

$$TB_{N-1} = TAU_I - VEX/AL$$

where  $I = N-1$  for  $KPHASE < N$  and  $I = N$  for  $KPHASE = N$ . Since this equation is used for all values of  $KPHASE$ , logic to specify the value of  $I$  is necessary.

Whenever  $TB_{N-1}$  is less than or equal to a small positive constant,  $ETB$ , then the constant acceleration guidance phase has been reached. Therefore, to prevent computational problems, the burn time  $TB_{N-1}$  and the integral  $LA_{N-1}$  are set to zero.  $KPHASE$  is set to  $N$ , and the burn time  $TGOA_{N-1}$  is set to zero. However, if  $TB_{N-1}$  exceeds



- the value of ETB, the following equation is used to compute the integral:

$$LA_{N-1} = -VEX \text{ LOG}(1 - TB_{N-1}/TAU_I)$$

At this point, engine failure compensation logic is required. If an SSME fails during the constant acceleration guidance phase (when KPHASE = N), the value of  $TB_{N-1}$  will exceed ETB, a result indicating that the current guidance phase is no longer a constant acceleration phase. In this case, the value of KPHASE must be set to N-1, and the value of  $TAU_{N-1}$  is set to  $TAU_N$ .

Next, a comparison between LREM and  $LA_{N-1}$  is required. A value of LREM less than or equal to that of  $LA_{N-1}$  implies that the G-limiting constant acceleration guidance phase will not be reached. Therefore, the following equations apply:

$$LA_N = 0$$

$$TB_N = 0$$

$$LA_{N-1} = LREM$$

$$TB_{N-1} = TAU_I (1 - \text{EXP}(-LA_{N-1}/VEX))$$

where  $I = N-1$  whenever KPHASE < N, or  $I = N$  whenever KPHASE = N. On the other hand, a value of LREM greater than  $LA_{N-1}$  implies that the G-limiting (constant acceleration) guidance phase will be reached. In this case, the thrust integral  $LA_N$  and the burn time  $TB_N$  of this phase are computed as follows:

$$LA_N = LREM - LA_{N-1}$$

$$TB_N = LA_N/AL$$

The computations continue at Subtask 3.

- (2) This subtask is performed during the ascent and abort orbit insertion maneuvers. Typically, for these maneuvers, only the OMS engines are used. However, for some abort maneuvers, RCS translation jets are required to assist the OMS, which may require two distinct thrust phases for the maneuver.



If only one thrust phase is required (KPHASE = N), then the following calculations are required:

$$\begin{aligned} LA_N &= VGOMAG \\ VRATIO_N &= LA_N / (6 VEXA_N) \\ TB_N &= 6 TAU_N VRATIO_N / (1. + 3 VRATIO_N + 3 VRATIO_N^2) \end{aligned}$$

However, if two thrust phases are currently required (KPHASE < N), then the following calculations are required; an estimate of the burn time required to achieve VGOMAG during the first phase is calculated as

$$\begin{aligned} VRATIO_1 &= VGOMAG / (6 VEXA_1) \\ TB\_EST &= 6 TAU_1 VRATIO_1 / (1. + 3 VRATIO_1 + 3 VRATIO_1^2) \end{aligned}$$

If predicted cutoff time of the first thrust phase (TGD + TB\_EST) is greater than the assumed time to cut off the RCS jets (T\_RCS\_OFF), then the following calculations are required:

If (TGD + TB\_EST) > T\_RCS\_OFF, then

$$\begin{aligned} TB_1 &= T\_RCS\_OFF - TGD \\ LA_1 &= -VEX \text{ LOG}(1 - TB_1 / TAU_1), \\ VRATIO_1 &= LA_1 / (6 VEXA_1) \end{aligned}$$

and the parameters for the second thrust phase are calculated. Otherwise (TGD + TB\_EST ≤ T\_RCS\_OFF), the following calculations are required:

$$\begin{aligned} LA_1 &= VGOMAG \\ TB_1 &= TB\_EST \end{aligned}$$

and the parameters for the second thrust phase are calculated.

The second thrust phase parameters calculated are:

$$\begin{aligned} LA_2 &= VGOMAG - LA_1 \\ VEXA_2 &= FT\_OMS / MDOT\_OMS \\ TAU_2 &= (TAU_1 - TB_1) MDOT / (N\_OMS MDOT\_OMS) \\ VRATIO_2 &= LA_2 / (6 VEXA_2) \\ TB_2 &= 6 TAU_2 VRATIO_2 / (1. + 3 VRATIO_2 + 3 VRATIO_2^2) \end{aligned}$$

The computations continue at Subtask 3.

- (3) In addition to the burn time for each guidance phase, the thrust integrals calculations require the accumulated TB's at the end of each guidance phase. This is accomplished by summing the TB of each phase from phase I = KPHASE to N,

$$TGOA_I = \sum TB_{JJ}, \text{ where } JJ = KPHASE \text{ to } I$$

The range-to-go calculations require the previous value of TGO (TGOP), as well as the current value. Therefore, the TGO calculations must save the previous value of TGO before assigning a new value to the TGO parameter. The equations are given in the proper order as follows:

$$TGOP = TGO$$

$$TGO = TGOA_N$$

The final computation required in the TGO subtask is the predicted thrust cutoff time. It is computed as follows:

$$TP = TGD + TGO$$

5. Thrust Integrals Subtask. The purpose of this subtask is to evaluate various time integrals of force over mass. These integrals are necessary to the prediction equations of PEG.

On each pass, initial values of the integrals must be set to zero.

$$\begin{array}{lll} L = 0 & S = 0 & JOL = 0 \\ J = 0 & Q = 0 & \end{array}$$

The thrust integrals are calculated for I = KPHASE to N, where KPHASE is the current phase indicator and N is the maximum number of thrust phases. Prior to the calculation of the integrals, TGOB is set to zero when I = 1; otherwise, it is set to TGOA<sub>I-1</sub>. TGOA<sub>I-1</sub> is the cumulative TGO until the end of the I-1 thrust phase.

If N<sub>SSME</sub> ≠ 0 AND I < N, then the thrust integrals are calculated as follows:

$$SA_I = -LA_I (TAU_I - TB_I) + VEXA_I TB_I$$

$$QA_I = SA_I (TAU_I + TGOB) - 0.5 VEXA_I TB_I^2$$

Otherwise, the thrust integrals are calculated as follows:

$$SA_I = 0.5 LA_I TB_I$$

$$QA_I = SA_I (TGOB + TB_I/3)$$

Then, if N<sub>SSME</sub> = 0, SA<sub>I</sub> = SA<sub>I</sub> (1. - VRATIO<sub>I</sub>).



In these equations,  $\text{TAU}_I$  is defined to be the ratio of exhaust velocity for the  $I$ th phase ( $\text{VEXA}_I$ ) to thrust acceleration for the  $I$ th thrust phase.  $\text{TB}_I$  is defined to be the TB for the  $I$ th thrust phase.

The required integrals are summed over all thrust phases:

$$S = S + \text{SA}_I + L \text{TB}_I$$

$$Q = Q + \text{QA}_I + J \text{TB}_I$$

$$L = L + \text{LA}_I$$

$$J = J + \text{LA}_I \text{TGOA}_I - \text{SA}_I$$

If  $L$  is not equal to zero, then the quantity  $JOL$  is calculated as  $JOL = J/L$ . If  $L = 0$ , then PEG is exited.

The quantity  $(Q - S JOL)$  is used in several equations in other PEG subtasks. Therefore, for computation purposes, the following quantity will be defined here:

$$\text{QPRIME} = Q - S JOL$$

The final computation required of the thrust integrals is the time associated with the reference thrust vector expressed in GMT seconds:

$$\text{TLAM} = \text{TGD} + \text{JOL}$$

6. Reference Thrust Vector Subtask. The purpose of this subtask is to determine a reference thrust vector,  $\text{LAM}$ , for all guidance modes. This vector is a unit vector in the direction of  $\text{VGO}$ . In a computational flow,  $\text{VGO}$  will have been defined previously. The reference thrust vector is computed by setting  $\text{LAM} = \text{VGO}/\text{VGOMAG}$  provided that  $\text{VGOMAG} \neq 0$ . If  $\text{VGOMAG}$  is zero, then PEG is to be exited.
7. Range-to-Go Subtask. The purpose of this subtask is to compute the position-to-be-gained vector,  $\text{RGO}$ . To determine  $\text{RGO}$ , it is necessary to estimate the second integral of gravitational acceleration,  $\text{RGRAV}$ , over the powered trajectory. The current value is estimated from the previously determined value (last cycle value) as follows:

$$\text{RGRAV} = (\text{TGO}/\text{TGOP})^2 \text{RGRAV}$$

where  $\text{TGO}$  is the current  $\text{TGO}$  and  $\text{TGOP}$  is the  $\text{TGO}$  from the previous guidance cycle.

Next,  $\bar{RGO}$  is determined on the basis of the difference between the desired position,  $\bar{RD}$ , specified in the previous cycle, and a corresponding position on the current coasting trajectory ( $\bar{RGD} + (\bar{VGD})TGO + \bar{RGRAV}$ ), where  $\bar{VGD}$  is the current velocity vector:

$$\bar{RGO} = \bar{RD} - (\bar{RGD} + \bar{VGD} TGO + \bar{RGRAV}) + \bar{RBIAS}$$

where  $\bar{RBIAS}$  is a bias vector that compensates for the difference between  $\bar{RGO}$  and  $\bar{RTHRUST}$ , computed in the burnout state vector prediction subtask.

Next, if the guidance mode is RTLS (SMODE = 5), the unit normal which defines the desired crossrange component of the position-to-be-gained is computed and saved.

If SMODE = 5, then

$$\bar{IY} = \text{UNIT}(\bar{LAM} \times \bar{IX})$$

$$\bar{IY}_{TVR} = \bar{IY}$$

and if SALT = ON,  $\bar{OMEGA} = \text{LAMDY} (\bar{LAM} \times \bar{IY})$ .

Next, an  $\bar{RGO}$  vector to be used for unconstrained terminal position components is computed as follows:

$$\bar{RGOPRIME} = \bar{QPRIME} (\bar{OMEGA} \times \bar{LAM}) + S \bar{LAM}$$

During each cycle through this subtask, it is required to monitor the status of the altitude constraint switch, SALT. If SALT is ON, the radial component of the position-to-be-gained,  $\bar{RGOX}$ , is computed as the projection of  $\bar{RGO}$  onto the unit vector of the desired position:

$$\bar{RGOX} = \bar{RGO} \cdot \bar{IX}$$

However, if SALT is OFF, then altitude is unconstrained and  $\bar{RGOX}$  is computed by the following equation:

$$\bar{RGOX} = \bar{RGOPRIME} \cdot \bar{IX}$$

Likewise on each cycle, it is required to monitor the status of the orbit plane constraint switch, SPLANE. If SPLANE is ON, the cross-range component of position-to-be-gained,  $\bar{RGOY}$ , is computed as follows:

$$\bar{RGOY} = \bar{RGO} \cdot \bar{IY}$$

However, if SPLANE is OFF, then the orbit plane is unconstrained and  $\bar{RGOY}$  is computed as follows:

$$\bar{RGOY} = \bar{RGOPRIME} \cdot \bar{IY}$$



The Z component (downrange component) of the  $\bar{RGO}$  vector is always unconstrained in the PEG formulation and is selected so that the dot product of the vectors  $\bar{LAM}$  and  $\bar{RGO}$  are equivalent to the integral S.

This selection is made by first computing the  $\bar{RGO}$  projection in the X (radial) - Y (crossrange) plane by the equations:

$$\bar{RGOXY} = \bar{RGOX} \bar{IX} + \bar{RGOY} \bar{IY}$$

and then computing the downrange component of  $\bar{RGO}$  by the equation

$$\bar{RGOZ} = (S - \bar{LAM} \cdot \bar{RGOXY}) / (\bar{LAM} \cdot \bar{IZ})$$

where  $\bar{IZ} = \bar{IX} \times \bar{IY}$ .

Then the  $\bar{RGO}$  vector is reconstructed by the following equation:

$$\bar{RGO} = \bar{RGOXY} + \bar{RGOZ} \bar{IZ}$$

8. Turning Rate Vector Subtask. The purpose of this subtask is the calculation of thrust turning rate,  $\bar{LAM}$ , from  $\bar{RGO}$  and previously calculated integrals.

$$\bar{LAM} = (\bar{RGO} - S \bar{LAM}) / QPRIME$$

The magnitude of  $\bar{LAM}$  is next calculated as follows:

$$LAMD\text{MAG} = \text{ABVAL}(\bar{LAM})$$

Then the maximum allowable value of  $LAMD\text{MAG}$  is computed as follows:

$$LAMD\text{MAX} = \text{MIN}(\text{PHIDOT\_MAX}, (0.5 + \text{PHI}) / \text{JOL})$$

If  $LAMD\text{MAG}$  is greater than  $LAMD\text{MAX}$ , it is set equal to this limiting value.

$$LAMD\text{MAG} = LAMD\text{MAX}$$

and the vectors  $\bar{LAM}$  and  $\bar{RGO}$  must be recomputed, with the limited  $LAMD\text{MAG}$ , as follows:

$$\bar{LAM} = LAMD\text{MAG} \text{UNIT}(\bar{LAM})$$

$$\bar{RGO} = S \bar{LAM} + QPRIME \bar{LAM}$$

In addition, the guidance convergence flag,  $S\dot{CONV}$ , is set to OFF.

If  $LAMD\text{MAG}$  is less than or equal to  $LAMD\text{MAX}$ ,  $S\dot{CONV}$  is set to ON.

The value of  $\text{PHI}$  is finally updated

$$\text{PHI} = \text{JOL} LAMD\text{MAG}$$



9. Steering Inputs Update Subtask. The purpose of this subtask is to provide new steering inputs to the G/C steering interface principal function.

The steering parameters are updated only when the following conditions are met:  $S\dot{S}TEER = ON$  and the predicted cutoff time change is sufficiently small ( $ABS(TP-TPREV) \leq EPSTGO TGO$ ), or  $S\dot{M}ODE = 7$ . An additional requirement for the standard ascent mode ( $S\dot{M}ODE = 1$ ) is that  $M EXP(-VGOMAG/VEX) > MASS\_MIN$ . If these conditions are met, then set

$$\bar{L}AMC = \bar{L}AM$$

$$\bar{L}AMDC = \bar{L}AMD$$

$$TLAMC = TLAM - TGMTLO$$

$$S\_GDRDY = ON$$

These parameters are a time-homogeneous set. Whether the steering inputs are updated or not, set

$$TPREV = TP$$

The initial value of  $TPREV$  is set to zero.

10. Burnout State Vector Prediction Subtask. The purpose of this subtask is to calculate the first integral of thrust and first and second time integrals of gravity as required in the prediction of the burnout state vector. The nature of the PEG design allows these integrals to be evaluated separately. The gravity integrals are functions of the thrust integrals, which implies that the thrust integrals must be computed first.

The thrust time integrals are obtained by calculating the thrust time integrals of each thrust phase and then summing up the contributions of each phase. The procedure is as follows:

- a. If the guidance mode is not ascent or RTLS, then  $\bar{R}THRUST$  is set equal to  $\bar{R}GO$ ,  $\bar{V}THRUST$  is computed as follows, and Items b and c are not executed.

If  $S\dot{M}ODE \neq 1$  and  $S\dot{M}ODE \neq 5$ , then

$$\bar{R}THRUST = \bar{R}GO$$

$$\bar{V}THRUST = (L + .5 QPRIME LAMDMAG^2) \bar{L}AM$$

Proceed to Item d.

- b. On each pass, initial values of the thrust time integrals must be set to zero

$$\bar{R}THRUST = 0$$

$$\bar{V}THRUST = 0$$

and the following parameters are computed

$$TI = -JOL$$

$$IF\_MAG\_I = \text{SQRT}(1 + \text{LAMD}MAG^2 TI^2)$$

- c. The following computations are executed for  $I = KPHASE$  to  $JJ$ , where  $JJ = N$  for  $LA_N$  nonzero and  $JJ = (N-1)$  for  $LA_N = 0$ .  $N$  is the maximum number of thrust phases and  $LA_N$  was computed in the TGO subtask.

$$(1) TF = TI + TB_I$$

$$IF\_MAG\_F = \text{SQRT}(1 + \text{LAMD}MAG^2 TF^2)$$

$$\bar{R}THRUST = \bar{R}THRUST + \bar{V}THRUST TB_I$$

- (2) To prevent computational problems if the thrusting arc of the current thrust phase is small, the following computations are executed and Parts 3 through 6 are bypassed.

If  $(\text{LAMD}MAG TB_I) < 0.090$ , then

$$TFMEANSQ = \text{ABS}(TF^2 + TI TF + TI^2) / 3$$

$$SMA\_GAIN = 1 / \text{SQRT}(1 + TFMEANSQ \text{LAMD}MAG^2)$$

$$\begin{aligned} \bar{R}THRUST &= \bar{R}THRUST + SMA\_GAIN (SA_I \bar{L}AM \\ &\quad + (QA_I - SA_I JOL) \bar{L}AMD) \end{aligned}$$

$$\begin{aligned} \bar{V}THRUST &= \bar{V}THRUST + SMA\_GAIN (LA_I \bar{L}AM \\ &\quad + (LA_I TGOA_I - SA_I - LA_I JOL) \bar{L}AMD) \end{aligned}$$

Proceed to Part 7.

- (3) If  $I = N$  then the constants B and C are set equal to zero and A is set equal to the I-load AL. If I is not equal to N, then the constants A, B, and C are computed as follows:

$$C = 60(.5 TB_I^2 LA_I + 3 TI SA_I - 3(QA_I - SA_I JOL)) / TB_I^5$$

$$B = 12(.5 TB_I LA_I - SA_I) / TB_I^3 - C (TF + TI)$$

$$A = LA_I TB_I - .5 B (TF + TI) - C (TB_I^2 / 3 + TI TF)$$

$$(4) \quad Y_1 = \text{LOG}[\text{ABS}((\text{TF LAMDMAG} + \text{IF\_MAG\_F}) / (\text{TI LAMDMAG} + \text{IF\_MAG\_I}))] / \text{LAMDMAG}$$

$$Y_2 = (\text{TF}^2 - \text{TI}^2) / (\text{IF\_MAG\_I} + \text{IF\_MAG\_F})$$

(5) The following two equations are executed for  $X = 1$  to 3

$$Y_{(X+2)} = [\text{IF\_MAG\_F} (\text{TF})^X - \text{IF\_MAG\_I} (\text{TI})^X - X Y_X] / ((X+1) \text{LAMDMAG}^2)$$

$$M_X = A Y_X + B Y_{(X+1)} + C Y_{(X+2)}$$

$$(6) \quad \bar{R}\text{THRUST} = \bar{R}\text{THRUST} + (\text{TF } M_1 - M_2) \bar{L}\text{AM} \\ + (\text{TF } M_2 - M_3) \bar{L}\text{AMD}$$

$$\bar{V}\text{THRUST} = \bar{V}\text{THRUST} + M_1 \bar{L}\text{AM} + M_2 \bar{L}\text{AMD}$$

$$(7) \quad \text{TI} = \text{TF}$$

$$\text{IF\_MAG\_I} = \text{IF\_MAG\_F}$$

d.  $\bar{R}\text{BIAS}$  is computed

$$\bar{R}\text{BIAS} = \bar{R}\text{GO} - \bar{R}\text{THRUST}$$

The technique used to approximate the gravity integrals is one that utilizes a coasting trajectory which remains close to the powered trajectory throughout the maneuver to predict the gravity effects. The integrals of gravity can be determined in a straightforward manner from a state extrapolation routine.

The equations for the initial state vector input to the state extrapolation routine are functions of the current guidance state vector,  $\bar{R}\text{GD}$  and  $\bar{V}\text{GD}$ , and the thrust integrals,  $\bar{R}\text{THRUST}$  and  $\bar{V}\text{THRUST}$ . These equations are given as follows:

$$\bar{R}\text{INIT} = \bar{R}\text{GD} - 0.1 \bar{R}\text{THRUST} - \bar{V}\text{THRUST TGO}/30$$

$$\bar{V}\text{INIT} = \bar{V}\text{GD} + (1.2 \bar{R}\text{THRUST}/\text{TGO}) - 0.1 \bar{V}\text{THRUST}$$

A navigation principal function, ASC PREC PRED, will be utilized to determine the desired gravity integrals over the powered flight time, TGO. The inputs to the ASC PREC PRED are the initial position vector ( $\bar{R}\text{INIT}$ ), the initial velocity vector ( $\bar{V}\text{INIT}$ ), the initial time ( $\text{T\_INIT} = \text{TGD}$ ), the final time ( $\text{T\_FINAL} = \text{TP}$ ), the gravity model degree flag (CMD\_PRED), the gravity model order flag (CMD\_PRED) (both set to zero for central body force only), and the desired integration step size (DT\_MAX). For this purpose, DT\_MAX is selected as the middle value DT\_LIMIT, DTMIN, and TGO/NSEG, where NSEG is desired number of integration segments.

$$\text{DT\_MAX} = \text{MIDVAL}(\text{DT\_LIMIT}, \text{DTMIN}, \text{TGO}/\text{NSEG})$$



The outputs of ASC PREC PRED used by PEG are the final position vector ( $\bar{R}_{FINAL}$ ) and the final velocity vector ( $\bar{V}_{FINAL}$ ).

After the extrapolated position and velocity vectors are obtained, the first and second gravity integrals may then be evaluated. The following equations are, by definition, the gravity integrals over a coasting trajectory and represent the requirements for gravity estimation:

$$\bar{V}_{GRAV} = \bar{V}_{FINAL} - \bar{V}_{INIT}$$

$$\bar{R}_{GRAV} = \bar{R}_{FINAL} - \bar{R}_{INIT} - \bar{V}_{INIT} TGO$$

After integrals of both thrust and gravity have been computed, the predicted terminal state vector is then computed by the following equations:

$$\bar{R}_P = \bar{R}_{GD} + \bar{V}_{GD} TGO + \bar{R}_{GRAV} + \bar{R}_{THRUST}$$

$$\bar{V}_P = \bar{V}_{GD} + \bar{V}_{GRAV} + \bar{V}_{THRUST}$$

11. Desired Orbit Plane Correction Subtask. The purpose of this subtask is to constrain the position ( $\bar{R}_D$ ) to be in a desired orbit plane whenever  $SPLANE = ON$  or to allow the position to remain in the predicted cutoff orbit plane whenever  $SPLANE = OFF$ .

To constrain the position to lie in a desired orbit plane ( $SPLANE = ON$ ), the following equation is required:

$$\bar{R}_D = \bar{R}_P - (\bar{R}_P \cdot \bar{I}_Y) \bar{I}_Y$$

where  $\bar{I}_Y$  is the unit vector normal to the desired orbit plane.

However, to allow the desired position to remain in the predicted cutoff plane ( $SPLANE = OFF$ ), the following equation is required:

$$\bar{R}_D = \bar{R}_P$$

12. Desired Position Subtask for Standard Ascent and RTLS. The purpose of this subtask is to correct the magnitude of the burnout position vector when cutoff altitude is being controlled ( $SALT = ON$ ) for the standard ascent mode and to compute a unit vector of the burnout position vector in either case. The unit vector is computed as follows:

$$\bar{I}_X = \text{UNIT}(\bar{R}_D)$$

Whenever  $SALT = ON$ , the position vector is corrected by the following equation:

$$\bar{R}_D = RDMAG \bar{I}_X$$

where  $RDMAG$  is the desired magnitude of the burnout position vector.

Whenever  $SALT = OFF$ , the above  $\bar{R}_D$  equation is not executed.

13. Desired Position Subtask for LTVCON Mode. There is no altitude constraint on the burnout position vector for this guidance mode. Therefore, the only calculation this subtask must perform is to compute the unit vector of the desired position:

$$\bar{I}X = \text{UNIT}(\bar{R}D)$$

where  $\bar{R}D$  is determined by the desired orbit plane correction subtask (11).

14. Desired Plane Subtask for RTLS. The purpose of this subtask is to calculate the vector normal to the desired cutoff plane,  $\bar{I}Y$ . This vector is used to specify the heading of the velocity vector at cutoff. First, the HAC center vector,  $\bar{R}TEF$ , is transformed from earth-fixed coordinates at the predicted time at the beginning of the powered pitchdown maneuver (TP), to M50 coordinates. The EARTH\_FIXED\_TO\_M50\_COORD task is a functional representation of the required transformation at a reference time.

$$\bar{R}T = \text{EARTH\_FIXED\_TO\_M50\_COORD}(TP) \bar{R}TEF$$

Next, the HAC center position vector is corrected by the radius of the alignment circle.

$$\bar{R}T = \bar{R}T - (\text{YSGNP\_RADIUS\_NEP} + \text{ET\_BIAS}) \text{UNIT}(\bar{R}T \times \bar{R}P)$$

The  $\bar{I}Y$  vector is normal to the plane defined by the corrected aim point vector and predicted cutoff vector

$$\bar{I}Y = \text{UNIT}(\bar{R}T \times \bar{R}P)$$

In addition, if this is an RTLS abort (SMODE = 5) and the altitude constraint switch is ON (SALT = ON), then the following computations are executed to determine the desired out-of-plane thrust vector turning rate (LAMDY) to zero the PPD sideslip angle:

$$\text{LAMDYJOL} = [(\bar{L}AM + (\text{TGO} - \text{JOL}) \bar{L}AMD) \cdot \bar{I}Z] \text{TAN}[-(\text{SIGN}(\bar{L}AM \cdot \bar{I}Y)) \\ (\text{ARCCOS}(\bar{I}Y_{\text{TVR}} \cdot \bar{I}Y))]$$

$$\text{LAMDY} = (\text{DTRD}/\text{TGO})(\text{LAMDYJOL}/(\text{TGO} - \text{JOL}))$$

where the vectors  $\bar{I}Y_{\text{TVR}}$  and  $\bar{I}Z$  were computed in the range-to-go subtask.

15. Desired Velocity Subtask for Standard Ascent. This subtask calculates the PEG standard ascent desired velocity vector,  $\bar{V}D$  from  $\bar{V}DMAG$ , the desired velocity magnitude, and  $\bar{G}AMD$ , the desired flight path angle.
- a. If a TAL is in progress ( $\bar{T}AL\_ABORT\_DECLARED = \text{ON}$ ),  $\bar{V}DMAG$  must be computed as a function of the surface range,  $\bar{R}THETA$ , between

predicted cutoff and an aim point vector,  $\overline{RT}$ , associated with the TAL landing site vector in earth-fixed coordinates,  $\overline{RTEF}$ , at the predicted cutoff time, TP. Additionally, the targeted orbit plane defined by  $\overline{IY}$  is set equal to the current orbit plane defined by the current position and velocity vectors. If the calculated crossrange based on the current TAL  $\overline{IY}$  and TAL aim point,  $\overline{RT\_AIM}$ , exceeds the maximum allowed crossrange (CR\_MAX), the TAL M50 aim point is adjusted so that the crossrange will equal CR\_MAX, and a new  $\overline{IY}$  is defined so that the target plane passes through the new  $\overline{RT\_AIM}$ . Using the EARTH\_FIXED\_TO\_M50\_COORD task,

$$\overline{RT} = \text{EARTH\_FIXED\_TO\_M50\_COORD}(TP) \overline{RTEF}$$

The surface range is computed by

$$R\theta = \text{ABVAL}(\overline{RTEF}) \text{ARCCOS}[\overline{IX} \cdot \text{UNIT}(\overline{RT})]$$

VDMAG is a cubic function of this range defined by

$$VDMAG = A_8 + A_9 R\theta + A_{10} R\theta^2 + A_{11} R\theta^3$$

This value is then limited between a minimum, VD\_TAL\_MIN, and a maximum, VD\_TAL\_MAX

$$VDMAG = \text{MIDVAL}(VD\_TAL\_MIN, VDMAG, VD\_TAL\_MAX)$$

Set SPLANE = OFF and calculate the time, measured from MECO, of closest approach to the TAL aim point, which is approximated by

$$T_{CA} = R\theta / VDMAG$$

The TAL M50 aim point at  $T_{CA}$  is calculated by

$$\overline{RT\_AIM} = \text{EARTH\_FIXED\_TO\_M50\_COORD}(TP + T_{CA}) \overline{RTEF}$$

The current TAL  $\overline{IY}$  is calculated as follows

$$\overline{IY} = \text{UNIT}(\overline{VGD} \times \overline{RGD})$$

The current crossrange is

$$CRNG\_D = \overline{RT\_AIM} \cdot \overline{IY}$$

If the absolute value of CRNG\_D is greater than CR\_MAX, do the next three operations:

$$(1) \quad \overline{IY} = \text{UNIT}(\overline{VP} \times \overline{RP})$$

Adjust the TAL aim point for the maximum allowed crossrange

$$(2) \quad \overline{RT\_AIM} = \overline{RT\_AIM} - \overline{IY} \text{CR\_MAX} \text{SGN}(CRNG\_D)$$



The new target  $\bar{IY}$  is then calculated by

$$(3) \quad \bar{IY} = \text{UNIT}(\bar{RT\_AIM} \times \bar{RP})$$

- b. If a TAL is not in progress ( $\bar{TAL\_ABORT\_DECLARED} = \text{OFF}$ )  $\bar{VDMAG}$  and  $\bar{IY}$  remain at the value set previously from I-loads.
- c. The desired velocity vector is calculated from the following equation:

$$\bar{VD} = \bar{VDMAG} [\bar{IX} \text{ SIN}(\bar{GAMD}) + \text{UNIT}(\bar{IX} \times \bar{IY}) \text{ COS}(\bar{GAMD})]$$

- d. Finally, if  $\bar{SPLANE} = \text{OFF}$ ,  $\bar{IY}$  is recomputed as follows:

$$\bar{IY} = \text{UNIT}(\bar{VD} \times \bar{RD})$$

16. Desired Velocity Subtask for the LTVCON Mode. The desired velocity subtask for this guidance mode employs the LTVCON task (Section 4.8.4) which solves the required velocity at an initial position to intercept a target position so that a specified linear relationship between the terminal radial and horizontal velocity components is satisfied:

$$V_{\text{RADIAL}} = C_1 + C_2 V_{\text{HORIZONTAL}}$$

The initial position input to the LTVCON function is the desired cutoff position ( $\bar{RD}$ ).

The targeting for the OMS ascent maneuvers places the target position vector be in the predicted orbital plane at OMS ignition. However, the guidance logic for the LTVCON mode does not require the burnout orbit plane to be constrained. Therefore, the target position vector will be projected onto the predicted cutoff plane by the following equation:

$$\bar{R1} = \bar{RT} - (\bar{RT} \cdot \bar{IY}) \bar{IY}$$

where  $\bar{IY}$  is first computed as follows:

$$\bar{IY} = \text{UNIT}(\bar{VP} \times \bar{RP})$$

The vectors  $\bar{IY}$  and  $\bar{R1}$  are input to the LTVCON TSK and the outputs of the LTVCON task used by PEG are desired velocity ( $\bar{VD}$ ), magnitude of desired cutoff position ( $\bar{RO\_MAG}$ ), horizontal velocity at the target ( $\bar{VH1}$ ), and the resulting transfer angle ( $\bar{THETA}$ ) and its trigonometric sine ( $\bar{SIN\_THETA}$ ).



Next, a scalar damping factor, RHOMAG, is required in the computation of VGO (refer to VGO correction subtask). It is computed by the following equations:

$$DTCOAST = THETA/THETA\_DOT$$

$$RHOMAG = 1/[1 + 0.75 TGO/DTCOAST]$$

$\bar{I}Y$  is then recomputed as follows:

$$\bar{I}Y = \text{UNIT}(\bar{V}D \times \bar{R}D)$$

Finally, the ideal turning rate of the  $\bar{L}AM$  vector is computed as follows:

$$\bar{O}MEGA = -WMAG \bar{I}Y$$

17. Desired Velocity Subtask for RTLS. This subtask calculates the PEG RTLS desired velocity,  $\bar{V}D$ . The magnitude of this velocity vector is calculated as a function of the surface range between predicted cutoff and the aim point vectors. The heading of this vector is determined by the  $\bar{I}Y$  previously calculated.

The surface range is calculated as follows:

$$RTHETA = \text{SGN}(\bar{I}Y \cdot \bar{I}Y\_SAVE) \text{ABVAL}(\text{RTMAG } \bar{I}X - \bar{R}T) + D\_ARC - X\_NEP$$

where SGN produces +1, 0, -1 when  $(\bar{I}Y \cdot \bar{I}Y\_SAVE)$  is positive, zero, or negative, respectively.

If RTHETA is less than a predetermined value (RNG\_TURN\_PRED), then the discrete SINIT is set to ON and the discrete SCONV is set to OFF. During the early portion of the fuel dissipation phase, it may not be possible to obtain a reasonable guidance solution because the Shuttle is too close to the specified landing site. Hence, a test is required to prevent PEG from attempting to solve for a solution when the surface range (RTHETA) is below a predetermined minimum value (RNG\_TURN\_PRED).

If  $RTHETA < \text{RNG\_TURN\_PRED}$ , then  $\text{SINIT} = \text{ON}$ ,  $\text{SCONV} = \text{OFF}$

The velocity magnitude is a linear function of range. One range velocity line is required for a two-engine ( $N\_SSME = 2$ ) RTLS and another for a three-engine ( $N\_SSME = 3$ ) RTLS. When an engine fails during RTLS, if TGO is greater than TGO\_IA, a new target line will be selected.

If  $TGO > TGO\_IA$ , then

$$IA = (2 N\_SSME) - 2$$

If  $N\_SSME = 1$ , then

$$IA = 2$$

Otherwise (if  $TGO \leq TGO_{IA}$ ), IA retains its previous value. Then the desired velocity magnitude is computed as a function of the surface range and the selected target line:

$$VDMAG = A_{IA-1} + A_{IA} RTHETA$$

The desired relative velocity vector is

$$\bar{V}_D = VDMAG [\bar{I}_X \sin(GAMD) + \text{UNIT}(\bar{I}_X \times \bar{I}_Y) \cos(GAMD)]$$

Since the desired velocity from the above equation is earth-relative, the target is made inertial by adding a term earth rate ( $\bar{W}_E$ ) crossed into the desired position ( $\bar{R}_D$ ).

$$\bar{V}_D = \bar{V}_D + \bar{W}_E \times \bar{R}_D$$

Finally,  $\bar{I}_Y$  is recomputed as follows:

$$\bar{I}_Y = \text{UNIT}(\bar{V}_D \times \bar{R}_D)$$

18. RHO Matrix Subtask for RTLS. The purpose of this subtask is to calculate a partial derivatives matrix that relates the change in VGO ( $\bar{D}VGO$ ) and throttle setting, K, to the velocity miss,  $\bar{V}MISS$ , and the characteristic velocity error,  $VGO\_ERR$ . This matrix is required to minimize the number of convergence iterations for the RTLS flyback. The following calculations are made to form the RHO matrix.

- a. Calculate the matrix to transform elements to the guidance coordinate system and perform the transformation:

$$\bar{I}_Z = \bar{I}_X \times \bar{I}_Y$$

$$MI_2G^* = \text{MATRIX}(\bar{I}_X, \bar{I}_Y, \bar{I}_Z)$$

$$VMISS\_G = MI_2G^* (\bar{V}_P - \bar{V}_D)$$

$$LAM\_G = MI_2G^* LAM$$

- b. Calculate terminal acceleration and intermediate elements of the RHO matrix:

$$ATRF = \text{MIN}(\text{SCALAR}(AL, \text{ATR EXP}(VGOMAG/VEX)))$$

ATRF is limited to the value of the acceleration limit, AL; then compute

$$VGRAVX = VGRAV \cdot \bar{I}_X$$

$$BETA1 = 1 + A_{IA} [TGO/2 + ((\bar{V}_D + 0.5 \bar{V}_GO) \cdot \bar{I}_Z) LAM\_G_3 / ATRF]$$

$$BETA2 = 1 + VGRAVX LAM\_G_1 / (ATRF TGO)$$



$$\text{BETA3} = 1 + \text{VDMAG TGO}/(2 \text{RTHETA})$$

$$\text{BETA4} = \text{K}/(\text{VGRAVX LAM}_G1)$$

- c. Calculate the  $\text{RHO1}$  AND  $\text{P\_RHO}$  vector elements and the desired throttle setting.

$$\text{RHO1} = \text{VECTOR}(0, -\text{LAM}_G2/\text{BETA3}, -\text{LAM}_G3/\text{BETA1})/\text{LAM}_G1$$

$$\text{P\_RHO} = \text{BETA4 VECTOR}(\text{LAM}_G1, \text{LAM}_G2 \text{BETA2}/\text{BETA3}, \text{LAM}_G3/\text{BETA1})$$

$$\text{BETA5} = \text{P\_RHO} \cdot \text{VMISS}_G$$

$$\text{KP} = \text{K}$$

If  $\text{STHROT} = \text{ON}$ , then

$$\text{VGO\_ERR} = \text{VGOMAG} - \text{VGOD}$$

$$\text{DELK} = \text{BETA5} - \text{BETA4 BETA2 VGO\_ERR}$$

$$\text{DELK} = \text{SIGN}(\text{DELK}) \text{MIN}(2, \text{ABS}(\text{DELK}))$$

$$\text{K} = \text{MIDVAL}(\text{KMAX}, \text{KMIN}, \text{KP} + \text{DELK})$$

- d. Update the characteristic velocity error to be consistent with the throttle change applied.

$$\text{DELK} = \text{K} - \text{KP}$$

$$\text{VGO\_ERR} = (\text{BETA5} - \text{DELK})/(\text{BETA4 BETA2})$$

- e. Calculate the change in velocity-to-be-gained and transform it to the M50 system.

$$\text{DVGO}_G = -\text{VECTOR}(\text{RHO1} \cdot \text{VMISS}_G + \text{VGO\_ERR}/\text{LAM}_G1, \text{VMISS}_G2/\text{BETA3}, \text{VMISS}_G3/\text{BETA1})$$

$$\text{DVGO} = \text{MI2G}^T \text{DVGO}_G$$

19. VGO Correction Subtask. The purpose of this subtask is to calculate a miss in velocity,  $\text{VMISS}$ , and a delta VGO vector ( $\text{DVGO}$ ), and to correct the VGO vector ( $\text{VGO}$ ). The velocity miss vector is computed as follows:

$$\text{VMISS} = \bar{\text{V}}\text{P} - \bar{\text{V}}\text{D}$$

The delta VGO vector for all PEG modes except RTLS is computed as follows:

$$\text{DVGO} = -\text{RHOMAG VMISS}$$

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For RTLS, it is computed in the RHO matrix subtask.

The VGO vector,  $\bar{VGO}$ , is corrected as follows:

$$\bar{VGO} = \bar{VGO} + D\bar{VGO}$$

In addition, if SMODE = 4, the component of  $\bar{VGO}$  normal to the predicted cutoff plane must be corrected as follows:

- a. If the current vehicle mass (M) is less than or equal to the desired minimum burnout mass (MBO), then there is no propellant margin, and no additional out-of-plane thrusting should occur. Hence, proceed to Subtask 20.
- b. Compute the present out-of-plane component of  $\bar{VGO}$ , the inplane VGO vector, and the square of the magnitude of the in-plane VGO vector.

$$VGOYP = \bar{VGO} \cdot \bar{IY}$$

$$\bar{VGOXZ} = \bar{VGO} - VGOYP \bar{IY}$$

$$VGOXZ\_SQ = \bar{VGOXZ} \cdot \bar{VGOXZ}$$

- c. Compute the square of the required velocity change to deplete the propellant margin, based on current vehicle mass (M) and the desired minimum burnout mass (MBO).

$$VGOMAX\_SQ = (VEX \text{ LOG}(M/MBO))^2$$

If VGOMAX\_SQ is less than VGOXZ\_SQ, then set VGOMAX\_SQ to VGOXZ\_SQ.

$$VGOMAX\_SQ = VGOXZ\_SQ$$

- d. Compute the square of the maximum allowable out-of-plane velocity component

$$VGOYMAX\_SQ = VGOMAX\_SQ - VGOXZ\_SQ$$

- e. Estimate the velocity miss resulting from the difference between the desired and predicted orbital planes. If the major mode is 104, the velocity miss is defined as

$$VMISSY = VH1 (\bar{IY\_DES} \cdot \bar{R1}) / (RO\_MAG \text{ SIN\_THETA})$$

If the major mode is 105

$$VMISSY = \bar{VD} \cdot \bar{IY\_DES}$$

- f. Compute the magnitude of the desired out-of-plane velocity component.

$$VGOY = VGOYP - RHOMAG VMISSY$$



- g. If the square of VGOY is greater than VGOYMAX\_SQ, then limit the magnitude of VGOY to that of VGOYMAX\_SQ

If  $(VGOY^2 > VGOYMAX\_SQ)$ , then

$$VGOY = SIGN(VGOY) SQRT(VGOYMAX\_SQ)$$

- h. Correct  $\bar{VGO}$

$$\bar{VGO} = \bar{VGOXZ} + VGOY \bar{IY}$$

- i. Update  $\bar{VMISS}$  so that it is consistent with the new  $\bar{VGO}$

$$\bar{VMISS} = \bar{VMISS} + ((VGOYP - VGOY)/RHOMAG) \bar{IY}$$

20. Convergence Check Subtask. The purpose of this subtask is to determine if the  $\bar{VGO}$  is converged and to generate a flag ( $\dot{S}CONV$ ) indicating whether or not  $\bar{VGO}$  is converged. This is accomplished by the following steps:

- a. Compute the magnitude of  $\bar{VGO}$  and the convergence criterion as follows:

$$VGOMAG = ABVAL(\bar{VGO})$$

$$EMISS = KMISS VGOMAG$$

- b. Determine whether or not  $\bar{VGO}$  is converged.

If  $ABVAL(\bar{VMISS}) > (EMISS)$ , then the guidance convergence flag ( $\dot{S}CONV$ ) is set to OFF.

- c. If the initialization flag ( $\dot{S}INIT$ ) is OFF and SMODE is equal to either 1 or 5, then the number of successive converged and unconverged PEG cycles is monitored by incrementing the counter SCOUNT as follows:

- (1) Store the previous value of DSCOUNT (initialized to zero)

$$DSCOUNT\_PREV = DSCOUNT$$

- (2) Determine the new value of DSCOUNT.

If  $\dot{S}CONV$  is OFF,  $DSCOUNT = 1$ ,

Otherwise  $DSCOUNT = -1$



## (3) Update SCOUNT

If DSCOUNT = DSCOUNT\_PREV, then  
 SCOUNT = MIDVAL(1, (SCOUNT + DSCOUNT),  
 NMAX\_CYCLES\_UNCONV)

If (DSCOUNT is not equal DSCOUNT\_PREV),  
 then SCOUNT = TCOUNT

- (4) If SCOUNT is equal to the I-load NMAX\_CYCLES\_UNCONV, then TCOUNT is set equal to NMAX\_CYCLES\_UNCONV and the flag S\_UNCONV is set to ON to cue the ADI PROC to stow the ADI error needles. If SCOUNT is equal to unity (1), then TCOUNT is set equal to 1 and the flag S\_UNCONV is set to OFF.

If SCOUNT = NMAX\_CYCLES\_UNCONV,  
 TCOUNT = NMAX\_CYCLES\_UNCONV, S\_UNCONV = ON

If SCOUNT = 1, TCOUNT = 1, S\_UNCONV = OFF

21. Throttle Constraint Release Subtask. When the burn time of the N-1 phase,  $TE_{N-1}$ , is  $\leq$  DTHROT (an I-load) and SCONV = ON, or if  $TE_{N-1} < (DTHROT - 10)$  and SINIT is OFF, then the throttle discrete is set to OFF (STHROT = OFF) and the desired throttle setting is set equal to the rounded value of the current value of K:

$$K = \text{ROUND}(K)$$

22. Cutoff Position Constraint Release Subtask. For reasons of flight control stability near cutoff, there is a guidance requirement to release position constraints at a fixed input TGO (DTRD). Therefore, if either altitude (SALT = ON) or the orbital plane (SPLANE = ON) is being constrained and if TGO is less than DTRD and VGO is converged (SCONV = ON), the position constraints are released. If VGO is unconverged when TGO first becomes less than DTRD and remains unconverged on subsequent cycles, the position constraints will be released when TGO becomes less than DTRD-6 and the PEG initialization discrete (SINIT) is OFF.

The position constraint release logic is as follows:

If (SALT = ON or SPLANE = ON)

and ((if either SCONV = ON and TGO < DTRD)

or (TGO < DTRD - 6 and SINIT = OFF))

then proceed as follows:

$$\bar{\Omega} = \bar{\Lambda} \times \bar{\Lambda} \text{MD}$$

$\dot{S}ALT = OFF$  $\dot{S}PLANE = OFF$ 

B. Interface Requirements. The input and output parameters and functional interfaces for the ascent PEG task are given in Tables 4.8.1-1 and 4.8.1-2. During OPS-9 and MM 101, the I-loaded vector IYD can be updated via uplink as part of the launch targeting data set (OP Code 0001111). Replacement of the original I-load vector with uplinked values will be transparent to the flight software.

C. Processing Requirements. In each cycle through the PEG calculations, the first operation is performing the position magnitude subtask (1). If the current cycle is the first pass through the PEG calculations, the initialization subtask described in the initialization requirements (Part D) must then be performed. However, if the current cycle is not the first pass, the VGO update subtask must be performed instead. The PEG processing must then proceed as described below. The applicable subsection number is shown in parentheses beside each required subtask.

The subtasks for the standard ascent mode (SMODE = 1) must be performed in the following order:

1. Position magnitude subtask (A-1).
2. Initialization subtask (D-1 and D-2; initial pass only, i.e., SINIT = ON).
3. VGO update subtask (A-3, except for the initialization pass)
4. TGO subtask (A-4)
5. Thrust integrals subtask (A-5)
6. Reference thrust vector subtask (A-6)
7. Range-to-go subtask (A-7)
8. Turning rate vector subtask (A-8)
9. Steering inputs update subtask (A-9)
10. Burnout state vector prediction subtask (A-10)
11. Desired orbit plane correction subtask (A-11)
12. Desired position subtask for standard ascent and RTLS (A-12)
13. Desired velocity subtask for standard ascent (A-15)
14. VGO correction subtask (A-19)
15. Convergence check subtask (A-20)
16. Cutoff position constraint release subtask (A-22)



The subtasks for the linear terminal velocity constraint mode (SMODE = 4) must be performed in the following order:

1. Position magnitude subtask (A-1)
2. Initialization subtask (D-1 and D-3; initial pass only, i.e., SINIT = ON)
3. VGO update subtask (A-3, except for the initialization pass)
4. TGO subtask (A-4)
5. Thrust integrals subtask (A-5)
6. Reference thrust vector subtask (A-6)
7. Range-to-go subtask (A-7)
8. Turning rate vector subtask (A-8)
9. Steering inputs update subtask (A-9)
10. Burnout state vector prediction subtask (A-10)
11. Desired orbit plane correction subtask (A-11)
12. Desired position subtask for the LTVCON mode (A-13)
13. Desired velocity subtask for the LTVCON mode (A-16)
14. VGO correction subtask (A-19)
15. Convergence check subtask (A-20)

The subtasks for the external delta-V mode (SMODE = 7) are performed in the following order:

1. Position magnitude subtask (A-1)
2. Initialization subtask (D-1 and D-4; initial pass only, i.e., SINIT = ON)
3. VGO update subtask (A-3, except for the initialization pass)
4. TGO subtask (A-4)
5. Reference thrust vector subtask (A-6)
6. Steering inputs update subtask (A-9)

The subtasks for the RTLS mode (SMODE = 5) must be performed in the following order:

1. Position magnitude subtask (A-1)
- 2a. RTLS PPD targets (A-2a) (when SINIT = ON or TGO > TGO<sub>IA</sub>)
- 2b. VGO desired subtask (A-2b)
3. Initialization subtask (D-1 and D-5; initial pass only, i.e., SINIT = ON)
4. VGO updates subtask (A-3, except for the initialization pass)
5. TGO subtask (A-4)





6. Thrust integrals subtask (A-5)
7. Reference thrust vector subtask (A-6)
8. Range-to-go subtask (A-7)
9. Turning rate vector subtask (A-8)
10. Steering inputs update subtask (A-9)
11. Burnout state vector prediction subtask (A-10)
12. Desired orbit plane correction subtask (A-11)
13. Desired position subtask for standard ascent and RTLS (A-12)
14. Desired plane subtask for RTLS (A-14)
15. Desired velocity subtask for RTLS (A-17)
16. RHO matrix subtask for RTLS (A-18)
17. VGO correction subtask (A-19)
18. Convergence check subtask (A-20)
19. Throttle constraint release subtask (A-21)
20. Cutoff position constraint release subtask (A-22)

D. Initialization Requirements. The purpose of the guidance initialization subtask is to assign initial values to parameters used in the other PEG functional blocks. Most of these parameters such as TGO, KPHASE, etc., are independent of the PEG mode. Others, such as target position constraint switches, SALT and SPLANE, and desired cutoff vectors,  $\bar{R}_D$  and  $\bar{I}_Y$ , are dependent upon the particular guidance mode. The following paragraphs specify the initialization subtask requirements for both mode-independent parameters and mode-dependent parameters:

1. Mode Independent. The following parameters are required to be initialized as indicated for all guidance modes:

$$KPHASE = 1$$

$$\bar{R}_{BIAS} = 0$$

$$PHI = 0$$

$$TPRIME = TGD$$

$$TGO = 1$$

$$\bar{\Omega} = 0$$

$$B = EARTH\_MU/RMAG^3$$

$$\bar{R}_{GRAV} = -0.5 B \bar{R}_D$$

$\dot{S}INIT = OFF$  $TPREV = 0$ 

2. Standard Ascent Guidance Mode (SMODE = 1). The burnout position constraints are enabled by the following operations:

 $DSCOUNT = 0$  $TCOUNT = 1$  $SCOUNT = 0$  $S\_UNCONV = OFF$  $S\dot{P}LANE = ON$  $S\dot{A}LT = ON$ 

If trajectory lofting is desired (TFAIL is not zero), then TFAIL is converted from MET to GMT and the number of thrust phases is set to 3.

 $TFAIL = TFAIL + T\_GMTLO; N = 3$ 

Otherwise (TFAIL = 0) the number of thrust phases is set to 2,  $N = 2$ .

If the variable  $\bar{I}Y$  option is selected premission ( $S\dot{I}Y = ON$ ) and AOA/ATO targeting has already been performed ( $S\dot{A}BORT\_CONTROL = ON$ ), a value for the desired orbit plane vector  $\bar{I}Y$  has already been determined by AOA/ATO targeting. Otherwise, the value of  $\bar{I}Y$  is calculated as follows: If the plane constraint is earth-fixed ( $EF\_PLANE\_SW = ON$ ), then

$$\bar{I}Y = EARTH\_FIXED\_TO\_M50\_COORD(T\_GMTLO) \bar{I}YD$$

else, compute  $\bar{I}Y$  by rotating  $\bar{I}YD$  to adjust for nodal regression

$$\bar{I}Y = \dot{M}\_NODE\_ADJ \bar{I}YD$$

The standard ascent mode requires an initial estimate of the  $\bar{V}GO$ . Therefore, the following functions are performed to initialize the  $\bar{V}GO$  vector:

- a. Initialize the predicted cutoff position and velocity and  $\bar{V}GO$  as follows:

$$\bar{R}P = \bar{R}GD$$
$$\bar{V}P = \bar{V}GD$$
$$\bar{V}GO = 0$$

b. Perform the following subtasks for standard ascent:

- (1) Desired orbit plane correction subtask
- (2) Desired position subtask for standard ascent
- (3) Desired velocity subtask for standard ascent
- (4) VGO correction subtask
- (5) Convergence check subtask

3. Linear Terminal Velocity Constraint Mode (SMODE = 4). The guidance logic for the LTVCON mode does not require the burnout orbit plane to be constrained. The unit normal to the desired orbital plane is obtained as follows: If the plane constraint is earth-fixed (EF\_PLANE\_SW = ON) then

$$\bar{IY}_{DES} = \text{EARTH\_FIXED\_TO\_M50\_COORD}(T\_GMTLO) \bar{IYD}$$

else, rotate  $\bar{IYD}$  to adjust for nodal regression

$$\bar{IY}_{DES} = \bar{M}_{NODE\_ADJ}^* \bar{IYD}$$

Furthermore, position constraint calculations are bypassed by setting the flags SPLANE and SALT to OFF.

A desired turning rate for the maneuver is computed as follows:

$$\text{THETA\_DOT} = \text{SQRT}(B)$$

$$\text{WMAG} = \text{KLAMDZX} \text{THETA\_DOT}$$

This mode also requires an initial estimate of the  $\bar{VGO}$ . Therefore, the following calculations are performed to initialize the VGO vector for this mode:

a. Initialize the predicted cutoff conditions and  $\bar{VGO}$  as for the standard ascent mode:

$$\bar{RP} = \bar{RGD}, \bar{VP} = \bar{VGD}, \bar{VGO} = 0$$

b. Perform the following subtasks for the LTVCON mode:

- (1) Desired orbit plane correction subtask
- (2) Desired position subtask for the LTVCON mode
- (3) Desired velocity subtask for the LTVCON mode

The initial value of the change in accumulated sensed velocity is set to zero.

$$\bar{DVS} = 0$$

4. External Delta-V Guidance Mode (SMODE = 7). For the external delta-V mode, the following functions must be performed:

- a. Initialize the thrust turning rate vector to zero:

$$\bar{LAMD} = 0$$

- b. Set the PEG convergence switch (SCONV) to ON.

5. RTLS Guidance Mode (SMODE = 5). The initial radial and out-of-plane directions must be established prior to construction of the  $\bar{VGO}$  vector. The launch site vector is constructed in M50 coordinates by premultiplying the input earth-fixed vector by the earth-fixed-to-M50 transformation:

$$\bar{RT} = \text{EARTH\_FIXED\_TO\_M50\_COORD}(TGD) \bar{RTEF}$$

$$RTMAG = \text{ABVAL}(\bar{RT})$$

$$\bar{IY} = \text{UNIT}(\bar{RT} \times \bar{RGD})$$

$$IY\_SAVE = \bar{IY}$$

$$\bar{IX} = \text{UNIT}(\bar{RGD})$$

$$DSCOUNT = 0$$

$$TCOUNT = 1$$

$$SCOUNT = 0$$

$$S\_UNCONV = \text{OFF}$$

The  $\bar{VGO}$  vector is then calculated as a function of the estimated burn time to deplete the propellant and the  $VGOD$ , which is consistent with the desired terminal mass.

$$VGOR = B \text{ RMAG} ((M-MBO)/MDOT) (K \text{ CMD}/K) - \bar{VGD} \cdot \bar{IX}$$

$$VGOR = \text{MIN}(VGOR, VGOD)$$

$$\bar{VGO} = VGOR \bar{IX} + \text{SQRT}(VGOD^2 - VGOR^2) (\bar{IX} \times \bar{IY})$$

The plane constraint is not required for RTLS since only the burnout heading is constrained. Therefore:

$$SPLANE = \text{OFF}$$

The altitude constraint is required and SALT = ON.

An initial value of desired position must be available prior to executing the range-to-go subtask, therefore:

$$\bar{RD} = \text{RDMAG } \bar{IX}$$

Also the earth rate vector is used later in the desired velocity subtask for RTLS, therefore:

$$\bar{WE} = \text{EARTH\_RATE } \bar{EARTH\_POLE}$$

The velocity target index LL is initialized to 1 in the BST GUID TSK (4.2.3). It is reset in the SSME-OUT SAF TSK (4.8.9) in the event of an SSME failure.

E. Supplemental Information. The PEG utilizes a modified linear tangent guidance algorithm. The associated vector equation which defines the commanded thrust vector as a function of time is:

$$\hat{U}_{fc} = \text{UNIT}(\hat{\lambda}_c + \dot{\bar{\lambda}}_c (t - t_{\lambda_c}))$$

where  $\hat{\lambda}_c$  is the reference thrust vector,  $\dot{\bar{\lambda}}_c$  is the reference thrust turning rate vector,  $t$  is the variable time, and  $t_{\lambda_c}$  is the time associated with  $\hat{\lambda}_c$  and  $\bar{\lambda}$ . This equation will be utilized by the G/C STEER principal function. The inputs  $\hat{\lambda}_c$ ,  $\dot{\bar{\lambda}}_c$ , and  $t_{\lambda_c}$  will be supplied by the PEG.

An initial value is assumed to be I-loaded into the vector  $\bar{IYD}$  that identifies the desired orbital plane for PEG mode (SMODE) equal to 1.  $\bar{IYD}$  is then updated for the OMS maneuvers.

Table 4.8.1-1. Ascent Powered Explicit Guidance Task Inputs

Definition	Symbol	Source	Precision	Units
Specific force limit during SSME maneuvers	AL	I-LOAD	SP	fps <sup>2</sup>
Thrust acceleration estimate input to PEG	ATR	ASC GUID TSK, FUL DISS TSK, AOA ONORB TGT SEL TSK, OMS GUID TSK, FLYBK TSK, PRE-MAN DISP SUPT TSK	SP	fps <sup>2</sup>
Maximum integration time step for gravity prediction	DT_LIMIT	AOA ONORB TGT SEL TSK, PRE-MAN DISP SUPT TSK, PFG-INP TSK	SP	sec
Minimum integration time step for gravity prediction	DTMIN	K-LOAD	SP	sec
TGO remaining to release all position constraints	DTRD	I-LOAD	SP	sec
Change in accumulated sensed velocity from previous value	DVS	PFG INP TSK	SP	fps
Earth's gravitational constant	EARTH_MU	CONSTANT	DP	ft <sup>3</sup> /sec <sup>2</sup>
PEG criterion for updating steering parameters	EPSTGO	K-LOAD	SP	ND
Minimum TB <sub>N-1</sub> in computation of TGO	ETB	K-LOAD	SP	sec
Nominal OMS thrust level	FT_OMS	I-LOAD	SP	lbf
Desired MECO flight path angle	GAMD	I-LOAD, GUID PRMT RINT TSK, AOA/ATO MECO TGT SEL TSK	SP	rad
Unit vector normal to desired trajectory plane in earth-fixed or M50 system	IYD	I-LOAD, DISP INIT TSK	DP	ND
Unit vector normal to desired trajectory plane in M50 coordinates	IY	GUID PRMT RINT TSK, AOA/ATO MECO TGT SEL TSK	DP	ND
EF plane constraint switch	EF_PLANE_SW	I-LOAD	D	N/A
Turning rate scale factor	KLAMDZX	I-LOAD	SP	ND
Decimal fraction for VGO to be used for convergence criterion for VMISS	KMISS	I-LOAD	SP	ND

Table 4.8.1-1. Ascent Powered Explicit Guidance Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
Total vehicle mass flow rate	MDOT	THRST PRM TSK	SP	slug/sec
Nominal OMS MASS flow rate	MDOT_OMS	I-LOAD	SP	slug/sec
One-engine and two-engine RTLS PPD relative velocity coefficients	A <sub>JJ</sub> (JJ=1,2)	RTLS/TAL TGT SEL TSK	SP	fps or sec <sup>-1</sup>
Three-engine RTLS PPD relative velocity coefficients	A <sub>JJ</sub> (JJ=3,4)	RTLS/TAL TGT SEL TSK	SP	fps or sec <sup>-1</sup>
TAL MECO inertial velocity coefficient	A <sub>JJ</sub> (JJ=8-11)	RTLS/TAL TGT SEL TSK	SP	fps, sec <sup>-1</sup> , ft <sup>-1</sup> , or sec <sup>-1</sup> ft <sup>-2</sup>
Maximum throttle setting of SSME	KMAX	I-LOAD, 1STG GUID INP TSK, ASC GUID TSK, FUL DISS TSK, FLYBK TSK	I	pct
Minimum throttle setting of SSME	KMIN	I-LOAD	I	pct
Guidance phase counter	KPHASE	GUID PRMT RINT TSK	I	N/A
Node adjustment matrix	* M_NODE_ADJ	ASC UPF	DP	ND
Burn time remaining before G-limiting to inhibit fuel depletion throttling	DTTHROT	I-LOAD	SP	sec
Number of thrust phases	N	GUID PRMT RINT TSK, PRE-MAN DISP SUPT TSK, AOA ONORB TGT SEL TSK, RTLS INIT TSK	I	N/A
Number of active OMS engines	N_OMS	PFG INP TSK, PRE-MAN DISP SUPT TSK	I	N/A
Number of integration time steps for gravity predictions	NSEG	I-LOAD	I	N/A
Number of active SSME engines	N_SSME	PFG INP TSK, PRE-MAN DISP SUPT TSK	I	N/A
A <sub>JJ</sub> is a 1 x 11 array				

Table 4.8.1-1. Ascent Powered Explicit Guidance Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
MECO radius	RDMAG	I-LOAD, GUID PRMT RINT TSK, AOA/ATO MECO TGT SEL TSK, RTLS INIT TSK, RTLS/TAL TGT SEL TSK	DP	ft
Vehicle position vector input to PEG	$\bar{R}_{GD}$	PFG INP TSK, PRE-MAN DISP SUPT TSK, AOA ONORB TGT SEL TSK, FUL DISS TSK, FLYBK TSK	DP	ft
Scalar damping factor applied to VMISS to correct VGO	RHOMAG	K-LOAD	SP	ND
Target position in inertial coordinates	$\bar{R}_T$	PRE-MAN DISP SUPT TSK, AOA ONORB TGT SEL TSK	DP	ft
PEG initialization discrete	S $\bar{I}$ INIT	ASC GUID TSK, PRE-MAN DISP SUPT TSK, RTLS INIT TSK, AOA ONORB TGT SEL TSK	D	N/A
Time guidance assumes an SSME failure in MET	TFAIL	I-LOAD	SP	sec
Time of lift-off in GMT	T $\bar{G}$ MTLO	FCOS	DP	sec
Time associated with $\bar{R}_{GD}$ and VGD	TGD	PFG INP TSK, PRE-MAN DISP SUPT, AOA ONORB TGT SEL TSK, FUL DISS TSK, FLYBK TSK	DP	sec
Variable IY targeting option flag	S $\bar{I}$ Y	I-LOAD	D	N/A
PEG mode indicator	SMODE	ASC GUID TASK, PRE-MAN DISP SUPT, RTLS INIT TSK, AOA ONORB TGT SEL TSK	I	N/A
Commanded SSME throttle setting	K $\bar{C}$ MD	FLYBK TSK, SSME-OUT SAF TSK, GUID PRMT RINT TSK, ASC GUID TSK	SP	pct
RCS cutoff time during AOA OMS 1 parallel OMS/RCS maneuver	T $\bar{R}$ C $\bar{S}$ _OFF	PRE-MAN DISP SUPT TSK, AOA ONORB TGT SEL TSK	DP	sec
Desired thrust cutoff M50 inertial velocity vector	$\bar{V}_D$	LTVCON TSK	SP	fps
AOA/ATO target complete flag	S $\bar{A}$ BORT $\bar{C}$ ONTROL	AOA/ATO OMS/RCS PRE-MECO BRN DET TSK	D	N/A



Table 4.8.1-1. Ascent Powered Explicit Guidance Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
Desired MECO velocity magnitude	VDMAG	I-LOAD, GUID PRMT RINT TSK, AOA/ATO MECO TGT SEL TSK	SP	fps
Maximum LAMDMAG	PHIDOT_MAX	I-LOAD	SP	sec
Minimum cutoff mass to allow steering	MASS_MIN	I-LOAD	SP	slugs
Range to begin turnaround prediction	RNG_TURN_PRED	I-LOAD	SP	ft
Equivalent exhaust velocity	VEX	THRST PRM TSK, FUL DISS TSK, FLYBK TSK	SP	fps
Vehicle velocity vector input to PEG	$\vec{V}_D$	PFG INP TSK, PRE-MAN DISP SUPT, AOA ONORB TGT SEL TSK	SP	fps
Current vehicle mass	M	ACC-MASS UPD TSK	SP	slugs
Velocity-to-be gained vector	$\vec{V}_G$	PRE-MAN DISP SUPT TSK	SP	fps
Desired PPD mass for 2 engine RTLS	MBOD(1)	I-LOAD	SP	slugs
Desired PPD mass for 3 engine RTLS	MBOD(2)	I-LOAD	SP	slugs
Earth equatorial rotation rate	EARTH_RATE	Constant	DP	rad/sec
Unit north pole vector in M50	$\vec{EARTH\_POLE}$	Constant	DP	ND
Desired throttle setting	K	RTLS INIT TSK, SSME-OUT SAF TSK, G-LIM TSK, FLYBK TSK	SP	pct
Predicted Shuttle position vector	$\vec{R}_{FINAL}$	ASC PREC PRED	DP	ft
Predicted Shuttle velocity vector	$\vec{V}_{FINAL}$	ASC PREC PRED	SP	fps
Steering enable flag	SSTEER	ASC GUID TSK, RTLS INIT TSK, FLYBK TSK, PRE-MAN DISP SUPT TSK, OMS GUID TSK	D	N/A
Throttling discrete	STHROT	PITCH CMD TSK, FUL DISS TSK	D	N/A

Table 4.8.1-1. Ascent Powered Explicit Guidance Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
Minimum TGO for selecting RTLS constraint	TGO_IA	K-LOAD	SP	sec
Index for selecting RTLS flight path angle target	LL	SSME-OUT SAF TSK, BST GUID TSK	I	N/A
Desired flight path angle for RTLS	GAM <sub>JJ</sub> (JJ=1,3)	RTLS/TAL TGT SEL TSK	SP	rad
Resulting transfer angle	THETA	LTVCON TSK	SP	rad
Desired minimum burnout mass	MBO	DISP INIT TASK	SP	slugs
Horizontal component of velocity at the target	VH1	LTVCON TSK	SP	fps
Magnitude of desired position vector at cutoff	RO_MAG	LTVCON TSK	DP	ft
Sine of the resulting transfer angle	SIN_THETA	LTVCON TSK	SP	ND
MM 104 discrete	MM104	MSC	D	N/A
MM 105 discrete	MM105	MSC	D	N/A
Number of successive unconverged PEG cycles before stowing the ADI error needles	NMAX_CYCLES_ UNCONV	I-LOAD	I	N/A
Arc length around HAC (WPI to NEP)	D_ARC	RTLS UPP	SP	ft
Runway X-component of the HAC center	X_NEP	I-LOAD	SP	ft
Indicator of vehicle position to runway	YSGNP	RTLS UPP	I	ND
Radius of nominal entry heading alignment circle	RADIUS_NEP	I-LOAD	SP	ft
TAL maximum value of VDMAG	VD_TAL_MAX	RTLS/TAL TGT SEL TSK	SP	fps
TAL minimum value of VDMAG	VD_TAL_MIN	RTLS/TAL TGT SEL TSK	SP	fps
Discrete to indicate that a TAL abort is in progress	TAL_ABORT_ DECLARED	MSC	D	N/A
Maximum TAL MECO crossrange	CR_MAX	RTLS/TAL TGT SEL TSK	SP	ft
Runway target vector in earth-fixed coords	RTEF	RTLS/TAL TGT SEL TSK	DP	ft
External tank aim point bias	ET_BIAS	RTLS/TAL TGT SEL TSK	SP	ft

Table 4.8.1-2. Ascent Powered Explicit Guidance Task Outputs

Definition	Symbol	Destination	Precision	Units
Time associated with desired thrust vector expressed in MET	TLAMC	G/C STEER, TRANS DAP, PRE-MAN DISP SUPT TSK, TLM	DP	sec
Predicted time to achieve PEG targets	TP	PRTLS SEQ, FLYBK TSK, FUL DISS TSK, TLM	DP	sec
M50 desired thrust vector	$\bar{L}AMC$	G/C STEER, TRANS DAP, PRE-MAN DISP SUPT TSK, TLM	SP	None
M50 desired thrust turning rate vector	$\bar{L}AMDC$	G/C STEER, TRANS DAP, PRE-MAN DISP SUPT TSK, TLM	SP	sec <sup>-1</sup>
Unit vector normal to the transfer plane and minus the direction of the angular momentum vector of the transfer plane	$\bar{I}Y$	LTVCON TSK, TLM, AOA ONORB TGT SEL TSK	DP	None
Desired thrust cutoff M50 position vector	$\bar{R}D$	PRE-MAN DISP SUPT TSK, LTVCON TSK	DP	ft
Guidance ready flag	S_GDRDY	MSC, PRE-MAN DISP SUPT TSK, TLM	D	N/A
Target inertial position vector	$\bar{R}l$	LTVCON TSK	DP	ft
Desired thrust cutoff M50 inertial velocity vector	$\bar{V}D$	PRE-MAN DISP SUPT TSK	SP	fps
Discrete indicating convergence	S_CONV	ASC GUID TSK, OMS GUID TSK, PRE-MAN DISP SUPT TSK, FLYBK TSK, AOA ONORB TGT SEL TSK, FUL DISS TSK, TLM	D	N/A
Time-to-go	TGO	ABT CNTL SEQ, 2STG SEQ, ASC DAP, ASC GUID TSK, MNVR DISP, FLYBK TSK, OMS GUID TSK, PRE-MAN DISP SUPT TSK, TLM	SP	sec
Velocity-to-be gained vector	$\bar{V}GO$	PRE-MAN DISP SUPT TSK, VGO DISP TSK, OMS GUID TSK	SP	fps
Magnitude of VGO vector	VGOMAG	AOA ONORB TGT SEL TSK, FUL DISS TSK, TLM	SP	fps
Desired reference thrust vector	$\bar{L}AM$	FUL DISS TSK	SP	None



Table 4.8.1-2. Ascent Powered Explicit Guidance Task Outputs (Cont)

Definition	Symbol	Destination	Precision	Units
Desired thrust turning rate vector	$\bar{L}\bar{A}\bar{M}\bar{D}$	FUL DISS TSK	DP	rad/sec
Time associated with desired reference thrust vector expressed in GMT	TLAM	FUL DISS TSK	DP	sec
Desired throttle setting	K	FLYBK TSK, FUL DISS TSK, TLM, SSME-OUT SAF TSK	SP	pct
Desired mass at end of flyback	MBO	FUL DISS TSK	SP	slugs
Shuttle position vector at T_INIT	$\bar{R}_{\bar{I}\bar{N}\bar{I}\bar{T}}$	ASC PREC PRED, PRE-MAN DISP SUPT TSK	DP	ft
Shuttle velocity vector at T_INIT	$\bar{V}_{\bar{I}\bar{N}\bar{I}\bar{T}}$	ASC PREC PRED, PRE-MAN DISP SUPT TSK	SP	fps
Time at beginning of prediction	T_INIT	ASC PREC PRED	DP	sec
Time at which state is required	T_FINAL	ASC PREC PRED	DP	sec
Maximum allowable time step size	DT_MAX	ASC PREC PRED	SP	sec
Gravity model degree	GMD_PRED	ASC PREC PRED	I	N/A
Gravity model order	GMO_PRED	ASC PREC PRED	I	N/A
Predicted Shuttle position vector	$\bar{R}_{\bar{F}\bar{I}\bar{N}\bar{A}\bar{L}}$	PRE-MAN DISP SUPT TSK	DP	ft
Predicted Shuttle velocity vector	$\bar{V}_{\bar{F}\bar{I}\bar{N}\bar{A}\bar{L}}$	PRE-MAN DISP SUPT TSK	SP	fps
Magnitude of RTLS target position vector	RTMAG	MPS GUID C/O TSK	DP	ft
Magnitude of LAMC	LAMDMAG	TLM	SP	sec <sup>-1</sup>
Desired MECO velocity	VDMAG	TLM	SP	fps
Guidance convergence status indicator	S_UNCONV	ASC ADI PROC	D	N/A
Unit vector to landing site	$\bar{I}\bar{Z}$	G/C STEER	DP	N/A
Unit normal to the plane of thrust vector rotation	$\bar{I}\bar{Y}_{\bar{T}\bar{V}\bar{R}}$	FUL DISS TSK	SP	N/A
Guidance coordinate system X-axis in M50 coordinates	$\bar{I}\bar{X}$	FUL DISS TSK	DP	N/A



#### 4.8.2 Acceleration-Mass Update Task (ACC-MASS UPD TSK)

The acceleration-mass update task is a general-purpose guidance task, the purpose of which is to provide other guidance and targeting tasks estimates of the current vehicle mass (M) and a scaling factor (FT\_FACTOR). FT\_FACTOR is used to scale the estimated thrust force on the vehicle so that a smoothed value of thrust acceleration can be calculated.

A. Detailed Requirements. The acceleration-mass update task calls the thrust parameters task (THRST PRM TSK) for estimates of thrust force (FT), mass flow rate (MDOT), and equivalent exhaust velocity (VEX) before performing the following subtasks.

1. Vehicle Mass Estimation Subtask. The purpose of this subtask is to compute a current estimate of the vehicle mass. This is accomplished by an exponential extrapolation (approximated by the first two terms of the Taylor series expansion) of sensed velocity divided by equivalent exhaust velocity:

$$M\_NEW = M (2./D-1.)$$

where

$$D = 1 + .5 DVSMAG/VEX.$$

If the current estimate of mass does not vary significantly from the past estimate, the mass estimate is not updated.

If  $(M-M\_NEW) > MUP\_TH$ , then

$$M = M\_NEW$$

where M\_NEW is the current mass estimate, M is the last mass estimate, and MUP\_TH is a specified minimum change in mass required for the mass to be updated.

2. Thrust Scaling Factor Subtask. The purpose of this subtask is to estimate the thrust scaling factor, FT\_FACTOR. For SSME maneuvers, FT\_FACTOR is a weighted average of four past values of the factor except under certain conditions. The FT\_FACTOR is estimated as follows only when a main engine burn occurs ( $N\_SSME \neq 0$ ), the throttle command has not changed since the last guidance cycle ( $MDOT = MDOT\_OLD$ ), and the fine countdown discrete has not been set ( $S\_MECO = OFF$ ).

First, the sample factors are updated by using the sample factor values from the past three guidance cycles:

$$X4 = X3$$

$$X3 = X2$$

$$X2 = X1$$

Then the current factor is calculated where DTGD is the time interval since the last guidance cycle and FT is the estimated thrust force:

$$FT\_S = M \text{ DVSMAG } D/DTGD$$

$$X1 = FT\_S/FT$$

The weighted average and the absolute difference between the weighted average and the current factor are calculated:

$$X\_WEIGHT = (X1 + X2 + X3 + X4) 0.25$$

$$X\_TEST = ABS(X1 - X\_WEIGHT)$$

If the current factor differs significantly from the weighted average ( $X\_TEST > EPS\_X$ ), then the current estimate (FT\_FACTOR) is not updated; otherwise, FT\_FACTOR = X\_WEIGHT. When FT\_FACTOR is updated and its value is less than FTF\_MIN, then FT\_FACTOR is set to FTF\_MIN. In the event of an SSME failure, SSME-OUT SAF TSK resets FT\_FACTOR to one and X1 to zero.

3. Output Parameters Subtask. The purpose of this subtask is to save the current value of mass flow rate: MDOT\_OLD = MDOT.

B. Interface Requirements. The input and output parameters for the acceleration-mass update task are given in Tables 4.8.2-1 and 4.8.2-2.

C. Processing Requirements. Each subtask must be executed in the order listed in the detailed requirements.

D. Initialization Requirements. The following parameters should be initialized to zero: X1, X2, X3, and MDOT\_OLD.

E. Supplemental Information. The current orbiter mass at the start of MM 104 (initial orbiter mass less any OMS and RCS propellant burned pre-MECO) is obtained from the AS MNVR DIP.

Table 4.8.2-1. Acceleration-Mass Update Task Inputs

Definition	Symbol	Source	Precision	Units
Difference between current and previous values of TGD	DTGD	PFG INP TSK	SP	sec
Magnitude of DVS vector	DVSMAG	PFG INP TSK	SP	fps
Criterion for rejecting the estimate of the thrust scaling factor	EPS_X	K-LOAD	SP	ND
Equivalent exhaust velocity	VEX	THRST PRM TSK	SP	fps
Current estimated thrust scaling factor	X1	SSME-OUT SAF TSK	SP	ND
Current vehicle mass	M	1STG GUID INP TSK, PRE-MAN DISP SUPT TSK	SP	slugs
Minimum change in mass required for mass to be updated	MUP_TH	CONSTANT	SP	slugs
Total vehicle mass flow rate	MDOT	THRST PRM TSK	SP	slugs/sec
Total vehicle thrust force	FT	THRST PRM TSK	SP	lbf
Number of active SSME's	N_SSME	PFG INP TSK, PRE-MAN DISP SUPT TSK	I	N/A
Thrust scaling factor	FT_FACTOR	I-LOAD, SSME-OUT SAF TSK	SP	ND
Fine countdown discrete	S_MECO	ASC GUID TSK, FLYBK TSK	D	N/A
Minimum value of FT_FACTOR	FTF_MIN	K-LOAD	SP	ND



Table 4.8.2-2. Acceleration-Mass Update Task Outputs

Definition	Symbol	Destination	Precision	Units
Current vehicle mass	M	2STG SEQ, ASC GUID TSK, PRTLS SEQ, PEG TSK, OMS GUID TSK, FLYBK TSK, ASC DAP, TLM, XXXXXX TRAJ DIP, PRE-MAN DISP SUPT TSK, AOA ONORB TGT SEL TSK, FUL DISS TSK, DISP INIT TSK, OMS RM, VGO DISP TSK	SP	slugs
Thrust scaling factor	FT_FACTOR	ASC GUID TSK, FUL DISS TSK, FLYBK TSK, TLM	SP	ND





4.8.3 G-Limiting Task (G-LIM TSK)

The g-limiting task is a general-purpose guidance task which determines when the 3-g limit has been achieved and then computes SSME throttle commands to limit the average acceleration to 3 g's. The throttling algorithm works on an integral and proportional error. This algorithm tends to drive the actual acceleration of the vehicle to the acceleration limit "on the average" since an accumulated error is included.

A. Detailed Requirements.

1. The measured vehicle acceleration, AT\_AVE, is calculated if DTGD is not zero. If  $DTGD \neq 0$ ,  $AT\_AVE = DVSMAG/DTGD$ .
2. When AT\_AVE is less than the premission-loaded constant, ALIM\_1, or manual throttling is being performed, the following initial values are calculated, and the g-limit switch is set to OFF:

$$AD = AD\_INIT$$

$$SUM\_DA = 0$$

$$S\_GLIMIT = OFF$$

3. When AT\_AVE is greater than the premission-loaded constant, ALIM\_2, or S\_GLIMIT = ON, and manual throttling is not being performed, then the following g-limit calculations are performed:

- a. Set S\_GLIMIT = ON
- b. Compute the accumulated acceleration error (SUM\_DA) as follows:

$$DA = AT\_AVE - AL$$

$$SUM\_DA = DA DTGD + SUM\_DA$$

- c. Compute the desired acceleration of the vehicle (AD) as the previous desired acceleration minus the accumulated acceleration error multiplied by the integral gain (K\_INT) minus the current acceleration error multiplied by the proportional gain (K\_PROP):

$$AD = AD - (DA K\_PROP + SUM\_DA K\_INT) DTGD$$

- d. If the elapsed time from the last throttle command (T\_KCMD) exceeds the K-load throttle lag time, TLAG, then the following computations are performed:

- (1) Update the commanded throttle setting as a function of the previous throttle setting, the desired acceleration (AD), and the current acceleration (AT\_AVE) and round off to the nearest percent:

$$K\_CMD = ROUND(K\_CMD AD/AT\_AVE)$$

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- (2) Limit the commanded throttle setting to be between KMIN and KMAX:

$$K\_CMD = MIDVAL(KMIN, K\_CMD, KMAX)$$

- (3) If the previously commanded throttle setting is different from K\_CMD, then the time of the throttle command is recorded as follows:

$$T\_KCMD = TGD$$

Set the PEG desired throttle setting to K\_CMD:  $K = K\_CMD$ .

B. Interface Requirements. The input and output parameters for the g-limiting task are given in Tables 4.8.3-1 and 4.8.3-2.

C. Processing Requirements. The subtasks must be performed in the order indicated.

D. Initialization Requirements. S\_GLIMIT must be initialized to OFF, and AT\_AVE = 0, and T\_KCMD = 0.

Table 4.8.3-1. G-Limiting Task Inputs

Definition	Symbol	Source	Precision	Units
Initial value for AD	AD_INIT	I-LOAD	SP	fps <sup>2</sup>
Initial limit for starting g-limit	ALIM_2	I-LOAD	SP	fps <sup>2</sup>
Specific force limit during SSME maneuvers	AL	I-LOAD	SP	fps <sup>2</sup>
Difference between current and previous values of TGD	DTGD	PFG INP TSK	SP	sec
Magnitude of DVS vector	DVSMAG	PFG INP TSK	SP	fps
G-limiting integral gain	K_INT	K-LOAD	SP	sec <sup>-2</sup>
Maximum throttle setting of SSME	KMAX	I-LOAD, 1STG GUID INP TSK, ASC GUID TSK, FUL DISS TSK, FLYBK TSK	I	pct
Minimum throttle setting of SSME	KMIN	I-LOAD	I	pct
Proportional gain	K_PROP	K-LOAD	SP	sec <sup>-1</sup>
Commanded SSME throttle setting	K_CMD	BST THROT TSK, SSME-OUT SAF TSK, RTLS INIT TSK, ASC GUID TSK, 1STG GUID INP TSK, FUL DISS TSK, GUID PRMT RINT TSK	I	pct
Lower limit for setting g-limit off	ALIM_1	I-LOAD	SP	fps <sup>2</sup>
Time associated with RGD and VGD	TGD	PFG INP TSK	DP	sec
Throttle lag time	TLAG	K-LOAD	SP	sec
Manual throttling discrete	S_MAN_THROT	SBTC SOP	D	N/A



Table 4.8.3-2. G-Limiting Task Outputs

Definition	Symbol	Destination	Precision	Units
Commanded SSME throttle setting	K_CMD	SSME SOP, THRST PRM TSK, MPS GUID C/O TSK, SSME-OUT SAF TSK, FLYBK TSK, TLM, SBTC SOP	I	pct
G-limit discrete	S_GLIMIT	ASC GUID TSK	D	N/A
Desired throttle setting	K	PEG TSK, FLYBK TSK, TLM	SP	pct
Desired acceleration	AD	TLM	SP	fps <sup>2</sup>

4.8.4 Linear Terminal Velocity Constraint Task (LTVCON TSK)

The LTVCON task computes the conic velocity required to transfer from an inertial initial position to an inertial target position while satisfying a linear relationship between the radial and horizontal velocity components at the target.

A. Detailed Requirements. The LTVCON subtask is required to compute the conic required velocity vector  $\bar{V}D$  at the initial position  $\bar{R}D$  that satisfies the desired linear terminal velocity constraint at the terminal position  $\bar{R}1$ . In this case, the following quadratic equation specifies the solution:

$$A \text{ VH1}^2 - 2B \text{ VH1} - C = 0$$

where the constants A, B, and C relate the orbital geometry and the terminal velocity constraints. They may be specified by the following calculations:

$$R0\_MAG = ABVAL(\bar{R}D)$$

$$R1\_MAG = ABVAL(\bar{R}1)$$

$$K = (R1\_MAG - R0\_MAG)/R0\_MAG$$

$$W = -((\bar{R}D \times \bar{R}1) \cdot \bar{I}Y)/(\text{R0\_MAG } R1\_MAG - (\bar{R}D \cdot \bar{R}1))$$

$$A = K (1 + W^2) + 2 (1 - C2 W)$$

$$B = C1 W$$

$$C = 2 \text{ EARTH\_MU}/R1\_MAG$$

$$\text{THETA} = \text{PI} + \text{ARCTAN2}(-2 W, 1 - W^2)$$

$$\text{SIN\_THETA} = 2 W/(1 + W^2)$$

The discriminant, D, is then calculated as follows:

$$D = B^2 + AC$$

If D is less than zero, no solution to the previous equation exists, in which case the following equations are not performed. However, if D is greater than or equal to zero, the required velocity computations proceed as follows:

$$\text{VH1} = C/(-B + \text{SQRT}(D))$$

$$\text{VR1} = C1 + C2 \text{ VH1}$$

$$\bar{V}D = ((K W \text{ VH1} - \text{VR1}) \bar{R}D + (1 + K) \text{ VH1 } (\bar{R}D \times \bar{I}Y))/R0\_MAG$$



B. Interface Requirements. The guidance internal input and output parameters for the linear terminal velocity constraint task are given in Tables 4.8.4-1 and 4.8.4-2. There are no guidance external interface parameters.

C. Processing Requirements. This task will be called as required by PEG on the guidance frequency.

D. Initialization Requirements. None.

E. Supplemental Information. These equations are valid in the region of  $0 < \theta < 360$  degrees, but they have a numerical accuracy problem for very small range angles.

0 7

21  
K

Table 4.8.4-1. Linear Terminal Velocity Constraint Task Inputs

Definition	Symbol	Source	Precision	Units
Earth gravitational constant	EARTH_MU	CONSTANT	DP	ft <sup>3</sup> /sec <sup>2</sup>
Target intercept constraint coefficient	C1	PRE-MAN DISP SUPT TSK	SP	fps
Target slope constraint coefficient	C2	PRE-MAN DISP SUPT TSK	SP	ND
Desired thrust cutoff position vector	$\overline{RD}$	PEG TSK	DP	ft
Target inertial position vector in predicted cutoff plane	$\overline{R1}$	PEG TSK	DP	ft
Ratio of circumference to diameter of a circle	PI	CONSTANT	SP	ND
Unit vector normal to the transfer plane	$\overline{IY}$	PEG TSK	DP	ND

Table 4.8.4-2. Linear Terminal Velocity Constraint Task Outputs

Definition	Symbol	Destination	Precision	Units
Desired thrust cutoff M50 inertial velocity vector	$\overline{VD}$	PEG TSK	SP	fps
Resulting transfer angle	THETA	PEG TSK	SP	rad
Horizontal component of velocity at the target position	VH1	PEG TSK	SP	fps
Magnitude of desired position vector at cutoff	R0_MAG	PEG TSK	DP	ft
Sine of resulting transfer angle	SIN_THETA	PEG TSK	SP	ND



#### 4.8.5 MPS Guidance Cutoff Task (MPS GUID C/O TSK)

The MPS guidance cutoff task is a general-purpose guidance task whose primary purpose is to compute a desired SSME cutoff time based upon a desired cutoff velocity magnitude. The cutoff time calculation must include the predicted velocity change from the time the minimum throttle setting is commanded until cutoff and the predicted tailoff impulse from each active SSME.

Secondary functions of this task are to command the minimum throttle setting at such a time that ensures the minimum thrust level is applied for a desired time prior to MECO command, and to set a flag when desired MECO time is less than two guidance cycles for the SSME OPS principal function to initiate the nominal shutdown countdown timer. However, if manual guidance is active, the minimum thrust command is inhibited during RTLS (MM 601).

This task is used by the ascent second-stage guidance and PRTLS guidance principal functions.

##### A. Detailed Requirements.

1. The MPS guidance cutoff task is required to perform the following calculations for the ascent second-stage guidance principal function (MM = 103).

- a. Compute the magnitude of the current velocity vector:

$$VMAG = ABVAL(\bar{VGD})$$

- b. Compute the component of the measured acceleration vector along the current velocity vector:

$$AT\_FCD = (\bar{VGD} \cdot \bar{DVS}) / (VMAG DTGD)$$

- c. Determine the MECO throttle setting:

If  $N\_SSME = 3$ , then

$$K\_CO = KMIN$$

Otherwise,

$$K\_CO = K\_CO\_MAX$$

- d. Predict the velocity change to be  $K\_CO = K\_CO\_MAX$  applied during the time required to decrease the throttle setting from the current command to the minimum setting:

$$DV\_RAMP = (K\_CMD + K\_CO) (K\_CMD - K\_CO) \\ AT\_FCD / (2 \bar{K}\_CMD \bar{K}DOT)$$





- e. Predict the velocity change to be applied during the desired time at minimum thrust level:

$$DV\_MIN\_K = AT\_FCD DT\_MIN\_K K\_CO/K\_CMD$$

- f. Compute the remaining velocity-to-be-gained until MECO command:

$$VGO\_FCD = VDMAG - VMAG$$

- g. Whenever VGO\_FCD first becomes less than the sum of the predicted velocity change over the next guidance cycle (AT\_FCD DT\_FCD), the predicted velocity change during throttle-down (DV\_RAMP), and the predicted velocity change during the desired time at minimum thrust level (DV\_MIN\_K), then K\_CMD = K\_CO and S\_KCO = ON.

If  $VGO\_FCD < AT\_FCD DT\_FCD + DV\_RAMP + DV\_MIN\_K$ , then

$$K\_CMD = K\_CO$$

$$S\_KCO = ON$$

- h. Compute time-to-go until MECO command:

$$ITLOF = MAX(INTEGER(N\_SSME-1), 1)$$

$$TGO = VGO\_FCD/AT\_FCD - DT\_TAILOFF_{ITLOF}$$

2. This task performs the following calculations for the PRTLS guidance (MM = 601).

- a. Compute the component of the acceleration vector along the current earth-relative velocity vector:

$$AT\_FCD = (V\_RHO \cdot DVS)/(V\_RHO\_MAG DTGD)$$

If AT\_FCD is less than 15, then exit the MPS GUID C/O TSK.

- b. Compute the position of the landing site at the estimated time of MECO:

$$\bar{R}T = EARTH\_FIXED\_TO\_M50\_COORD(TGD + TGO - DTGD) RTEF$$

$$\bar{R}T = \bar{R}T - (YSGNP RADIUS\_NEP + ET\_BIAS) UNIT(\bar{R}T \times \bar{R}GD)$$

- c. Compute the distance from the current position to the estimated position of the landing site at MECO:

$$RTHETA = ABVAL(UNIT(\bar{R}GD) RTMAG - \bar{R}T) + D\_ARC - X\_NEP$$

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- d. If FLT\_PATH\_ANG has been updated this cycle, then compute and limit the rate of change of the flight path angle and set the past angle equal to the current angle:

If FLT\_PATH\_ANG\_TIME > PREVIOUS\_FLT\_PATH\_ANG\_TIME, then

$$\text{FLT\_PATH\_DOT} = \frac{(\text{FLT\_PATH\_ANG} - \text{FLT\_PATH\_PAST})}{(\text{FLT\_PATH\_ANG\_TIME} - \text{PREVIOUS\_FLT\_PATH\_ANG\_TIME})}$$

During the powered pitchdown (when the MPS GUID C/O TSK is active), the vehicle should be pitching down to a -4 degree angle of attack, which means that the flight path angle should be decreasing. If the flight path angle is not decreasing, the following logic will prevent a prematurely commanded MECO:

If FLT\_PATH\_DOT > 0, then FLT\_PATH\_DOT = 0

Then the current values are saved for the next FLT\_PATH\_ANG update cycle.

PREVIOUS\_FLT\_PATH\_ANG\_TIME = FLT\_PATH\_ANG\_TIME

FLT\_PATH\_PAST = FLT\_PATH\_ANG

FLT\_PATH\_ANG\_RTLS = FLT\_PATH\_ANG

- e. If FLT\_PATH\_ANG is not updated, then predict the current flight path angle:

FLT\_PATH\_ANG\_RTLS = FLT\_PATH\_ANG\_RTLS + FLT\_PATH\_DOT DTGD

- f. Compute the velocity-to-be-gained:

VGOMAG = A<sub>5</sub> + A<sub>6</sub> RTHETA - A<sub>7</sub> FLT\_PATH\_ANG\_RTLS - V\_RHO\_MAG.

- g. Compute the time rate of change of the velocity-to-be-gained:

VGO\_DOT = AT\_FCD + A<sub>6</sub> V\_RHO\_MAG + A<sub>7</sub> FLT\_PATH\_DOT

If VGO\_DOT is less than 1 fps<sup>2</sup>, then exit the MPS GUID C/O TSK.

- h. Compute time-to-go to MECO:

TGO = VGOMAG/VGO\_DOT

- i. Compute the MECO time in MET for the RTLS display:

TMET\_MECO = TGD + TGO - T\_GMTLO

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3. Whenever time-to-go becomes less than a minimum number of guidance cycles that will ensure an accurate guided cutoff, then the following must be performed (for both MM's 103 and 601):

- a. Compute the time to command MECO:

$$T_{\text{MECO}} = \text{TGD} + \text{TGO}$$

- b. Set a flag ( $S_{\text{TMECO}}$ ) for the SSME OPS principal function to initiate the nominal shutdown countdown timer.

B. Interface Requirements. The input and output parameters for the MPS guidance cutoff task are given in Tables 4.8.5-1 and 4.8.5-2.

C. Processing Requirements. This task will be initiated when  $S_{\text{MECO}}$  is ON, and terminated when  $S_{\text{TMECO}}$  is set, or to Events 33 or A36 during manual throttling. It will be cycled repetitively at a rate of  $1/\text{DT}_{\text{FCD}}$  Hz. The current value of  $\text{DT}_{\text{FCD}}$  is 320 milliseconds when the major mode is 103 or 601. When  $\text{MM} = 103$ , Subtasks 1d, 1e, 1g, and 3 are not performed during manual throttling. When  $\text{MM} = 601$ , Subtask 3 is not done if manual throttling is being performed.

D. Initialization Requirements.

$$\text{FLT\_PATH\_PAST} = 0.0$$

$$\text{PREVIOUS\_FLT\_PATH\_ANG\_TIME} = 0.0$$

$$S_{\text{RCO}} = \text{OFF}$$

E. Supplemental Information.  $\text{DT}_{\text{MIN}_K}$  should be biased by  $\text{DT}_{\text{TAILOFF}}$  for neglecting tailoff impulse in  $\text{VGO}_{\text{FCD}}$ .

Required MECO accuracy is  $\pm 40$  ms. This is the time difference between desired start of tailoff and actual start of thrust tailoff. It is a function of two types of variables: (1) GPC software timing (software design responsibility) and (2) an engine controller timing variation.

$$\text{MECO accuracy} = \pm 30 \text{ ms}(\text{GPC Timing}) \pm 10 \text{ ms}(\text{Controller Timing}) = \pm 40 \text{ ms}$$

The  $\pm 10$ -ms component of MECO accuracy due to engine controller timing results from variable processing of the shutdown (S/D) command in the controller software plus any subsequent hardware delays (18 to 38 ms, currently) before the propellant valves start closing.

$$\text{Controller timing variation} = 18 \text{ to } 38 \text{ ms}$$

Guidance computes  $T_{\text{MECO}}$  early by the amount of  $\text{DT}_{\text{TAILOFF}}$ , which should allow for the engine tailoff  $\Delta V$  to be added to the vehicle velocity resulting in the correct targeted post-MECO velocity. However, the constant  $\text{DT}_{\text{TAILOFF}}$  is derived from the total shutdown impulse of the main engines.



The total impulse is currently obtained from the vehicle/main engine interface control document (ICD) and includes the worst-case controller software delay of 38 ms. Thus, T\_MECO is not only computed early to allow for the tailoff delta-V; it is 38 ms earlier than the start of thrust tailoff. Since the actual controller timing variation will be between 18 and 38 ms, T\_MECO will be 20 ms earlier than desired if the actual delay is only 18 ms, and exactly on time if the actual delay is 38 ms.

This MECO accuracy variation of 0 to 20 ms must be corrected to  $\pm 10$  ms by adjusting the value of DT\_TAILOFF by 10 ms. Specifically, 10 ms must be subtracted from the value obtained by dividing the total impulse by the 65-percent thrust value:

$$DT\_TAILOFF = \frac{\text{Total Impulse}}{\text{Thrust (65\%)}} - 10 \text{ ms, where Total Impulse includes}$$

engine operation for the 38-ms max controller delay. This will result in T\_MECO being exactly 28 ms before the time of "begin thrust tailoff." The MECO accuracy component due to the controller timing variation will then be  $\pm 10$  ms.

The additional  $\pm 30$  ms GPC software variation means the S/D command will go out at T\_MECO  $\pm 30$  ms resulting in a MECO accuracy of  $\pm 40$  ms.

To assure this, the SSME OPS will initiate output command processing based on a MECO Lead Time = Software Lead Time (I-load), which is purely a function of software timing.

As long as the controller timing variation does not change, MECO accuracy will be  $\pm 40$  ms.

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Table 4.8.5-1. MPS Guidance Cutoff Task Inputs

Definition	Symbol	Source	Precision	Units
Vehicle position vector input to PEG	$\overline{RGD}$	PFG INP TSK	DP	ft
Vehicle velocity vector input to PEG	$\overline{VGD}$	PFG INP TSK	SP	fps
Number of active SSME's	$N_{SSME}$	PFG INP TSK	I	N/A
Change in accumulated sensed velocity from previous value	$\overline{DVS}$	PFG INP TSK	SP	fps
Difference between current and previous values of TGD	DTGD	PFG INP TSK	SP	sec
Commanded SSME throttle setting	$K_{CMD}$	G-LIM TSK, SSME-OUT SAF TSK, GUID PRMT RINT TSK, SBTC SOP	I	pct
Magnitude of RTLS target position vector	RTMAG	PEG TSK	DP	ft
Minimum throttle setting of SSME	KMIN	I-LOAD	I	pct
MECO throttle cmd for 2 SSME's	$K_{CO\_MAX}$	I-LOAD	I	pct
Maximum throttle change rate	KDOT	K-LOAD	SP	pct/sec
Desired time at minimum thrust level	$DT_{MIN\_K}$	K-LOAD	SP	sec
Tailoff time at MPL	$DT_{TAILOFF_I}$ ( $I=1,2$ )	I-LOAD	SP	sec
Desired MECO velocity magnitude	VDMAG	I-LOAD, GUID PRMT RINT TSK, AOA/ATO MECO TGT SEL TSK	SP	fps
Planned guidance cycle time for MPS GUID C/O TSK	$DT_{FCD}$	K-LOAD	SP	sec
Time associated with $\overline{RGD}$ and $\overline{VGD}$	TGD	PFG INP TSK	DP	sec
Earth-relative velocity vector in M50 system	$\overline{V_{RHO}}$	RTLS UPP	SP	fps
Magnitude of vehicle velocity	$\overline{V_{RHO\_MAG}}$	RTLS UPP	SP	fps

Table 4.8.5-1. MPB Guidance Cutoff Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
RTLS MECO relative velocity coefficient	$A_5$	RTLS/TAL TGT SEL TSK	SP	sec
RTLS MECO relative velocity coefficient	$A_6$	RTLS/TAL TGT SEL TSK	SP	sec
RTLS MECO relative velocity coefficient	$A_7$	RTLS/TAL TGT SEL TSK	SP	1.56-sec
MM 103 flag	MM103	MBC	D	#
MM 601 flag	MM601	MBC	D	#
Ground relative flight path angle	FLT_PATH_ANG	RTLS UPF	SP	rad
Time of computing of FLT_PATH_ANG	FLT_PATH_ANG_TIME	RTLS UPF	DP	sec
Manual throttle discrete	S_MAN_THROAT	SBTC SOP	D	#
Arc length around HAC	D_ARC	RTLS UPF	SP	ft
Runway X-component of the HAC center	X_NEP	I-LOAD	SP	ft
Indicator of vehicle position to runway	YSGNP	RTLS UPF	I	RD
Radius of nominal entry alignment circle	RADIUS_NEP	I-LOAD	SP	ft
Runway target vector in earth-fixed coordinates	$\vec{RTEF}$	RTLS/TAL TGT SEL TSK	DP	-
External tank aim point bias	ET_BIAS	RTLS/TAL TGT SEL TSK	SP	-
Time of liftoff in GMT	T_GMTLO	FCOS	DP	sec



Table 4.8.5-2. MPS Guidance Cutoff Task Outputs

Definition	Symbol	Destination	Precision	Units
Commanded SSME throttle setting	K_CMD	SSME SOP, SBTC SOP, TLM	I	pct
Desired SSME cutoff time	T_MECO	SSME OPS	DP	sec
Discrete indicating T_MECO has been set	S_TMECO	SSME OPS, PRTLS SEQ, 2STG SEQ	D	N/A
Discrete to indicate pre-MECO throttle-down complete	S_KCO	2STG SEQ, PRTLS SEQ	D	N/A
Predicted SSME C/O in MET	TMET_MECO	XXXXXX TRAJ, TLM	SP	sec
Time to go	TGO	2STG SEQ, TLM	SP	sec



#### 4.8.6 H-θ-to-M50 Target Task (H-θ-M50 TGT TSK)

The H-θ-to-M50 target task computes a target position vector ( $\bar{R}_T$ ) for PEG, given inputs of altitude (HTGT), and central angle (THETA).

##### A. Detailed Requirements. The following steps are required:

1. Two unit vectors in the downrange and radial direction are calculated where RGD is the position vector corresponding to the time of ignition.

$$\bar{I}_{DR} = \text{UNIT}(\bar{R}_{GD} \times (\bar{V}_{GD} \times \bar{R}_{GD}))$$

$$\bar{I}_R = \text{UNIT}(\bar{R}_{GD})$$

2. The angle between the ignition position vector and the target is calculated where  $\bar{R}_{LS\_M50}$  is a vector to which THETA is referenced.

$$\text{THETA\_LS} = \text{ARCTAN2}(-\bar{R}_{LS\_M50} \cdot \bar{I}_{DR}, \bar{R}_{LS\_M50} \cdot \bar{I}_R)$$

If THETA\_LS is negative, then  $\text{THETA\_LS} = \text{THETA\_LS} + 2 \text{ PI}$ .

$$\text{DTHETA} = \text{THETA} - \text{THETA\_LS}$$

If this is the first pass through the H-θ-to-M50 TGT TSK (first call made by AS MNVR DIP at transition to MM 104), save THETA\_LS for later use by AOA/ATO TGT:

$$\text{THETA\_LSS} = \text{THETA\_LS}$$

3. A unit vector in the direction of the target is calculated.

$$\bar{I}_R T = \bar{I}_R \cos(\text{DTHETA}) + \bar{I}_{DR} \sin(\text{DTHETA})$$

4. Compute the magnitude of the target position vector:

$$\text{RTMAG} = \text{RE} + \text{HTGT},$$

where RE is the earth's mean equatorial radius. This value of RTMAG is used for all maneuvers except the AOA OMS-2 burn, where HTGT is relative to the Fischer ellipsoid. Also for AOA OMS-2, the range angle THETA is referenced to the position at the time of ignition.





Thus, if the burn is AOA OMS-2 (S\_AOA\_OMS2 = ON), do the following computations:

$$RTMAG = HTGT + RFE$$

where

$$RFE = -H\_ELLIPSOID(I\bar{R}T)$$

$$THETA = DTHETA$$

where the H\_ELLIPSOID function computes the altitude of the input position vector above the Fischer ellipsoid.

5. Last, the target position is calculated using the direction and magnitude:

$$R\bar{T} = RTMAG I\bar{R}T$$

- B. Interface Requirements. The input and output parameters for the H-θ-to-M50 task are given in Tables 4.8.6-1 and 4.8.6-2.
- C. Processing Requirements. Each subtask is performed once in the order indicated.
- D. Initialization Requirements. None.
- E. Supplemental Information. The H-θ-to-M50 task is called by both the AS MNVR DIP and AOA/ATO TGT principal functions to calculate the target position vector for PEG. For the abort OMS-2 burn, the THETA referenced to the time of ignition is also supplied to AOA/ATO TGT.



Table 4.8.6-1. H-θ-To-M50 TGT Task Inputs

Definition	Symbol	Source	Precision	Units
Target altitude	HTGT	AOA ONORB TGT SEL TSK, PRE-MAN DISP SUPT TSK	SP	ft
Mean equatorial radius	RE	CONSTANT	DP	ft
Vehicle position vector input to PEG	$\overline{\text{RGD}}$	AOA ONORB TGT SEL TSK, PRE-MAN DISP SUPT TSK	DP	ft
Vehicle velocity vector input to PEG	$\overline{\text{VGD}}$	AOA ONORB TGT SEL TSK, PRE-MAN DISP SUPT TSK	SP	fps
M50 position vector of launch site at lift-off	$\overline{\text{RLS}}_{\text{M50}}$	ASCENT UPP	DP	ft
AOA OMS-2 burn discrete	S_ AOA_OMS2	AOA ONORB TGT SEL TSK	D	N/A
Central angle between reference position and target position vector	THETA	AOA ONORB TGT SEL TSK, PRE-MAN DISP SUPT TSK	DP	rad
Ratio of circumference of a circle to the diameter	PI	CONSTANT	SP	ND

Table 4.8.6-2. H-θ-To-M50 TGT Task Outputs

Definition	Symbol	Destination	Precision	Units
Target inertial position vector in OMS ignition plane	$\overline{\text{RT}}$	PEG TSK, PRE-MAN DISP SUPT TSK	DP	ft
Central angle between reference position and target position vector	THETA	AOA ONORB TGT SEL TSK	SP	rad
Central angle between launch site reference and OMS-1 TIG	THETA_LSS	AOA ONORB TGT SEL TSK	SP	rad



#### 4.8.7 Thrust Parameters Task (THRST PRM TSK)

The purpose of this task is to compute the estimated thrust and associated vehicle performance parameters for the necessary operation of PEG. These parameters are total thrust force (FT), total mass flow rate (MDOT), and equivalent exhaust velocity (VEX).

##### A. Detailed Requirements.

1. The estimated main engine thrust force is calculated as a function of the current throttle command (K\_CMD), the number of main engines thrusting (N\_SSME), and an I-loaded estimate of thrust force for a single main engine (FT\_SSME). The corresponding estimates of force for the OMS engines and RCS jets are added:

$$FT = 0.01 K\_CMD N\_SSME FT\_SSME + N\_OMS FT\_OMS + N\_RCS FT\_RCS$$

2. The estimated mass flow rate for the main engines is calculated as a function of K\_CMD, N\_SSME, and an I-loaded estimate of mass flow rate (MDOT\_SSME) for a single main engine. Correspondingly, the estimates of flow rates for the OMS engines and RCS jets are added. Note that the RCS null jets have to be included in the MDOT calculation:

$$MDOT = 0.01 K\_CMD N\_SSME MDOT\_SSME + N\_OMS MDOT\_OMS + (N\_RCS + N\_RCS\_NULL) MDOT\_RCS$$

3. An estimate of equivalent exhaust velocity is then calculated:

$$VEX = FT/MDOT$$

B. Interface Requirements. The input and output parameters for the thrust parameters task are given in Tables 4.8.7-1 and 4.8.7-2.

C. Processing Requirements. None.

D. Initialization Requirements. None.

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Table 4.8.7-1. Thrust Parameters Task Inputs

Definition	Symbol	Source	Precision	Units
Commanded SSME throttle setting	<u>K_CMD</u>	G-LIM TSK, GUID PRMT RINT TSK, SSME-OUT SAF TSK, RTLS INIT TSK, FLYBK TSK, BST THROT TSK, SBTC SOP, ASC GUID TSK, 1STG GUID INP TSK, FUL DISS TSK	I	pct
Number of active SSME engines	<u>N_SSME</u>	PFG INP TSK, PRE-MAN DISP SUPT TSK	I	N/A
Nominal SSME thrust level	<u>FT_SSME</u>	I-LOAD	SP	lbf
Number of active OMS engines	<u>N_OMS</u>	PFG INP TSK, PRE-MAN DISP SUPT TSK, AOA ONORB TGT SEL TSK	I	N/A
Nominal RCS thrust	<u>FT_RCS</u>	I-LOAD	SP	lbf
Nominal OMS thrust	<u>FT_OMS</u>	I-LOAD	SP	lbf
Nominal SSME mass flow rate	<u>MDOT_SSME</u>	I-LOAD	SP	slug/sec
Nominal OMS mass flow rate	<u>MDOT_OMS</u>	I-LOAD	SP	slug/sec
Nominal RCS mass flow rate	<u>MDOT_RCS</u>	K-LOAD	SP	slug/sec
Number of active RCS engines	<u>N_RCS</u>	PFG INP TSK, PRE-MAN DISP SUPT TSK, AOA ONORB TGT SEL TSK	I	N/A
Number of active RCS null engines	<u>N_RCS_NULL</u>	PFG INP TSK, PRE-MAN DISP SUPT TSK	I	N/A

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Table 4.8.7-2. Thrust Parameters Task Outputs

Definition	Symbol	Destination	Precision	Units
Equivalent exhaust velocity	VEX	ACC-MASS UPD TSK, PEG TSK, FUL DISS TSK, FLYBK TSK	SP	fps
Total vehicle thrust force	FT	ACC-MASS UPD TSK, ASC GUID TSK, FUL DISS TSK, PRE-MAN DISP SUPT TSK, FLYBK TSK, OMS GUID TSK, AOA ONORB TGT SEL TSK	SP	lbf
Total vehicle mass flow rate	MDOT	ACC-MASS UPD TSK, PEG TSK, ASC DAP, FLYBK TSK, FUL DISS TSK, TLM	SP	slug/sec

Units  
pct  
N A  
lbf  
N A  
lbf  
lbf  
slug se  
slug sec  
slug se  
N A  
N A

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#### 4.8.8 PFG Input Task (PFG INP TSK)

The PFG input task is a general-purpose guidance task which supports all of the ascent guidance principal functions. Its purpose is to provide a consistent set of navigation and engine configuration data to other guidance tasks.

##### A. Detailed Requirements.

1. To provide a consistent set of navigation data for all guidance tasks, the following computations are required:

$$D\bar{V}S = \bar{V}S - V\bar{S}P$$

$$DVS\_RTLS = D\bar{V}S$$

$$DVSMAG = ABVAL(D\bar{V}S)$$

$$V\bar{S}P = \bar{V}S$$

$$DTGD = T\_NAV - T\_NAV\_PREV$$

$$TGD = T\_NAV$$

$$T\_NAV\_PREV = T\_NAV$$

2. In general, the guidance state vector is equivalent to the navigation state vector supplied by ASCENT UPP. However, the state required by ORB INS GUID must be consistent with the targeting compensation technique of removing from the true targets the effects of noncentral body forces from planned ignition to the target point. Therefore, if the major mode is either 104 or 105 and current navigation time ( $T\_NAV$ ) is greater than planned time of ignition (TIG), the guidance state is integrated from the previous guidance state:

$$R\bar{G}D = R\bar{G}D + DTGD (V\bar{G}D + 0.5(D\bar{V}S + G\bar{C}B DTGD))$$

$$G\bar{C}B\_NEW = - EARTH\_MU R\bar{G}D / (ABVAL(R\bar{G}D))^3$$

$$V\bar{G}D = V\bar{G}D + D\bar{V}S + 0.5(G\bar{C}B + G\bar{C}B\_NEW) DTGD$$

$$G\bar{C}B = G\bar{C}B\_NEW$$

where  $G\bar{C}B$  initially is computed prior to TIG as

$$G\bar{C}B = - EARTH\_MU R\bar{G}D / (ABVAL(R\bar{G}D))^3.$$

However, if the above conditions are not true, then the guidance state is set to the navigation state:

$$R\bar{G}D = \bar{R}\_NAV$$

$$V\bar{G}D = \bar{V}\_NAV$$



3. The following computations are required during all pre-MECO major modes to identify the number of active thrusting engines. The number of SSME's (N\_SSME) is determined by subtracting the total MPS engine-out flags from three.

$$N\_SSME = 3 - \text{SUM}(\text{INTEGER}(S\_EO\_E1, S\_EO\_E2, S\_EO\_E3))$$

If the OMS engines are thrusting pre-MECO (S\_OMS\_IGN = ON), then the number of active OMS is set as indicated:

$$N\_OMS = 2$$

Otherwise, if S\_OMS\_IGN = OFF or if S\_OMS\_CUTOFF = ON

$$N\_OMS = 0$$

If the +X RCS jets are thrusting pre-MECO (S\_RCS\_IGN = ON), then the total number thrusting is set as indicated:

$$N\_RCS = 4$$

Otherwise, (S\_RCS\_IGN = OFF)

$$N\_RCS = 0$$

If eight null RCS jets are thrusting pre-MECO (S\_RCS\_NULL8 = ON), then

$$N\_RCS\_NULL = 8$$

If 14 null RCS jets are thrusting pre-MECO (S\_RCS\_NULL14 = ON), then

$$N\_RCS\_NULL = 14$$

If 20 null RCS jets are thrusting pre-MECO (S\_RCS\_NULL20 = ON), then

$$N\_RCS\_NULL = 20$$

Otherwise, (S\_RCS\_NULL8 = OFF, S\_RCS\_NULL14 = OFF, S\_RCS\_NULL20 = OFF)

$$N\_RCS\_NULL = 0$$

4. The following computations are required during all post-MECO phases (MM's 104 and 105) to identify the number of active thrusting engines:

- a. The number of active OMS engines is determined by subtracting the total number of current OMS failures from SOMS:

$$N\_OMS = \text{SOMS} - \text{SUM}(\text{INTEGER}(S\_OMS1\_FAIL, S\_OMS2\_FAIL))$$



- b. If  $T\_RCS\_OFF$  exceeds zero and current time ( $T\_NAV$ ) equals or exceeds  $T\_RCS\_OFF$ , then  $N\_RCS$  is set to zero, and  $T\_RCS\_OFF$  is set to zero.
- c. If  $N\_OMS = 0$  and  $N\_RCS = 0$ , then  $N\_RCS = 4$ .
- d. Set  $PROP\_FLAG\_OFS = 1$ .
- If  $N\_OMS = 1$  and  $S\_OMS1\_FAIL$  is set, then set  $PROP\_FLAG\_OFS = 3$ .
- If  $N\_OMS = 1$  and  $S\_OMS2\_FAIL$  is set, then set  $PROP\_FLAG\_OFS = 2$ .
- If  $N\_OMS = 0$ , then set  $PROP\_FLAG\_OFS = 4$ .
5. The maximum integration time step ( $DT\_LIMIT$ ) for the gravity prediction is selected during all pre- and post-MECO phases (MM's 103, 104, 105, and 601).

$$DT\_LIMIT = DTMAX$$

B. Interface Requirements. The input and output parameters for the PFG input task are given in Tables 4.8.8-1 and 4.8.8-2.

C. Processing Requirements. Subtasks 1 and 2 are performed each time this task is executed for all major modes. Subtasks 3 and 4 are mutually exclusive. Subtask 3 is performed each time this task is executed prior to MECO; i.e., for MM's 103 and 601. If the major mode is otherwise, Subtask 4 is performed each time this task is executed. Subtask 5 is performed after the other subtasks each cycle throughout PFG input task.

D. Initialization Requirements. The following parameters must be initialized as indicated the first time that Subtask 1 is executed in MM 103.

$$T\_NAV\_PREV = T\_NAV$$

$$VSP = VS$$

Upon entry into MM 104 ( $MM104 = ON$ ), the number of active SSME's ( $N\_SSME$ ) is initialized to zero.





The following values must be initialized during post-MECO major modes the first time that Subtask 1 is executed after a load:

For current time ( $T_{NAV}$ ) greater than time of ignition (TIG),

$$T_{NAV\_PREV} = TGD$$

$$\overline{GCB} = -EARTH\_MU \overline{RGD} / (ABVAL(\overline{RGD}))^3$$

and  $\overline{VSP}$  is initialized by the PRE-MAN DISP SUPT TSK.

For  $T_{NAV} \leq TIG$ ,

$$T_{NAV\_PREV} = T_{NAV}$$

$$\overline{VSP} = \overline{VS}$$

E. Supplemental Information. The variable  $\overline{VGD}$  must be represented such that the least significant bit for each component is less than 0.005 ft/sec.

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Table 4.8.8-1. PFG Input Task Inputs

Definition	Symbol	Source	Precision	Units
Current Shuttle position vector in M50	$\bar{R}_{NAV}$	ASC UPP, RTLS UPP	DP	ft
Assumed number of active OMS engines	SOMS	PRE-MAN DISP SUPT TSK	I	N/A
Pre-MECO OMS ignition command	S $\dot{O}$ MS_IGN	ABT CNTL SEQ	D	N/A
Pre-MECO OMS cutoff command	S $\dot{O}$ MS_CUTOFF	ABT CNTL SEQ	D	N/A
L OMS engine shutdown	S $\dot{O}$ MS1_FAIL	OMS RM	D	N/A
R OMS engine shutdown	S $\dot{O}$ MS2_FAIL	OMS RM	D	N/A
Abort +X RCS ON/OFF command	S $\dot{R}$ CS_IGN	ABT CNTL SEQ	D	N/A
MPS E1 engine-out flag	S $\dot{E}$ O_E1	SSME OPS	D	N/A
MPS E2 engine-out flag	S $\dot{E}$ O_E2	SSME OPS	D	N/A
MPS E3 engine-out flag	S $\dot{E}$ O_E3	SSME OPS	D	N/A
Time associated with current state	T $\dot{N}$ AV	ASC UPP, RTLS UPP	DP	sec
Current Shuttle velocity vector in M50	$\bar{V}_{NAV}$	ASC UPP, RTLS UPP	SP	fps
Accumulated sensed velocity vector	$\bar{V}_S$	ASC UPP, RTLS UPP	DP	fps
RCS 8 null jets ON/OFF COMMAND flag	S $\dot{R}$ CS_NULL8	ABT CNTL SEQ	D	N/A
RCS 14 null jets ON/OFF COMMAND flag	S $\dot{R}$ CS_NULL14	ABT CNTL SEQ	D	N/A
RCS 20 null jets ON/OFF COMMAND flag	S $\dot{R}$ CS_NULL20	ABT CNTL SEQ	D	N/A
RCS cutoff time during AOA OMS-1 parallel OMS/RCS maneuver	T $\dot{R}$ CS_OFF	PRE-MAN DISP SUPT TSK	DP	sec
OMS/RCS ignition time	TIG	PRE-MAN DISP SUPT TSK	DP	sec

Table 4.8.8-1. PFG Input Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
Earth gravitational constant	EARTH_MU	CONSTANT	DP	ft <sup>3</sup> /sec <sup>2</sup>
MM 103 flag	MM103	MSC	D	N/A
MM 104 flag	MM104	MSC	D	N/A
MM 105 flag	MM105	MSC	D	N/A
MM 601 flag	MM601	MSC	D	N/A
Maximum integration step size	DTMAX	K-LOAD	SP	sec
Time associated with $\overline{RGD}$ , $\overline{VGD}$	TGD	PRE-MAN DISP SUPT TSK	DP	sec
Vehicle position vector input to PEG	$\overline{RGD}$	PRE-MAN DISP SUPT TSK	DP	ft
Vehicle velocity vector input to PEG	$\overline{VGD}$	PRE-MAN DISP SUPT TSK	SP	fps
Previous value of accumulated sensed velocity vector	$\overline{VSP}$	PRE-MAN DISP SUPT TSK	DP	fps

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Table 4.8.8-2. PFG Input Task Outputs

Definition	Symbol	Destination	Precision	Units
Difference between current and previous values of TGD	DTGD	G-LIM TSK, ACC-MASS UPD TSK, VEL RES TSK, MPS GUID C/O TSK, FLYBK TSK	SP	sec
Change in accumulated sensed velocity from previous value	$\overline{DVS}$	PEG TSK, VEL RES TSK, MPS GUID C/O TSK	SP	fps
Magnitude of DVS vector	DVSMAG	G-LIM TSK, ACC-MASS UPD TSK	SP	fps
Number of active OMS engines	N_OMS	PEG TSK, AOA ONORB TGT SEL TSK, THRST PRM TSK, OMS GUID TSK, TLM	I	N/A
Number of active RCS engines	N_RCS	THRST PRM TSK, CMD BDY ATT TSK, TLM	I	N/A
Number of active SSME engines	N_SSME	2STG SEQ, PEG TSK, AOA/ATO MECO TGT SEL TSK, ACC-MASS UPD TSK, THRST PRM TSK, PRTL SEQ, RTLS INIT TSK, TLM, MPS GUID C/O TSK, PPD TSK, FUL DISS TSK	I	N/A
Time associated with $\overline{RGD}$ and $\overline{VGD}$	TGD	PEG TSK, OMS GUID TSK, TLM, G-LIM TSK, MPS GUID C/O TSK	DP	sec
Vehicle velocity vector input to PEG	$\overline{VGD}$	PEG TSK, MPS GUID C/O TSK, CMD BDY ATT TSK, TLM	SP	fps
Number of active RCS null engines	N_RCS_NULL	THRST PRM TSK, TLM, FLYBK TSK, FUL DISS TSK	I	N/A
Vehicle position vector input to PEG	$\overline{RGD}$	PEG TSK, CMD BDY ATT TSK, MPS GUID C/O TSK, TLM	DP	ft
Change in sensed velocity	$\overline{DVS\_RTLS}$	FUL DISS TSK, PRTL SEQ	SP	fps
Prime propulsive system flag	PROP_FLAG_OFS	CMD BDY ATT TSK	I	N/A
Maximum integration stepsize for gravity prediction	DT_LIMIT	PEG TSK	SP	sec

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#### 4.8.9 SSME-Out Safing Task (SSME-OUT SAF TSK)

The SSME-out safing task is a general-purpose guidance task used by ascent first-stage guidance, ascent second-stage guidance, and PW RTLS guidance when an SSME fails. The purpose of this task is to command a two-engine power level equivalent to three engines or a full power level to obtain maximum vehicle performance within the flight constraints and to provide required data for the abort guidance and targeting functions.

##### A. Detailed Requirements.

1. This task is required to store the earth-relative velocity magnitude for use by the AOA/ATO targeting function and the PW RTLS guidance function, respectively. For AOA/ATO targeting, the failure velocity is saved:

$$V\_ME\_OUT = V\_RHO\_MAG$$

For PRTLS, a reference velocity and altitude rate are saved. If an SSME fails during ascent first stage, the 1STG GUID INP TSK saves these parameters at the last guidance cycle of MM 102. If MM103 = ON, then  $V\_RTLS\_FD = V\_RHO\_MAG$  and  $H\_DOT\_FD = H\_DOT\_ELLIPSOID$  at failure.

2. The index for selecting the RTLS flight path target (LL) must be reset to reflect the engine-out configuration:

If  $S\_EO\_E1 = ON$ , then  $LL = 2$ ;

otherwise  $LL = 3$

3. If  $V\_RHO\_MAG$  is less than  $V\_PYR\_SW$ , then the first-stage pitch bias index is reset for the engine-out condition ( $L = LL$ ). Also, if  $L > 1$ , and this is the first pass through this task, do the following computations:

$$DELSEL = V\_RHO\_MAG P\_SLP(L-1) + P\_INT(L-1)$$

If  $V\_RHO\_MAG$  is greater than  $V\_EO\_SW$ , set

$$DELSEL = DEL\_CST(L-1) \text{ and}$$

$$S\_LOAD\_RMP = ON$$

DELSEL is the I-load-dependent engine-out pitch bias which is used in the calculation of the first-stage engine-out pitch command in the BST GUID TSK.  $S\_LOAD\_RMP$  is an indicator of whether the engine failure occurred in a high loads region of first stage.



4. If MM102 = ON, then  $K\_CMD = KMAX$ ; otherwise, the throttle command must be set to the minimum of the three-engine equivalent value or  $KMAX$ :

$$K\_CMD = \text{MIN}[\text{INTEGER}(\text{ROUND}(1.5 K\_CMD)), KMAX]$$

Set and limit the desired throttle setting:

$$K = \text{MIN}(1.5K, KMAX)$$

None of the above changes to  $K$  and  $K\_CMD$  are made if manual throttling is being performed.

5. This task resets the values of the thrust scaling factor and the current estimated thrust scaling factor, respectively:

$$FT\_FACTOR = 1$$

$$X1 = 0$$

B. Interface Requirements. The input and output parameters for the SSME-out safing task are given in Tables 4.8.9-1 and 4.8.9-2.

C. Processing Requirements. This task is called only on the first guidance cycle following an engine failure.

D. Initialization Requirements.  $L$  and  $LL$  must be initialized to 1. This is done as an initialization of the BST GUID TSK in first-stage guidance.



Table 4.8.9-1. SSME-Out Safing Task Inputs

Definition	Symbol	Source	Precision	Units
MM 102 flag	MM102	MSC	D	N/A
MM 103 flag	MM103	MSC	D	N/A
Navigated earth-relative velocity magnitude	V_RHO_MAG	ASC UPF	SP	fps
MPS E1 engine-out flag	S_EO_E1	SSME OPS	D	N/A
MPS E2 engine-out flag	S_EO_E2	SSME OPS	D	N/A
MPS E3 engine-out flag	S_EO_E3	SSME OPS	D	N/A
Maximum throttle setting of SSME	KMAX	I-LOAD, 1STG GUID INP TSK, ASC GUID TSK, FUL DISS TSK, FLYBK TSK	I	pct
Commanded SSME throttle setting	K_CMD	G-LIM TSK, GUID PRMT RINT TSK, RTLS INIT TSK, BST THROT TSK, FLYBK TSK, SBTC SOP, ASC GUID TSK, 1STG GUID INP TSK, FUL DISS TSK	I	pct
Maximum velocity for changing pitch/yaw profile in first stage	V_PYR_SW	I-LOAD	SP	fps
Manual throttle discrete	S_MAN_THROT	SBTC SOP	D	N/A
EST altitude rate	H_DOT_ELLIPSOID	ASC UPF	SP	fps
Pitch bias intercepts for early first-stage engine failure	P_INT(I) (I=1,2)	I-LOAD	SP	rad
Pitch bias slopes for early first-stage engine failure	P_SLP(I) (I=1,2)	I-LOAD	SP	rad/fps
Constant pitch bias for later first-stage engine failure	DEL_CST(I) (I=1,2)	I-LOAD	SP	rad
Engine-out pitch bias selection switch velocity	V_EO_SW	I-LOAD	SP	fps
Desired throttle setting	K	PEG TSK	SP	pct

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Table 4.8.9-2. SSME-Out Safing Task Outputs

Definition	Symbol	Destination	Precision	Units
Commanded SSME throttle setting	K_CMD	SSME SOP, FLYBK TSK, MPS GUID C/O TSK, G-LIM TSK, 1STG GUID INP TSK, THRST PRM TSK, FUL DISS TSK, PEG TSK, TLM, SBTC SOP	I	pct
Index for selecting RTLS flight path angle target	LL	PEG TSK	I	N/A
Relative velocity magnitude at SSME failure time	V_ME_OUT	AOA/ATO MECO TGT SEL TSK, AOA/ATO OMS/RCS PRE-MECO BRN DET TSK, TLM	SP	fps
Index for nominal/engine-out pitch and yaw polynomials	L	BST GUID TSK, TLM	I	N/A
RTLS fuel dissipation reference velocity magnitude	V_RTLS_FD	PITCH CMD TSK	SP	fps
Desired throttle setting	K	PEG TSK, FUL DISS TSK, FLYBK TSK, TLM	SP	pct
Thrust scaling factor	FT_FACTOR	ACC-MASS UPD TSK, ASC GUID TSK, FUL DISS TSK, FLYBK TSK, TLM	SP	ND
Current estimated thrust scaling factor	XI	ACC-MASS UPD TSK	SP	ND
RTLS Fuel Dissp reference HDOT	H_DOT_FD	PITCH CMD TSK	SP	fps
Engine-out pitch bias	DELSEL	BST GUID TSK	SP	rad
Engine-out pitch bias load ramp discrete	S_LOAD_RMP	BST GUID TSK	D	N/A



4.8.10 Commanded Body Attitude Task (CMD BDY ATT TSK)

This task computes a quaternion relating body axes to the mean-of-50 coordinate system initially for use in computing a preburn attitude alignment and cyclically for use in computing attitude errors for the ADI. This task also computes the desired vehicle burn attitude during the burn.

A. Detailed Requirements. Computation of an M50 inertial-to-commanded body quaternion is based upon a unit thrust vector in the body axis coordinate system ( $\overline{\text{THRUST\_BODY}}$ ), the desired thrust orientation vector in M50 ( $\overline{\text{UF}}$ ), the roll reference vector ( $\overline{\text{ROLL\_REF}}$ ), and the desired thrust vector roll angle ( $\text{TVR\_ROLL}$ ). This quaternion also serves as the reference attitude for the generation of attitude errors.

The body-fixed thrust direction is assumed to remain fixed throughout a maneuver if an engine reconfiguration does not occur. Therefore, a new body-fixed thrust direction must be computed if either of the following conditions occur:

1. A new target set is evaluated.
2. An engine fails during the maneuver.

These conditions are satisfied each time the current propulsion system flag is set or reset:

If ( $\text{PROP\_FLAG\_OFS} \neq \text{PROP\_FLAG\_OFS\_P}$ ), then execute Item 1 to compute the body-fixed thrust direction.

If ( $\text{PROP\_FLAG\_OFS} = \text{PROP\_FLAG\_OFS\_P}$ ), then skip Item 1 and go to Item 2.

1a. If the prime propulsive system is RCS ( $\text{PROP\_FLAG\_OFS} = 4$ ), then the body thrust vector is set equal to the I-load vector that defines the force direction resulting from firing the high acceleration +X RCS thrusters ( $\overline{\text{THRUST\_BODY\_RCS\_X}}$ ), the OMS thrust calculations are omitted, and the next calculation is the  $\overline{\text{UF}}$  vector below.

If  $\text{PROP\_FLAG\_OFS} = 4$ , then  $\overline{\text{THRUST\_BODY}} = \overline{\text{THRUST\_BODY\_RCS\_X}}$  and skip Item 1b.

b. If an OMS configuration is to be used or if a parallel OMS, RCS maneuver is required ( $\text{PROP\_FLAG\_OFS} \neq 4$ ), then the body thrust vector is calculated as a function of the OMS trim angles and the RCS thrust. These OMS trim angles are related to the displayed desired OMS trim angles through constant bias terms. These bias terms transform the displayed desired OMS trim angles from an electrical null reference to a body axis reference.

For premaneuver calculations ( $\text{PROP\_FLAG\_OFS\_P} = 0$ ), the trim angles are input from the TRANS DAP principal function. If an engine fails during the maneuver, the trim angles are updated with I-loads for one engine.

If (PROP\_FLAG\_OFS\_P = 0), then:

$$YAW\_TRIM_1 = OMS\_YAW\_TRIM_1$$

$$YAW\_TRIM_2 = OMS\_YAW\_TRIM_2$$

$$PITCH\_TRIM = OMS\_PITCH\_TRIM$$

If (PROP\_FLAG\_OFS\_P  $\neq$  0), then

$$YAW\_TRIM_1 = ONE\_ENG\_OMS\_YAW\_TRIM_1$$

$$YAW\_TRIM_2 = ONE\_ENG\_OMS\_YAW\_TRIM_2$$

$$PITCH\_TRIM = ONE\_ENG\_OMS\_PITCH\_TRIM$$

The subscript 1 denotes LEFT OMS and 2 denotes RIGHT OMS.

$$OMS\_YAW\_BODY_1 = YAW\_TRIM_1 \text{ RAD\_PER\_DEG} + YAW\_BIAS$$

$$OMS\_YAW\_BODY_2 = YAW\_TRIM_2 \text{ RAD\_PER\_DEG} - YAW\_BIAS$$

Set the subscript limits (J1, J2) for the appropriate OMS system selected:

$$\text{Set } J1 = 1, J2 = 2$$

$$\text{If PROP\_FLAG\_OFS} = 2 \text{ then } J2 = 1 \text{ (LEFT OMS)}$$

$$\text{If PROP\_FLAG\_OFS} = 3 \text{ then } J1 = 2 \text{ (RIGHT OMS)}$$

Convert the displayed pitch trim values to a body reference and compute the OMS thrust body vector for each OMS:

$$OMS\_PITCH\_BODY = PITCH\_BIAS - PITCH\_TRIM \text{ RAD\_PER\_DEG}$$

Do for J = J1 to J2

$$C\_YAW = \cos(OMS\_YAW\_BODY_J)$$

$$\begin{aligned} \bar{THRUST\_BODY\_OMS}_J = & \text{VECTOR}(\cos(OMS\_PITCH\_BODY) C\_YAW, \\ & \sin(OMS\_YAW\_BODY_J), \sin(OMS\_PITCH\_BODY) C\_YAW) \end{aligned}$$

The resultant body unit thrust direction is computed:

$$\begin{aligned} \bar{THRUST\_BODY} = & \text{UNIT}(\text{FT\_RCS } N\_RCS \text{ THRUST\_BODY\_RCS\_X} + \text{FT\_OMS} ((2-J1) \\ & \bar{THRUST\_BODY\_OMS}_1 + (J2-1) \bar{THRUST\_BODY\_OMS}_2)) \end{aligned}$$



After computing the body-fixed thrust direction for either OMS or RCS, PROP\_FLAG\_OFS\_P must be set equal to PROP\_FLAG\_OFS:

$$\text{PROP\_FLAG\_OFS\_P} = \text{PROP\_FLAG\_OFS}$$

2. The commanded unit thrust vector ( $\bar{U}_F$ ) at the desired time ( $T_{CA}$ ) is calculated from the LAMC, LAMDC, TLAMC parameters.

$$\bar{U}_F = \text{UNIT}(\bar{L}AMC + \bar{L}AMDC (T_{CA} - TLAMC - T_{GMTLO}))$$

If  $T_{CA} > TIG$ , then perform Items b and c. Otherwise, perform Items a and c.

- a. The roll reference vector ( $\bar{R}OLL\_REF$ ) defined to be the unit radius vector is calculated:

$$\bar{R}OLL\_REF = \text{UNIT}(\bar{R}GD)$$

where  $\bar{R}GD$  is the radius vector used by guidance to solve for LAMC, LAMDC, and TLAMC.

The cosine of the angle (CBETA) between the roll reference vector ( $\bar{R}OLL\_REF$ ) and the desired thrust vector ( $\bar{U}_F$ ) is computed:

$$CBETA = \bar{R}OLL\_REF \cdot \bar{U}_F$$

If  $ABS(CBETA) > CBETA\_EPS$ , then a different roll reference must be saved. The new roll reference is determined as follows:

$$\bar{R}OLL\_REF = -\bar{V}GD \text{ for } CBETA > 0$$

$$\bar{R}OLL\_REF = \bar{V}GD \text{ for } CBETA \leq 0$$

where  $CBETA\_EPS$  is a K-load quantity.

The attitude matrix ( $MTP^*$ ) is then computed:

$$\bar{Y}N = \text{UNIT}(\bar{T}HRUST\_BODY \times \text{VECTOR}(0, -1, 0))$$

$$\begin{aligned} \bar{Y}T &= \text{UNIT}(\bar{U}_F \times \bar{R}OLL\_REF) \text{ SIN}(TVR\_ROLL \text{ RAD\_PER\_DEG}) \\ &\quad - \bar{U}_F \times \text{UNIT}(\bar{U}_F \times \bar{R}OLL\_REF) \text{ COS}(TVR\_ROLL \text{ RAD\_PER\_DEG}) \end{aligned}$$

$$MTP^* = \text{MATRIX}(\bar{T}HRUST\_BODY, \bar{T}HRUST\_BODY \times \bar{Y}N, -\bar{Y}N)$$

$$MTP^* = MTP^{*T} \text{ MATRIX}(\bar{U}_F, \bar{U}_F \times \bar{Y}T, -\bar{Y}T)$$

The M50-to-commanded body quaternion ( $Q_{CB\_M50\_S}$ ,  $Q_{CB\_M50\_V}$ ) is computed by calling the MAT\_TO\_QUAT utility routine:

CALL MAT\_TO\_QUAT

Inputs:  $MTP^*$

Outputs:  $Q_{CB\_M50\_S}$ ,  $Q_{CB\_M50\_V}$



b. The following computations are performed whenever item (T\_CA) is greater than time of ignition.

- (1) The commanded unit thrust vector is transformed into current body coordinates by calling the QUAT\_XFORM utility routine

CALL QUAT\_XFORM

Inputs:  $Q_{B_I_S}$ ,  $Q_{\bar{B}_I_V}$ ,  $U\bar{F}$

Outputs:  $U\bar{F}_B$

- (2) Obtain the difference of  $\bar{T}H_RU_S_T_B_O_D_Y$  and  $U\bar{F}_B$

$$\bar{Y}_N = U\bar{F}_B - \bar{T}H_RU_S_T_B_O_D_Y$$

If the magnitude of  $\bar{Y}_N$  is less than 0.001, then no attitude change is required; hence, set the body-to-commanded body quaternion to identity and proceed to Item (5).

IF  $ABVAL(\bar{Y}_N) < 0.001$ , then  $Q_{CB_B_S} = 1$ ,  $Q_{\bar{C}B_B_V} = 0$ , and proceed to Item (5).

- (3) Construct the single rotation axis

$$\bar{S}_R_A = UNIT(0, Y_{N_3}, -Y_{N_2})$$

If  $\bar{S}_R_A \cdot U\bar{F}_B < 0$ , then  $\bar{S}_R_A = -\bar{S}_R_A$ .

- (4) Compute the body-to-commanded body quaternion

$$\bar{A}_T_B = (\bar{S}_R_A \times \bar{T}H_RU_S_T_B_O_D_Y) \times \bar{S}_R_A$$

$$\bar{B} = UNIT(\bar{A}_T_B + 0.5 \bar{Y}_N)$$

$$\bar{A}_T_B = UNIT(\bar{A}_T_B)$$

$$Q_{CB_B_S} = \bar{B} \cdot \bar{A}_T_B$$

$$Q_{\bar{C}B_B_V} = [(\bar{B} \times \bar{A}_T_B) \cdot \bar{S}_R_A] \bar{S}_R_A$$

- (5) Compute the M50-to-commanded body quaternion by calling the QUAT\_MULT utility routine

CALL QUAT\_MULT

Inputs:  $Q_{CB_B_S}$ ,  $Q_{\bar{C}B_B_V}$ ,  $Q_{B_I_S}$ ,  $Q_{\bar{B}_I_V}$

Outputs:  $Q_{CB_M50_S}$ ,  $Q_{\bar{C}B_M50_V}$

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## c. Compute the commanded body attitude.

The ADI-to-commanded body quaternion ( $Q_{CB\_ADI\_S}$ ,  $Q_{CB\_ADI\_V}$ ) is obtained by multiplying the M50-to-commanded body quaternion with the I-load ADI to M50 quaternion ( $Q_{M50\_INTRL\_ASCENT}$ ):

CALL QUAT\_MULT

Inputs:  $Q_{CB\_M50\_S}$ ,  $Q_{CB\_M50\_V}$ ,  $Q_{M50\_INTRL\_ASCENT}$

Outputs:  $Q_{CB\_ADI\_S}$ ,  $Q_{CB\_ADI\_V}$

The resulting quaternion ( $Q_{CB\_ADI\_S}$ ,  $Q_{CB\_ADI\_V}$ ) is used in deriving the sines and cosines of the Euler angles by the QUAT\_TO\_ADI\_ANG module as documented in the Flight Control Level C FSSR.

CALL QUAT\_TO\_ADI\_ANG

Inputs:  $Q_{CB\_ADI\_S}$ ,  $Q_{CB\_ADI\_V}$

Outputs: PTCHSINE, PTCHCOS, YAWSINE, YAWCOS, ROLLSINE, ROLLCOS, X\_FLAG

If X\_FLAG is OFF, the remaining calculations of this item are bypassed.

$VEH\_PITCH = \text{ARCTAN2}(-PTCHSINE, -PTCHCOS)/RAD\_PER\_DEG + 180$

$VEH\_YAW = \text{ARCTAN2}(-YAWSINE, -YAWCOS)/RAD\_PER\_DEG + 180$

$VEH\_ROLL = \text{ARCTAN2}(-ROLLSINE, -ROLLCOS)/RAD\_PER\_DEG + 180$

B. Interface Requirements. The input and output parameters for the commanded body attitude task are given in Tables 4.8.10-1 and 4.8.10-2.

C. Processing Requirements. The commanded body attitude task is performed once each time the premaneuver display support task (4.7.8) is called and cyclically from when current time ( $T_{GMT}$ ) exceeds time of ignition (TIG) until transition to the next major mode.

D. Initialization Requirements. None.



Table 4.8.10-1. Commanded Body Attitude Task Inputs

Definition	Symbol	Source	Precision	Units
OMS pitch trim angle	OMS_PITCH_TRIM	TRANS DAP	SP	deg
Left OMS yaw trim angle	OMS_YAW_TRIM <sub>1</sub>	TRANS DAP	SP	deg
Right OMS yaw trim angle	OMS_YAW_TRIM <sub>2</sub>	TRANS DAP	SP	deg
Prime propulsion system indicator	PROP_FLAG_OFS	PFG INP TSK, PRE-MAN DISP SUPT TSK	I	N/A
Previous value for prime propulsion system indicator flag	PROP_FLAG_OFS_P	PRE-MAN DISP SUPT TSK	I	N/A
Nominal RCS thrust	FT_RCS	I-LOAD	SP	lbf
Nominal OMS thrust	FT_OMS	I-LOAD	SP	lbf
Number of active RCS engines	N_RCS	PFG INP TSK, PRE-MAN DISP SUPT TSK	I	N/A
Unit body thrust vector for the 4 +X RCS propulsive system in body coordinates	$\bar{T}H_{RCS\_BODY\_X}$	I-LOAD	SP	ND
Unit desire thrust direction vector in M50 coordinates	$\bar{L}AMC$	PEG TSK	SP	ND
Desired thrust direction turning rate in M50 coordinates	$\bar{L}AMDC$	PEG TSK	SP	sec <sup>-1</sup>
Time associated with reference thrust vectors (LAMC, LAMDC)	TLAMC	PEG TSK	SP	sec
GMT to compute commanded body attitude	T_CA	PRE-MAN DISP SUPT TSK, OMS GUID TSK	SP	sec
Time of lift-off in GMT	T_GMTLO	FCOS	DP	sec
Vehicle position vector input to PEG	$\bar{R}GD$	PFG INP TSK, PRE-MAN DISP SUPT TSK	DP	ft
Vehicle velocity vector input to PEG	VGD	PEG INP TSK, PRE-MAN DISP SUPT TSK	S	fps

Table 4.8.10-1. Commanded Body Attitude Task Inputs (Cont)

Definition	Symbol	Source	Precision	Units
Thrust vector roll angle	TVR_ROLL	I-LOAD	SP	deg
Constant bias term to convert OMS engine electrical null pitch trim angles to the body axis reference	PITCH_BIAS	K-LOAD	SP	rad
Constant bias term to convert OMS engine electrical null yaw trim angles to the body axis reference	YAW_BIAS	K-LOAD	SP	rad
Degrees to radians conversion factor	RAD_PER_DEG	CONSTANT	SP	rad/deg
Tolerance on allowable angle between commanded thrust direction and radius vector before a new reference must be established	CBETA_EPS	K-LOAD	SP	ND
M50-to-body quaternion	Q_B_I_S Q_B_I_S	A/E ATT PROC	SP	ND
Time of ignition	TIG	PRE-MAN DISP SUPT TASK	DP	sec
Left OMS engine yaw trim for one engine*	ONE_ENG_OMS_ YAW_TRIM <sub>1</sub>	I-LOAD	SP	deg
Right OMS engine yaw trim for one engine*	ONE_ENG_OMS_ YAW_TRIM <sub>2</sub>	I-LOAD	SP	deg
Pitch trim for one engine*	ONE_ENG_OMS_ PITCH_TRIM	I-LOAD	SP	deg
ADI to M50 quaternion	Q_M50_INTRL_ ASCENT	K-LOAD	SP	ND

\*This I-load is shared with the Transition Dap principal function (4.201).



Table 4.8.10-2. Commanded Body Attitude Task Outputs

Definition	Symbol	Destination	Precision	Units
M50-to-commanded body quaternion	Q_CB_M50_S Q_CB_M50_V	PRE-MAN DISP SUPT TSK, TRANS DAP	SP	ND
Desired vehicle burn attitude in ADI coordinates	VEH_PITCH VEH_YAW VEH_ROLL	MNVR DISP, (6.35), TLM	SP	deg
Unit engine thrust direction in body coordinates	THRUST_BODY	OMS GUID TSK	SP	ND





#### 4.8.11 RTLS/TAL Target Selection Task (RTLS/TAL TGT SEL TSK)

This task is used by the TAL ascent second-stage guidance and PRTLS guidance principal functions. Its function is to allow selection of alternate landing sites for RTLS and TAL aborts and reselect appropriate guidance targets according to the target selected. This task tests the compatibility of the abort mode with the selected landing site and will not allow incompatible targets to be selected.

##### A. Detailed Requirements

This task stores up to five different target sets that are shared by RTLS and TAL landing sites. The desired target set is selected by the integer AREA\_SEL and the array TARGET1. Each of the five elements has a value of  $\pm 1$ . If this value is positive, the target is a TAL site; otherwise, the target is an RTLS site. The integer AREA\_SEL serves as the array's index to select a particular target site.

1. If a TAL is in progress (TAL\_ABORT\_DECLARED = ON), the abort mode is compared with the selected target area in order to check for compatibility. The abort mode designator I-load, TARGET1(AREA\_SEL), is set to a positive integer for a TAL abort.

If TARGET1(AREA\_SEL) > 0, then

TAL\_AREA = AREA\_SEL

RTEF(1) = R\_LS\_EF(1)

RTEF(2) = R\_LS\_EF(2)

RTEF(3) = R\_LS\_EF(3)

The guidance targets are set to the appropriate targeting I-loads according to the TAL area selected.

A<sub>8</sub> = TARGET2(TAL\_AREA)

A<sub>9</sub> = TARGET3(TAL\_AREA)

A<sub>10</sub> = TARGET4(TAL\_AREA)

A<sub>11</sub> = TARGET5(TAL\_AREA)

GAMD = TARGET6(TAL\_AREA)

RDMAG = TARGET7(TAL\_AREA)

CR\_MAX = TARGET8(TAL\_AREA)

VD\_TAL\_MAX = TARGET9(TAL\_AREA)

VD\_TAL\_MIN = TARGET10(TAL\_AREA)

2. If an RTLS abort is in progress (MM601 = ON), the abort mode is compared with the selected target area in order to check for compatibility. The abort mode designator I-load, TARGET1(AREA\_SEL), is set to a negative integer for an RTLS abort.

If TARGET1(AREA\_SEL) < 0, then

RTLS\_AREA = AREA\_SEL

RTEF(1) = R\_CC\_EF(1)

RTEF(2) = R\_CC\_EF(2)

RTEF(3) = R\_CC\_EF(3)

The guidance targets are equivalenced to the appropriate targeting I-loads according to the RTLS area selected.

A<sub>1</sub> = TARGET2(RTLS\_AREA)

A<sub>2</sub> = TARGET3(RTLS\_AREA)

A<sub>3</sub> = TARGET4(RTLS\_AREA)

A<sub>4</sub> = TARGET5(RTLS\_AREA)

A<sub>5</sub> = TARGET6(RTLS\_AREA)

A<sub>6</sub> = TARGET7(RTLS\_AREA)

A<sub>7</sub> = TARGET8(RTLS\_AREA)

GAM(1) = TARGET9(RTLS\_AREA)

GAM(2) = TARGET10(RTLS\_AREA)

GAM(3) = TARGET11(RTLS\_AREA)

RDMAG = TARGET12(RTLS\_AREA)

ET\_BIAS = TARGET13(RTLS\_AREA)

B. Interface Requirements. The input and output parameters for the RTLS/TAL target selection task are given in Tables 4.8.11-1 and 4.8.11-2.

C. Processing Requirements. This task is executed at every guidance pass following the selection of an RTLS or TAL abort.

D. Initialization Requirements.

TAL\_AREA = TAL\_PRIME\_AREA

RTLS\_AREA = RTLS\_PRIME\_AREA



Table 4.8.11-1. RTLS/TAL Target Selection Task Inputs

Definition	Symbol	Source	Precision	Units
Discrete to indicated that a TAL abort is in progress	TAL_ABORT_DECLARED	MSC	D	N/A
Selected area	AREA_SEL	ASC SITE LOOKUP	I	N/A
Abort mode designator	TARGET1 <sub>J</sub> (J=1,5)	I-LOAD	I	N/A
RTLS/TAL landing area guidance targets	TARGET2 <sub>J</sub> (J=1,5)	I-LOAD	SP	fps
RTLS/TAL landing area guidance targets	TARGET3 <sub>J</sub> (J=1,5)	I-LOAD	SP	sec <sup>-1</sup>
RTLS/TAL landing area guidance targets	TARGET4 <sub>J</sub> (J=1,5)	I-LOAD	SP	fps or sec <sup>-1</sup> ft <sup>-1</sup>
RTLS/TAL landing area guidance targets	TARGET5 <sub>J</sub> (J=1,5)	I-LOAD	SP	sec <sup>-1</sup> or sec <sup>-1</sup> ft <sup>-1</sup>
RTLS/TAL landing area guidance targets	TARGET6 <sub>J</sub> (J=1,5)	I-LOAD	SP	fps or rad
RTLS/TAL landing area guidance targets	TARGET7 <sub>J</sub> (J=1,5)	I-LOAD	SP	sec <sup>-1</sup> or ft
RTLS/TAL landing area guidance targets	TARGET8 <sub>J</sub> (J=1,5)	I-LOAD	SP	ft or ft-rad <sup>-1</sup> sec <sup>-1</sup>
RTLS/TAL landing area guidance targets	TARGET9 <sub>J</sub> (J=1,5)	I-LOAD	SP	fps or rad
RTLS/TAL landing area guidance targets	TARGET10 <sub>J</sub> (J=1,5)	I-LOAD	SP	fps or rad
RTLS/TAL landing area guidance targets	TARGET11 <sub>J</sub> (J=1,5)	I-LOAD	SP	rad
RTLS/TAL landing area guidance targets	TARGET12 <sub>J</sub> (J=1,5)	I-LOAD	SP	ft
TAL prime area designator	TAL_PRIME_AREA	I-LOAD	I	N/A
RTLS prime area designator	RTLS_PRIME_AREA	I-LOAD	I	N/A
HAC center position vector	R <sub>CC</sub> _EF	RTLS UPP	DP	ft
TAL runway target vector	R <sub>LS</sub> _EF	ASC SITE LOOKUP	DP	ft
External tank aim point bias	TARGET13 <sub>J</sub> (J=1,5)	I-LOAD	SP	N/A
MM 601 flag	MM601	MSC	D	N/A



Table 4.8.11-2. RTLS/TAL Target Selection Task Outputs

Definition	Symbol	Destination	Precision	Units
TAL MECO inertial velocity coefficient	A <sub>8</sub>	PEG TSK	SP	fps
TAL MECO inertial velocity coefficient	A <sub>9</sub>	PEG TSK	SP	sec <sup>-1</sup>
TAL MECO inertial velocity coefficient	A <sub>10</sub>	PEG TSK	SP	sec <sup>-1</sup> ft <sup>-1</sup>
TAL MECO inertial velocity coefficient	A <sub>11</sub>	PEG TSK	SP	sec <sup>-1</sup> ft <sup>-2</sup>
Desired MECO flight path angle	GAMD	PEG TSK	SP	rad
Desired MECO radius	RDMAG	PEG TSK	DP	ft
Maximum TAL MECO crossrange	CR_MAX	PEG TSK	SP	ft
One- and two-engine RTLS PPD relative velocity coefficient	A <sub>1</sub>	PEG TSK	SP	fps
One- and two-engine RTLS PPD relative velocity coefficient	A <sub>2</sub>	PEG TSK	SP	sec <sup>-1</sup>
Three-engine RTLS PPD relative velocity coefficient	A <sub>3</sub>	PEG TSK	SP	fps
Three-engine RTLS PPD relative velocity coefficient	A <sub>4</sub>	PEG TSK	SP	sec <sup>-1</sup>
RTLS MECO relative velocity coefficient	A <sub>5</sub>	MPS GUID C/O TSK	SP	fps
RTLS MECO relative velocity coefficient	A <sub>6</sub>	MPS GUID C/O TSK	SP	sec <sup>-1</sup>
RTLS MECO relative velocity coefficient	A <sub>7</sub>	MPS GUID C/O TSK	SP	ft-rad <sup>-1</sup> - sec <sup>-1</sup>
Desired flight path angle for RTLS	GAM <sub>J</sub> (J=1-3)	PEG TSK	SP	rad
TAL maximum value of VDMAG	VD_TAL_MAX	PEG TSK	SP	fps
TAL minimum value of VDMAG	VD_TAL_MIN	PEG TSK	SP	fps
Runway target vector in earth-fixed coordinates	RTEF	PEG TSK, MPS GUID C/O TSK	DP	ft
External tank aim point bias	ET_BIAS	PEG TSK, MPS GUID/CO TSK	SP	ft

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Units
fps
sec <sup>-1</sup>
sec <sup>-1</sup> ft <sup>-1</sup>
sec <sup>-1</sup> ft <sup>-2</sup>
rad
ft
ft
fps
sec <sup>-1</sup>
fps
sec <sup>-1</sup>
fps
sec <sup>-1</sup>
ft-rad <sup>-1</sup> sec <sup>-1</sup>
rad
fps
fps
ft
ft

#### 4.9 GUIDANCE AND TARGETING SEQUENCING



#### 4.9 GUIDANCE AND TARGETING SEQUENCING

The following paragraphs describe briefly the sequencing of principal functions needed to perform guidance and targeting during MM's 104 and 105. Each major mode is divided into three time periods:

1. From entry into the major mode until orbit insertion guidance is started 15 seconds before the desired ignition time
2. From the start of orbit insertion guidance until the OMS ignition is enabled when the BURN\_ENABLE discrete is set to ON
3. From ignition enabled to the next major mode

During the first period (before guidance is initiated), AS MNVR DIP is executed cyclically. If either of the S\_AOA or S\_ATO abort discrettes is ON or is set to ON during this period, AOA/ATO TGT is executed on the first or next guidance cycle before AS MNVR DIP is executed.

During the second period, the guidance and targeting software is sequenced as follows:

1. ASC UPP is executed first.
2. A/E ATT PROC and ORB INS GUID are executed next; either one may be executed first.
3. If either the S\_AOA or S\_ATO abort discrete is set to ON during this period, AOA/ATO TGT is executed next on the first pass in which the discrete is ON.
4. The AS MNVR DIP is then executed.

In the third period (BURN\_ENABLE = ON to the next major mode), the sequencing is the same as in the second period, except that AOA/ATO TGT will not be performed. If either of the abort discrettes is set to ON during this period, and MM = 104, AOA/ATO TGT will be performed on the first guidance cycle of MM 105.

Entry to the next major mode is accomplished by crew action after engine cutoff.

If S\_AOA is ON upon entry into MM 105 or is turned on before the BURN\_ENABLE discrete is set to ON, AOA/ATO TGT and AS MNVR DIP are executed in the sequences described above. Transfer to OPS 3 can then occur.

In MM 106, only AS MNVR DIP is executed cyclically.

5.0 SUPPLEMENTAL MATERIAL

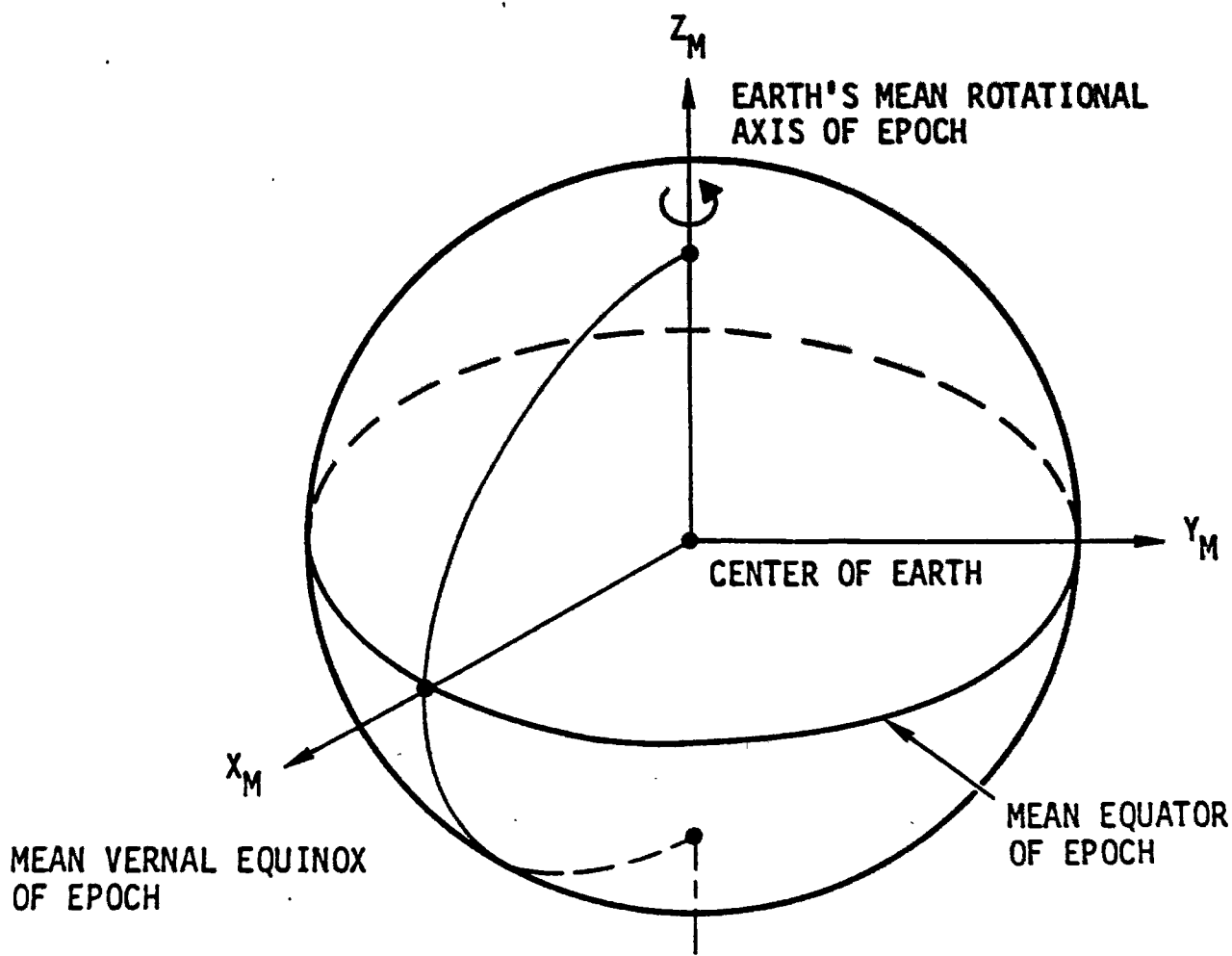
## 5.0 SUPPLEMENTAL MATERIAL

### 5.1 COORDINATE SYSTEMS

The terms used within the coordinate system definitions are defined as follows:

Inertial Coordinate System	A system whose coordinate axes are fixed, relative to the stars, at infinite distances. That is, the rotation rates about all axes, relative to the stars, are zero.
Quasi-Inertial System	A system that rotates with time from an inertial system and whose instantaneous rates of rotation and translational velocity between respective origins are, by definition, equal to zero. Thus, a velocity-vector transformation between quasi-inertial systems does not include the rotation rates of axes; hence, velocity magnitudes are invariant under such a transformation.
Nonrotating Systems	An inertial or quasi-inertial system. That is, any system whose rates of rotation about all axes, relative to any inertial system, are zero.
Rotating Systems	A reference frame which varies with time from an inertial system and whose rates of rotation about axes are included in transformations of velocity vectors to derive relative velocity.
Cartesian Systems	A system whose reference frame consists of a triad of mutually perpendicular directed lines originating from a common point, in which a vector is expressed by components that are scalar magnitude projections along each axis.





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.

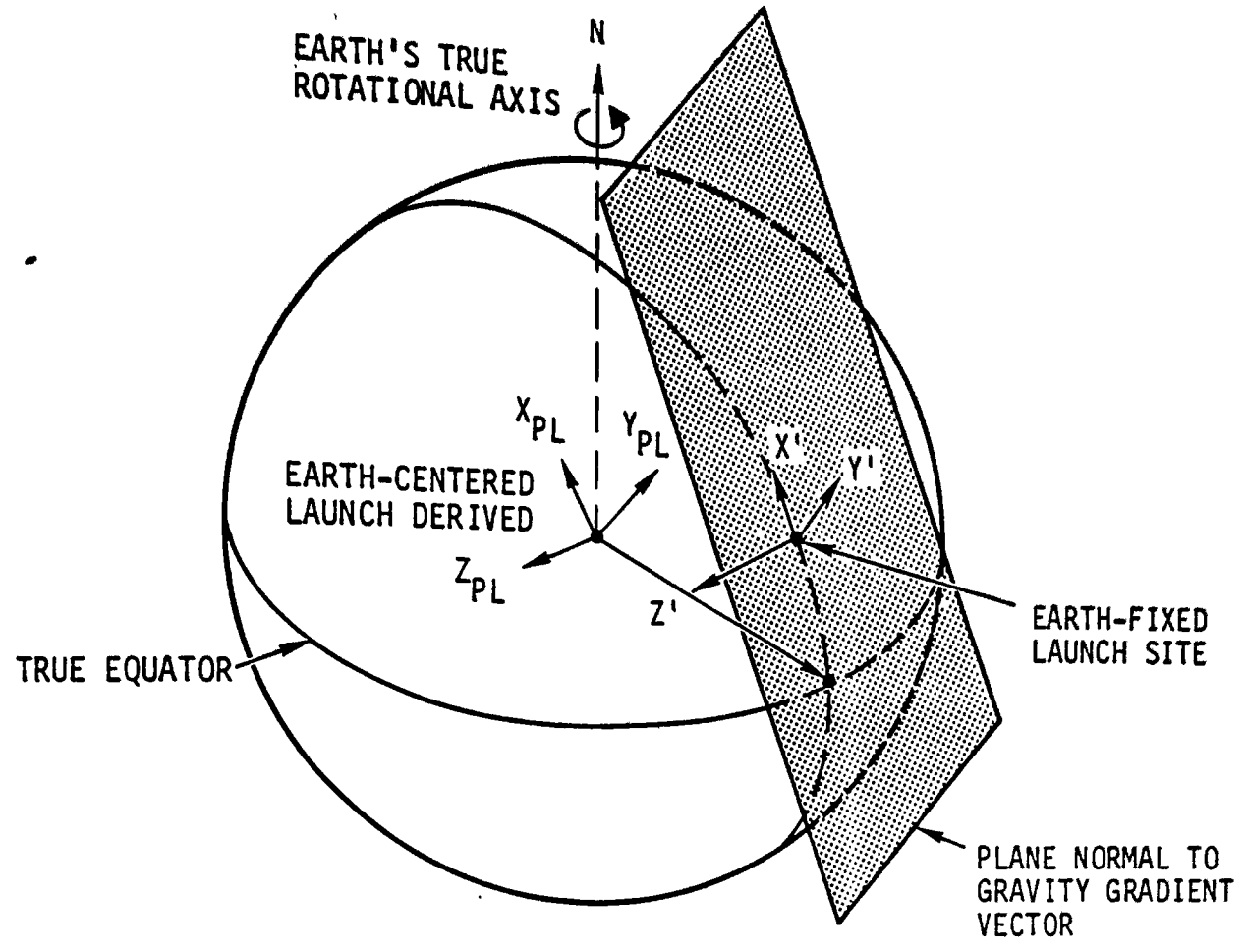
The  $X_M$  -axis is directed toward the mean vernal equinox of epoch.

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 5.1-1



NAME: Boost reference coordinate system.

ORIGIN: At the center of the earth.

ORIENTATION AND DIRECTIONS:

The  $Z_{PL}$  -axis is parallel to the gravity gradient ( $Z'$ ) which passes through the launch site and is positive in the direction of gravity. The  $Z_{PL}$  -axis is fixed at a specifically stated time.

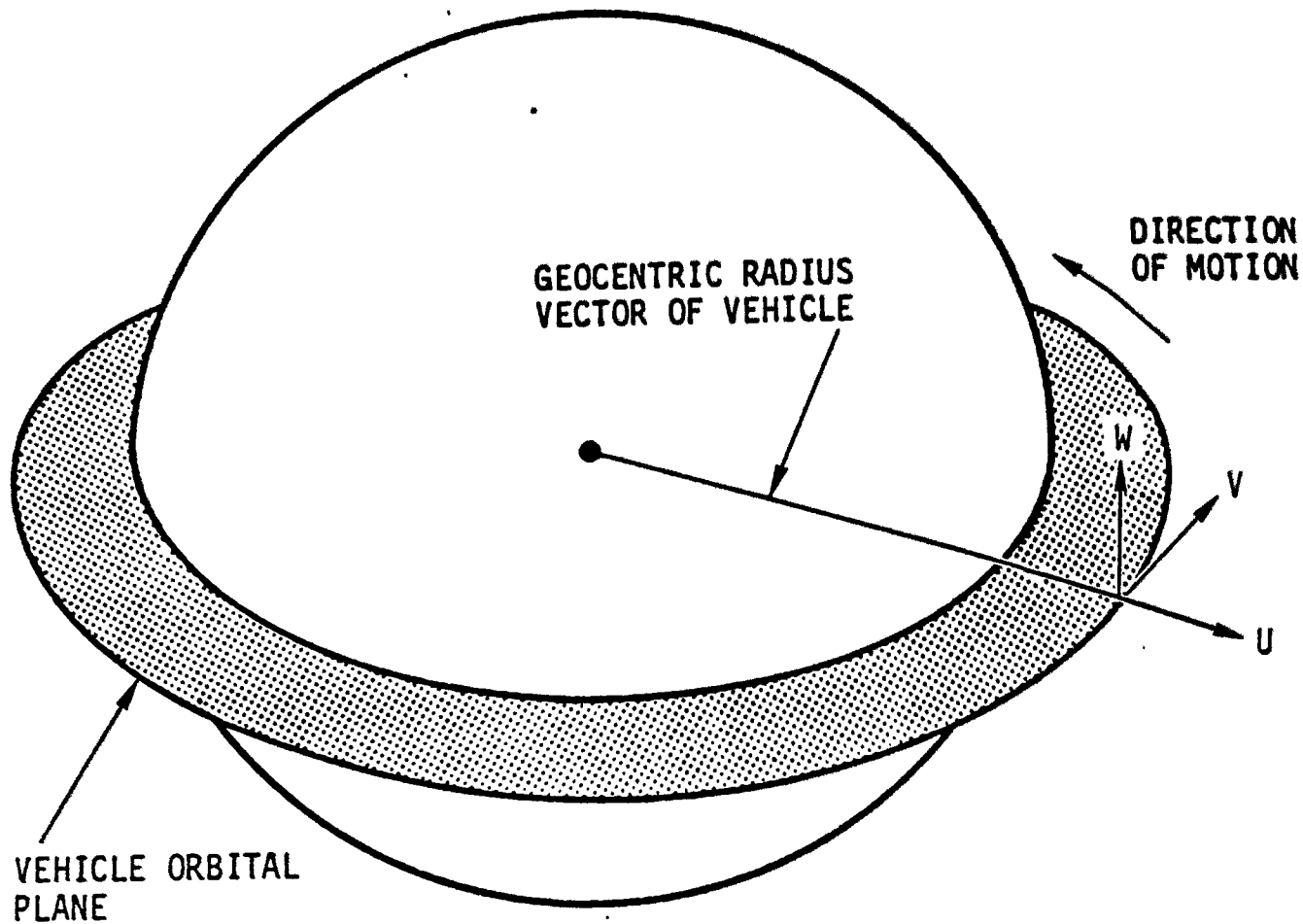
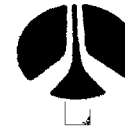
The  $X_{PL}$  -axis is parallel to  $X'$  which is along the launch site meridian and is positive northward.

The  $Y_{PL}$  -axis is parallel to the  $Y'$  and completes a standard right-handed system; i.e., positive east.

The  $X_{PL}$  -  $Y_{PL}$  plane is normal to the launch site gravity gradient vector.

CHARACTERISTICS: Inertial, right-handed, Cartesian.

Figure 5.1-2



NAME: U, V, W coordinate system.

ORIGIN: Point of interest

ORIENTATION: The U-V plane is the instantaneous orbit plane at epoch.

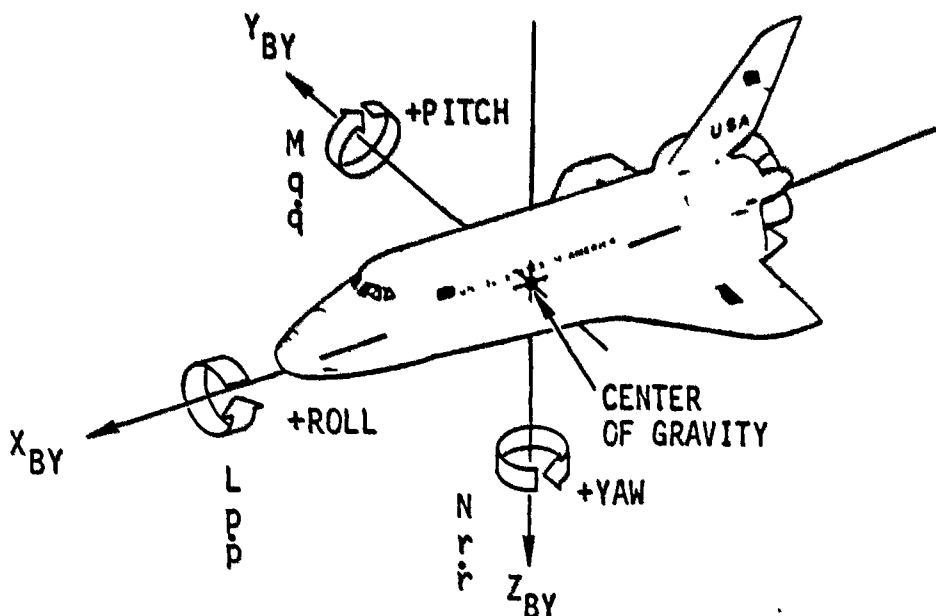
The U axis lies along the geocentric radius vector to the vehicle and is positive radially outward.

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.

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 5.1-3



NAME: Body axis coordinate system.

ORIGIN: Center of mass.

ORIENTATION:  $X_{BY}$ -axis is parallel to the orbiter structural body  $X_0$ -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.

CHARACTERISTICS:

$Y_{BY}$ -axis completes the right-handed orthogonal system.

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, and roll sequence, where  $\psi$  = yaw,  $\theta$  = pitch, and  $\phi$  = roll or bank. This attitude sequence is yaw, pitch, and roll around the  $Z_{BY}$ ,  $Y_{BY}$ , and  $X_{BY}$  axes, respectively.

Figure 5.1-4



## 5.2 HAL PROGRAMMING LANGUAGE SYNTAX DEFINITIONS

The syntax notations commonly used throughout the document are defined as follows:

$\bar{A} \cdot \bar{B}$	Vector dot product
$\bar{A} \times \bar{B}$	Vector cross product
ABVAL( $\bar{A}$ )	Magnitude of vector $\bar{A}$
UNIT( $\bar{A}$ )	Unit vector of vector $\bar{A}$
EXP(A)	$e^A$
SIGN(A)	(+1) for a positive or zero value of A, and (-1) for a negative value of A
ABS(A)	Absolute value of A
MIDVAL(A, B, C)	Value of the argument which is between the other two
ROUND(A)	Nearest integral value of A
ARCCOS(A)	Arc cosine of A
ARCSIN(A)	Arc sine of A
ARCTAN2(A, B)	Arc tangent of A/B in the proper quadrant
ARCTAN(A)	Arc tangent of A
COS(A)	Cosine of A
LOG(A)	Natural log of A
SIN(A)	Sine of A
SQRT(A)	Square root of A
TAN(A)	Tangent of A
SUM(A)	Sum of all elements of A
MAX(A)	Maximum of all elements of A
MIN(A)	Minimum of all elements of A
SGN(A)	+1, 0, or -1 for A positive, zero, or negative, respectively

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defined as

and (-1)

other

RECEIVED



INTEGER(A<sub>1</sub>, A<sub>2</sub>, ..., A<sub>N</sub>)

Array of integers formed from elements of A where A may be any type; e.g., integers, scalar, Boolean, etc.

SCALAR(A<sub>1</sub>, A<sub>2</sub>, ..., A<sub>N</sub>)

Array of scalars formed from elements of A where A may be any type; e.g., integers, scalar, Boolean, etc.

VECTOR(A<sub>1</sub>, A<sub>2</sub>, A<sub>3</sub>)

Vector (3) formed by elements of A where A may be integer or scalar type only

MATRIX(A<sub>1</sub>, A<sub>2</sub>, ..., A<sub>q</sub>)

Matrix formed by elements of A where A may be integer, scalar, vector, or matrix-type only

MOD(A,B)

Remainder of A ÷ B; i.e., MOD(A, B) = A - B truncate (A ÷ B)

TRUNCATE(A)

Rounded low value of A



### 5.3 ABBREVIATIONS AND ACRONYMS

The abbreviations and acronyms commonly used throughout this document are defined as follows:

AOA	Abort-once-around
ARCS	Aft reaction control system
ATO	Abort-to-orbit
ATR	Current estimated acceleration
c.g.	Center-of-gravity
C/O	Cutoff
CPDS	Computer program development specification
CRT	Cathode ray tube display
DAP	Digital autopilot
DIP	Display interface processing
$\Delta V$	Delta velocity
EI	Entry interface
ET	External tank
FDI	Fault detection and identification
FPL	Full power level (109%)
G	Acceleration due to gravity
G/C	Guidance to control
GN&C	Guidance, navigation, and control
L/O	Lift-off
LTVCON	Linear terminal velocity constraint
M50	Mean of 1950
MECO	Main engine cutoff
MM	Major mode
MPL	Minimum power level (65%)
MPS	Main propulsion system
MSC	Mode, sequencing, and control
OME	Orbital maneuvering engine
OMS	Orbital maneuvering system
OPS	Operational sequence
PBI	Pushbutton indicator
PEG	Powered explicit guidance
PFG	Powered flight guidance
PRO	Crew initiated action

-	
q	Dynamic pressure
r	Apogee radius magnitude
RCS	Reaction control system
RPL	Rated power level (100%)
RTLS	Return-to-launch-site
SOP	Subsystem operating program
SRB	Solid rocket booster
SSME	Space Shuttle main engine
TB	Burn time
TGO	Time-to-go
TIG	Time of ignition
TVC	Thrust vector control
UPP	User parameter processor
VGO	Velocity-to-be-gained



APPENDIX A. DETAILED FLOW CHARTS

4.2 FIRST STAGE FLOW CHARTS

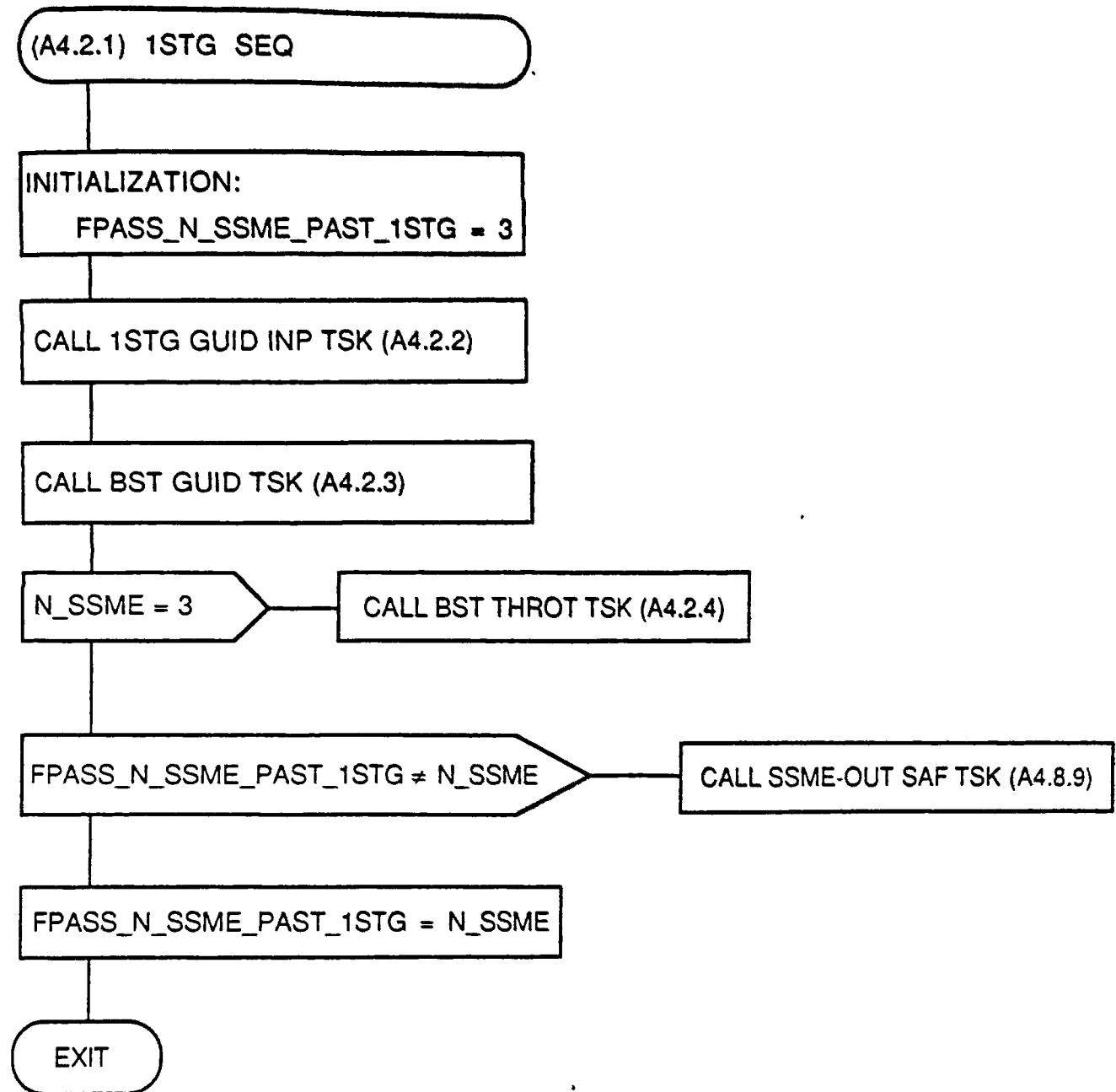


Figure A4.2.1. 1STG SEQ Flow Diagram

(A4.2.2) 1STG GUID INP TSK

INITIALIZATION:  
TGD = T\_NAV  
FPASS\_MAX = OFF

$N_{SSME} = 3 - \text{SUM} [\text{INTEGER} (S_{EO\_E1}, S_{EO\_E2}, S_{EO\_E3})]$   
DTGD = T\_NAV - TGD  
TGD = T\_NAV  
 $M = M - .01 (DTGD K\_CMD \dot{M}DOT_{SSME} N_{SSME})$

N\_SSME < 3

V\_RTLS\_FD = V\_RHO\_MAG  
H\_DOT\_FD = H\_DOT\_ELLIPSOID

MAX\_THROT\_CMD = ON

FPASS\_MAX = OFF

KMAX = KMAX\_SECONDARY  
K\_CMD\_MODE\_BNDRY = KMAX\_SECONDARY  
FPASS\_MAX = ON

S\_MAN\_THROT = OFF  
AND  
N\_SSME < 3

K\_CMD = KMAX\_SECONDARY

EXIT

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Figure A4.2.2. 1STG GUID INP TSK Flow Diagram

K\_CMD = KMAX SECONDARY  
AND  
N SSME < 3

(A4.2.3) BST GUID TSK

INITIALIZATION:  
DELT = 0.0  
THETP = 0.0  
PSIP = 0.0  
DELSEL = 0.0  
S\_LOAD\_RMP = OFF  
S\_LOAD\_MEO = OFF  
S\_RMP\_MEO = OFF  
S\_ALPH\_TO = OFF  
PHIP = 0.0  
I = 1  
LL = 1  
L = 1  
S\_QUAT = OFF  
K\_RAMP = 1  
TDEL\_ADJUST = 0  
S\_THRT\_INIT = OFF

$V\_RHO\_MAG \geq PPOLY_2$  (A)

$THETC = THET_1 + THETP \cdot DELT$

$V\_RHO\_MAG > VREF\_ADJUST$   
AND  $S\_THRT\_INIT = OFF$   
AND  $L = 1$  (B)

(C)

EXIT

FIGURE A4-2.2. 1STG GUID INP TSK FLOW DIAGRAM

Figure A4.2.3. BST GUID TSK Flow Diagram (Sheet 1 of 3)

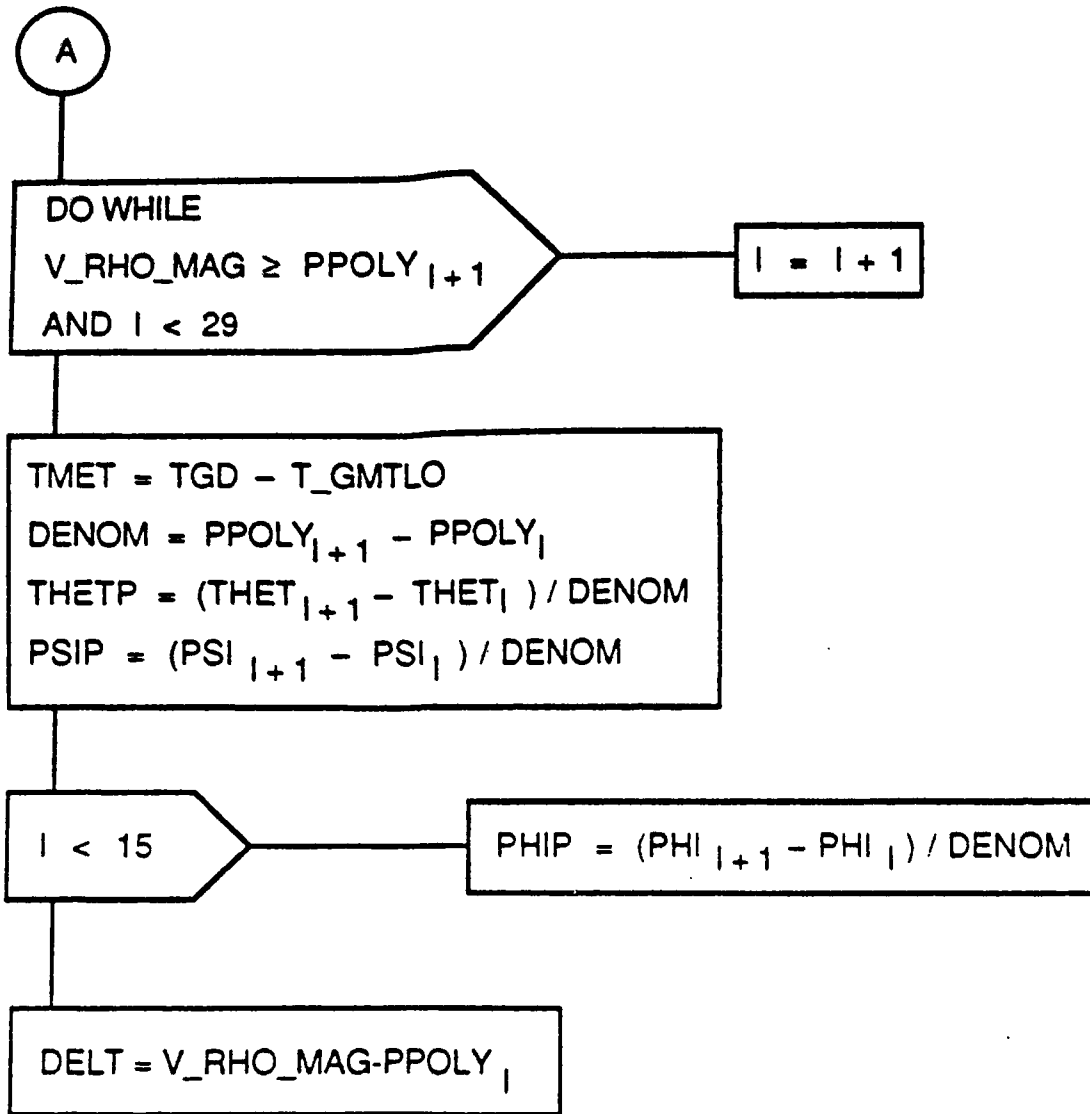


Figure A4.2.3. BST GUID TSK Flow Diagram (Sheet 2 of 3)

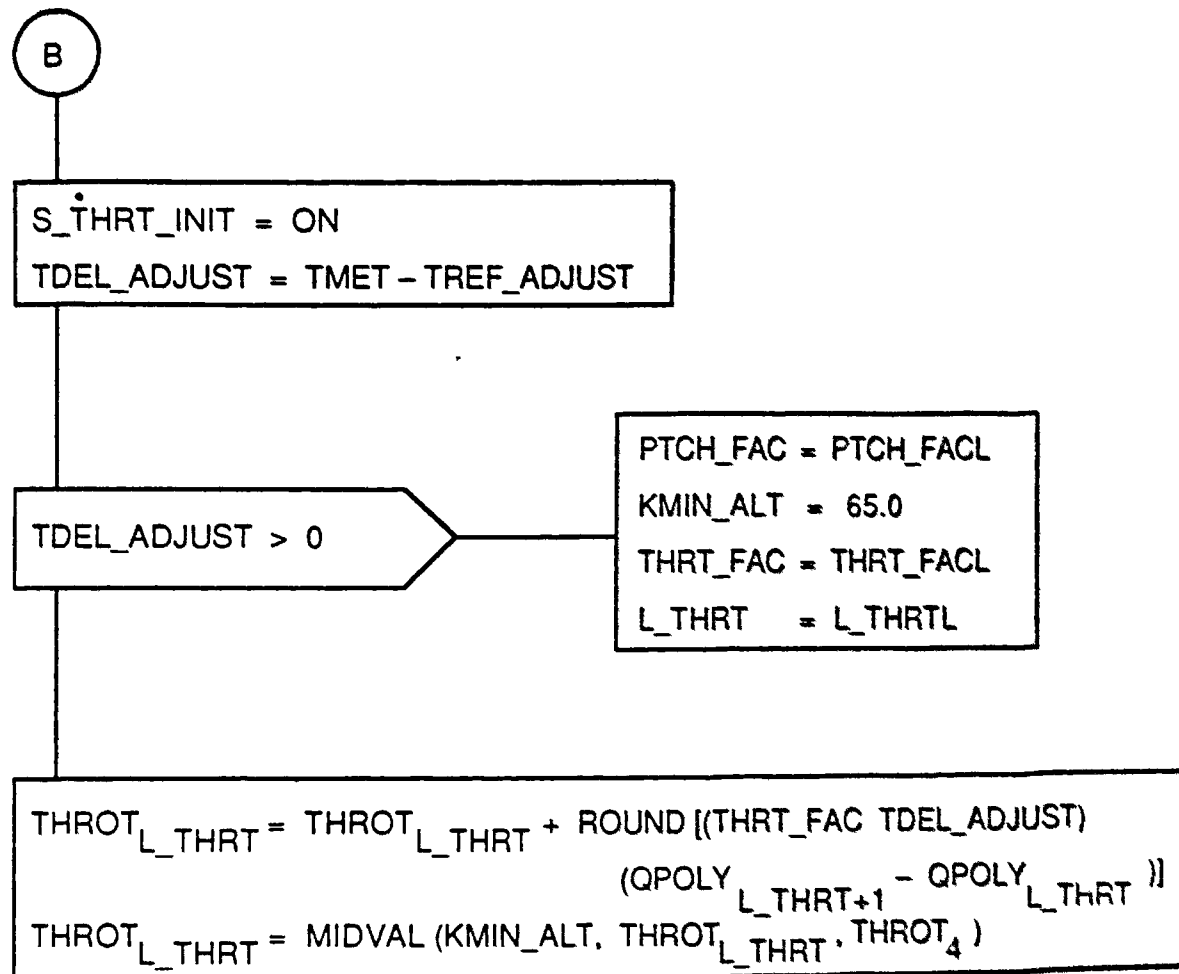


Figure A4.2.3. BST GUID TSK Flow Diagram (Sheet 3 of 8)

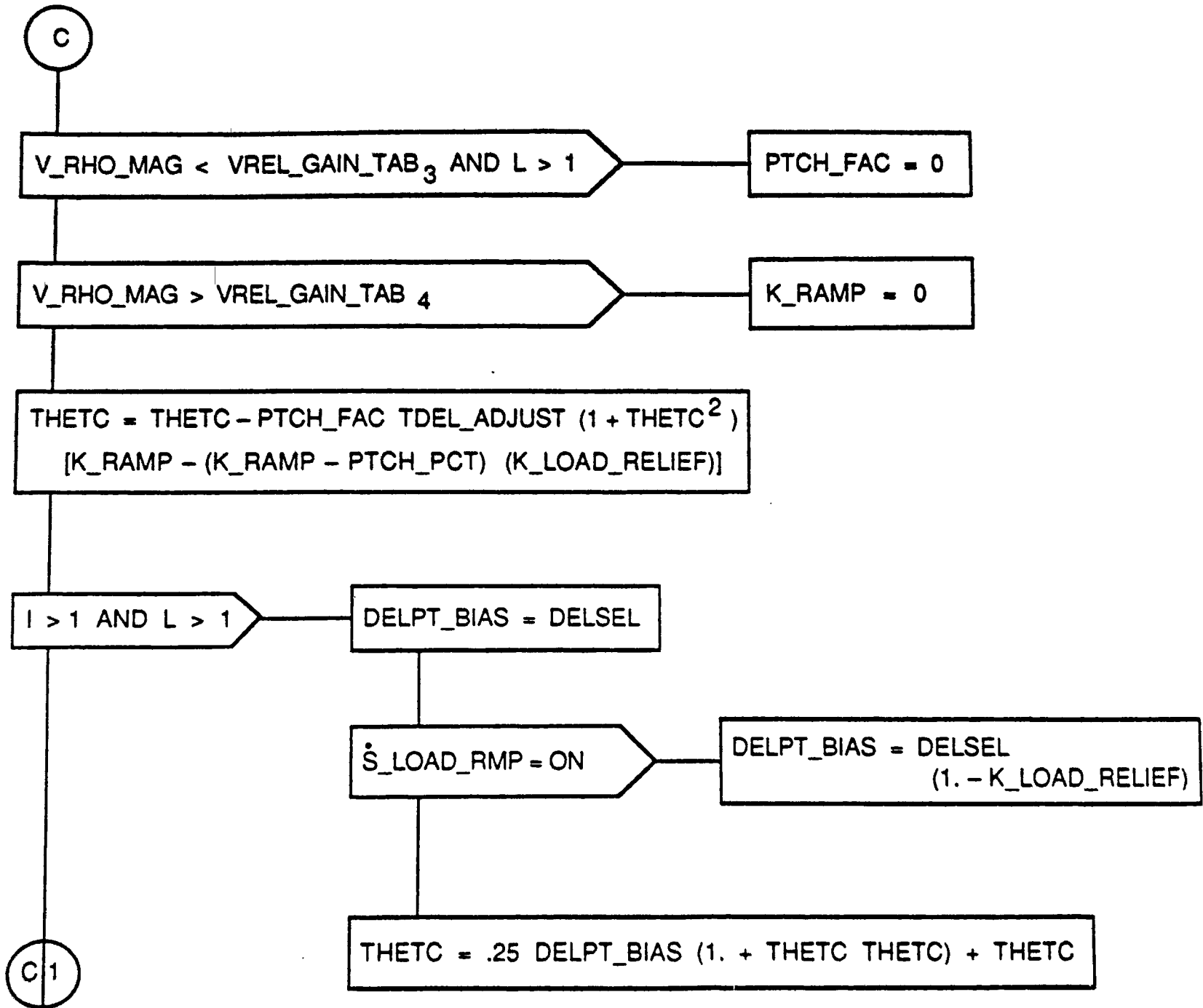


Figure A4.2.3. BST GUID TSK Flow Diagram (Sheet 4 of 8)



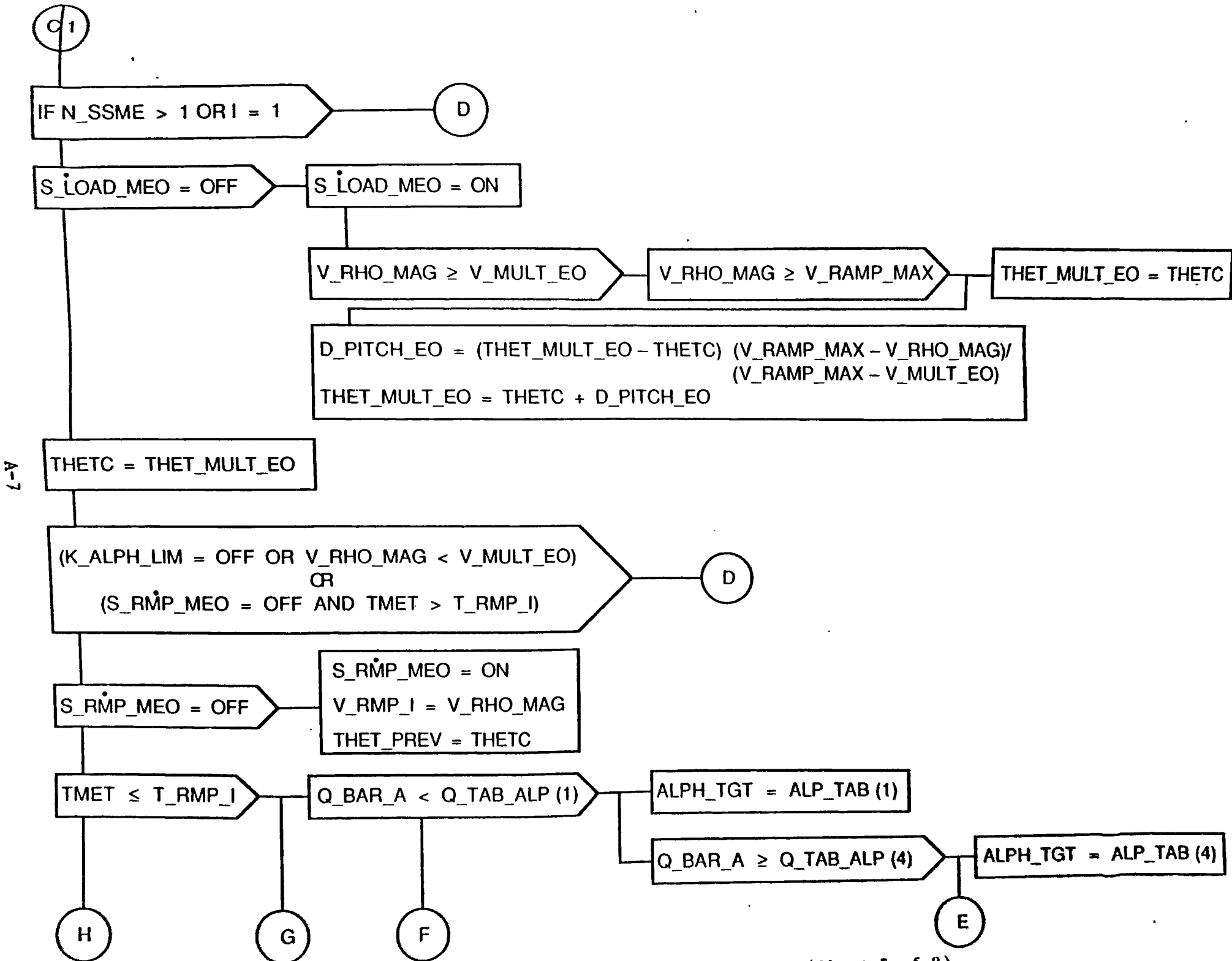
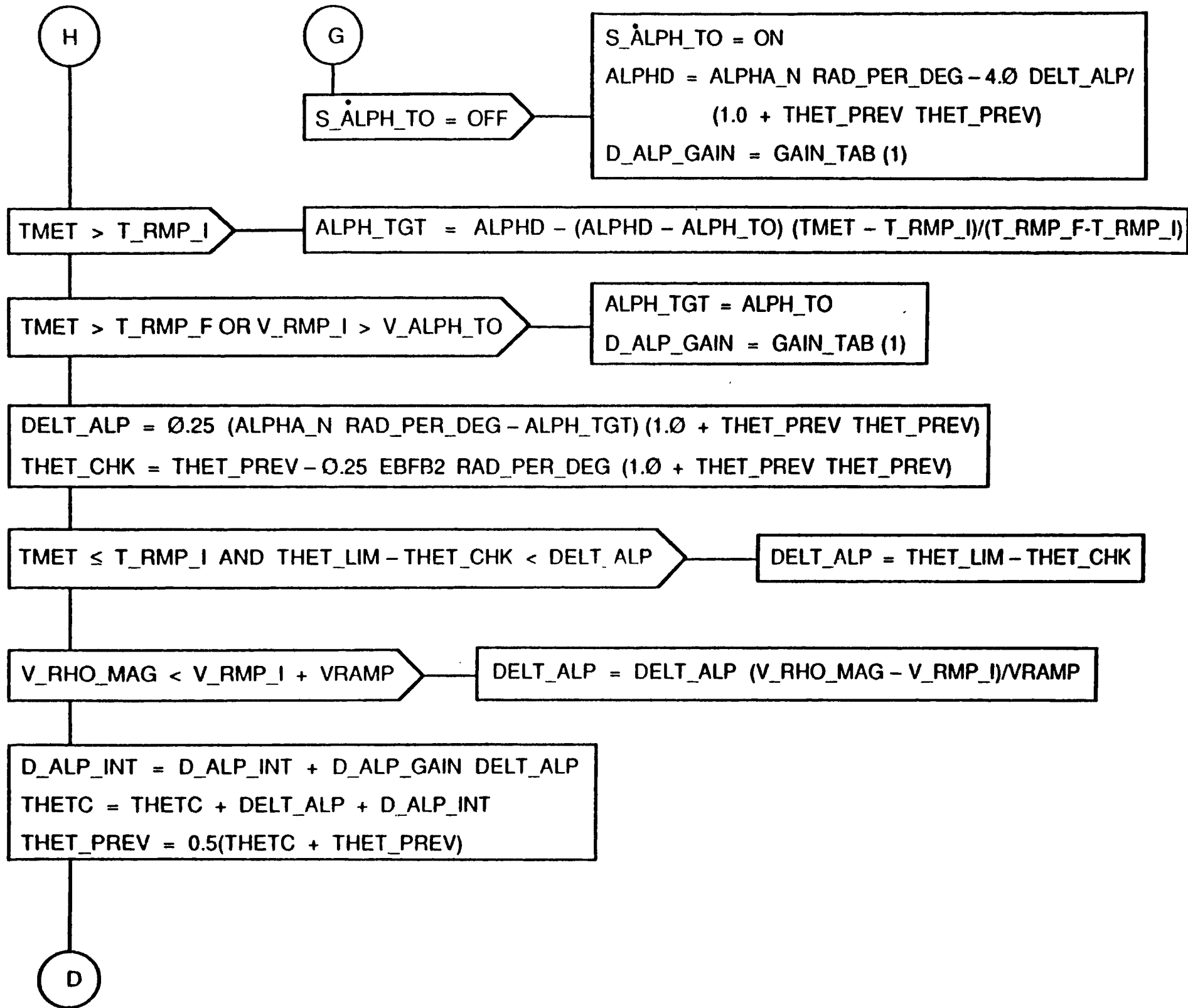


Figure A4.2.3. BST GUID TSK Flow Diagram (Sheet 5 of 8)



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Figure A4.2.3. BST GUID TSK Flow Diagram (Sheet 6 of 8)

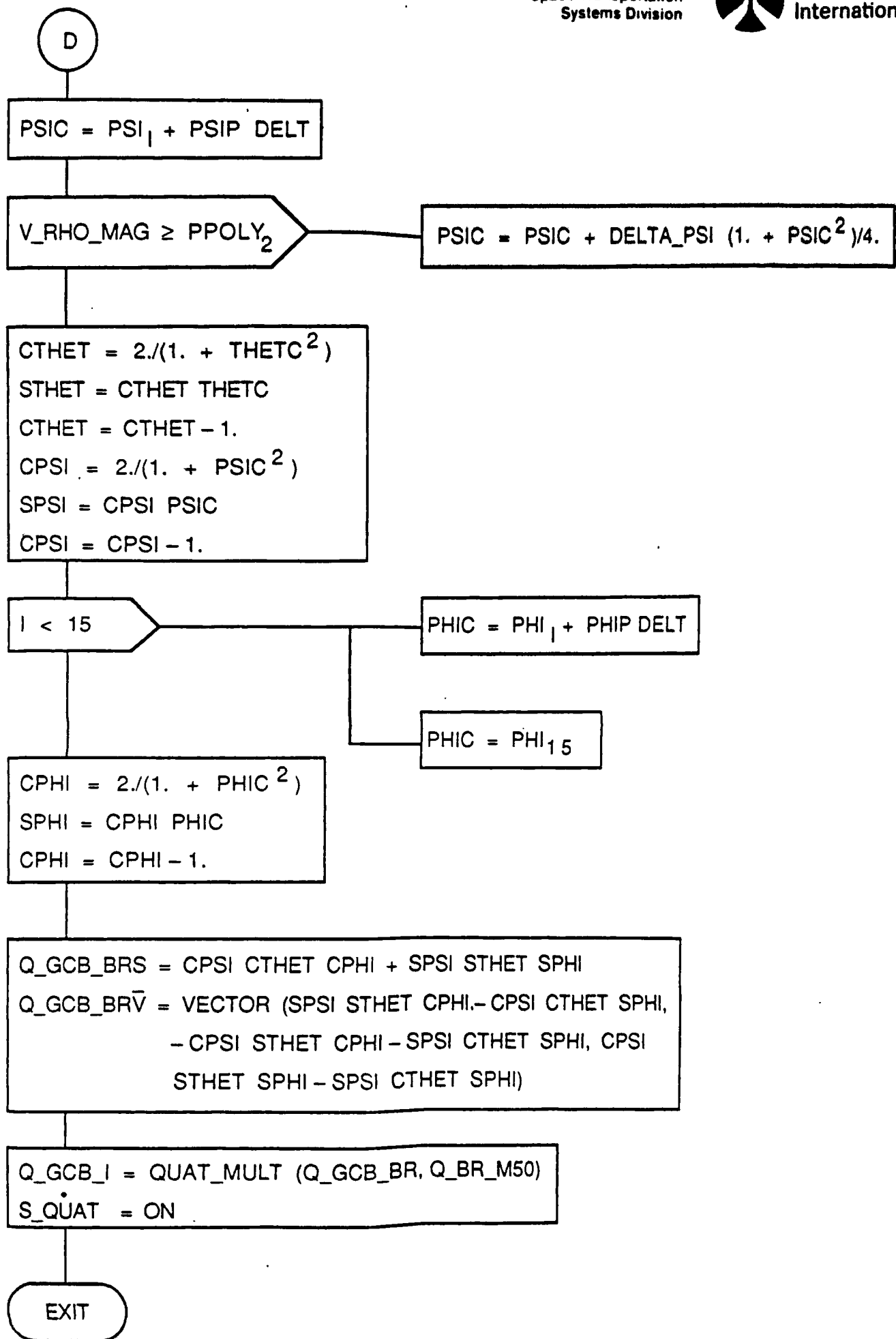


FIGURE A4.2.3. BST GUID TSK Flow Diagram (Sheet 6 of 8)

Figure A4.2.3. BST GUID TSK Flow Diagram (Sheet 7 of 8)

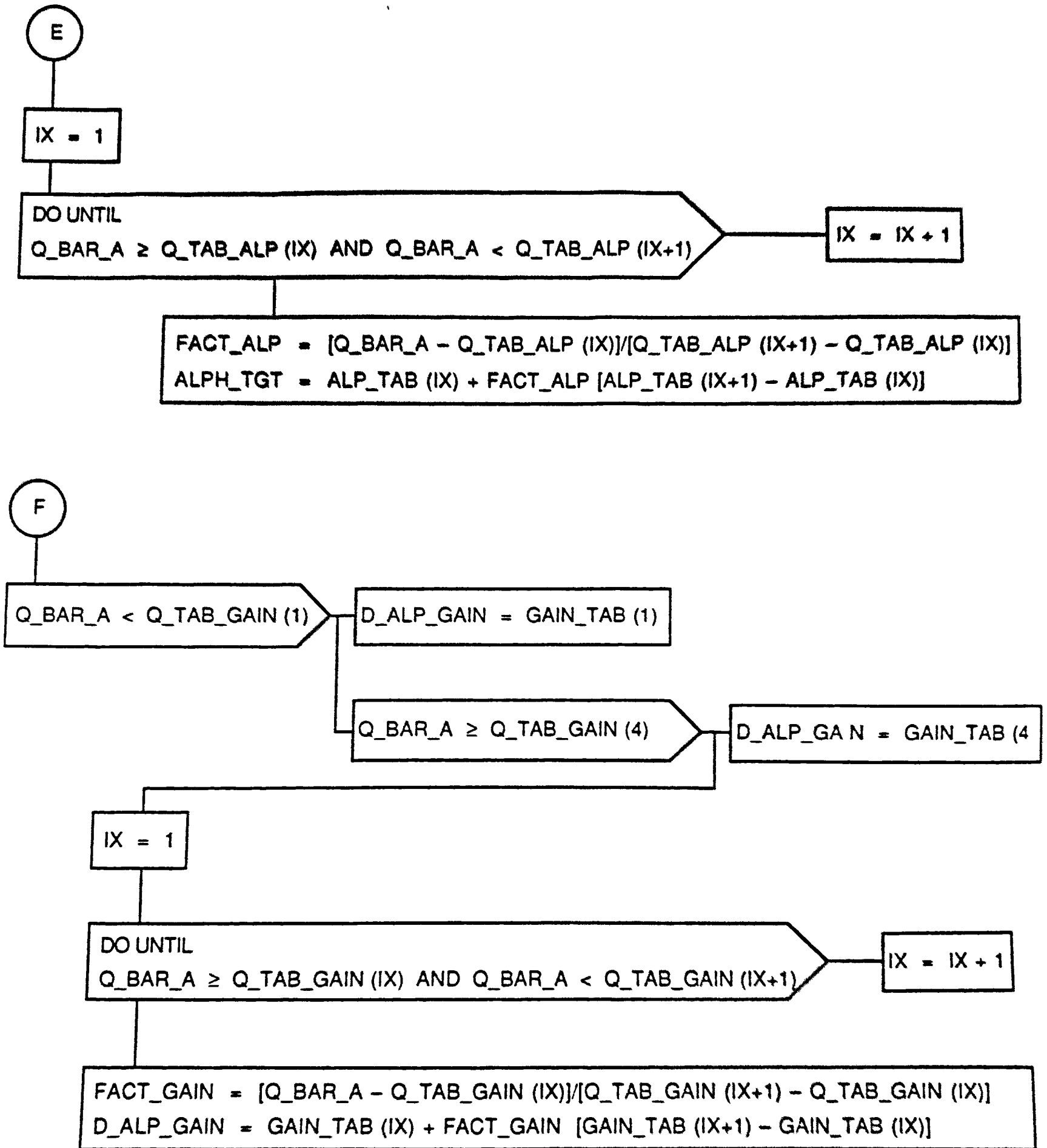


Figure A4.2.3. BST GUID TSK Flow Diagram (Sheet 8 of 8)

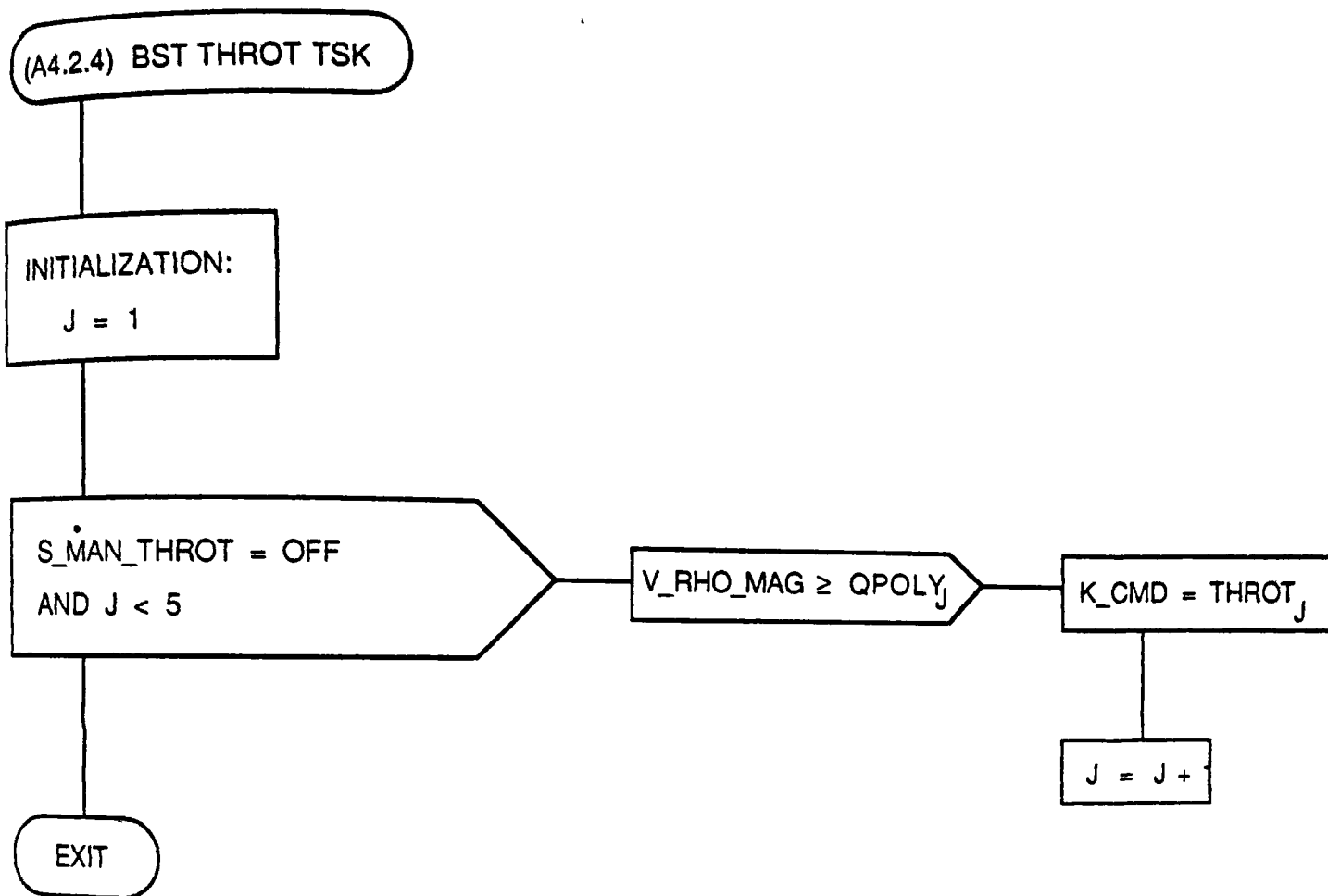


Figure A4.2.4. BST THROT TSK Flow Diagram

4.3 SECOND STAGE FLOW CHARTS

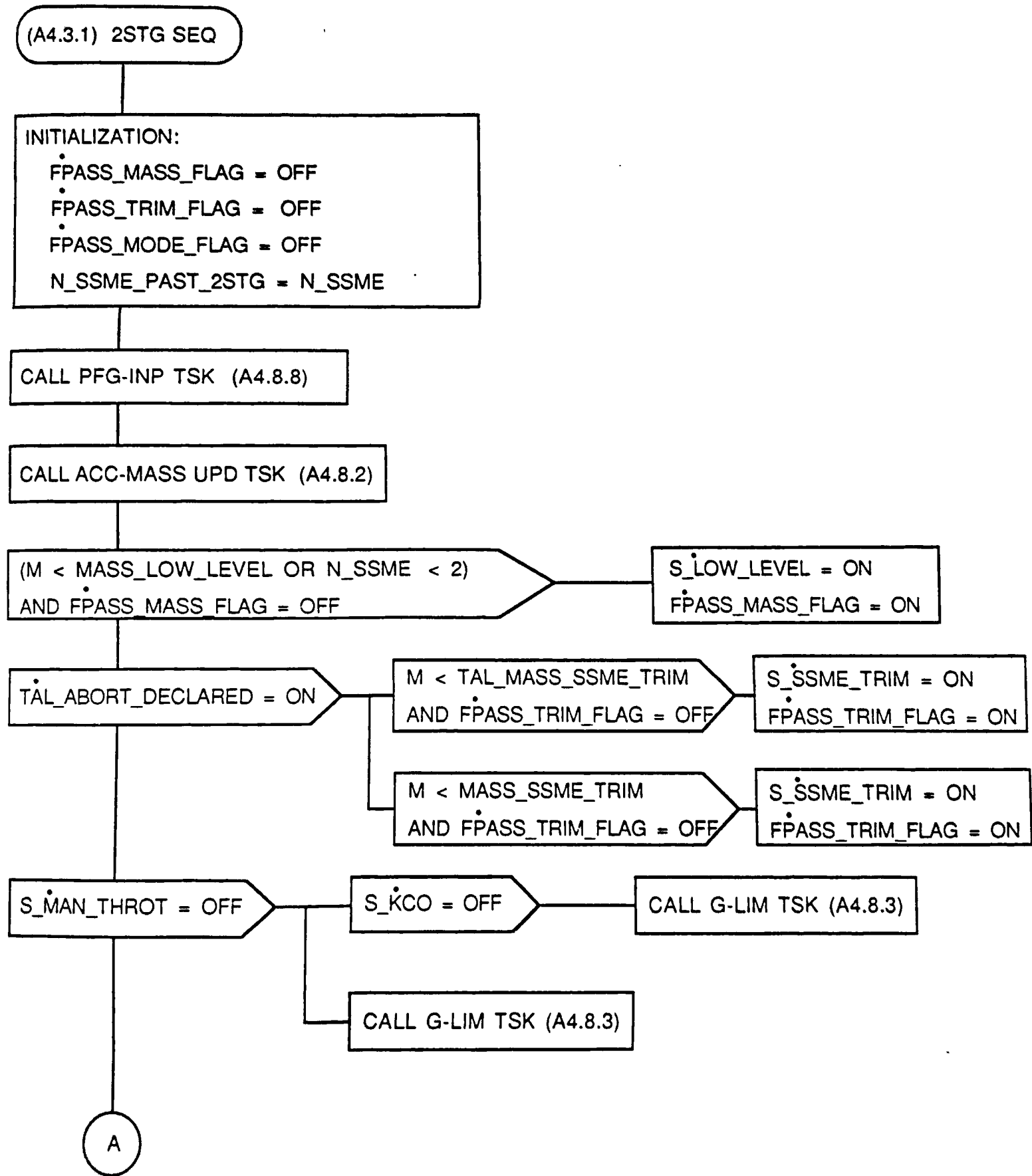


Figure A4.3.1. 2STG SEQ Flow Diagram (Sheet 1 of 2)

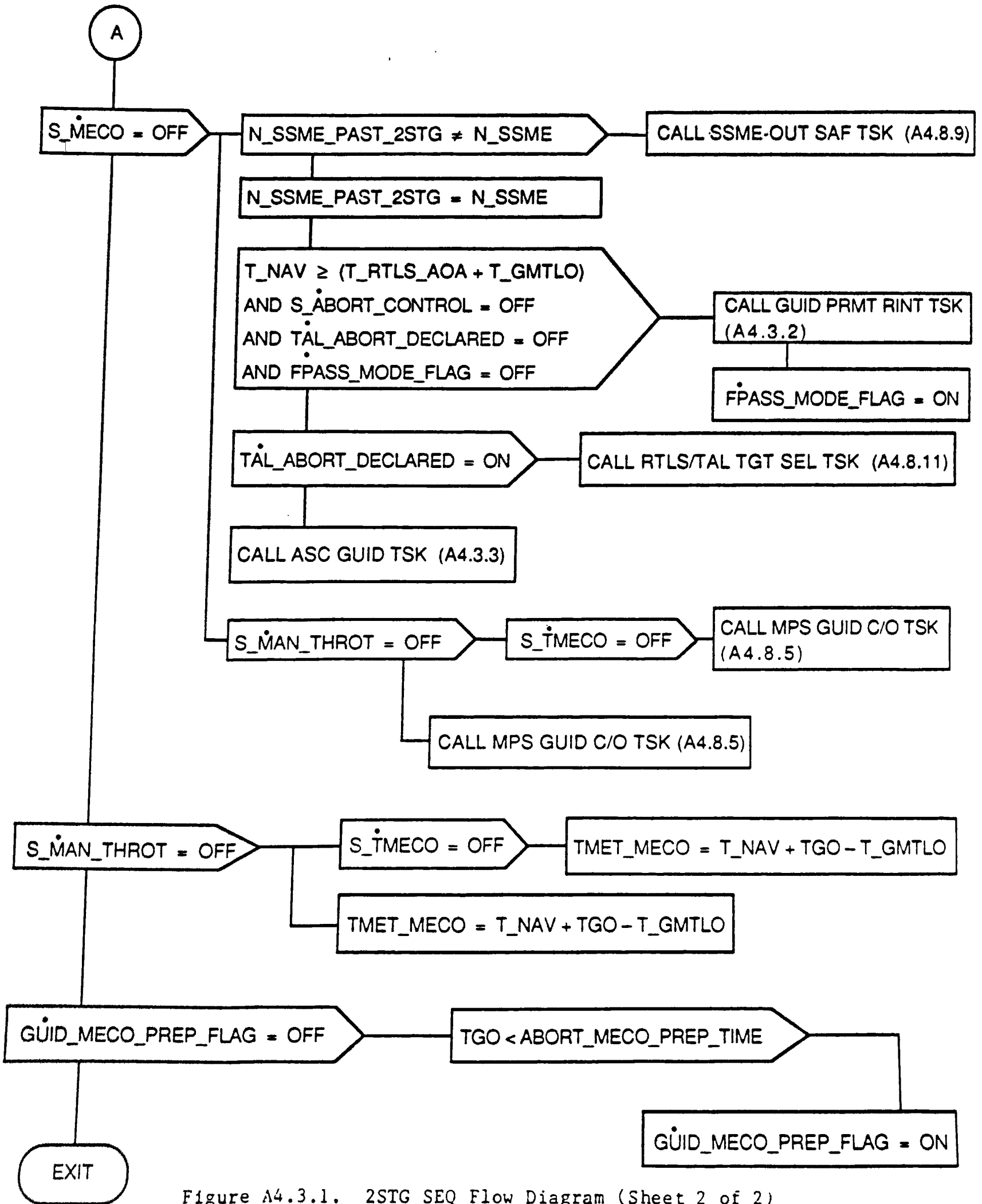


Figure A4.3.1. 2STG SEQ Flow Diagram (Sheet 2 of 2)



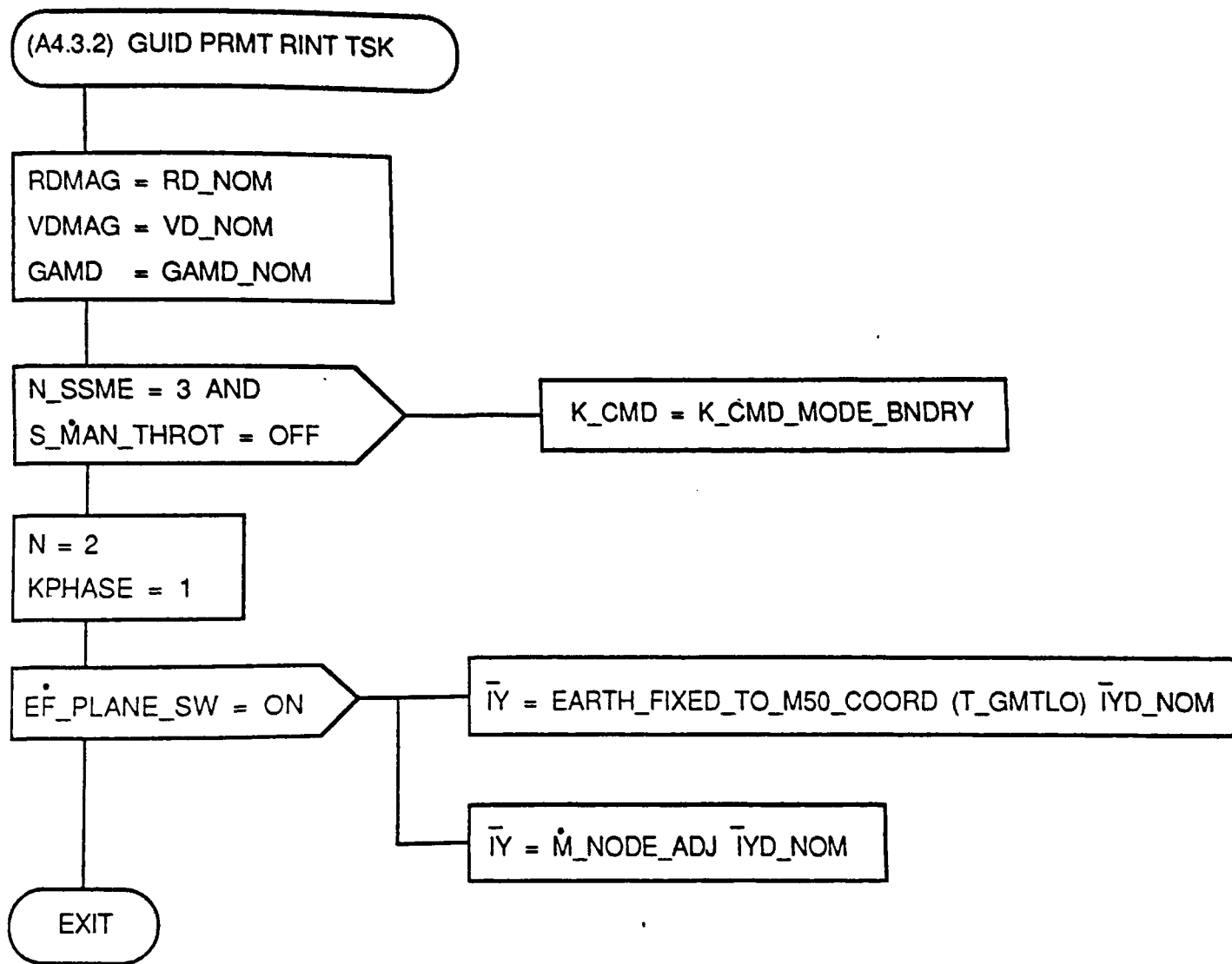


Figure A4.3.2. GUID PRMT RINT TSK Flow Diagram

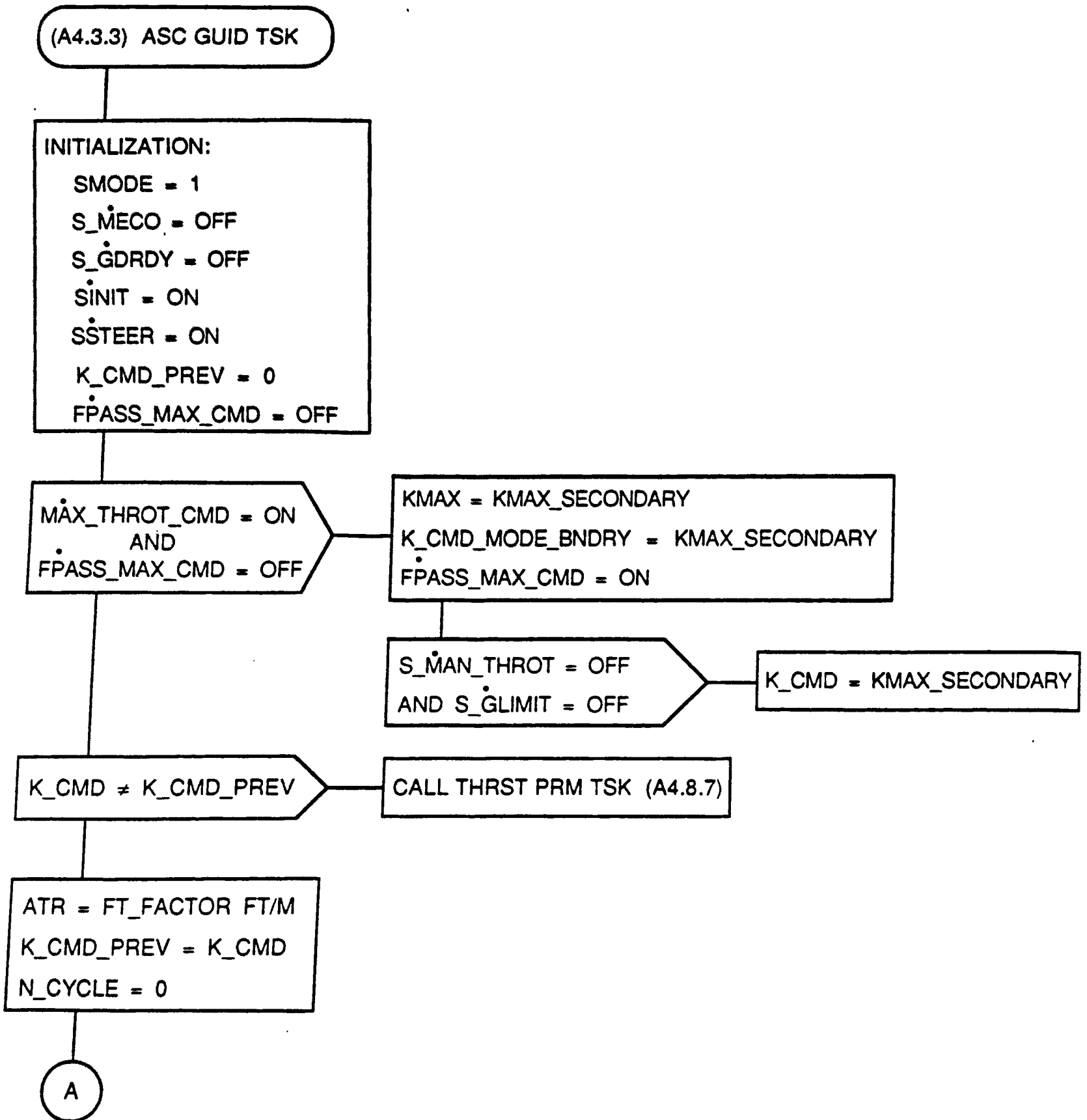
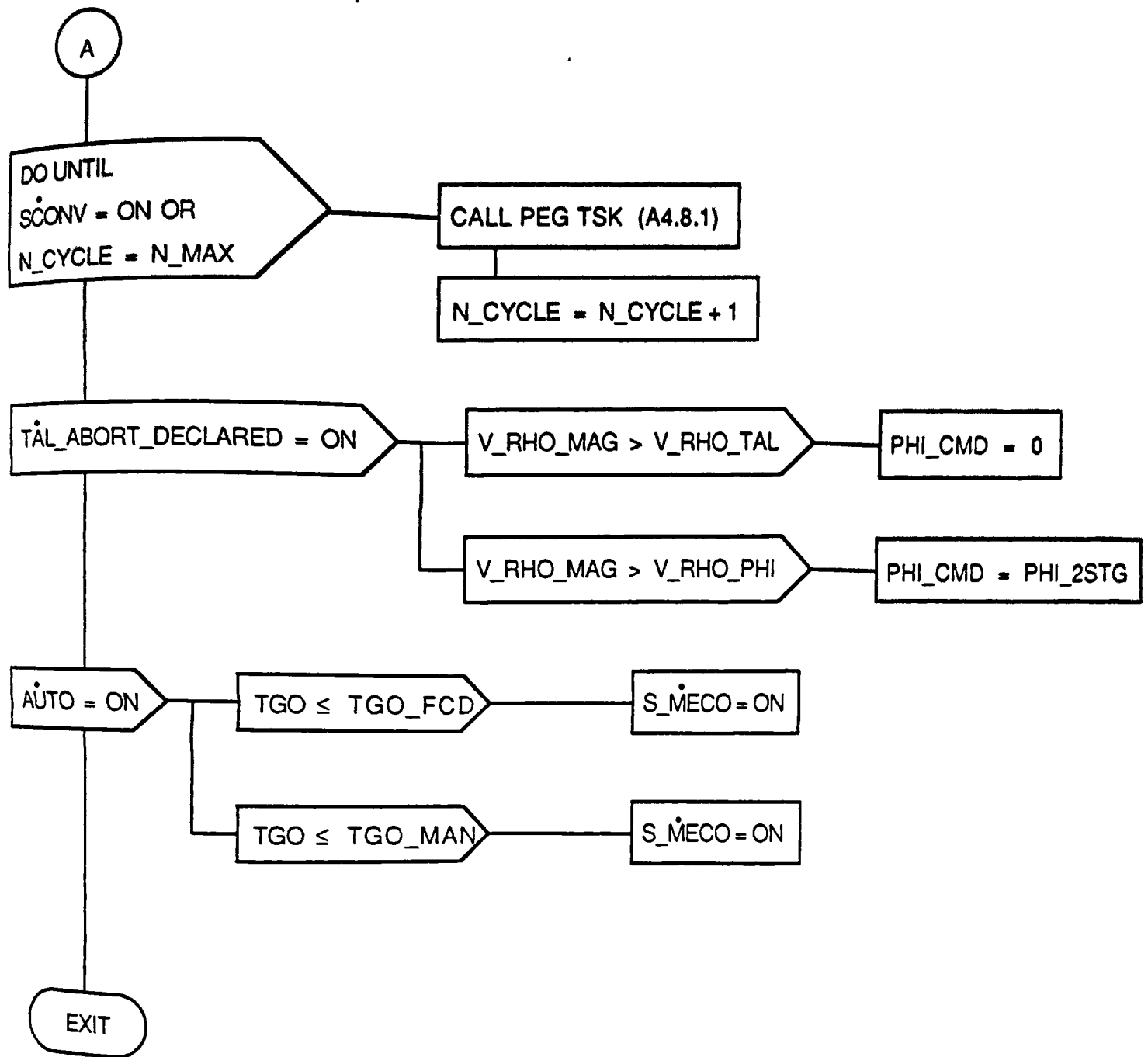


Figure A4.3.3. ASC GUID TSK Flow Diagram (Sheet 1 of 2)



MAX\_SECONDARY

Figure A4.3.3. ASC GUID TSK Flow Diagram (Sheet 2 of 2)

4.4 ORBIT INSERTION FLOW CHARTS

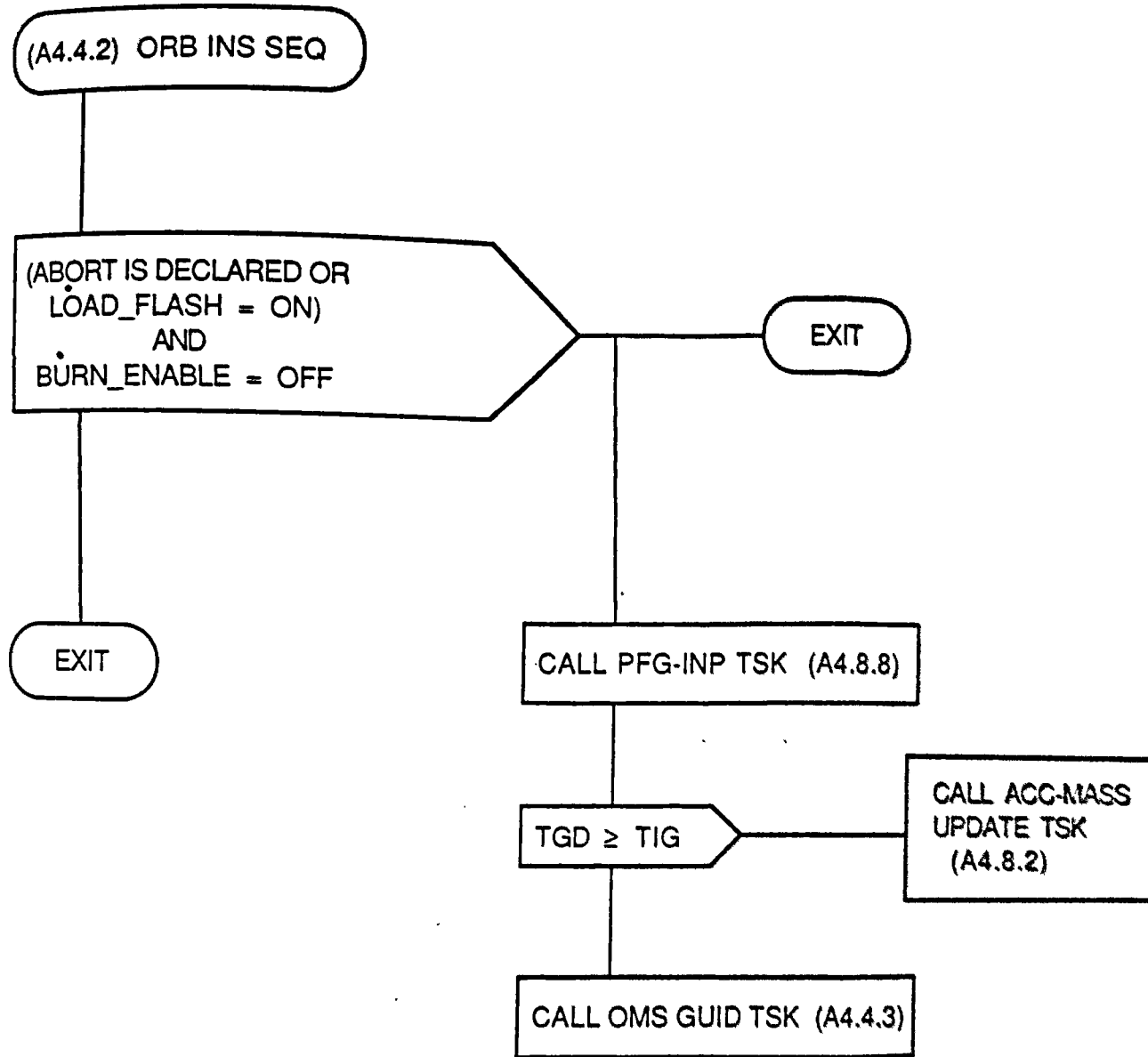


Figure A4.4.2. ORB INS SEQ Flow Diagram

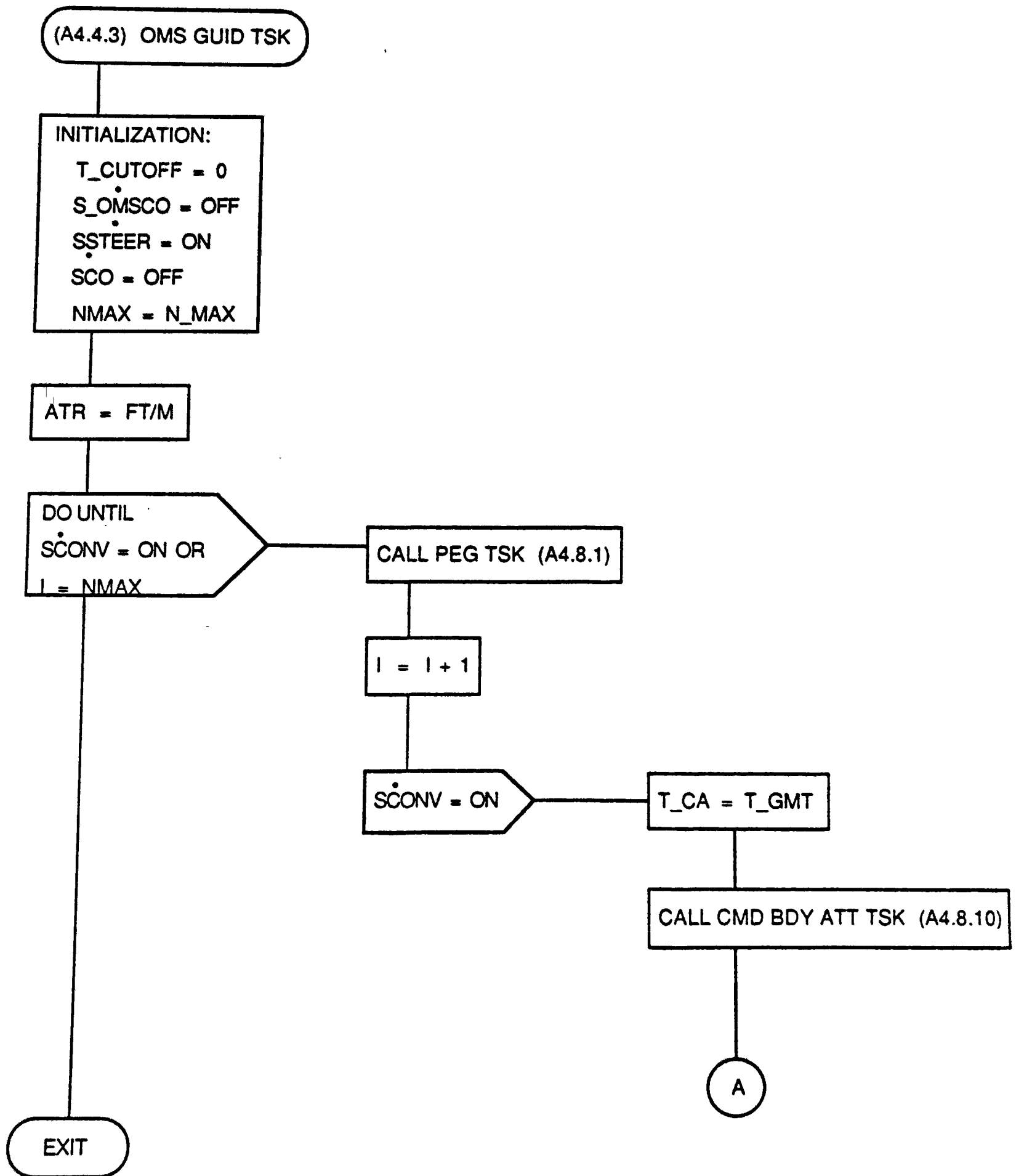
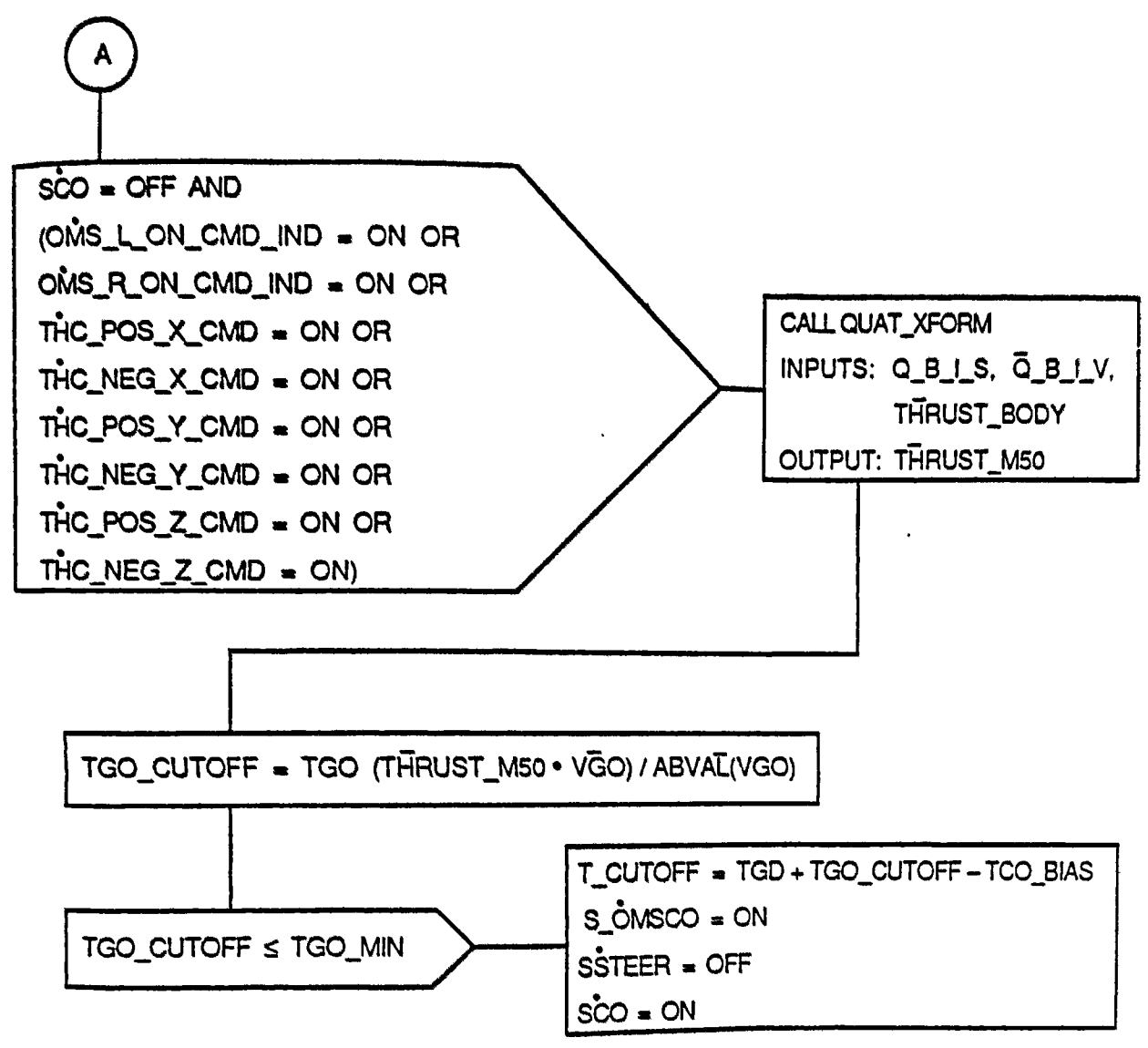


Figure A4.4.3. OMS GUID TSK Flow Diagram (Sheet 1 of 2)



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T TSK (A4.8.10)

Figure A4.4.3. OMS GUID TSK Flow Diagram (Sheet 2 of 2)

4.5 AOA AND ATO TARGETING FLOW CHARTS



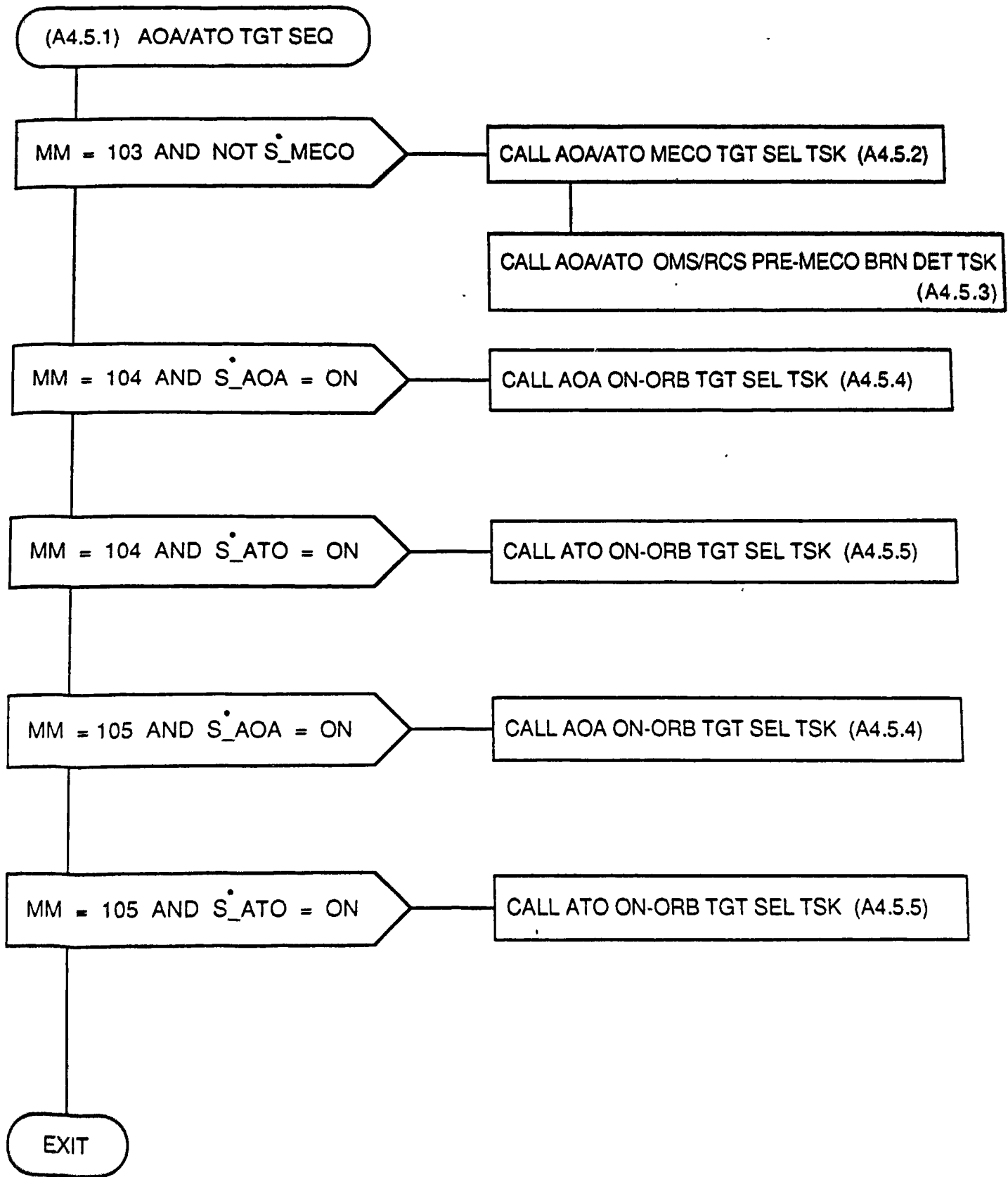


Figure A4.5.1. AOA/ATO TGT SEQ Flow Diagram

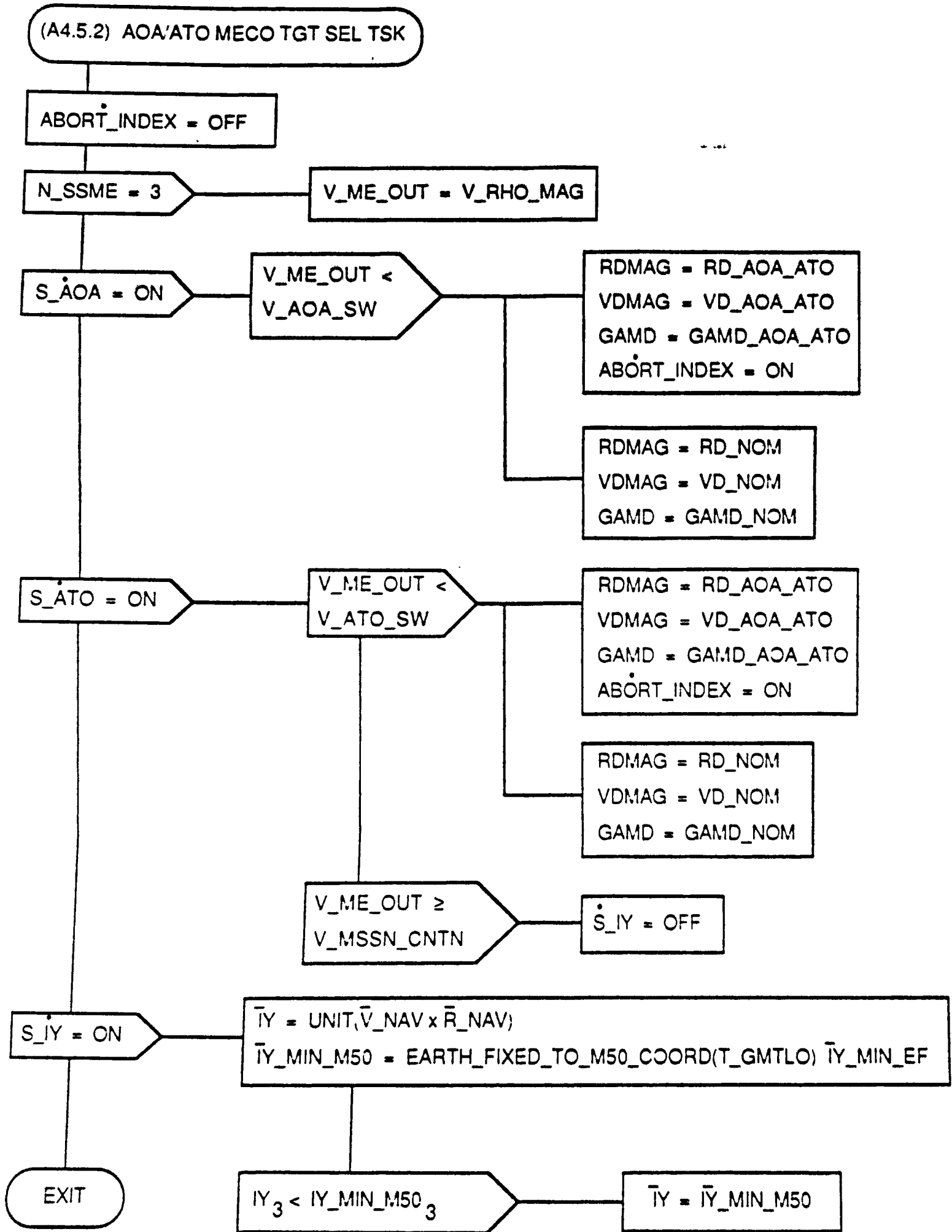


Figure A4.5.2. AOA/ATO MECO TGT SEL TSK Flow Diagram

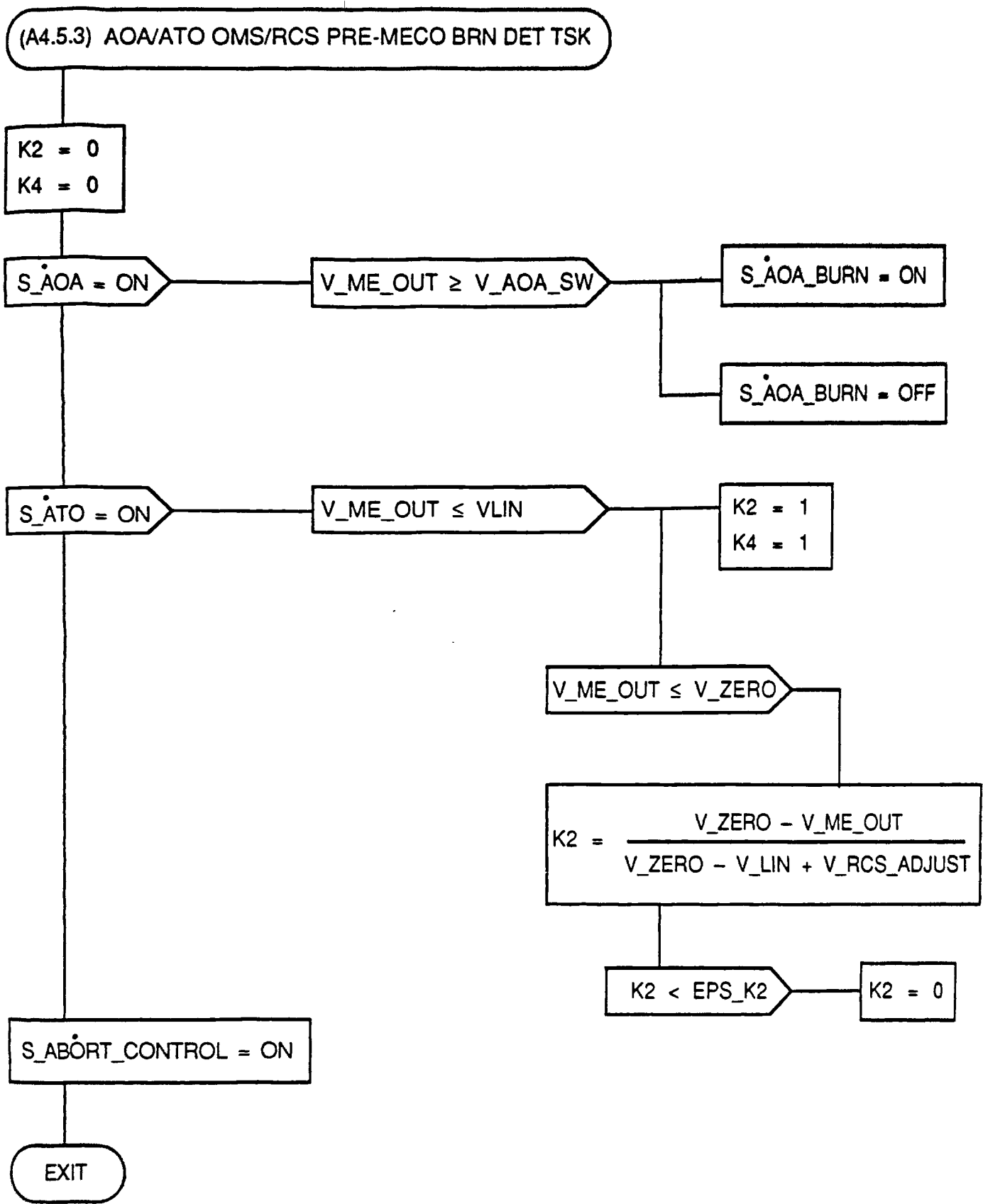


Figure A4.5.3. AOA/ATO OMS/RCS PRE-MECO BRN DET TSK Flow Diagram

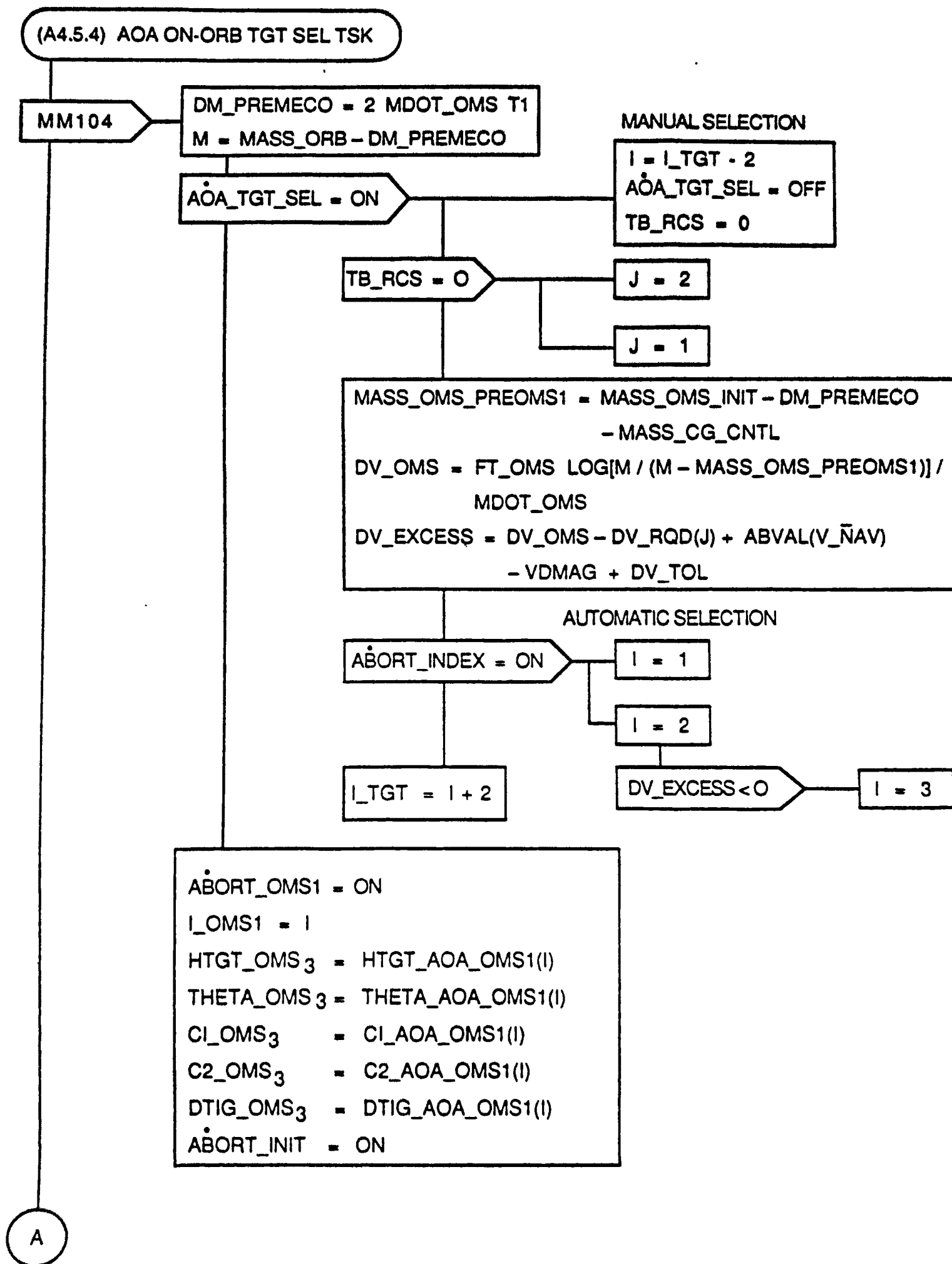


Figure A4.5.4. AOA ON-ORB TGT SEL TSK Flow Diagram (Sheet 1 of 3)

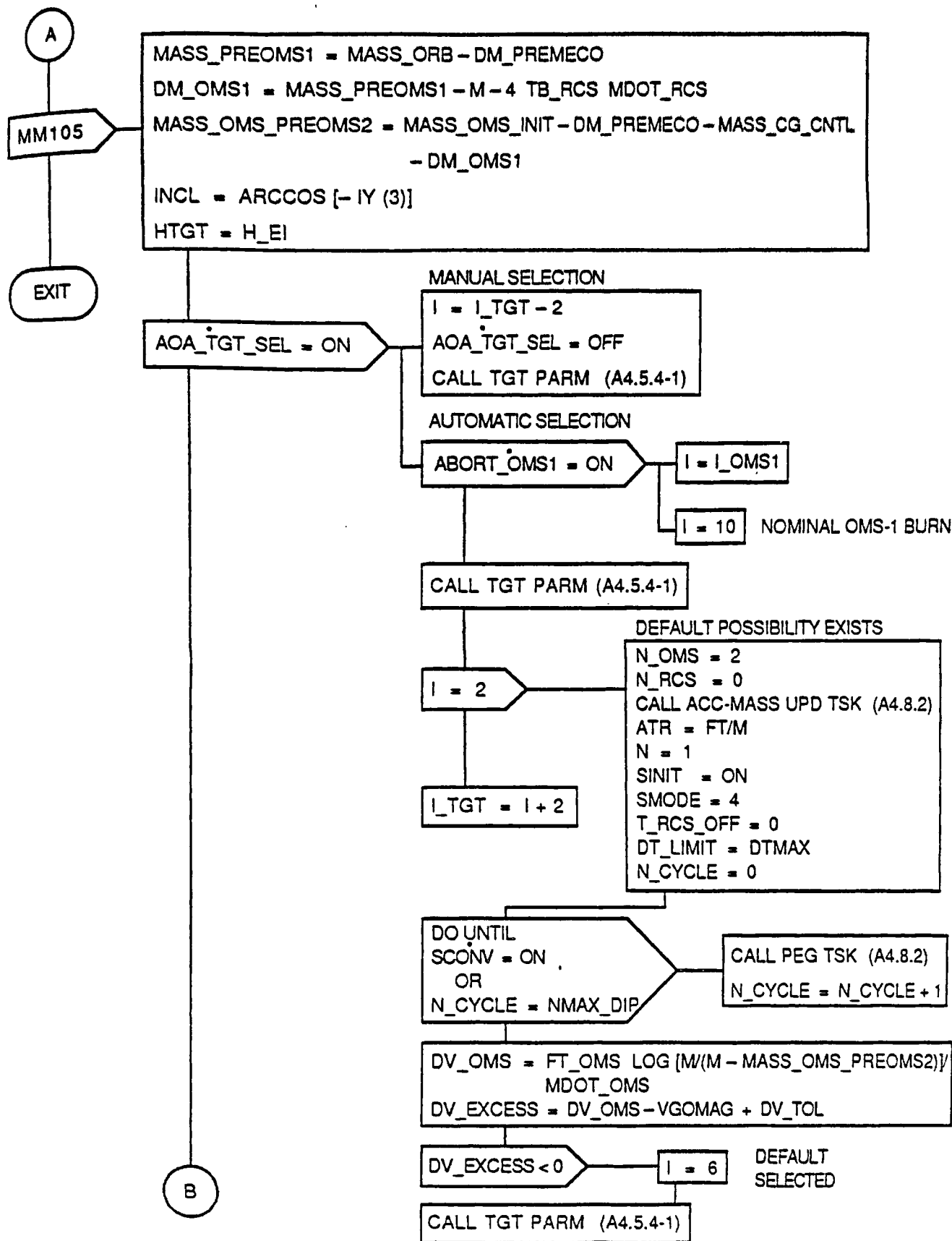
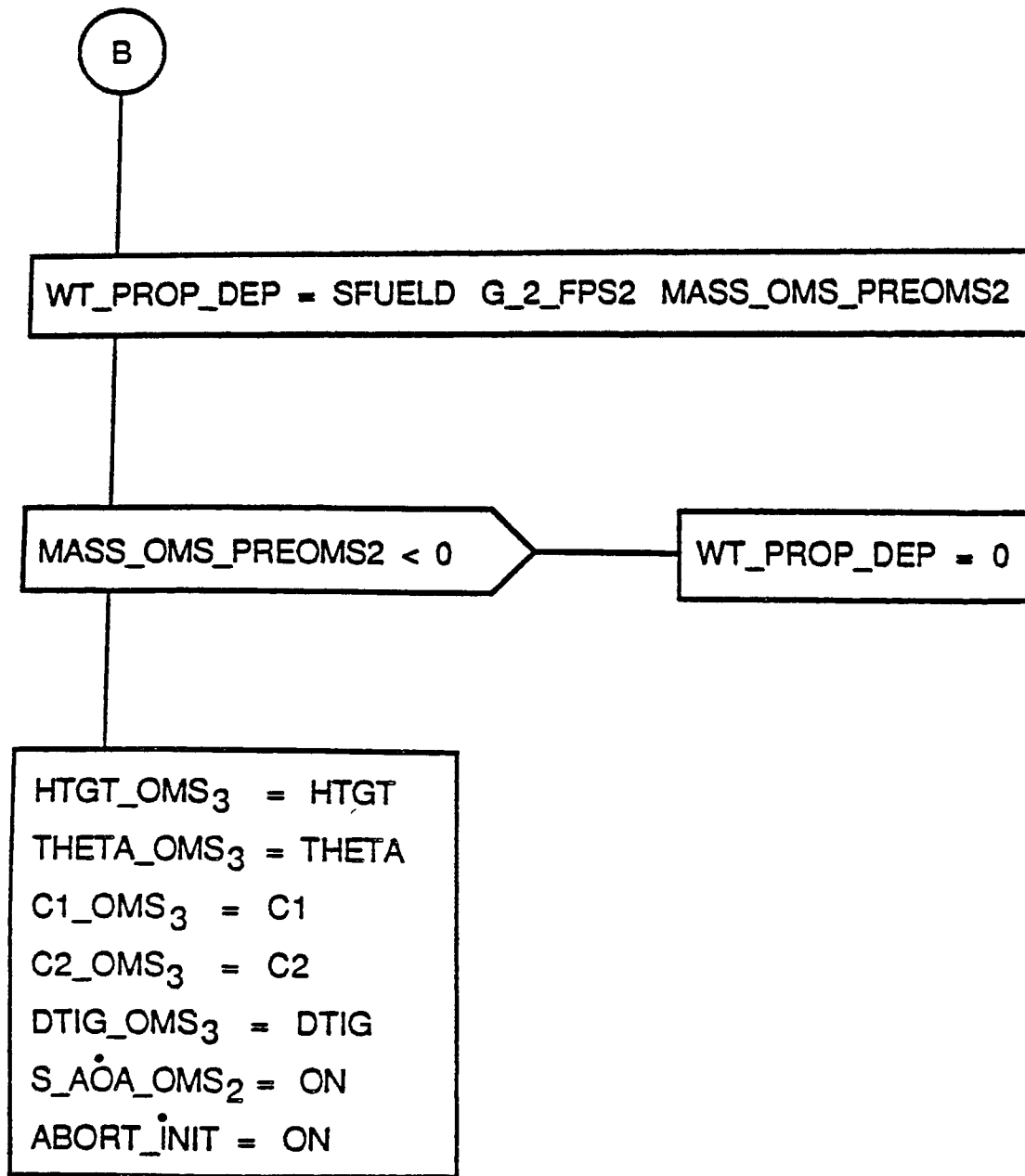


Figure A4.5.4. AOA ON-ORB TGT SEL TSK Flow Diagram (Sheet 2 of 3)

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Figure A4.5.4. AOA ON-ORB TGT SEL TSK Flow Diagram (Sheet 3 of 3)

(A4.5.4.1) TGT PARM SUBTASK

$THETA = THETA\_AOA\_OMS2(I, 1) + THETA\_AOA\_OMS2(I, 2)$   
 $INCL + THETA\_AOA\_OMS2(I, 3) INCL^2$

$DTIG = DTIG\_AOA\_OMS2(I, 1) + DTIG\_AOA\_OMS2(I, 2)$   
 $INCL + DTIG\_AOA\_OMS2(I, 3) INCL^2$

$C1 = C1\_AOA\_OMS2(I, 1) + C1\_AOA\_OMS2(I, 2)$   
 $INCL + C1\_AOA\_OMS2(I, 3) INCL^2$

$C2 = C2\_AOA\_OMS2(I, 1) + C2\_AOA\_OMS2(I, 2)$   
 $INCL + C2\_AOA\_OMS2(I, 3) INCL^2$

$TIG\_ADJ = (THETA\_LSS - THETA\_LS\_REF) * ORB\_RATE$

$DTIG\_OMS = DTIG - TIG\_ADJ$

$TG\_OPS3 = DTIG\_OMS + T\_ET\_SEP$

$GMD\_PRED = 4$   
 $GMO\_PRED = 4$

CALL ASC PRED PRED  
 NPUTS.  $\bar{R}\_NAV, \bar{V}\_NAV, T\_NAV, TIG\_OPS3, DT\_AOA\_PRED$   
 OUTPUTS.  $\bar{R}\_GD, \bar{V}\_GD$

$TGD = T\_FINAL$   
 CALL H-Θ-M50 TGT TSK (A4.8.6)

EXT

Figure A4.5.4.1. TGT PARM SUBTASK Flow Diagram

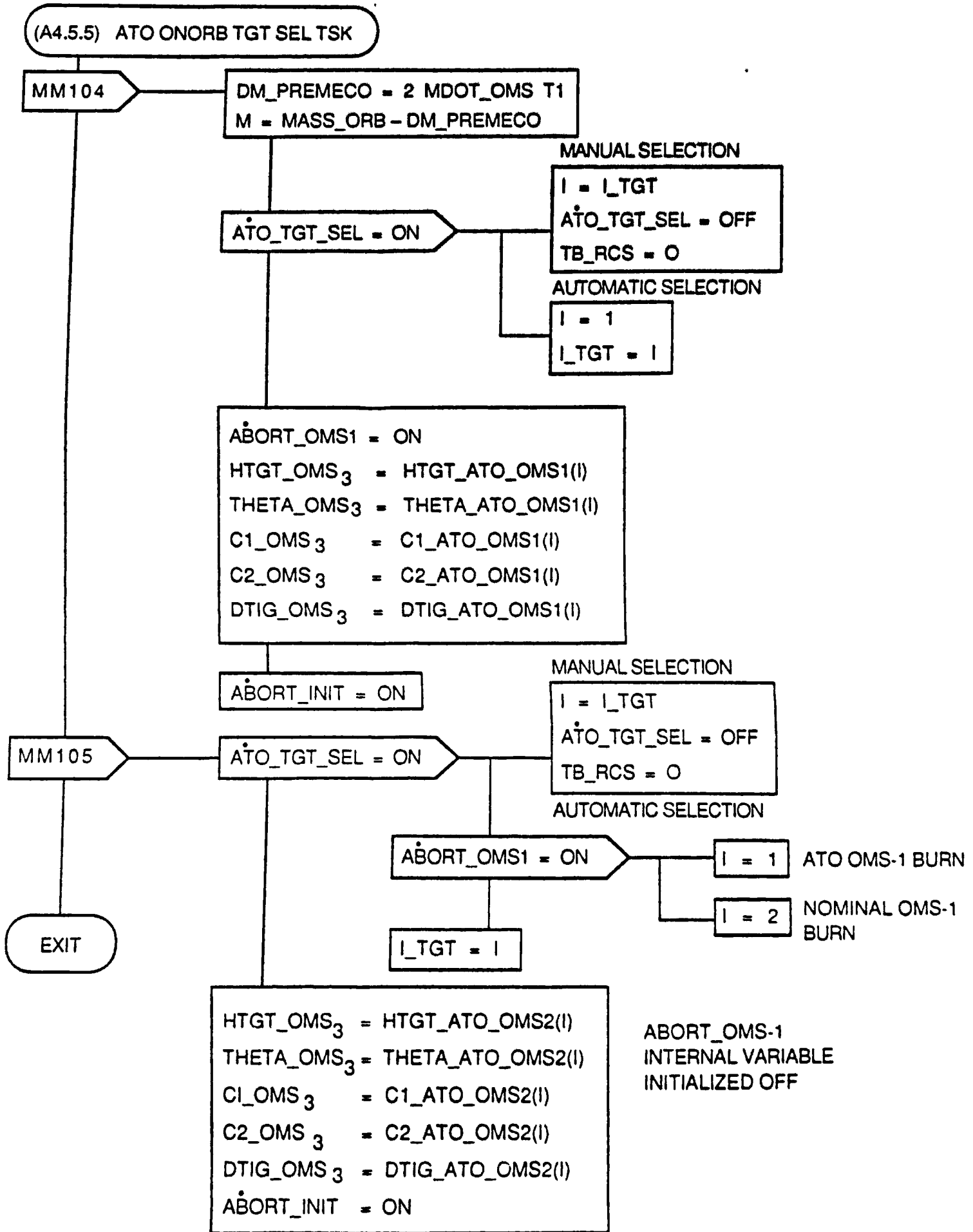


Figure A4.5.5. ATO ON-ORB TGT SEL TSK Flow Diagram



Rockwell  
International

4.6 PRTLS GUIDANCE FLOW CHARTS

MS-1 BURN  
AL OMS-1

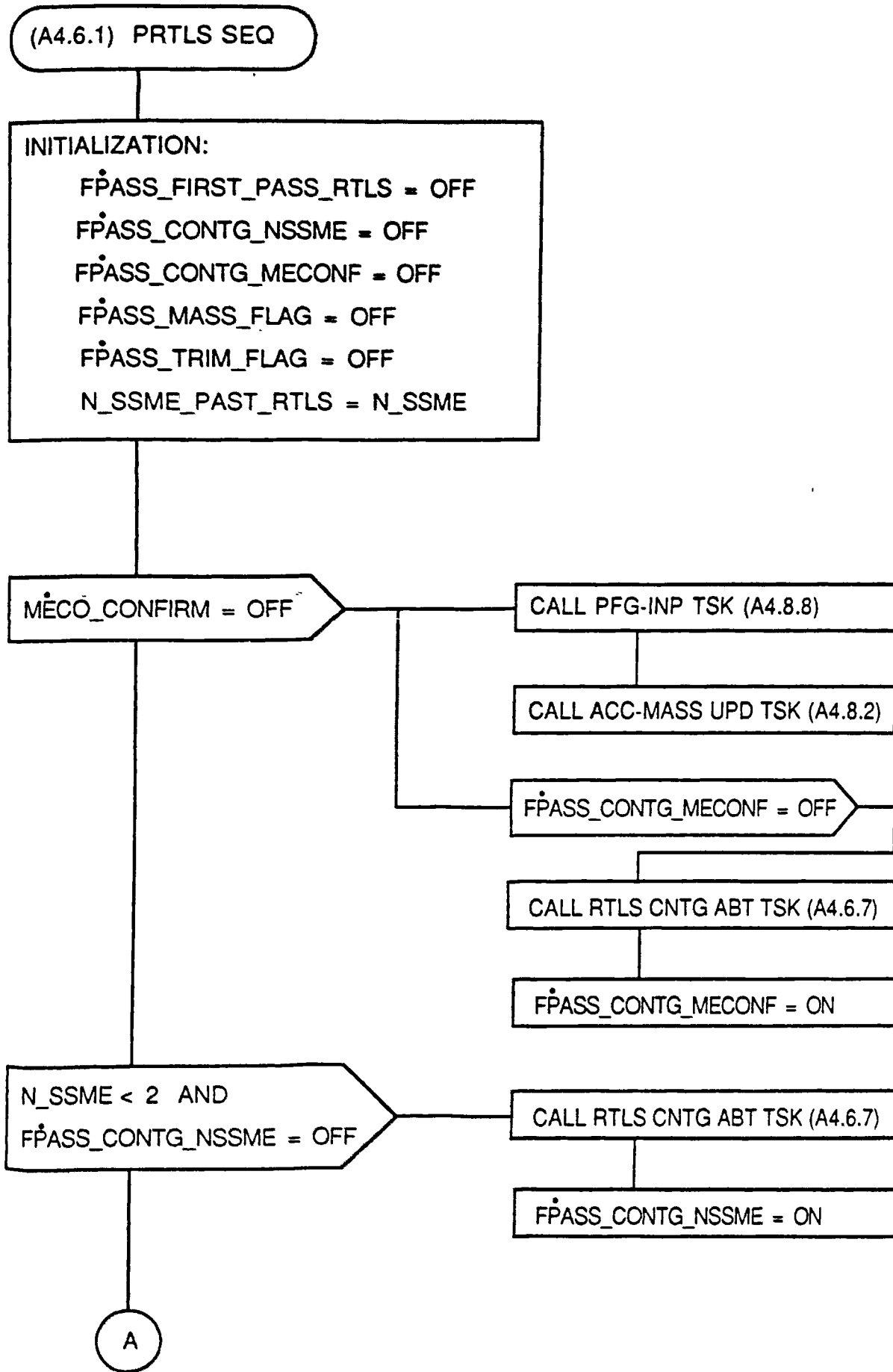


Figure A4.6.1. PRTLS SEQ Flow Diagram (Sheet 1 of 4)

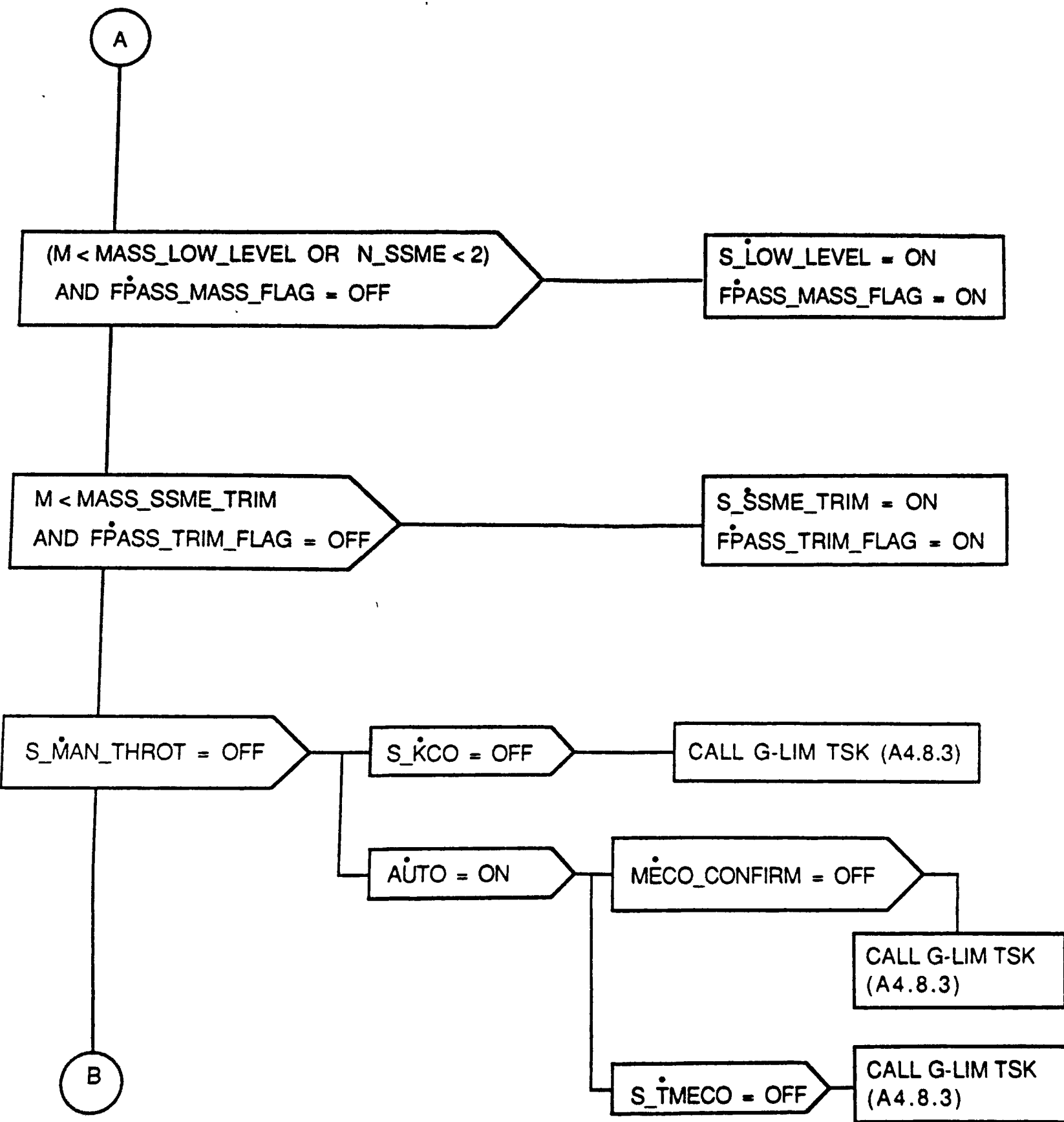


Figure A4.6.1. PRTLS SEQ Flow Diagram (Sheet 2 of 4)

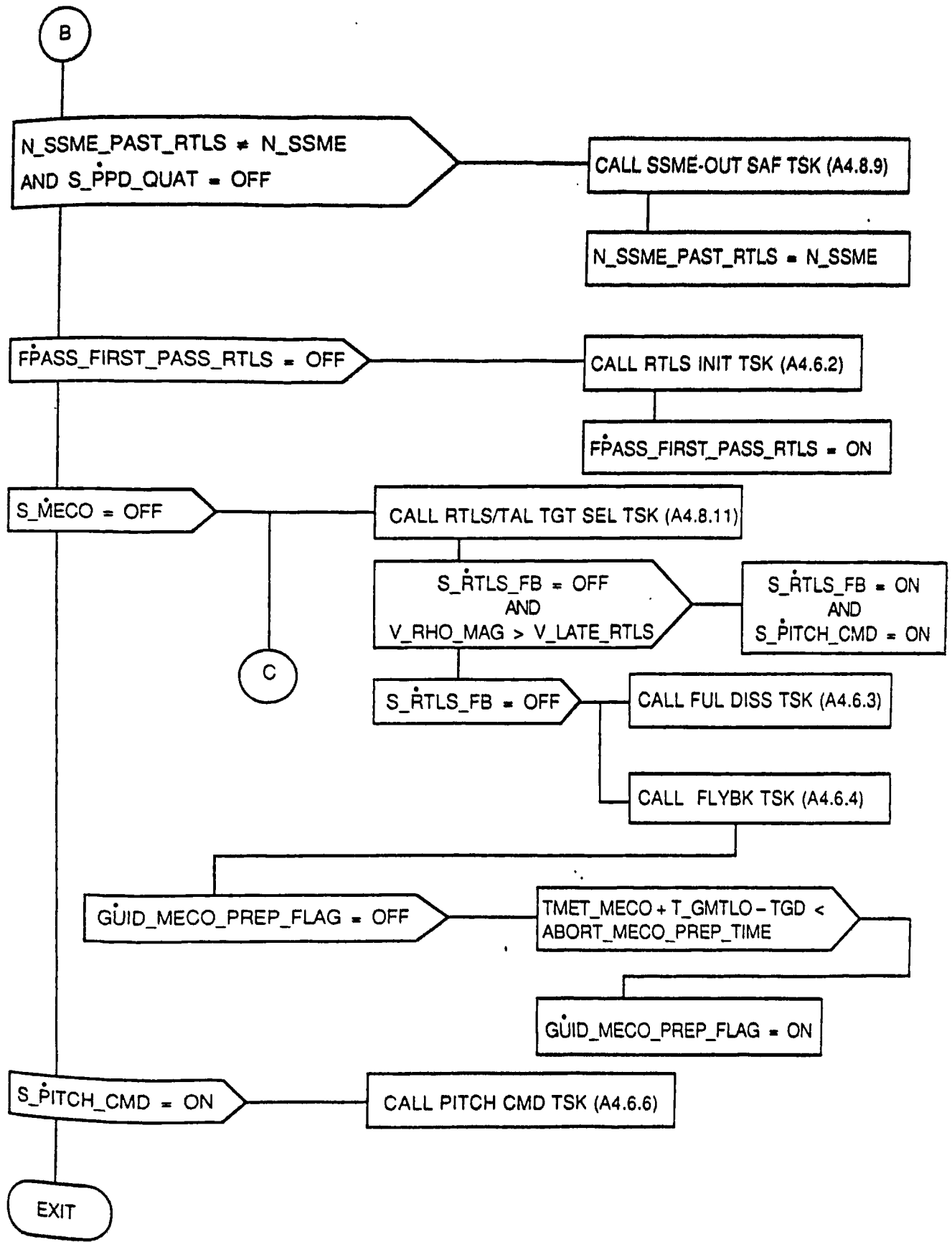


Figure A4.6.1. PRTLs SEQ Flow Diagram (Sheet 3 of 4)

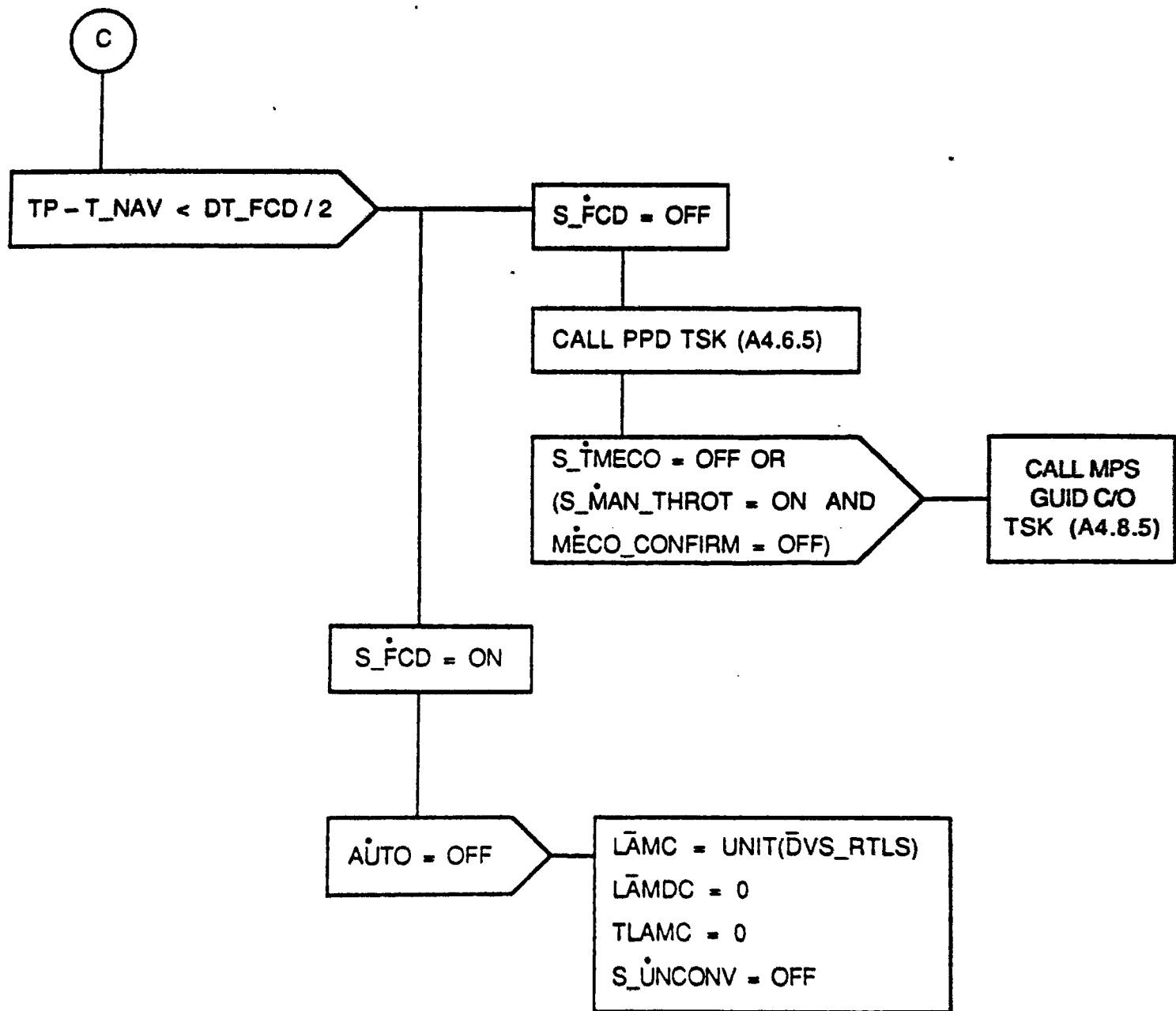


Figure A4.6.1. PRTLS SEQ Flow Diagram (Sheet 4 of 4)

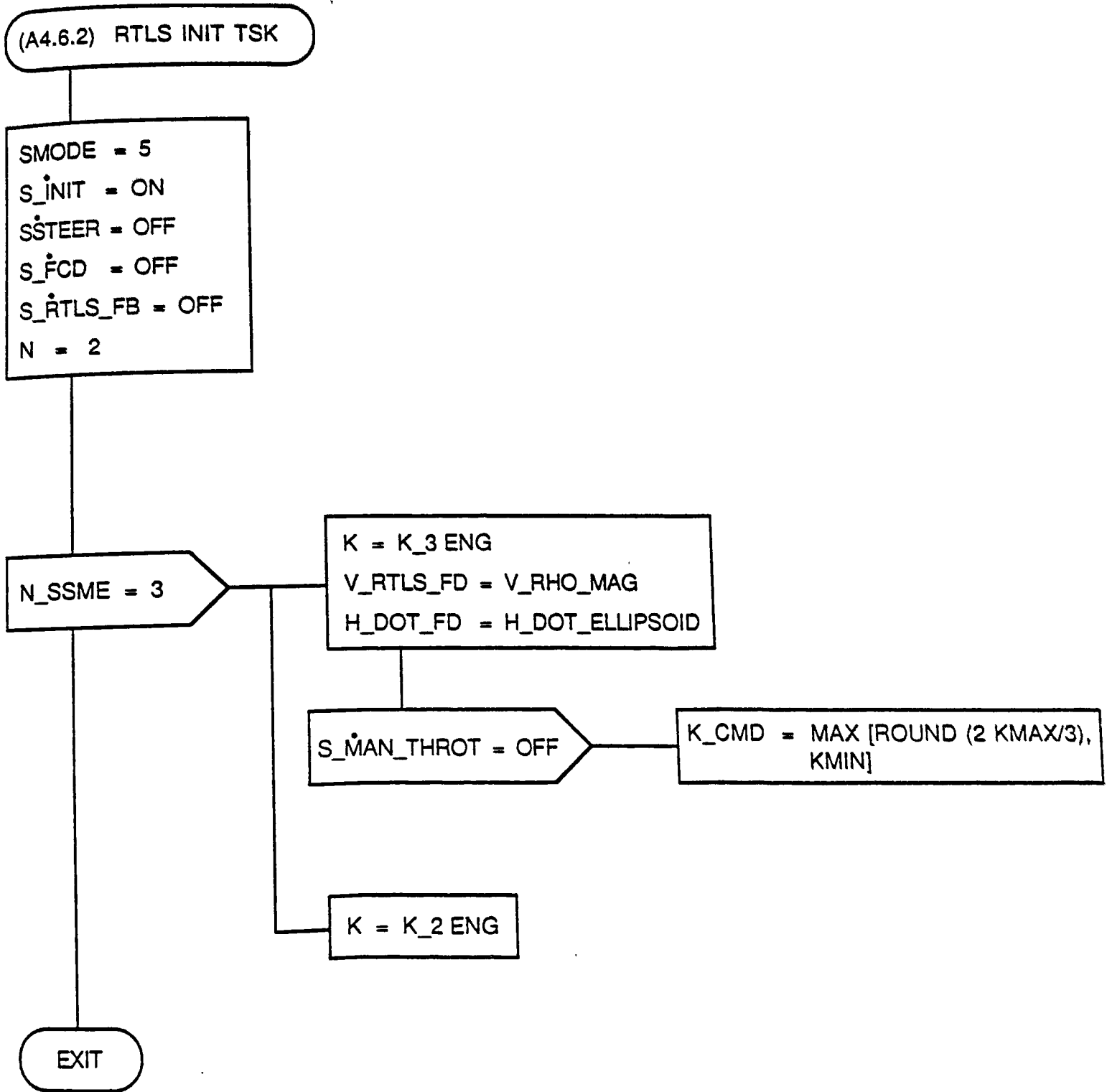
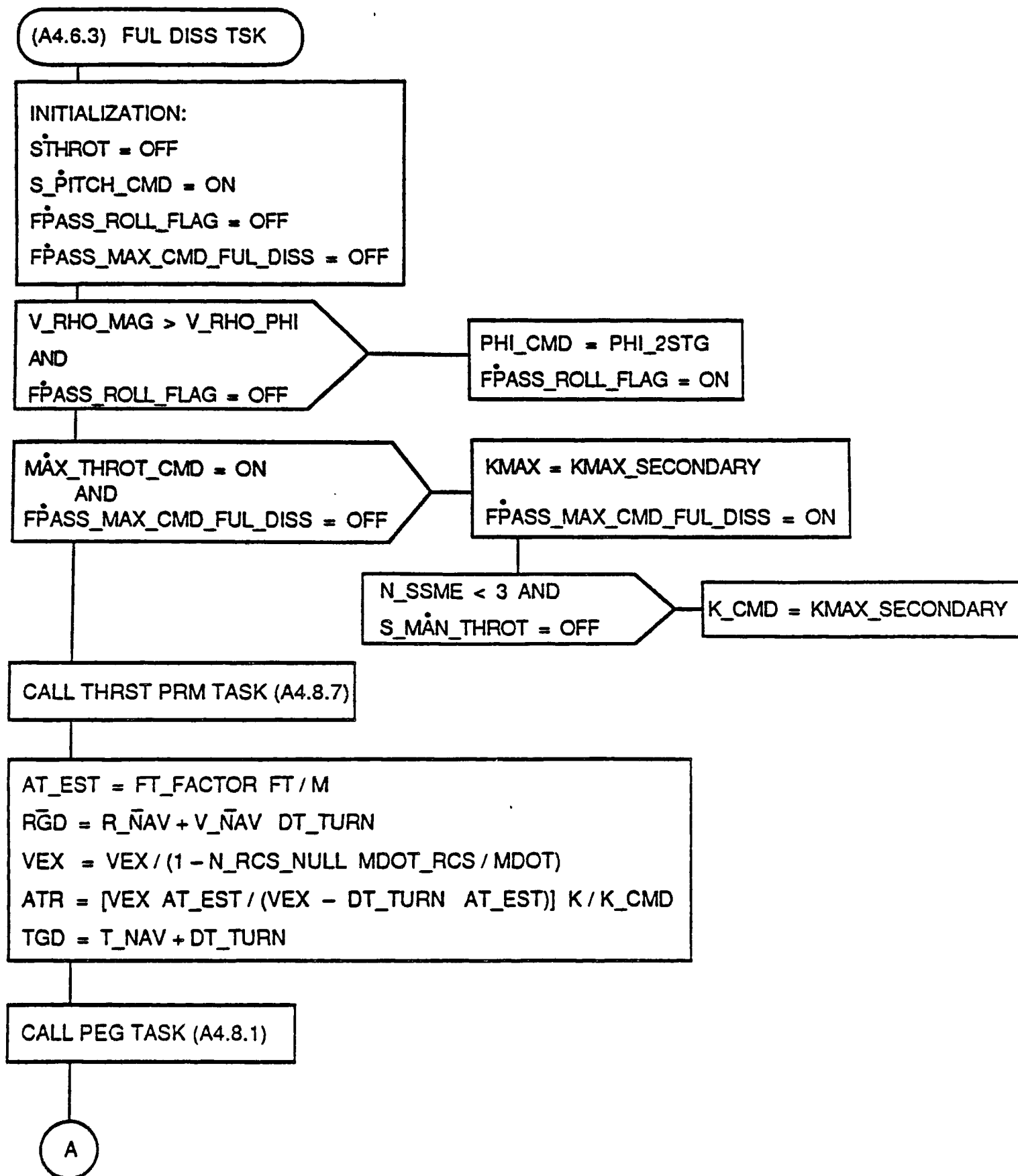


Figure A4.6.2. RTLS INIT TSK Flow Diagram



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Figure A4.6.3. FUL DISS TSK Flow Diagram (Sheet 1 of 2)

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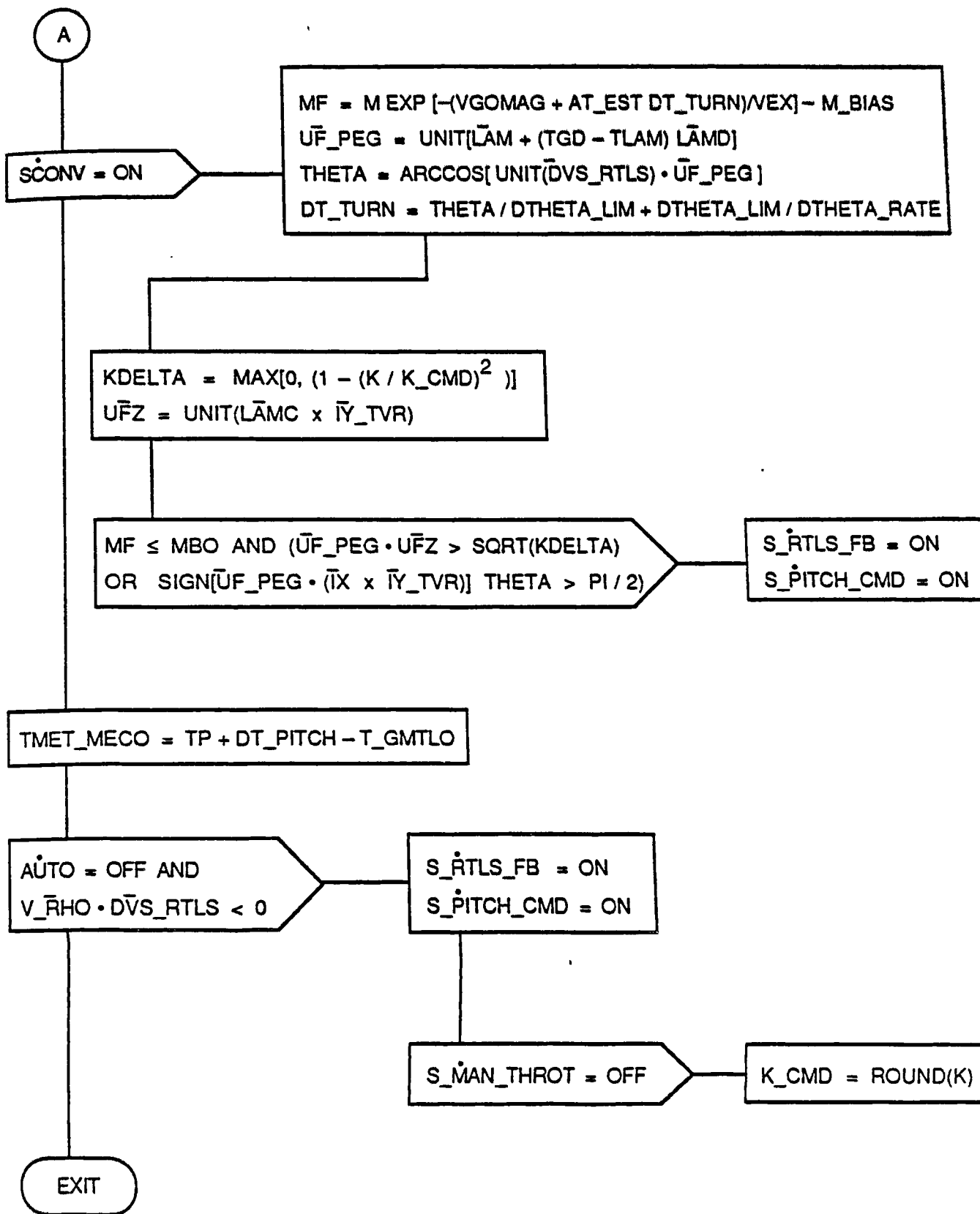


Figure A4.6.3. FUL DISS TSK Flow Diagram (Sheet 2 of 2)





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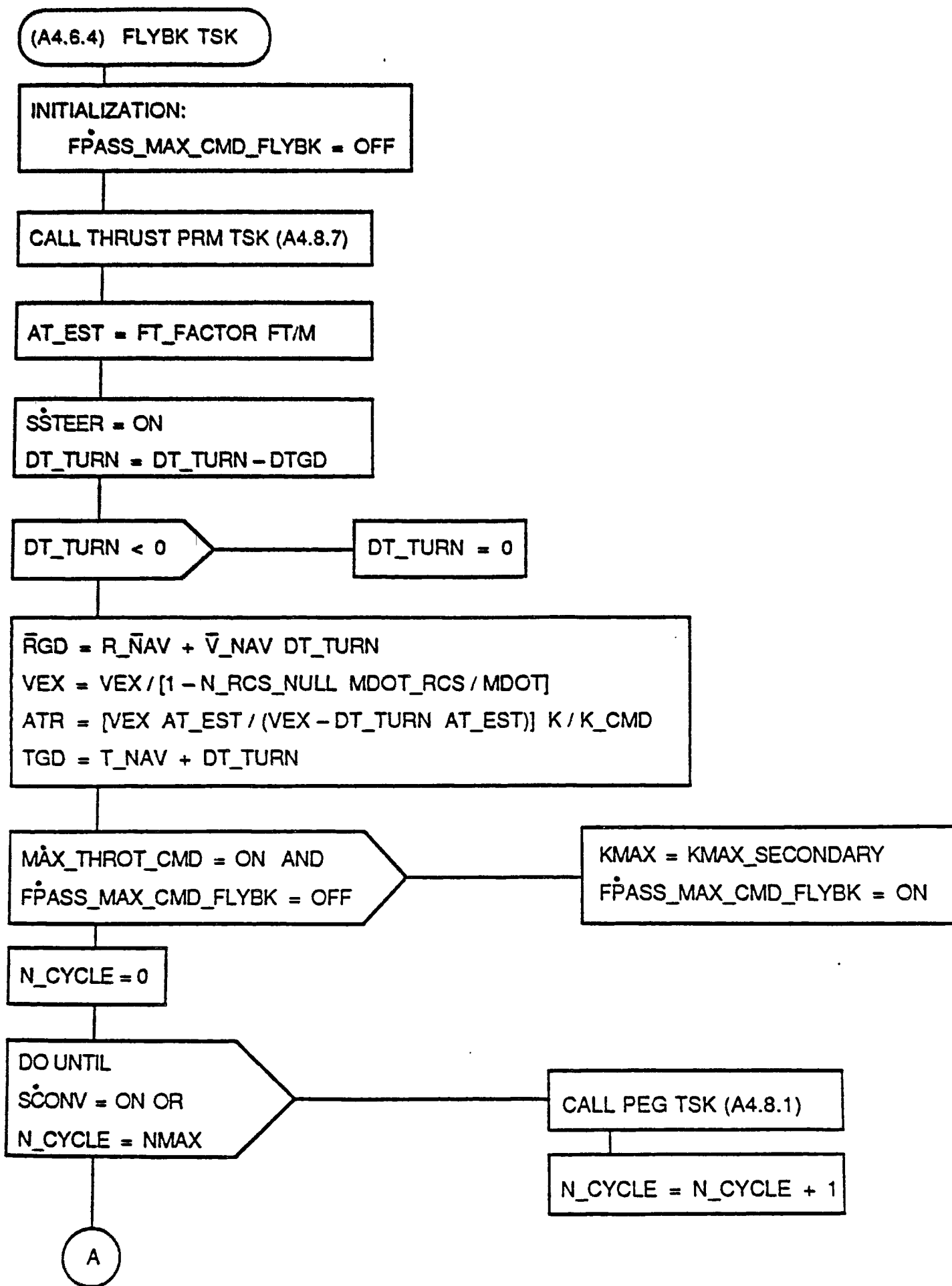
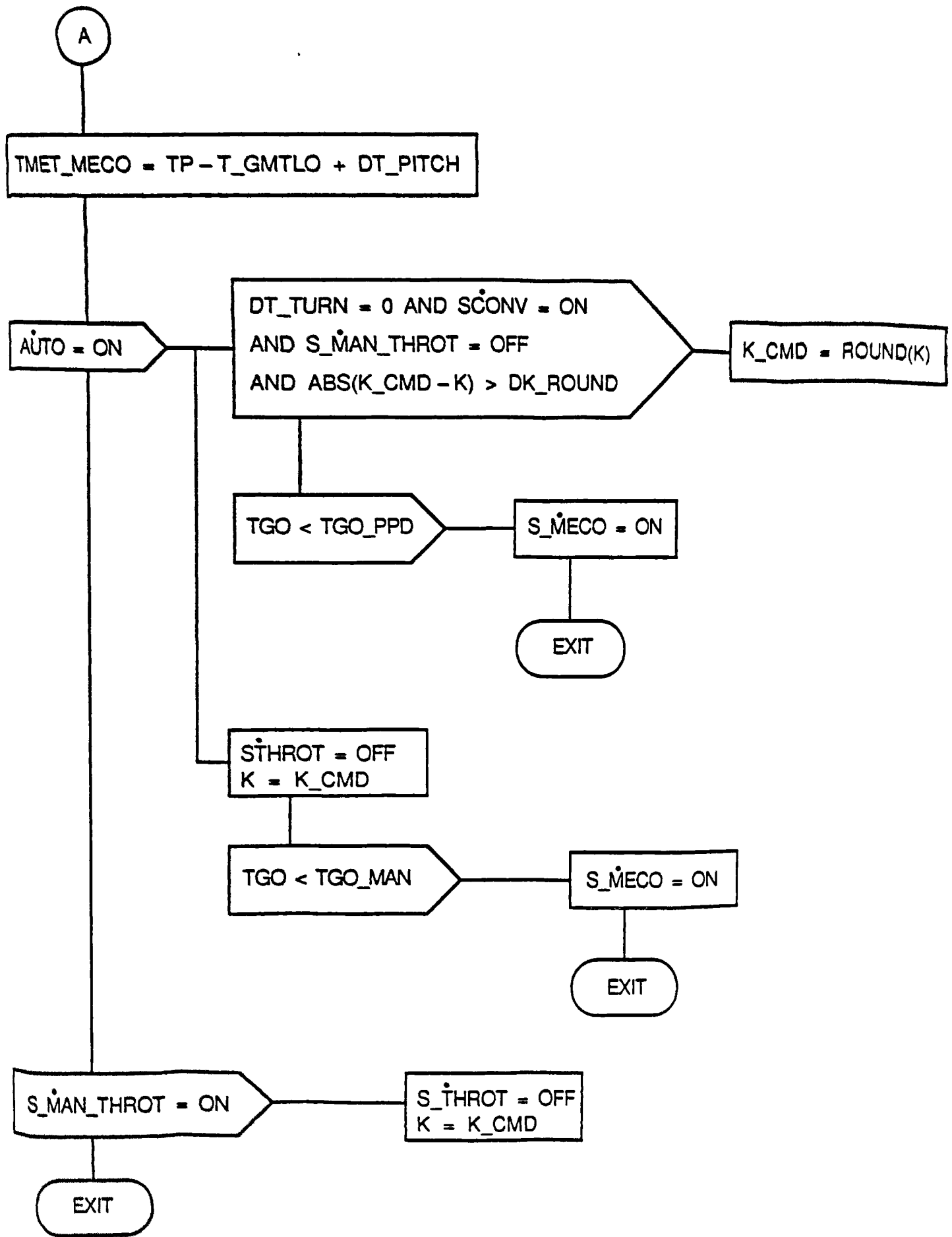


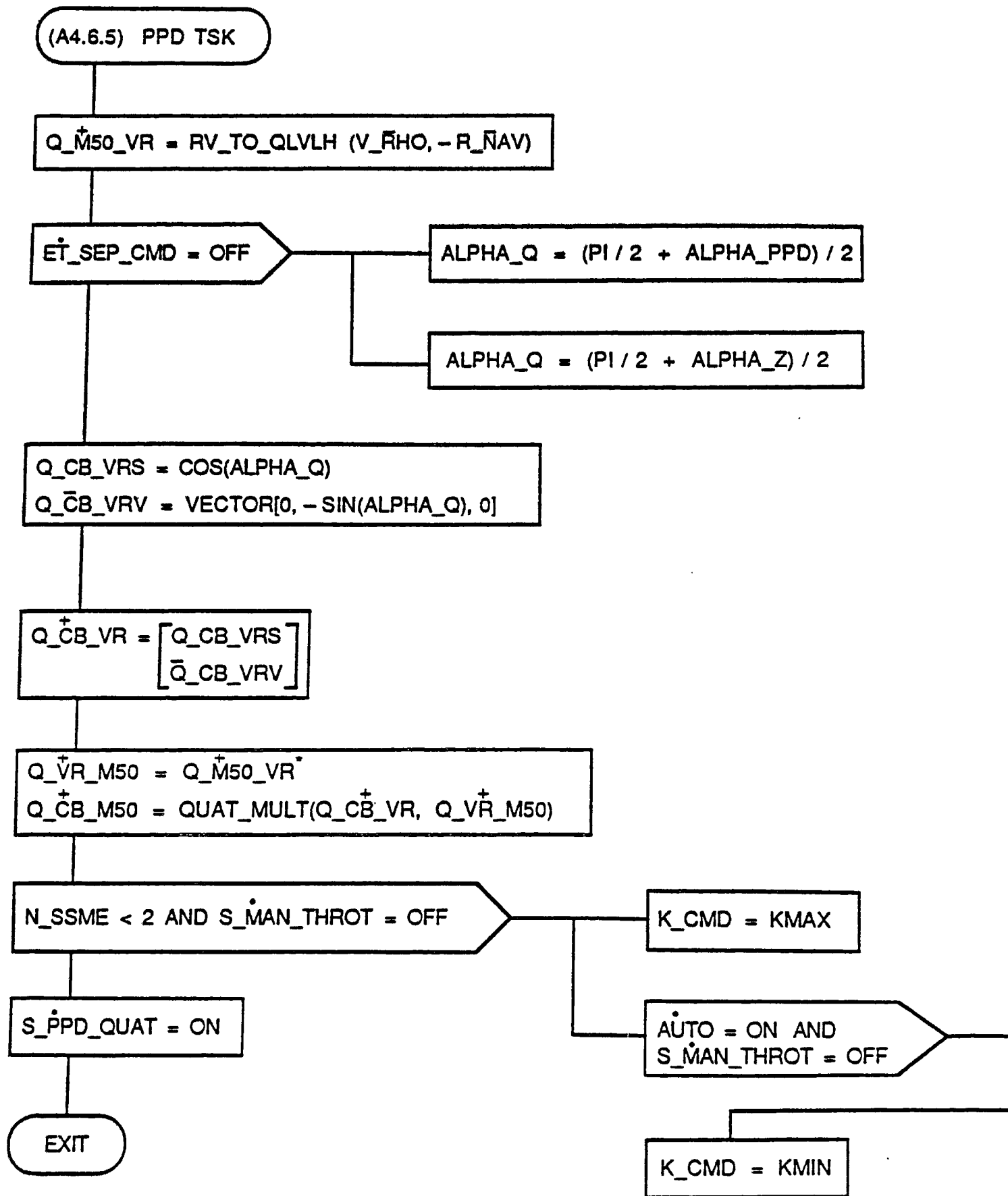
Figure A4.6.4. FLYBK TSK Flow Diagram (Sheet 1 of 2)



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Y = ON

Figure A4.6.4. FLYBK TSK Flow Diagram (Sheet 2 of 2)



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Figure A4.6.5. PPD TSK Flow Diagram

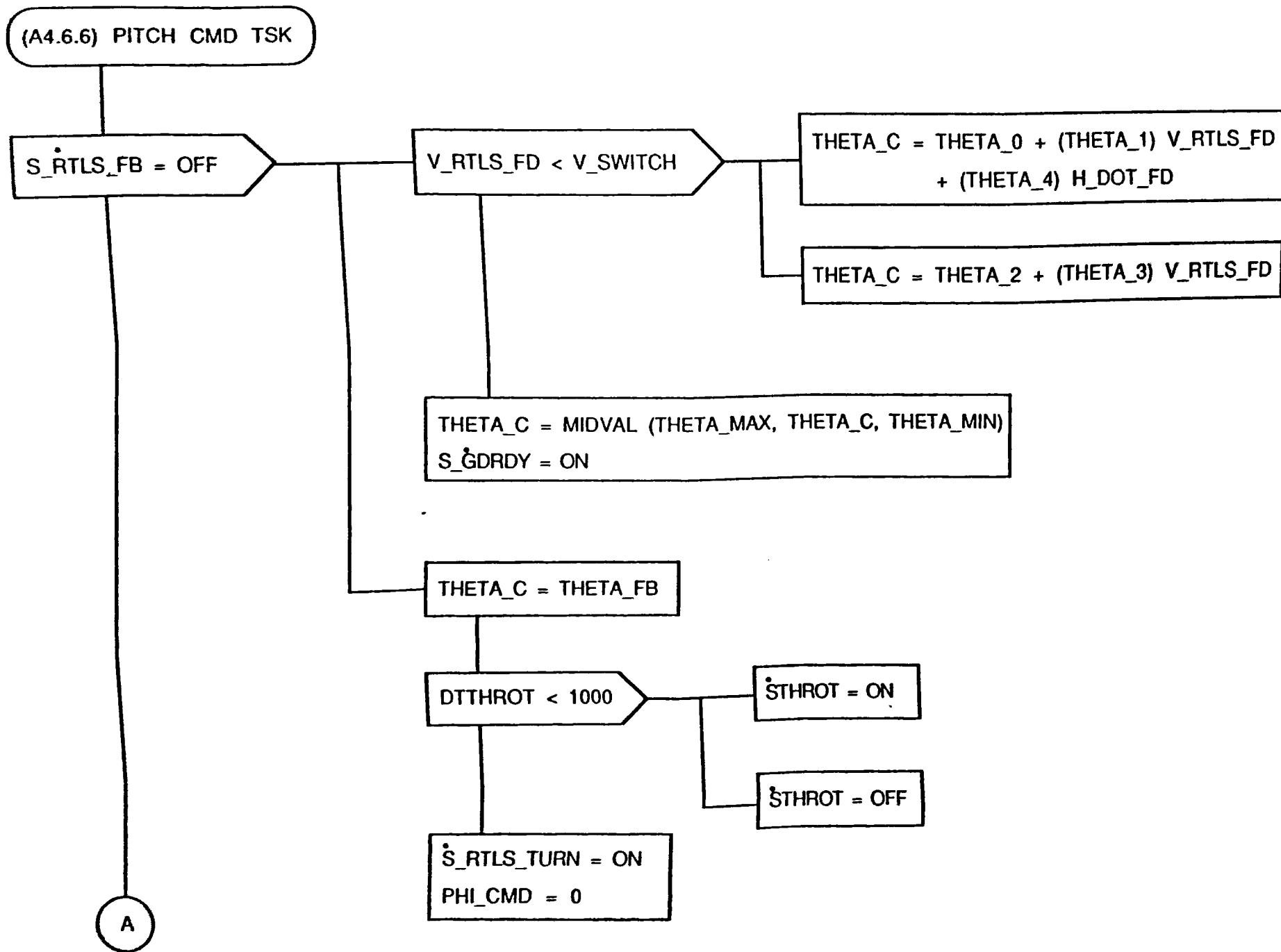
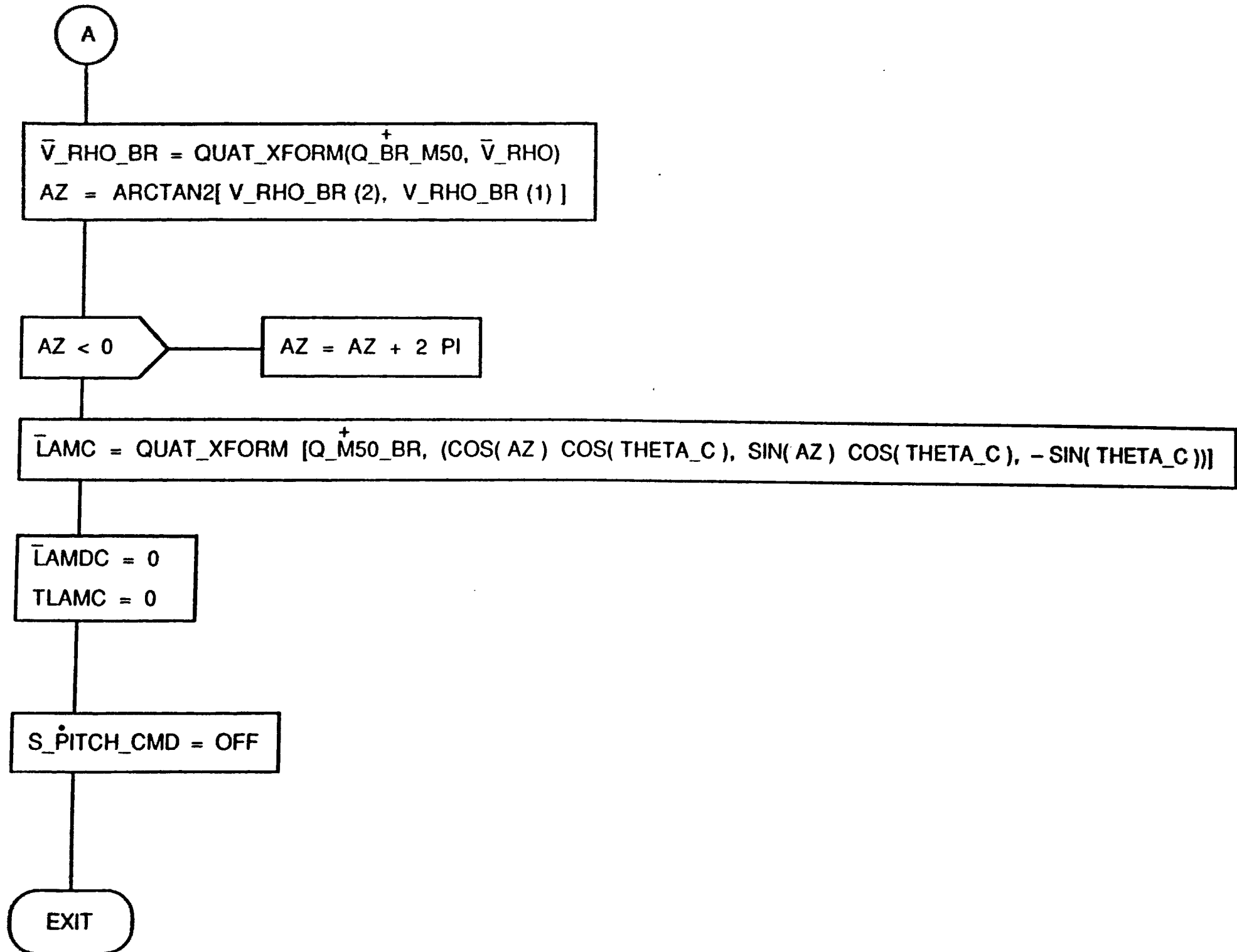


Figure A4.6.6. PITCH CMD TSK Flow Diagram (Sheet 1 of 2)



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Figure A4.6.6. PITCH CMD TSK Flow Diagram (Sheet 2 of 2)

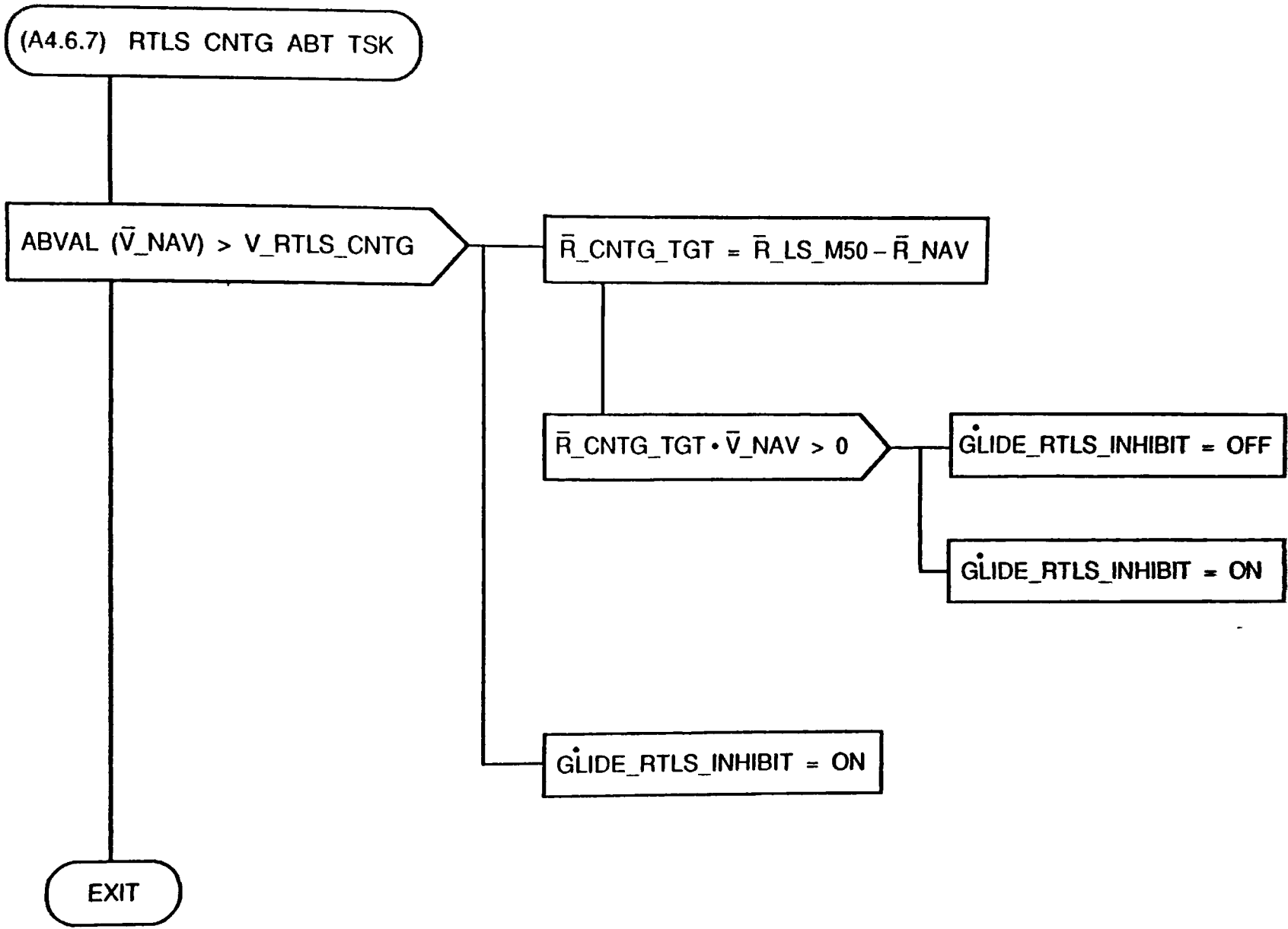


Figure A4.6.7. RTLS CNTG ABT TSK Flow Diagram

4.7 ASCENT MANEUVER DISPLAY INTERFACE  
PROCESSING FLOW CHARTS

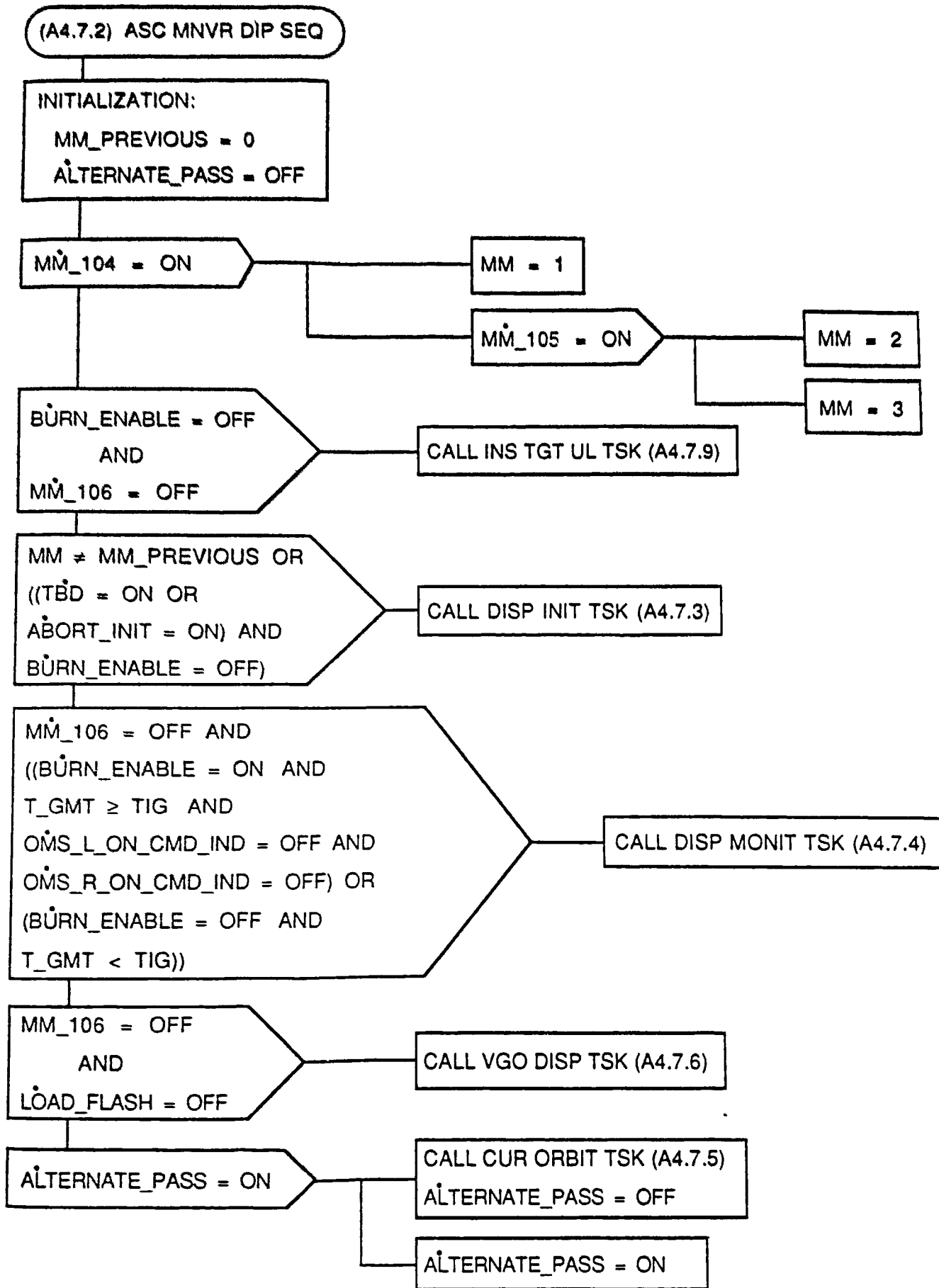


Figure A4.7.2. ASC MNVR DIP SEQ Flow Diagram



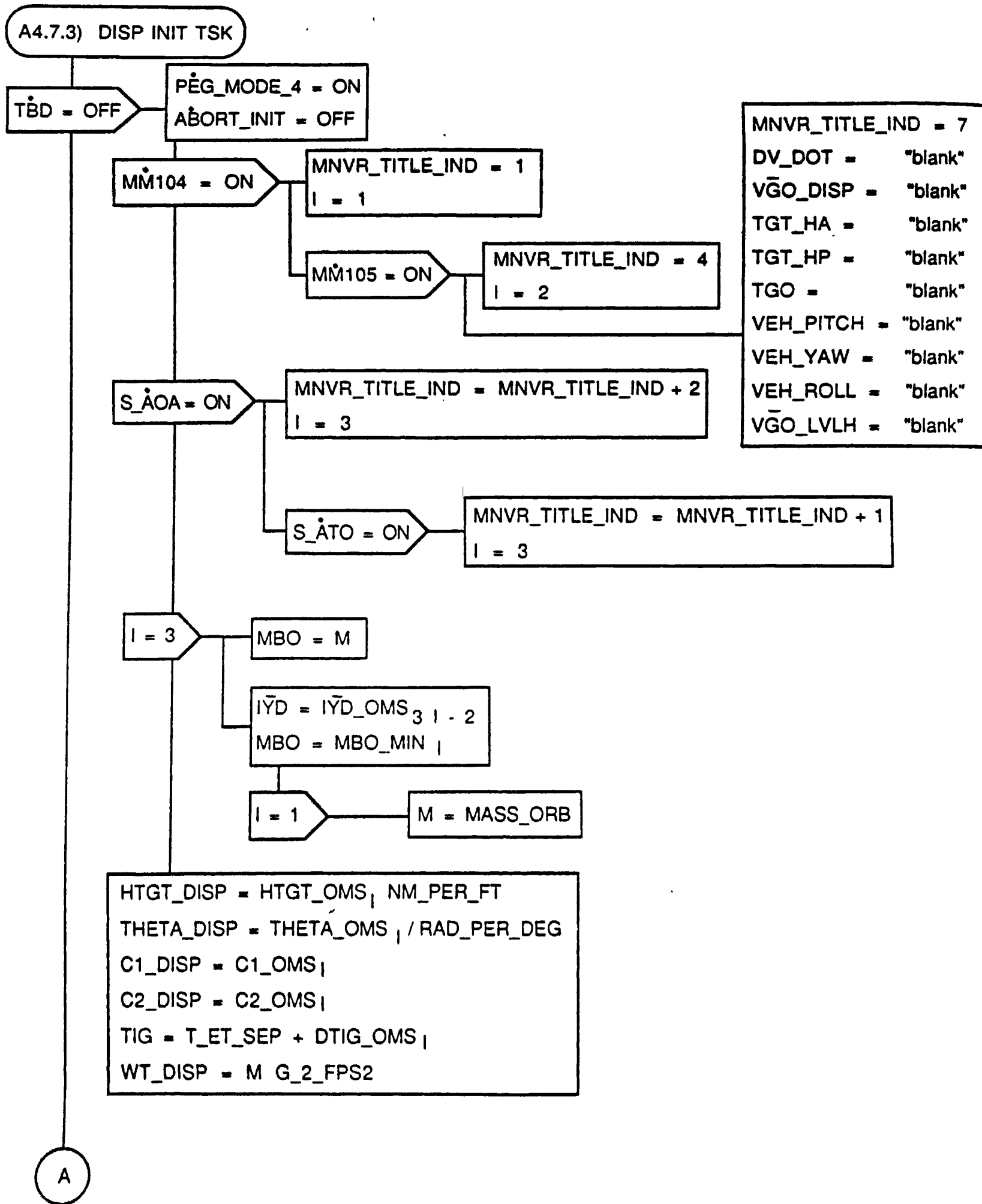


Figure A4.7.3. DISP INIT TSK Flow Diagram (Sheet 1 of 2)

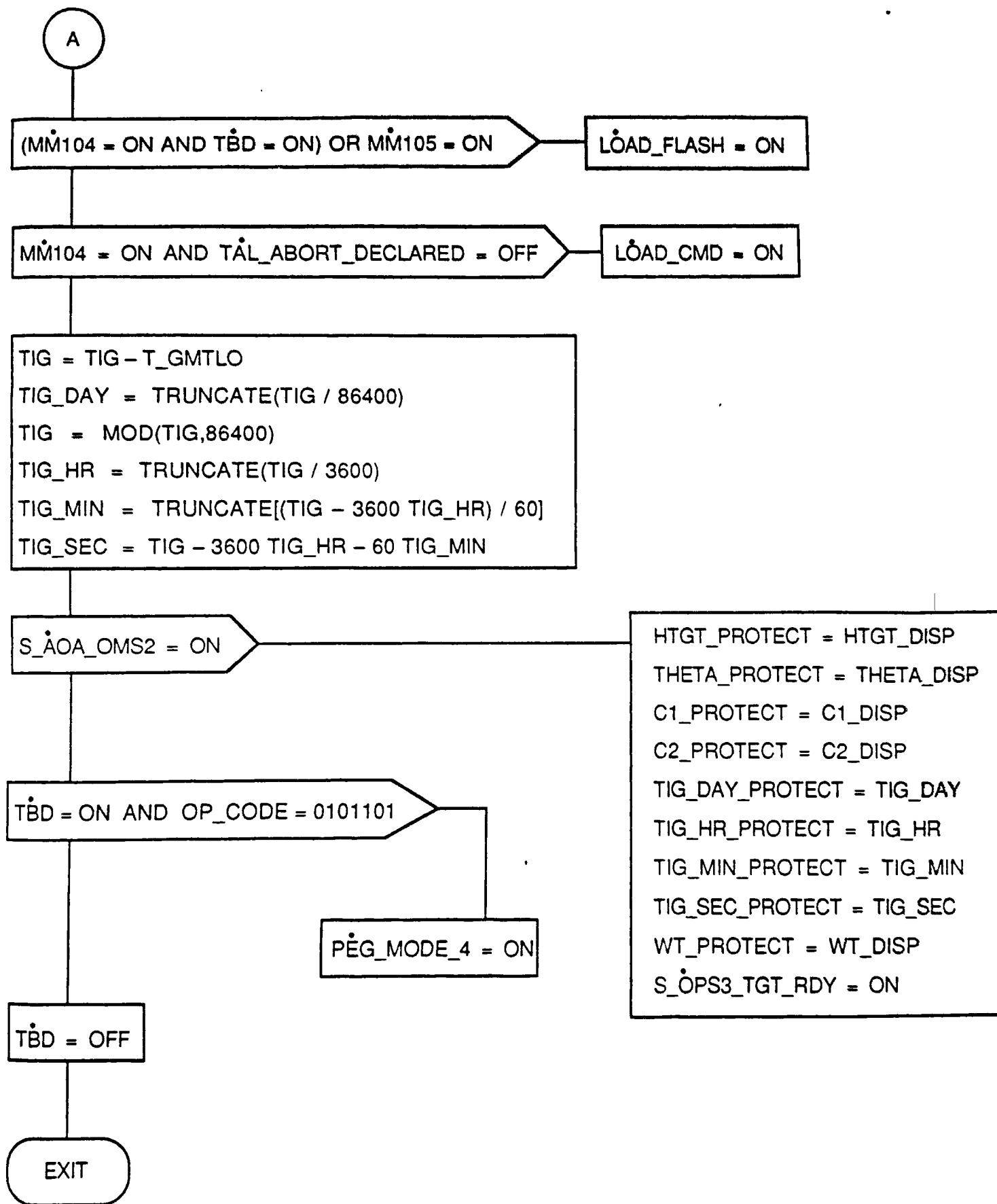


Figure A4.7.3. DISP INIT TSK Flow Diagram (Sheet 2 of 2)

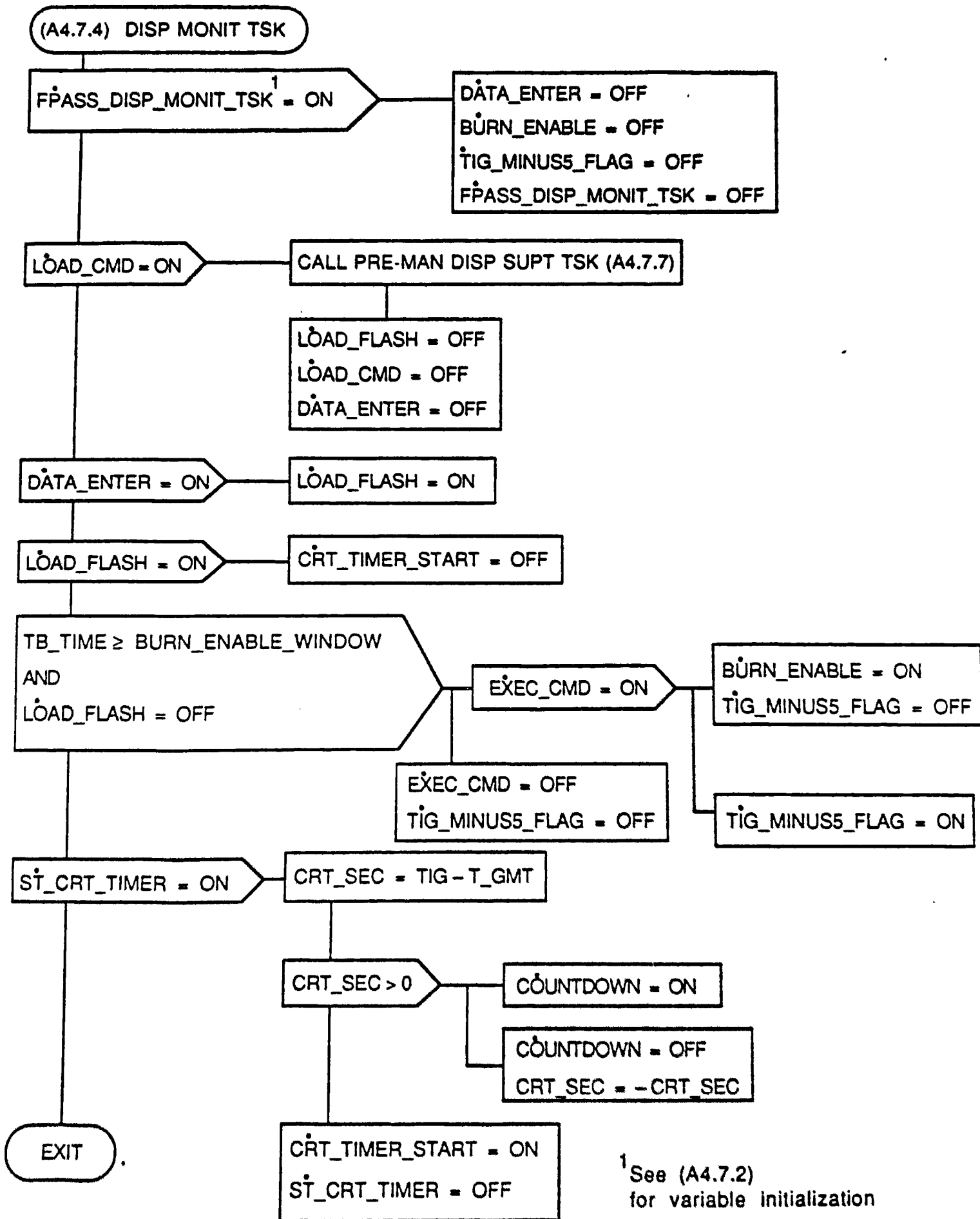


Figure A4.7.4. DISP MONIT TSK Flow Diagram

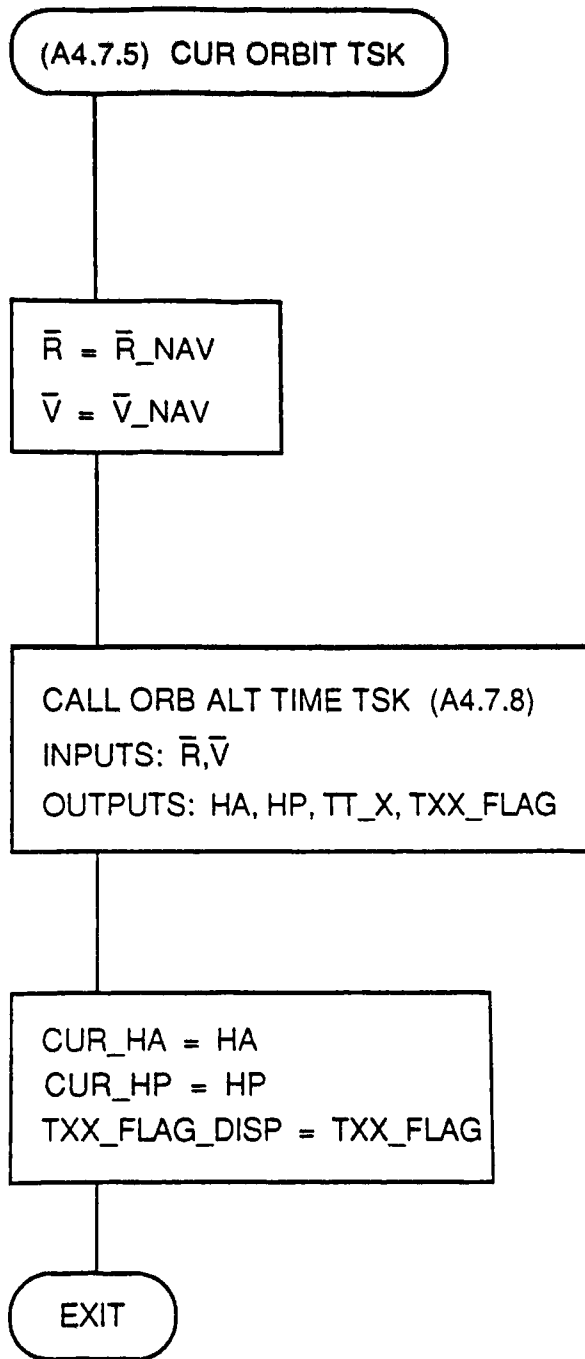
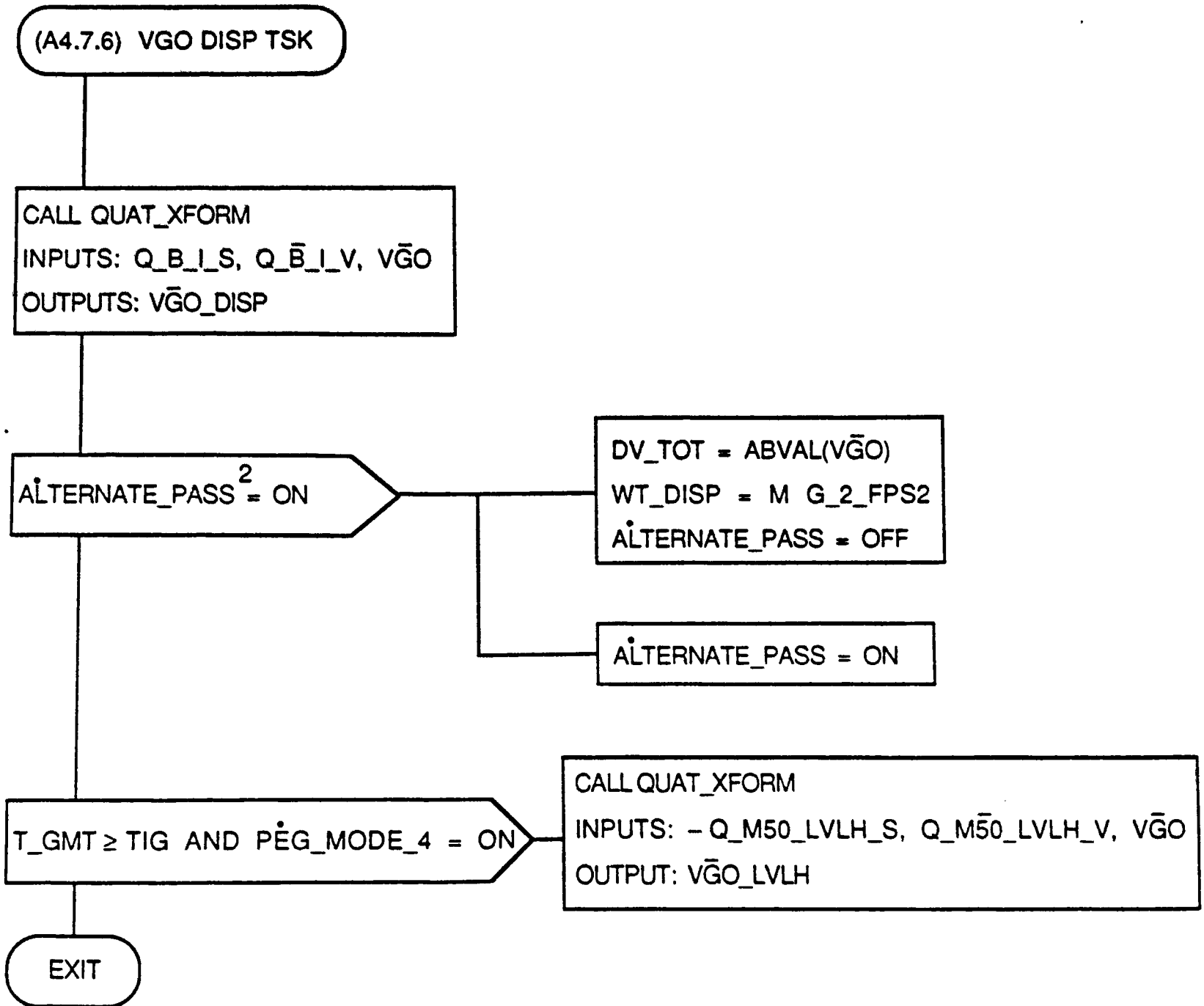


Figure A4.7.5. CUR ORBIT TSK Flow Diagram



<sup>2</sup> Internal variable

Figure A4.7.6. VGO DISP TSK Flow Diagram

(A4.7.7) PRE-MAN DISP SUPT TSK

$TIG = TIG\_SEC + TIG\_MIN \cdot 60 + TIG\_HR \cdot 3600 + TIG\_DAY \cdot 86400 + T\_GMTLO$

$T\_GMT - TIG > 300.$   
OR  
 $TIG - T\_GMT > 43200.$

"ILLEGAL ENTRY"

TB\_ENABLE = ON  
GMD\_PRED = 4  
GMO\_PRED = 4

CALL ASC\_PREC\_PRED  
INPUTS:  $\bar{R}\_NAV, \bar{V}\_NAV, T\_NAV, TIG, DTMIN, GMD\_PRED, GMO\_PRED$   
OUTPUT:  $\bar{R}\_FINAL, \bar{V}\_FINAL$

$\bar{R}GD = \bar{R}\_FINAL$   
 $\bar{V}GD = \bar{V}\_FINAL$

A

EXIT

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Figure A4.7.7. PRE-MAN DISP SUPT TSK Flow Diagram (Sheet 1 of 6)

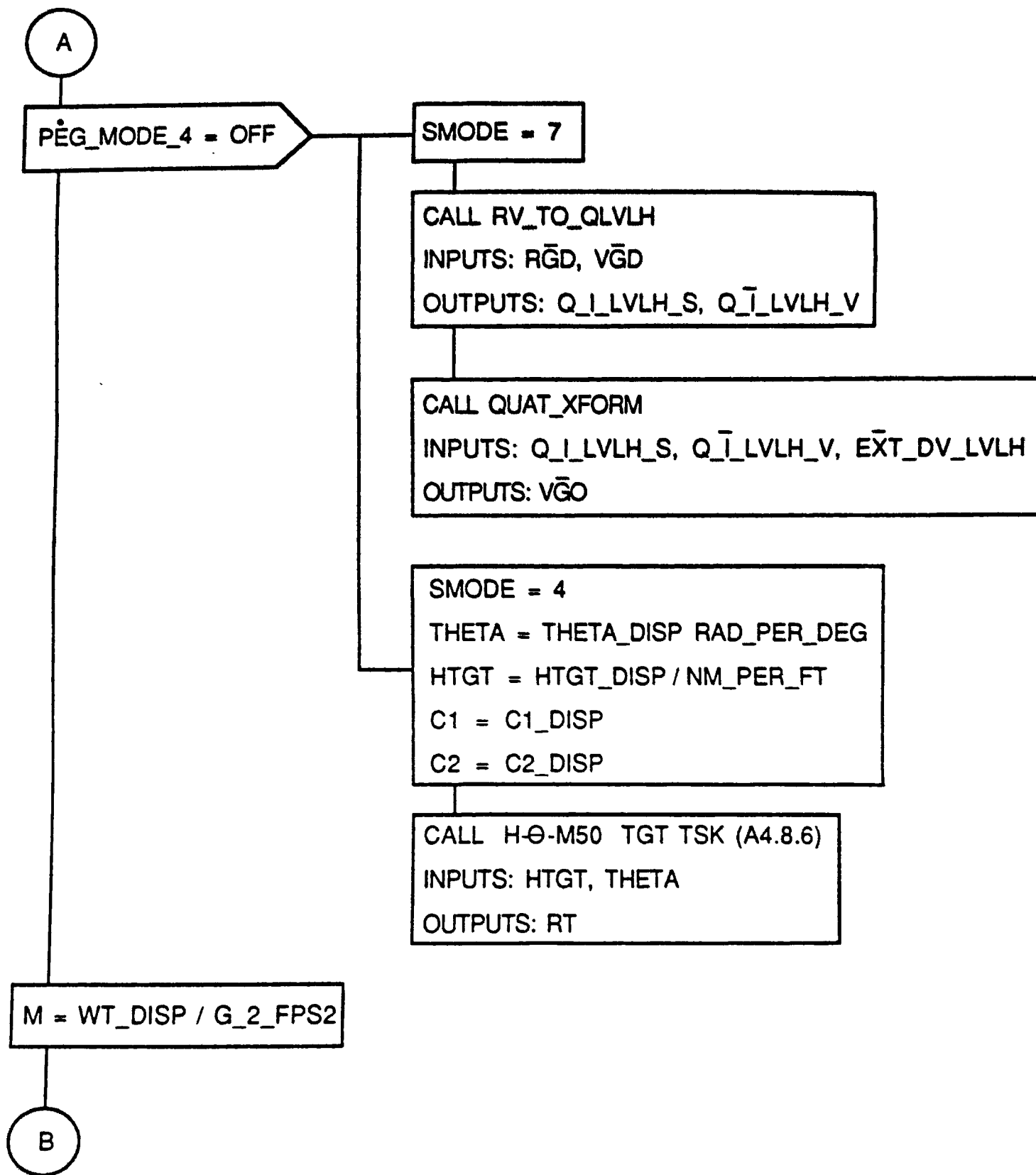


Figure A4.7.7. PRE-MAN DISP SUPT TSK Flow Diagram (Sheet 2 of 6)

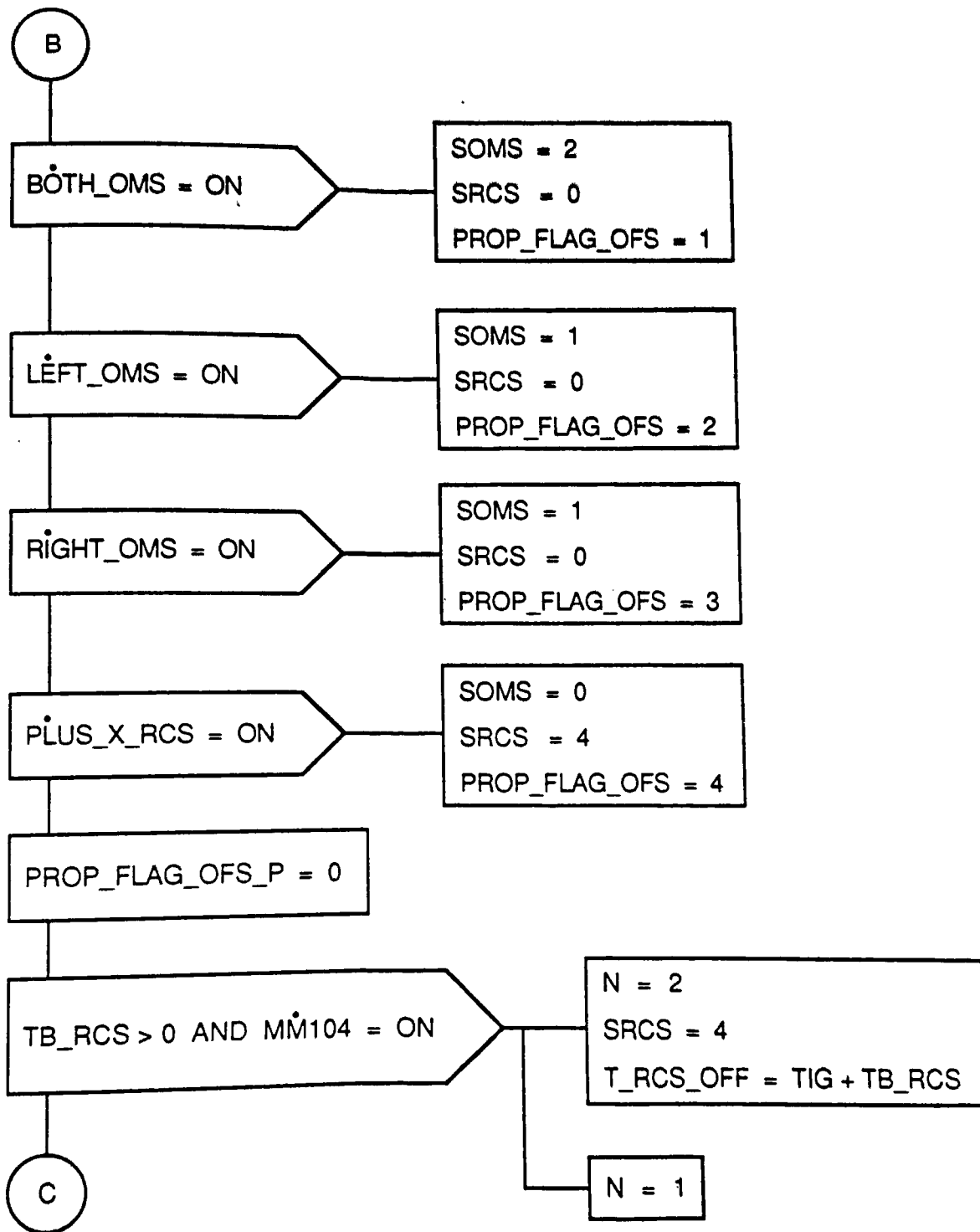


Figure A4.7.7. PRE-MAN DISP SUPT TSK Flow Diagram (Sheet 3 of 6)



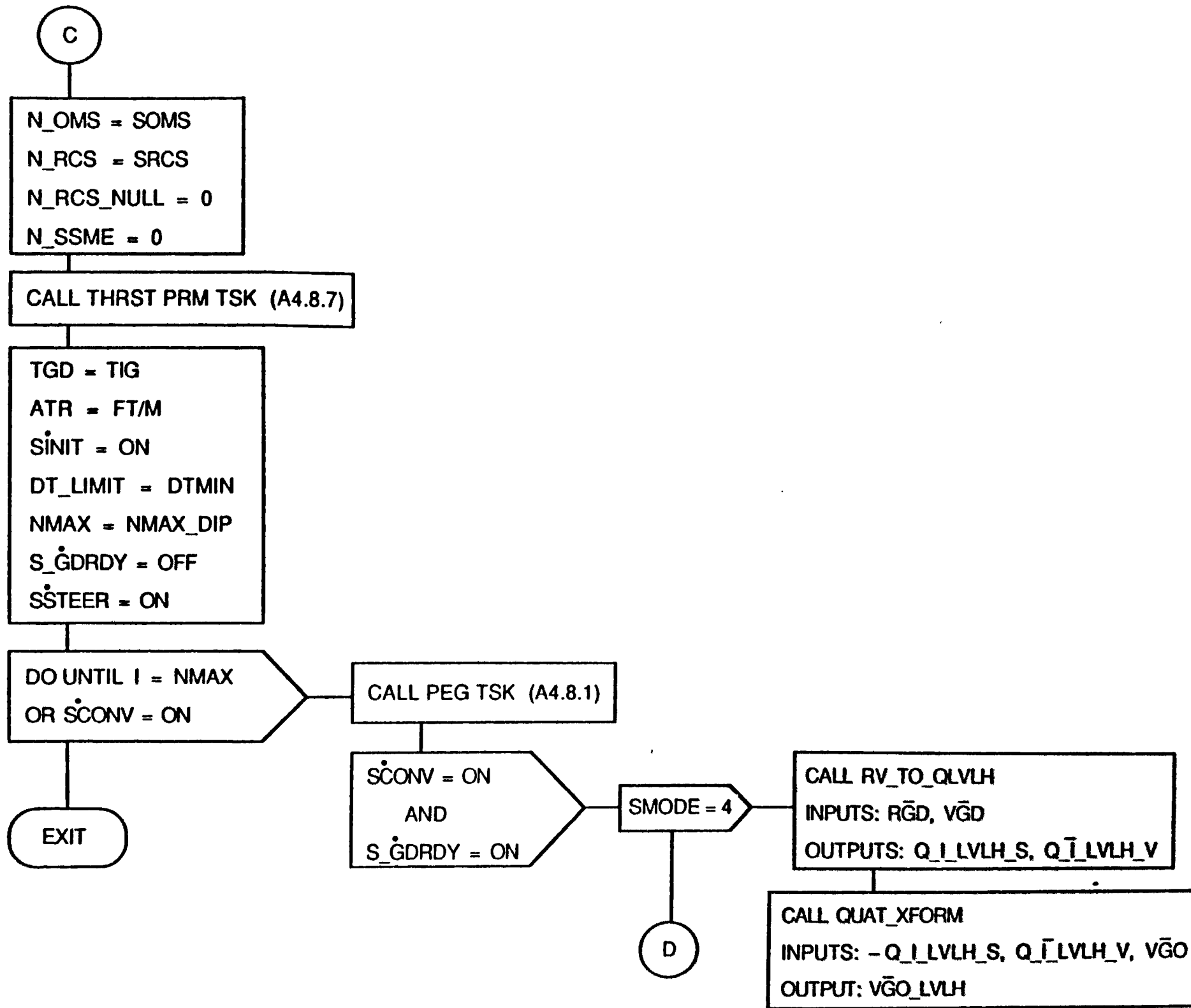


Figure A4.7.7. PRE-MAN DISP SUPT TSK Flow Diagram (Sheet 4 of 6)



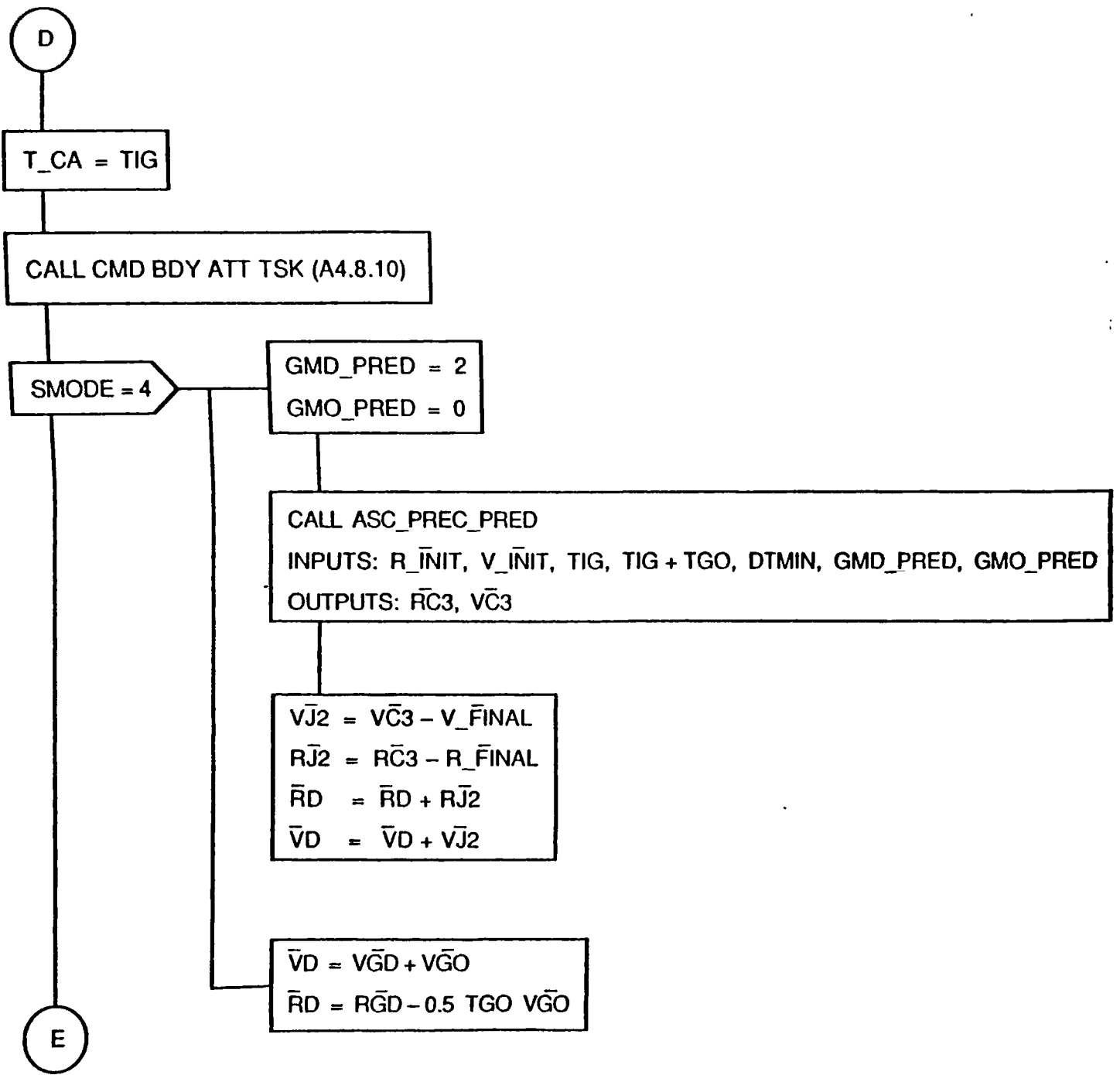


Figure A4.7.7. PRE-MAN DISP SUPT TSK Flow Diagram (Sheet 5 of 6)

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Space Transportation  
Systems Division



Rockwell  
International

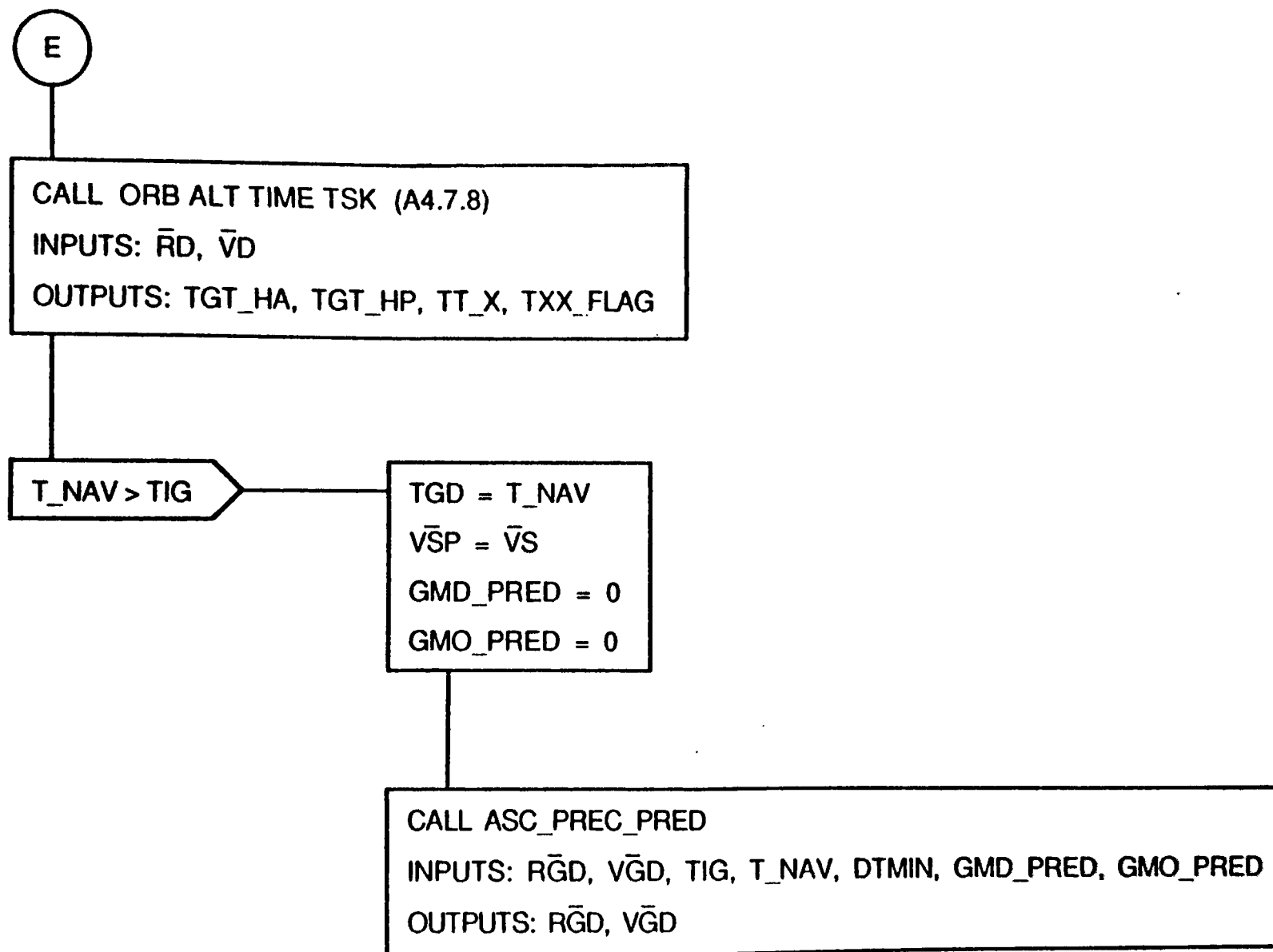


Figure A4.7.7. PRE-MAN DISP SUPT TSK Flow Diagram (Sheet 6 of 6)



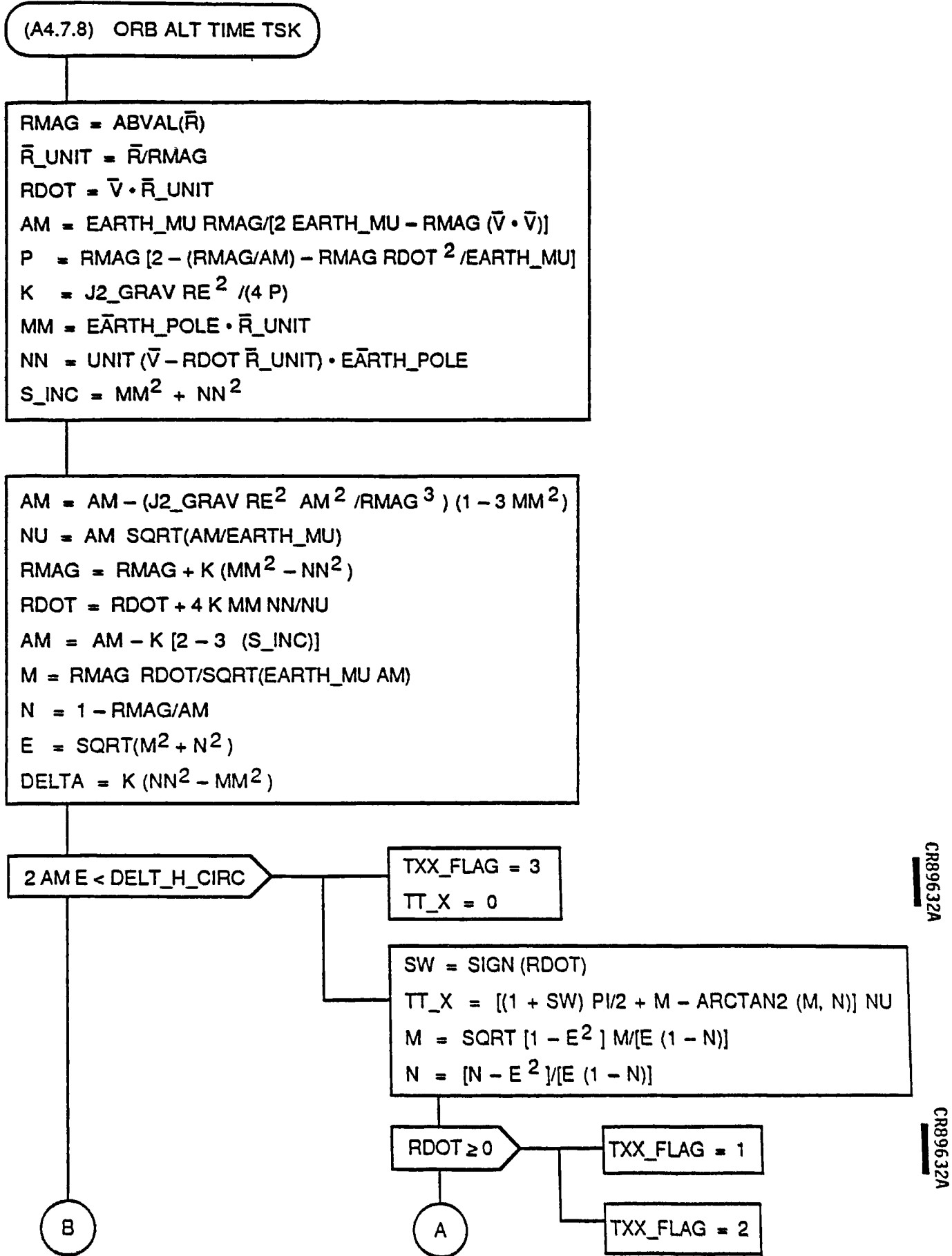


Figure A4.7.8. ORB ALT TIME TSK Flow Diagram (Sheet 1 of 2)

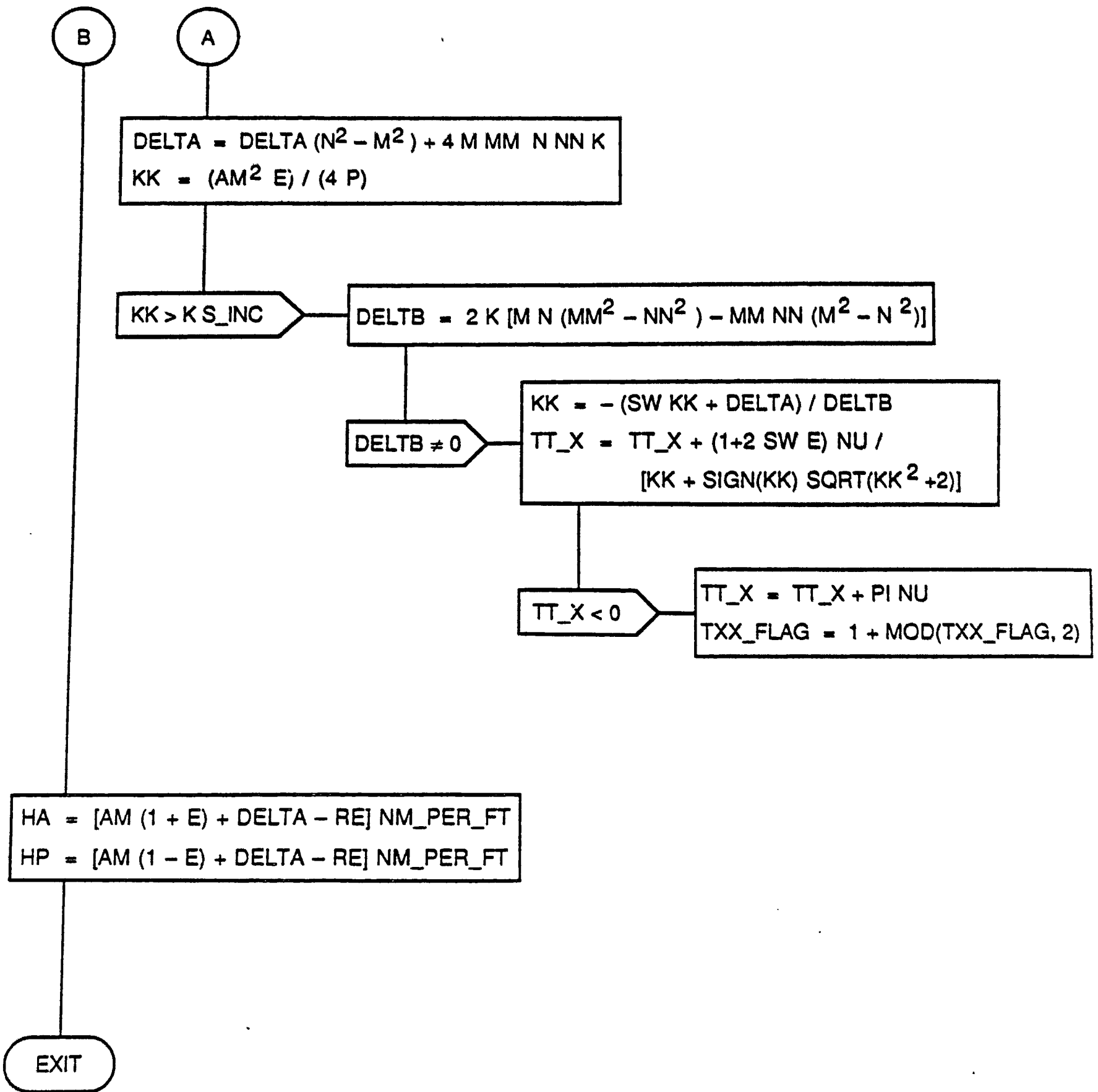
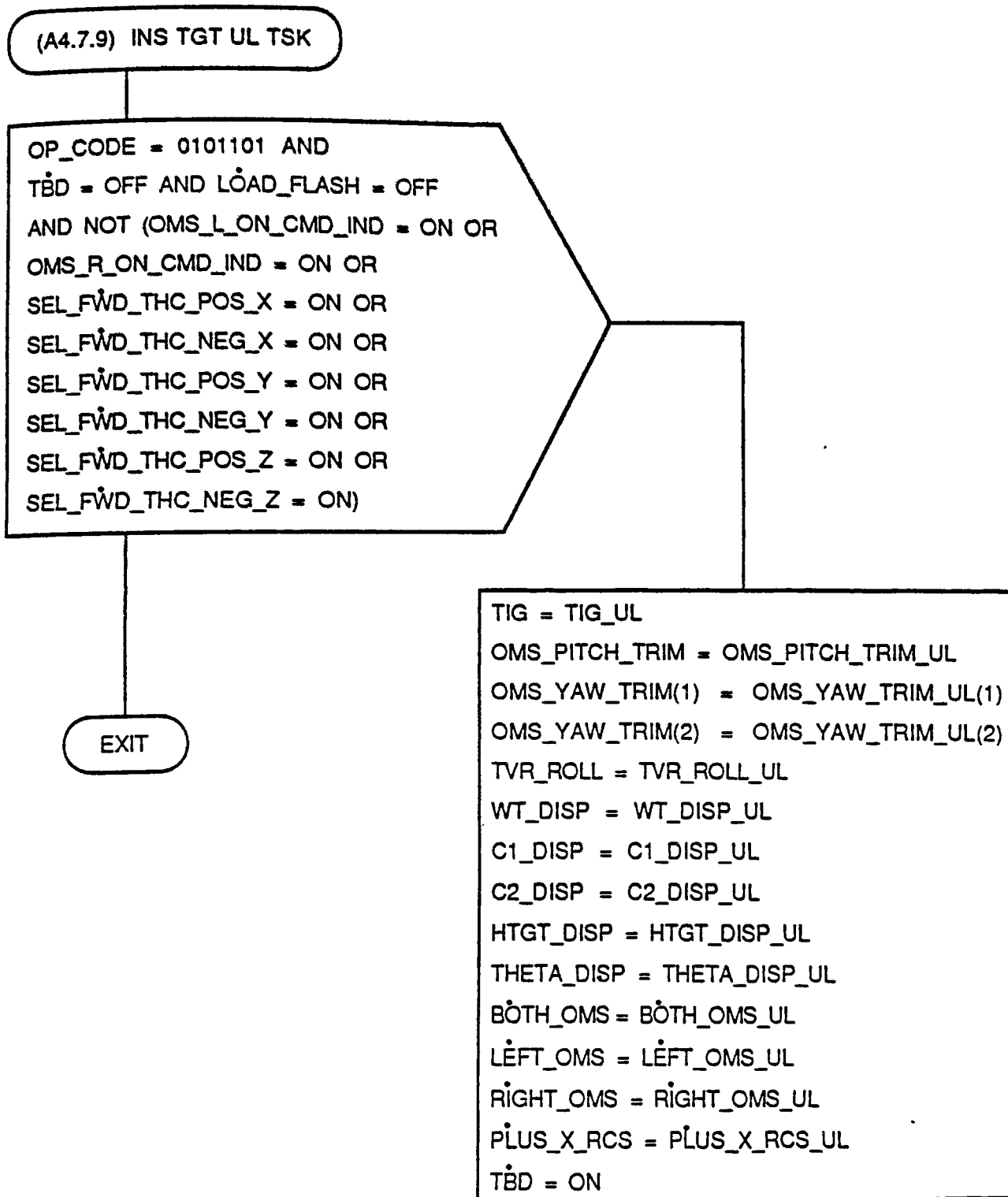


Figure A4.7.8. ORB ALT TIME TSK Flow Diagram (Sheet 2 of 2)



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Figure A4.7.9. INS TGT UL TSK Flow Diagram

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4.8 GENERAL GUIDANCE AND TARGETING MODULES FLOW CHARTS

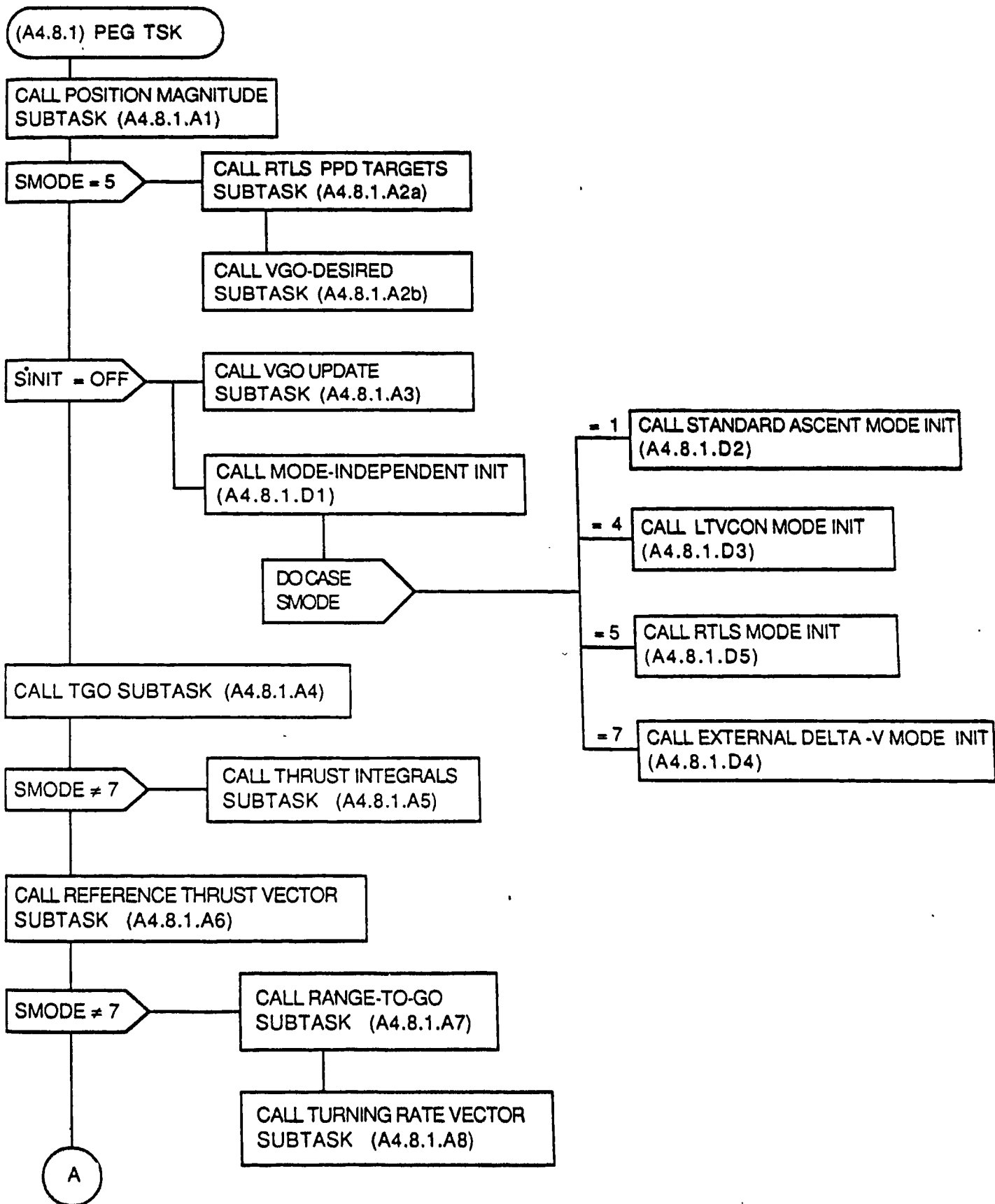


Figure A4.8.1. PEG TSK Flow Diagram (Sheet 1 of 3)



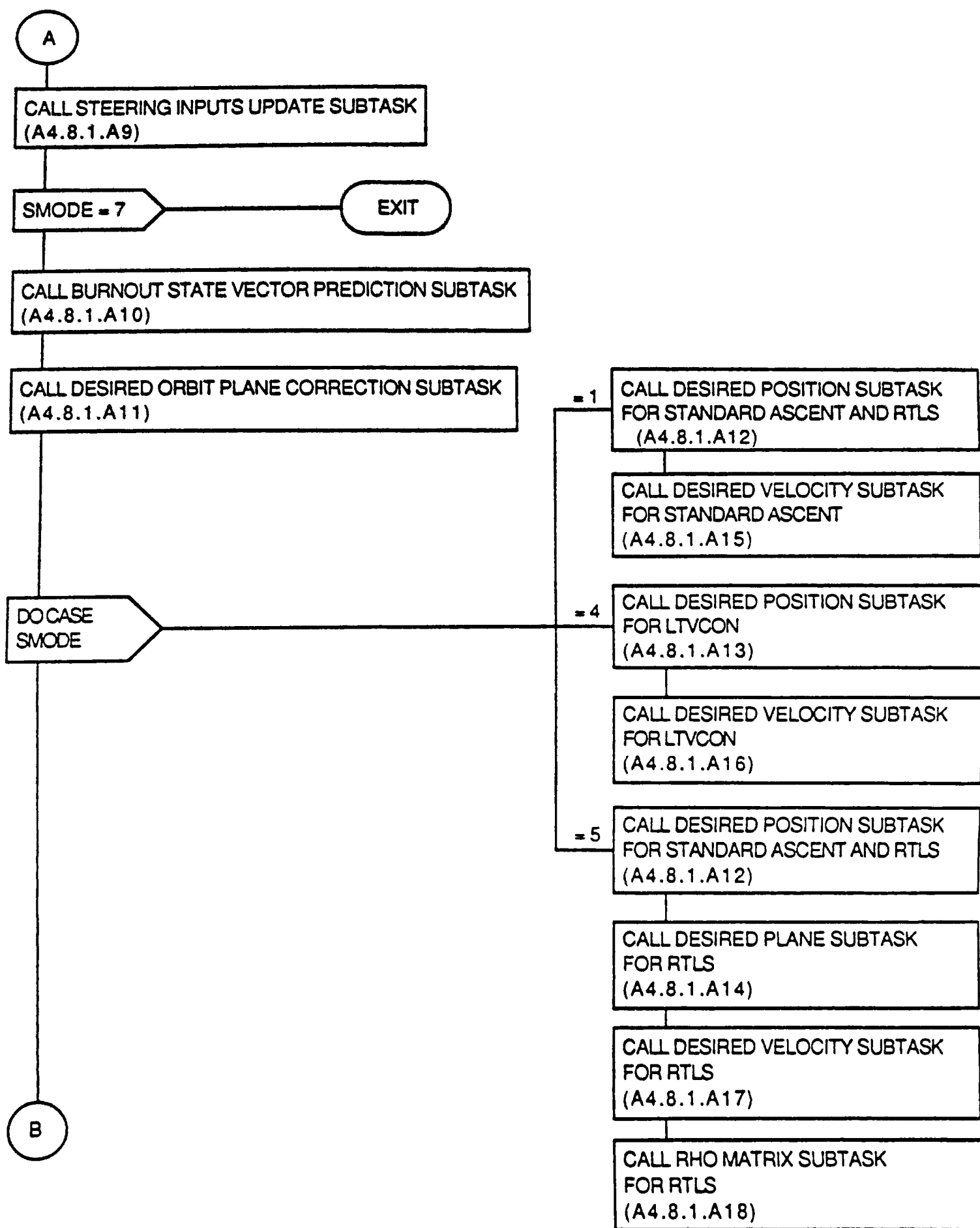


Figure A4.8.1. PEG TSK Flow Diagram (Sheet 2 of 3)

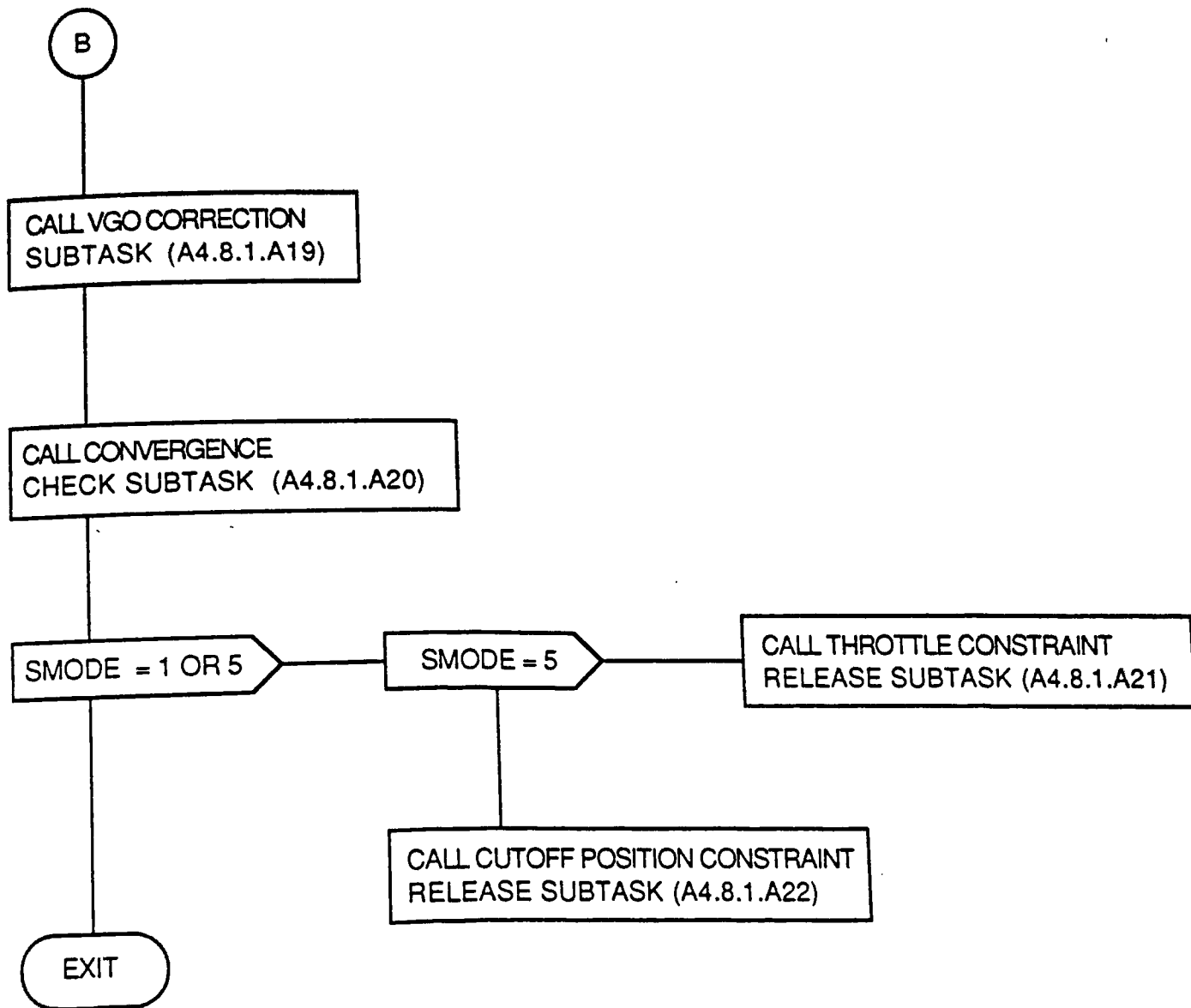


Figure A4.8.1. PEG TSK Flow Diagram (Sheet 3 of 3)

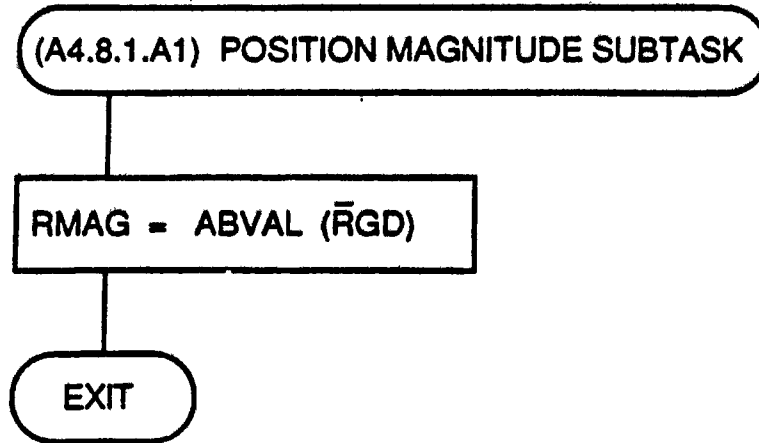


Figure A4.8.1.A1. PEG TSK (POSITION MAGNITUDE SUBTASK) Flow Diagram

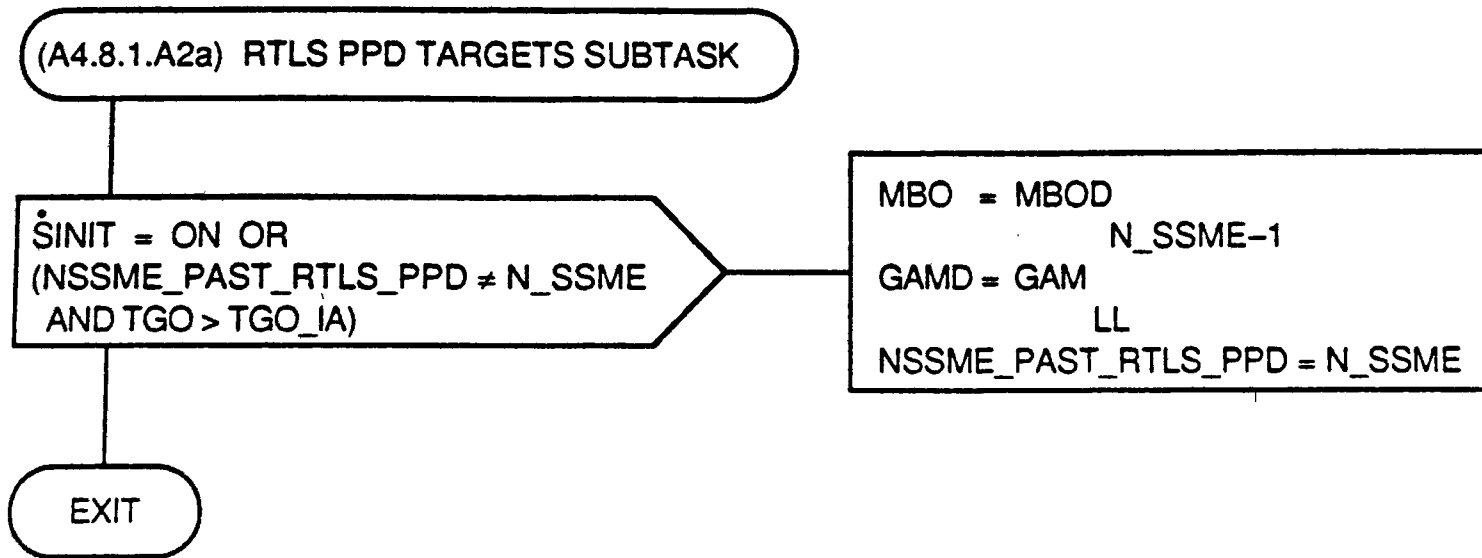


Figure A4.8.1.A2a. PEG TSK (RTLS PPD TARGETS SUBTASK) Flow Diagram

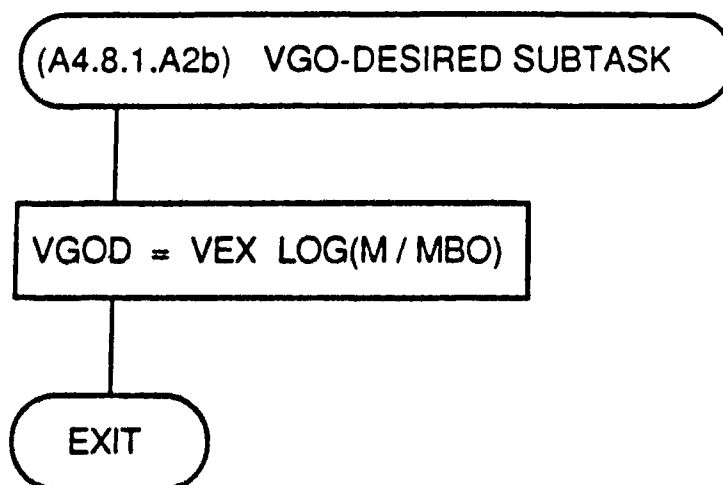


Figure A4.8.1.A2b. PEG TSK (VGO-DESIRED SUBTASK) Flow Diagram

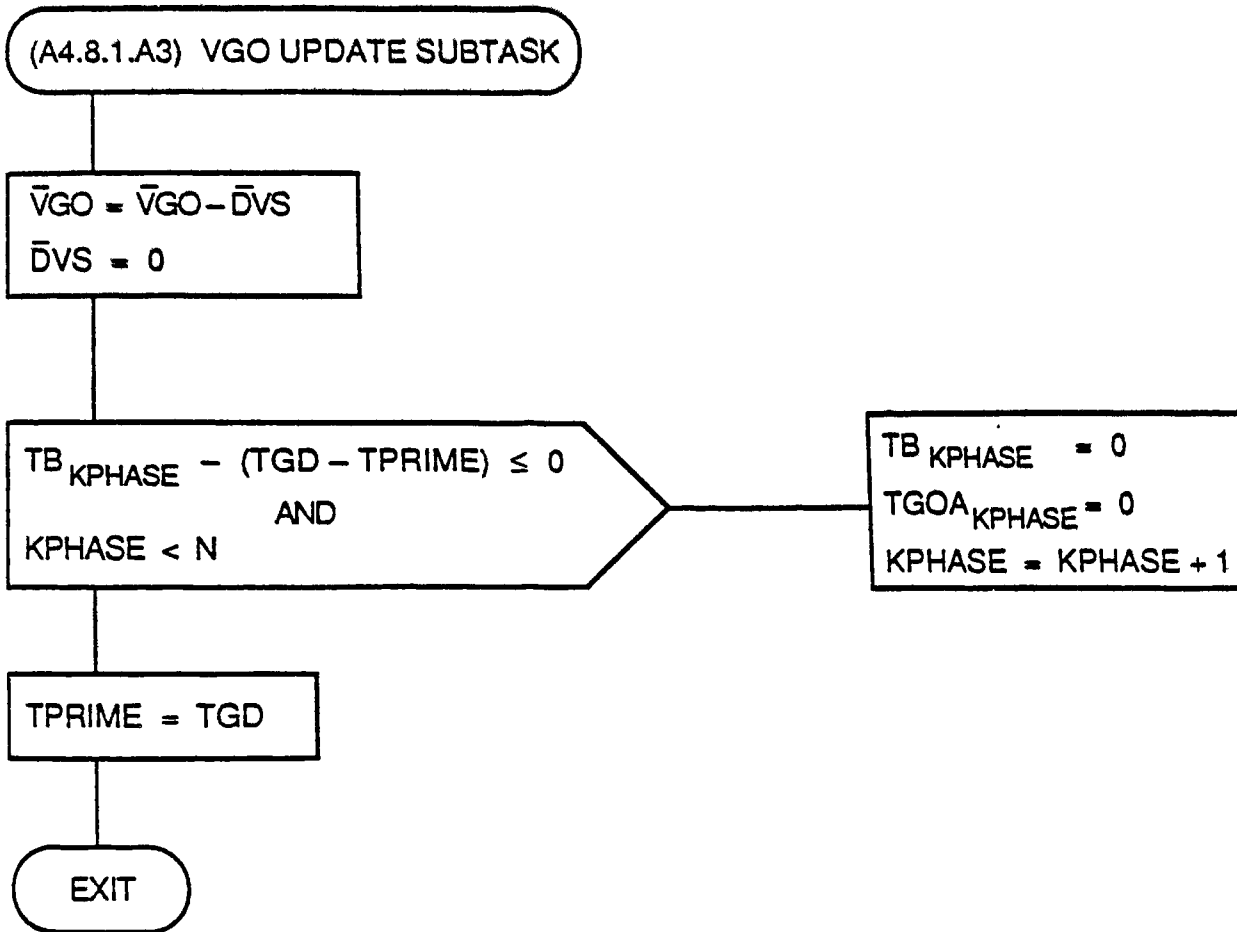


Figure A4.8.1.A3. PEG TSK (VGO UPDATE SUBTASK) Flow Diagram



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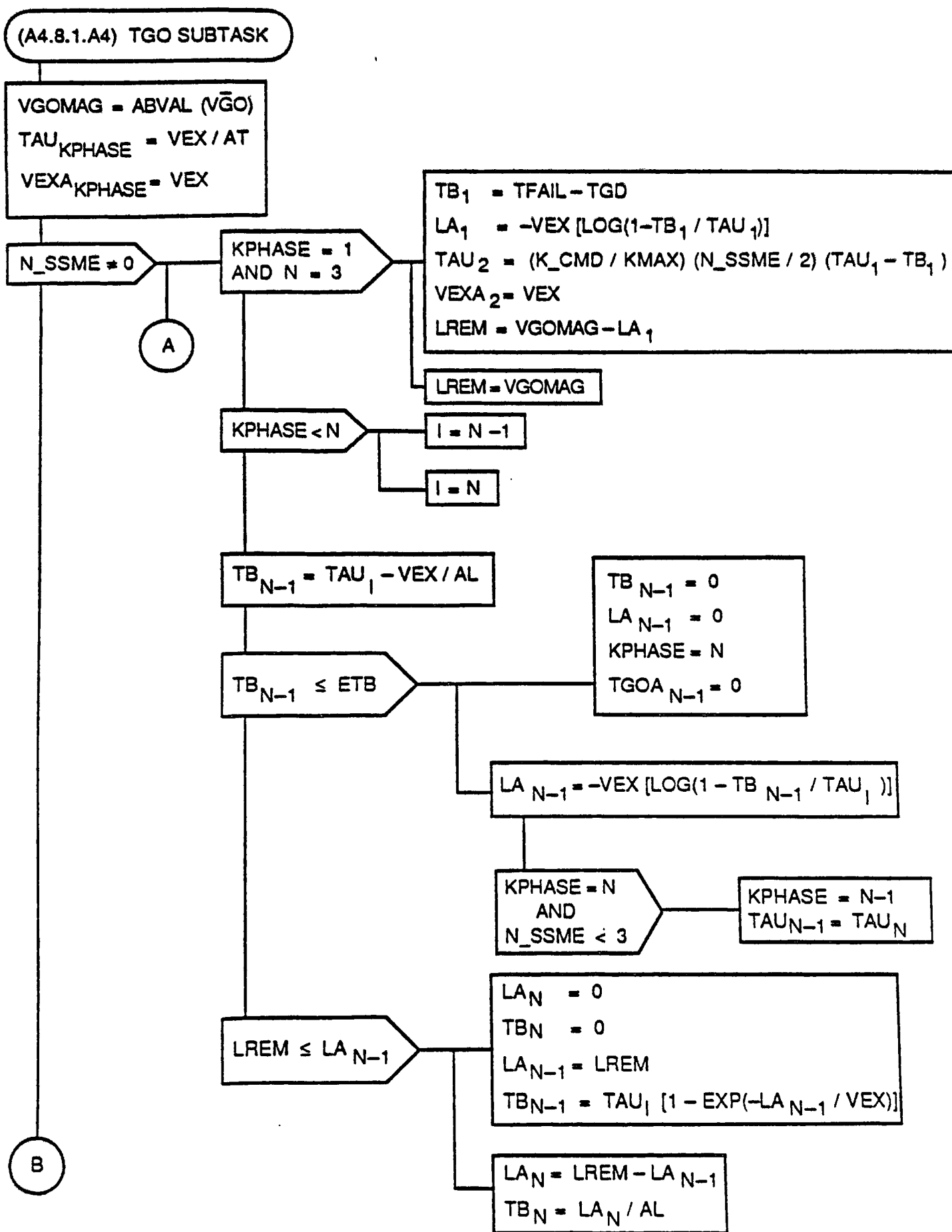


Figure A4.8.1.A4. PEG TSK (TGO SUBTASK) Flow Diagram (Sheet 1 of 3)

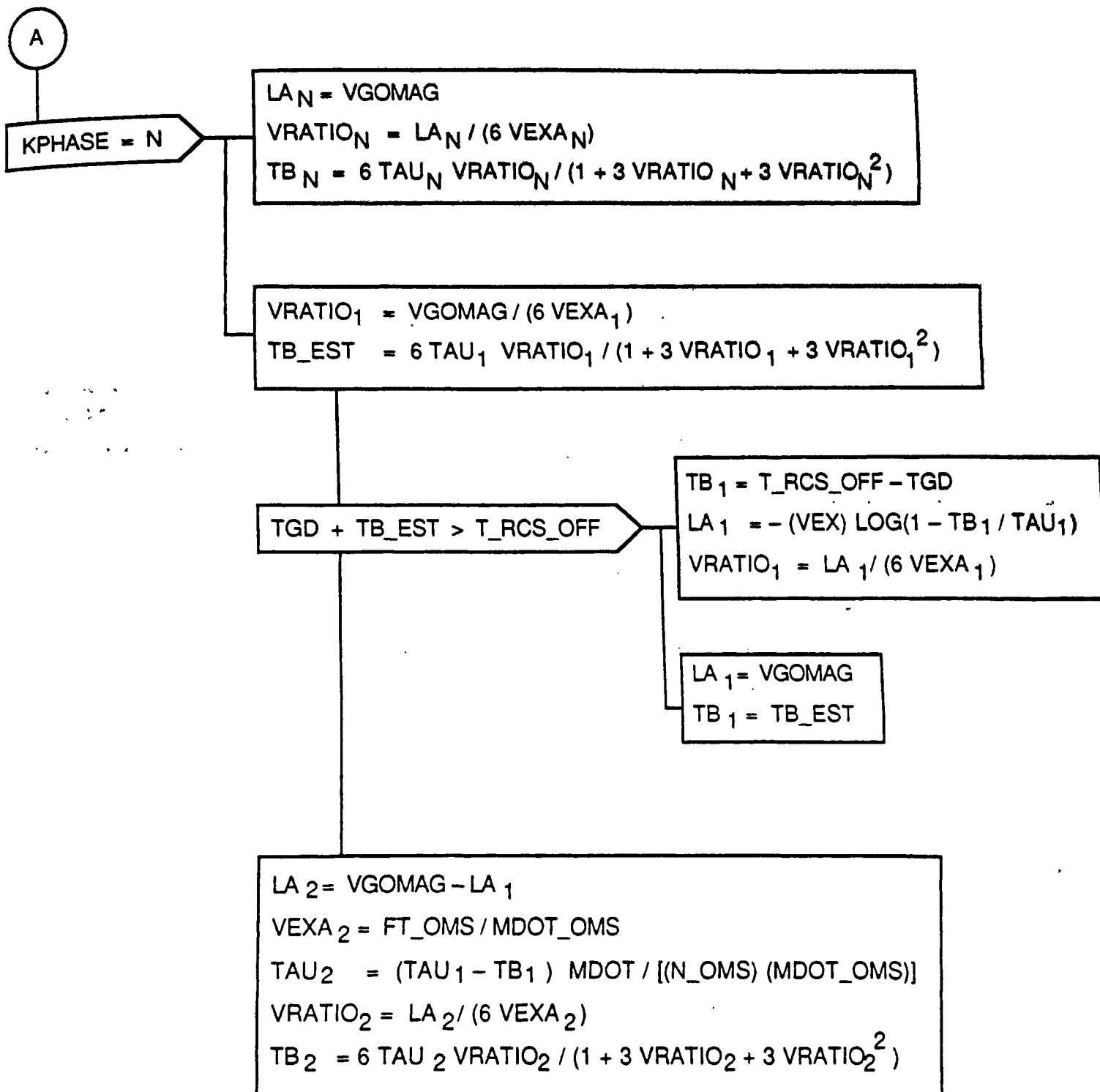


Figure A4.8.1.A4. PEG TSK (TGO SUBTASK) Flow Diagram (Sheet 2 of 3)

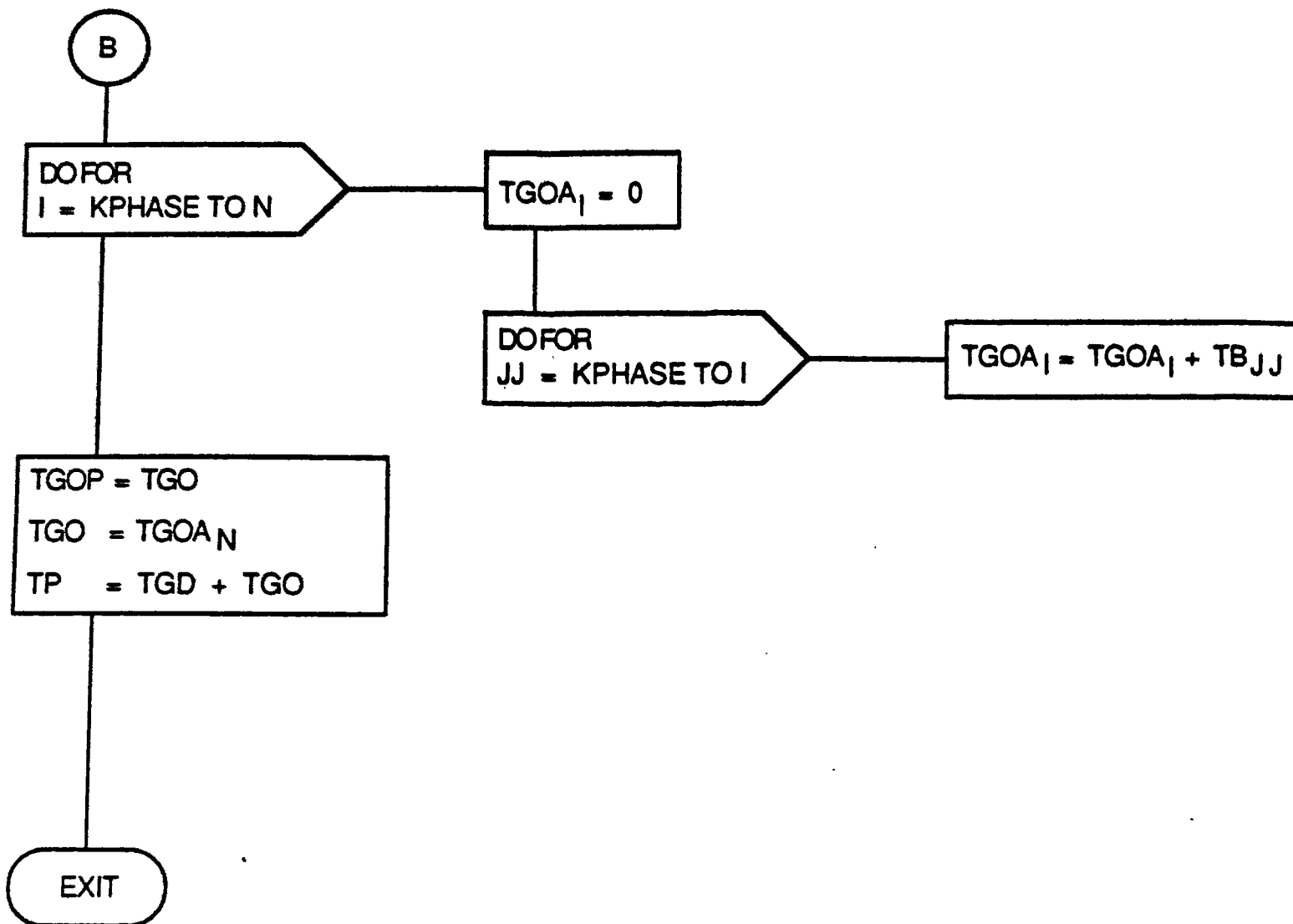


Figure A4.8.1.A4. PEG TSK (TGO SUBTASK) Flow Diagram (Sheet 3 of 3)

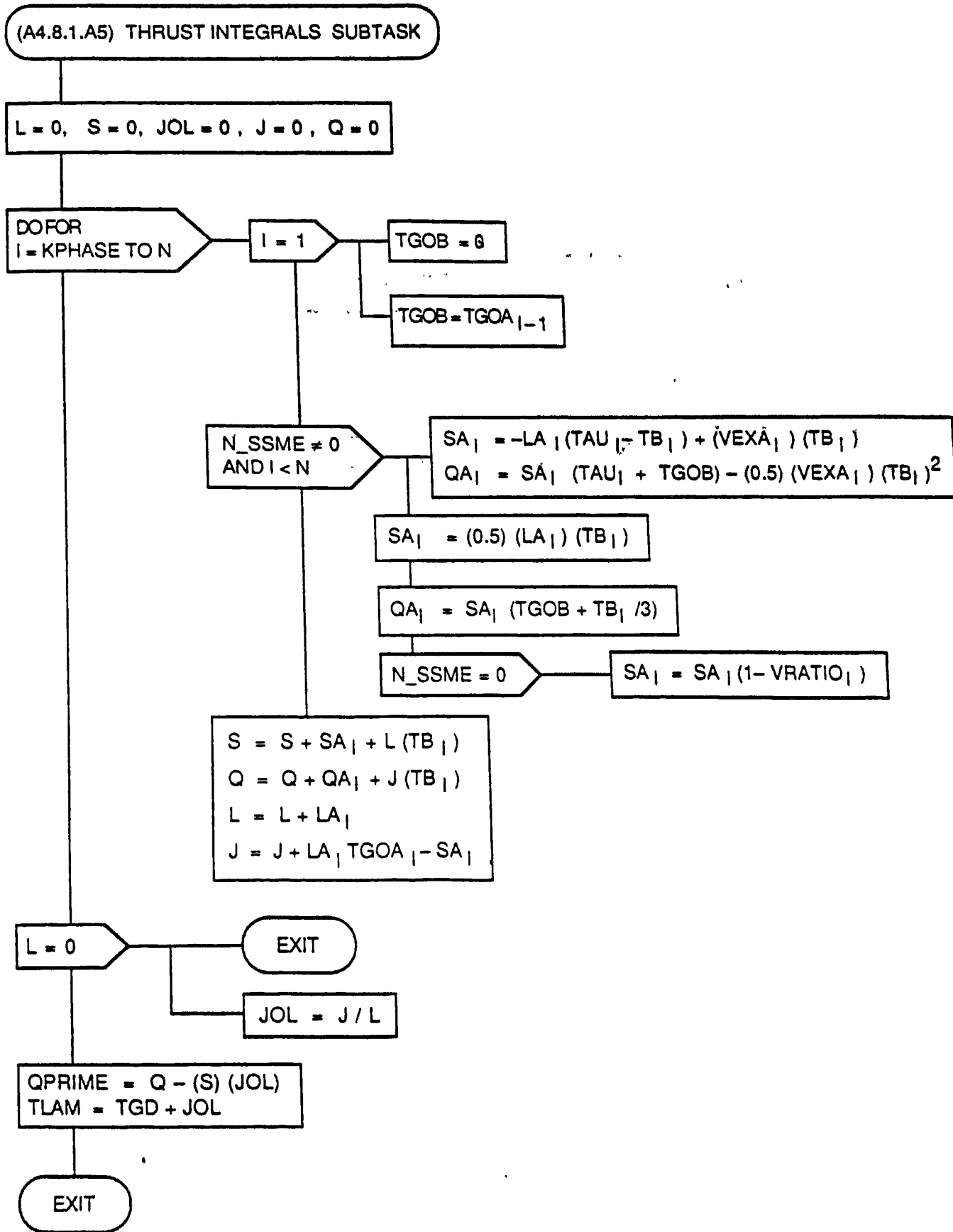


Figure A4.8.1.A5. PEG TSK (THRUST INTEGRALS SUBTASK) Flow Diagram



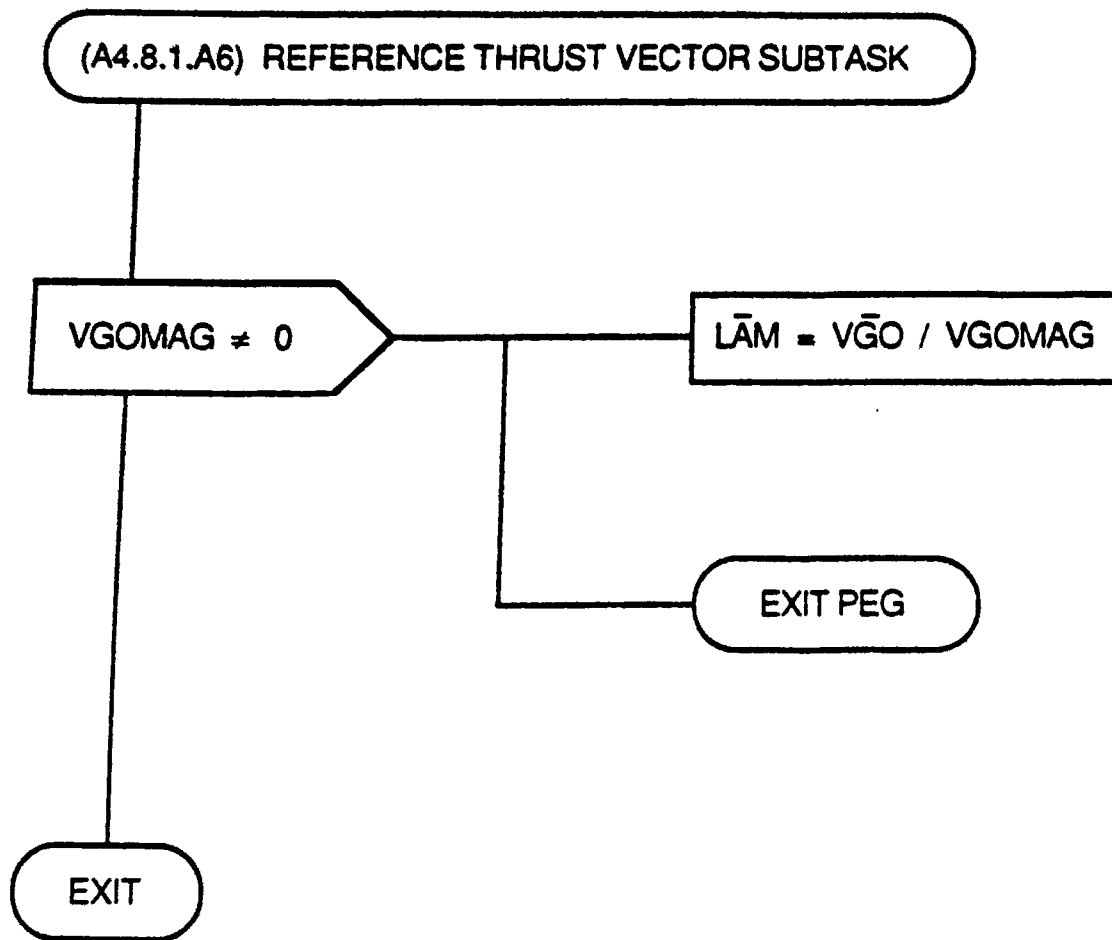


Figure A4.8.1.A6. PEG TSK (REFERENCE THRUST VECTOR SUBTASK) Flow Diagram

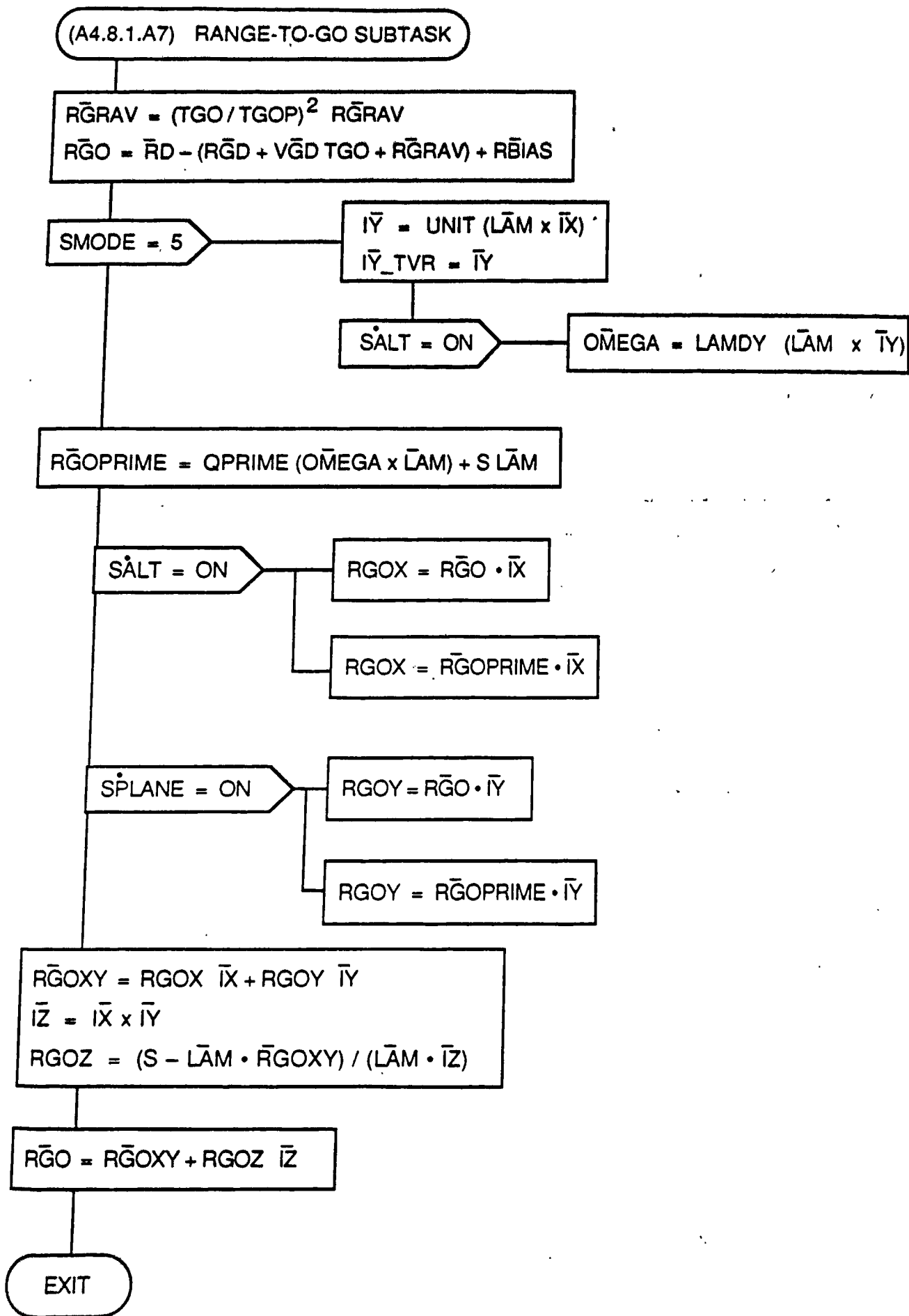


Figure A4.8.1.A7. PEG TSK (RANGE-TO-GO-SUBTASK) Flow Diagram

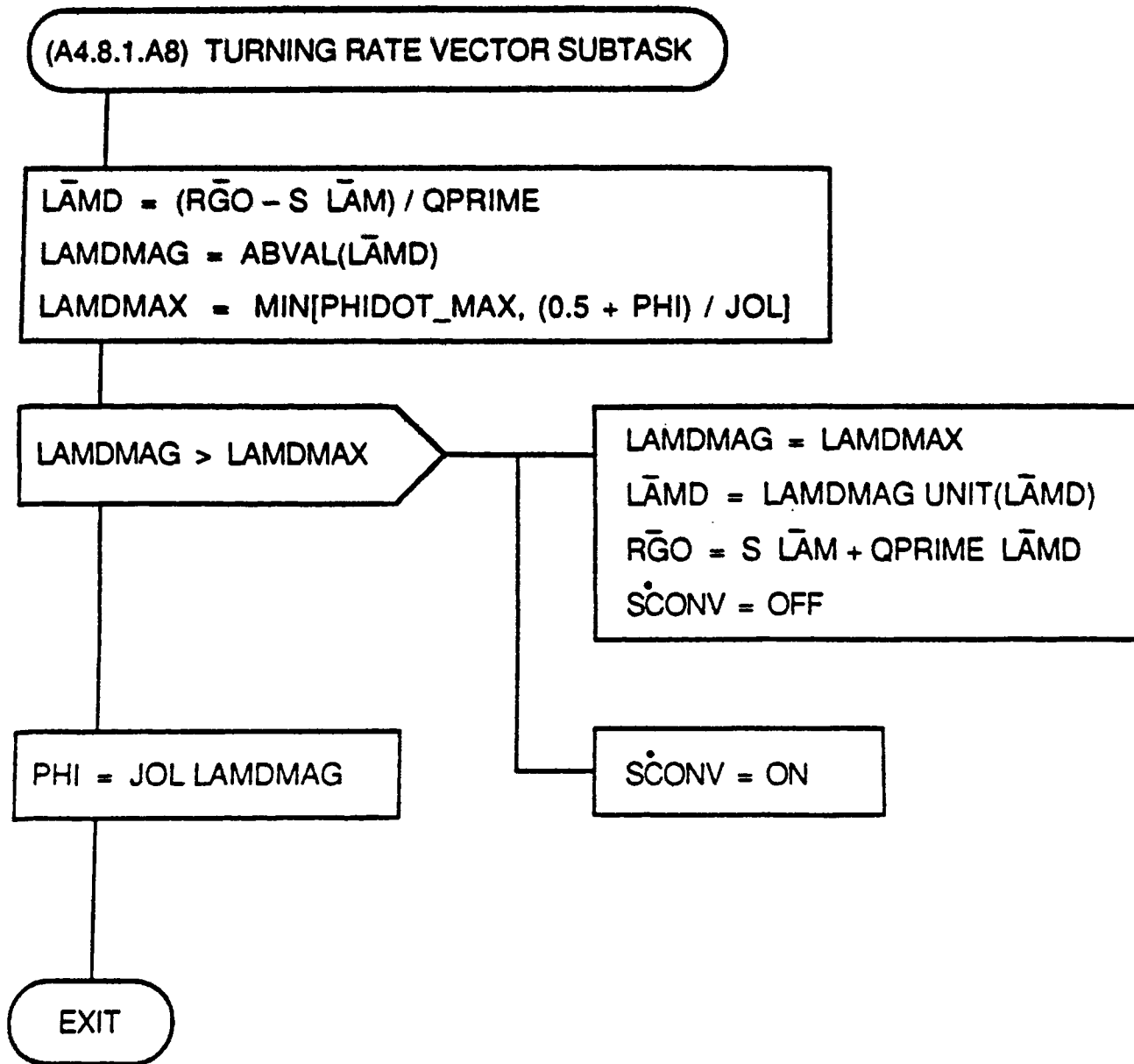


Figure A4.8.1.A8. PEG TSK (TURNING RATE VECTOR SUBTASK) Flow Diagram

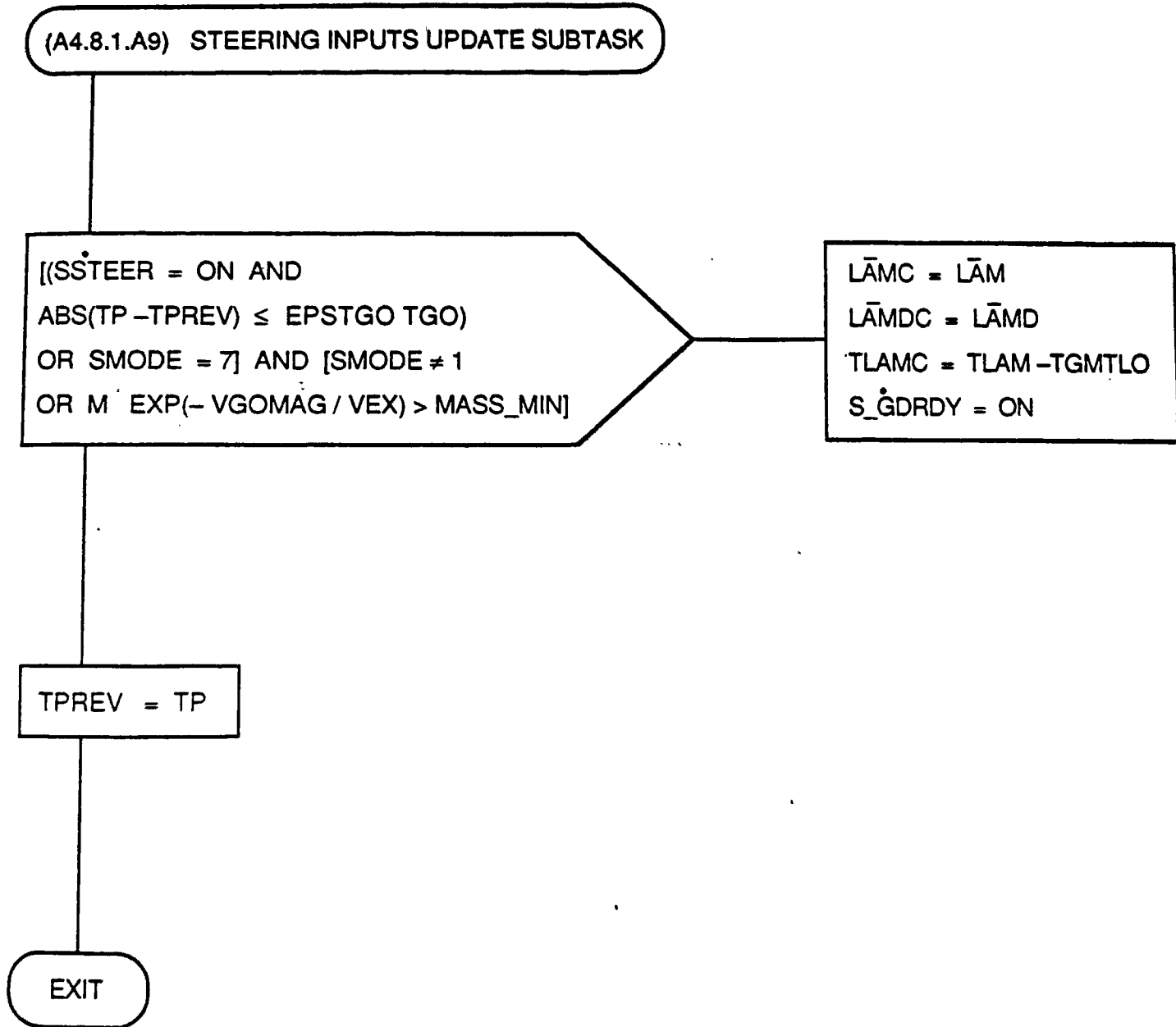


Figure A4.8.1.A9. PEG TSK (STEERING INPUTS UPDATE SUBTASK) Flow Diagram

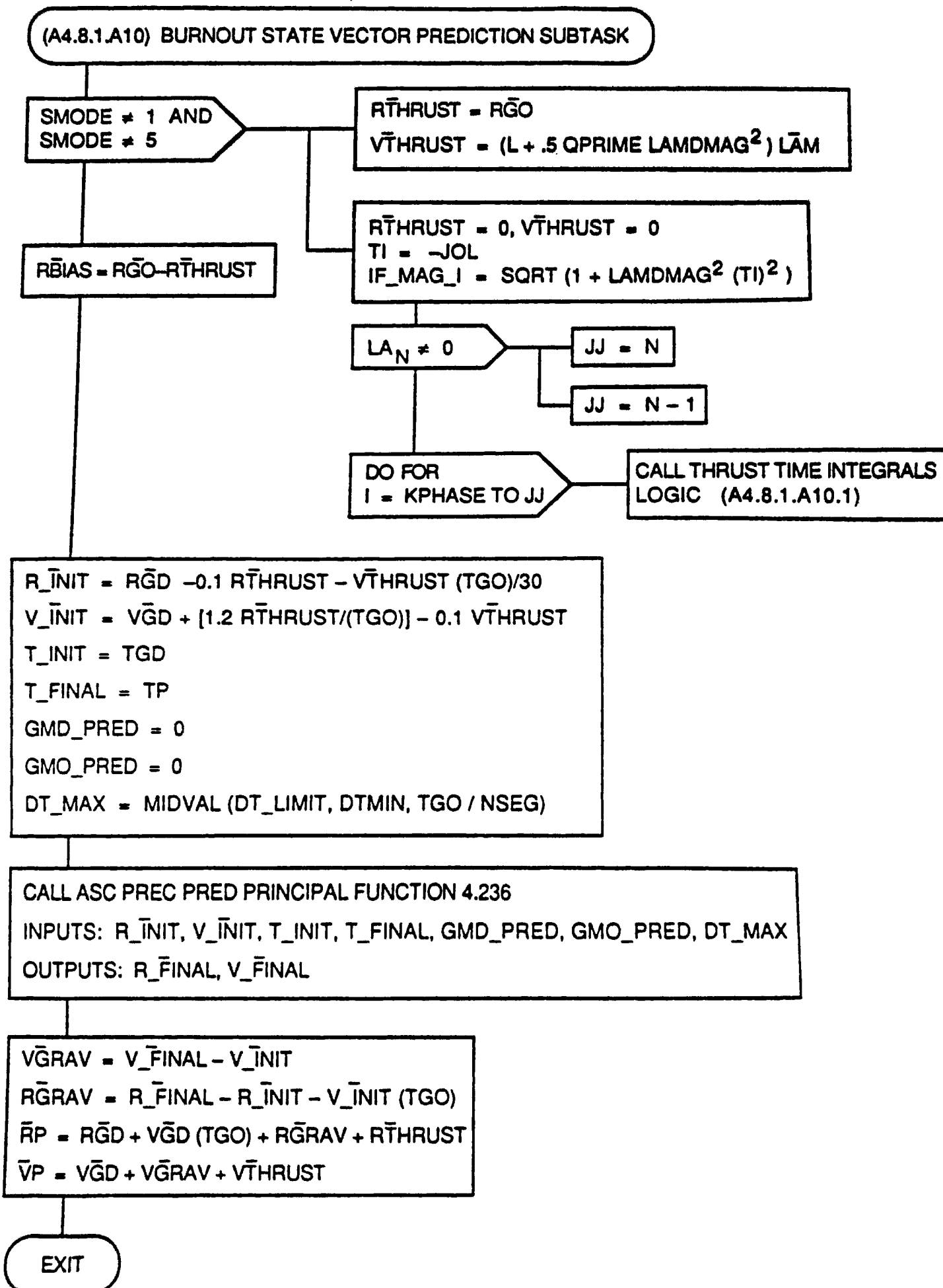


Figure A4.8.1.A10. PEG TSK (BURNOUT STATE VECTOR PREDICTION SUBTASK)  
Flow Diagram (Sheet 1 of 2)

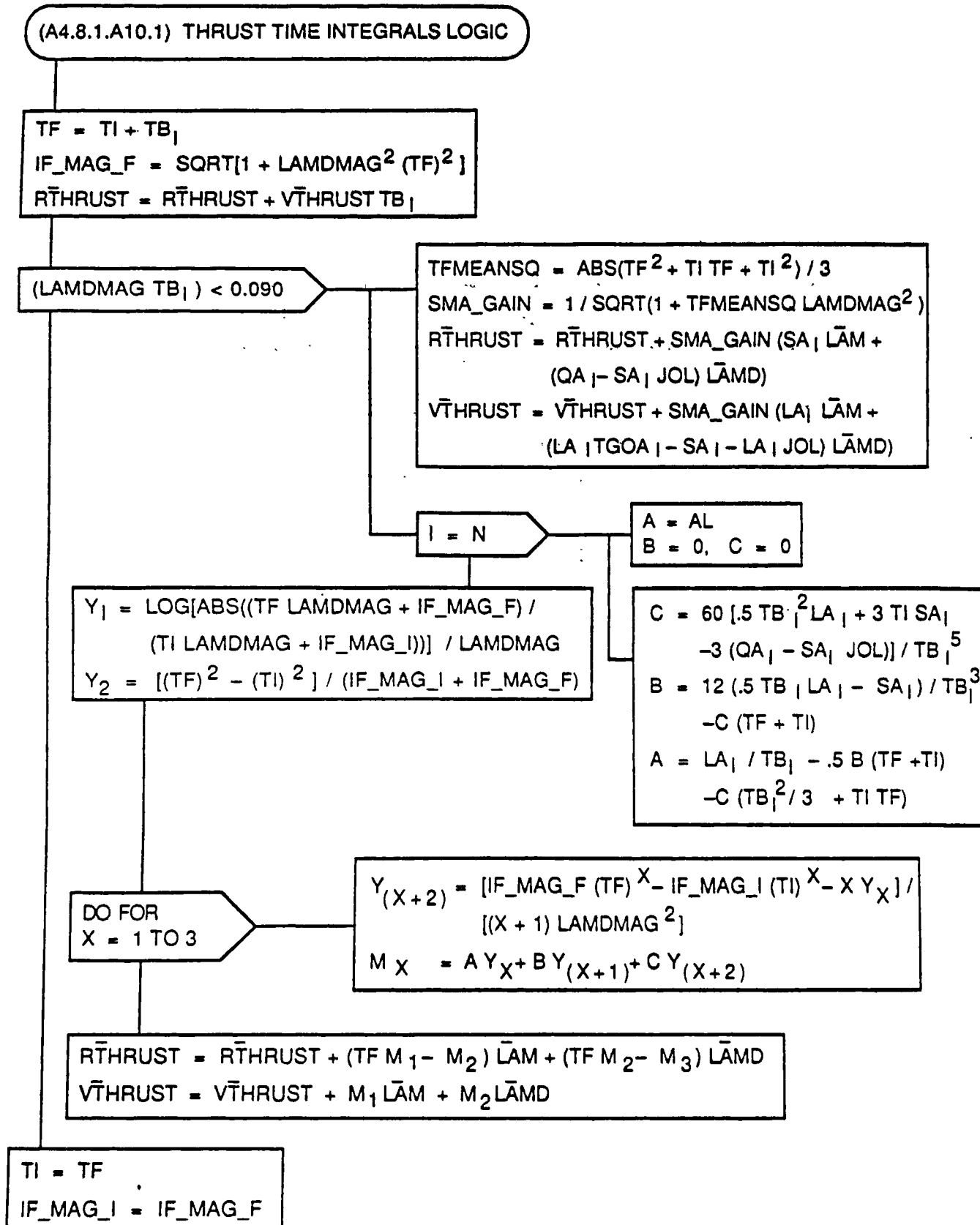


Figure A4.8.1.A10. PEG TSK (BURNOUT STATE VECTOR PREDICTION SUBTASK)  
Flow Diagram (Sheet 2 of 2)

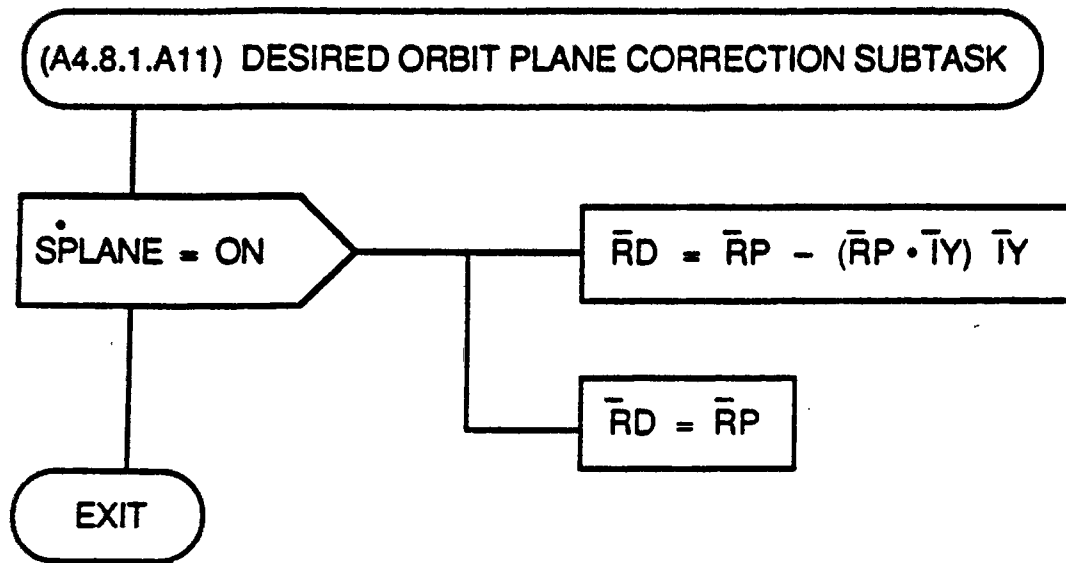


Figure A4.8.1.A11. PEG TSK (DESIRED ORBIT PLANE CORRECTION SUBTASK) Flow Diagram

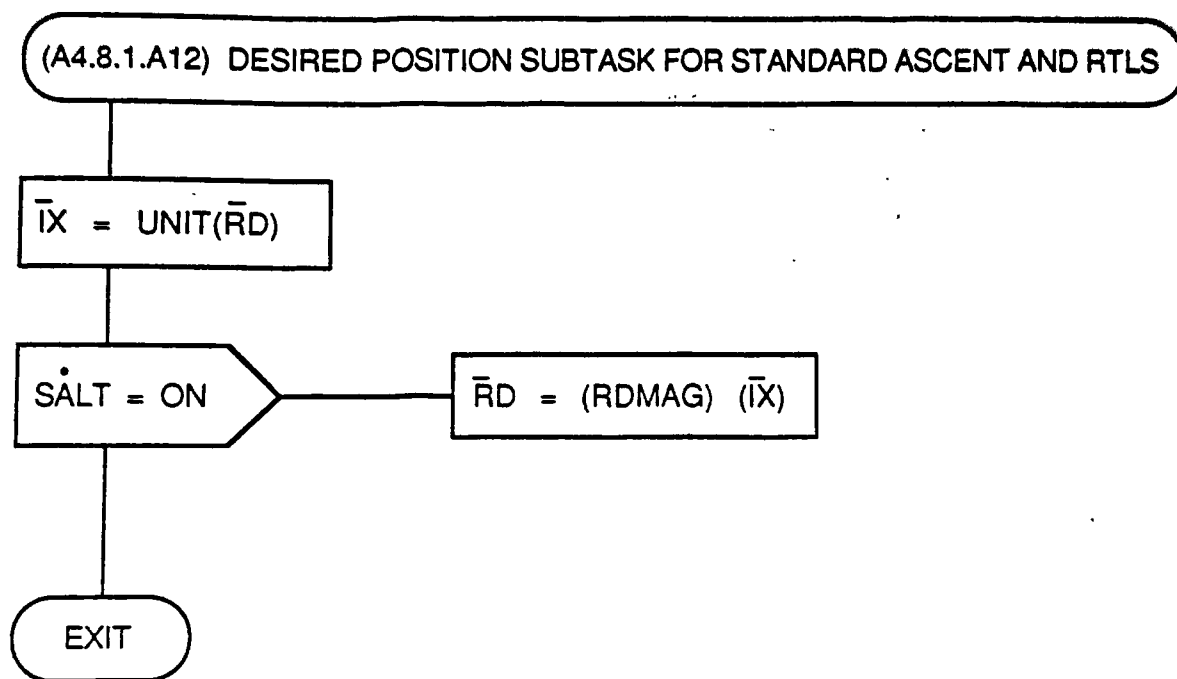


Figure A4.8.1.A12. PEG TSK (DESIRED POSITION SUBTASK FOR STANDARD ASCENT AND RTLS) Flow Diagram



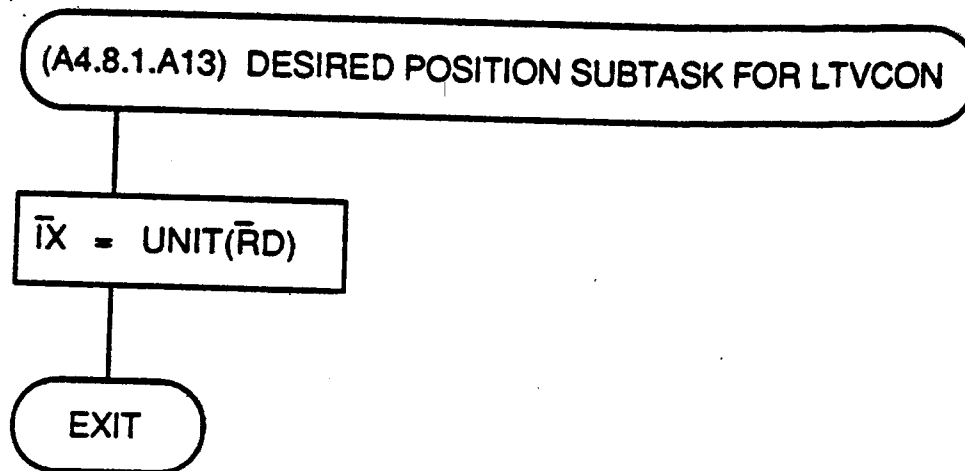


Figure A4.8.1.A13. PEG TSK (DESIRED POSITION SUBTASK FOR LTVCON) Flow Diagram

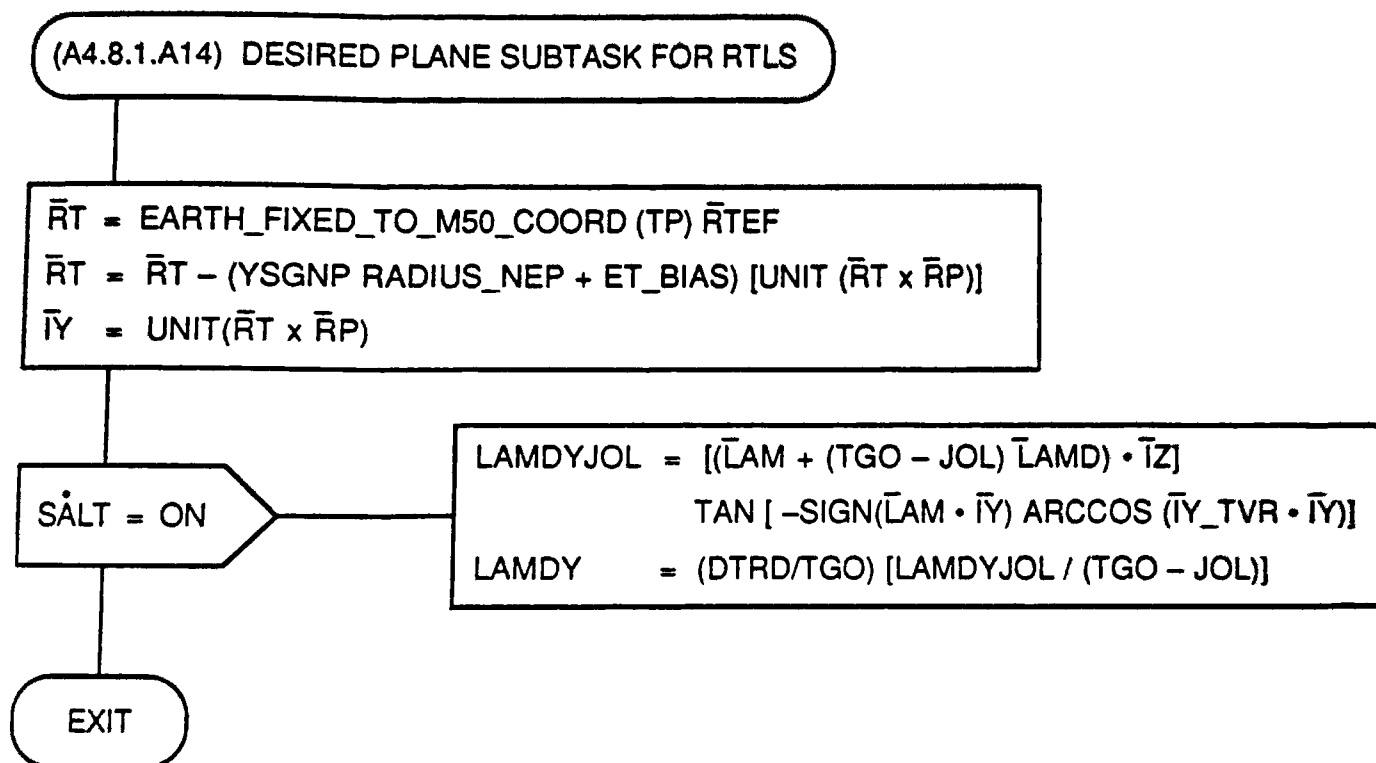


Figure A4.8.1.A14. PEG TSK (DESIRED PLANE SUBTASK FOR RTLS) Flow Diagram

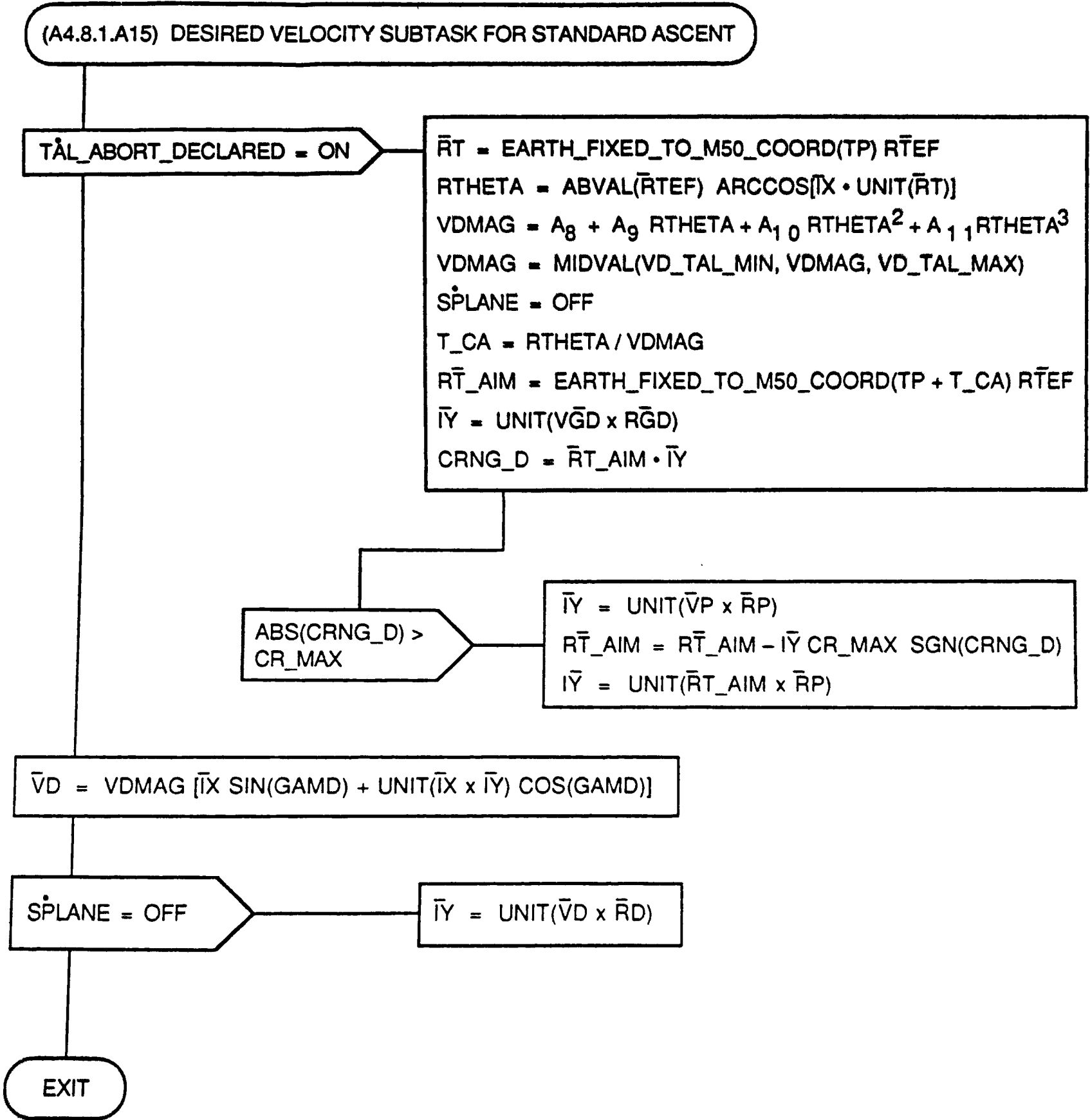


Figure A4.8.1.A15. PEG TSK (DESIRED VELOCITY SUBTASK FOR STANDARD ASCENT) Flow Diagram

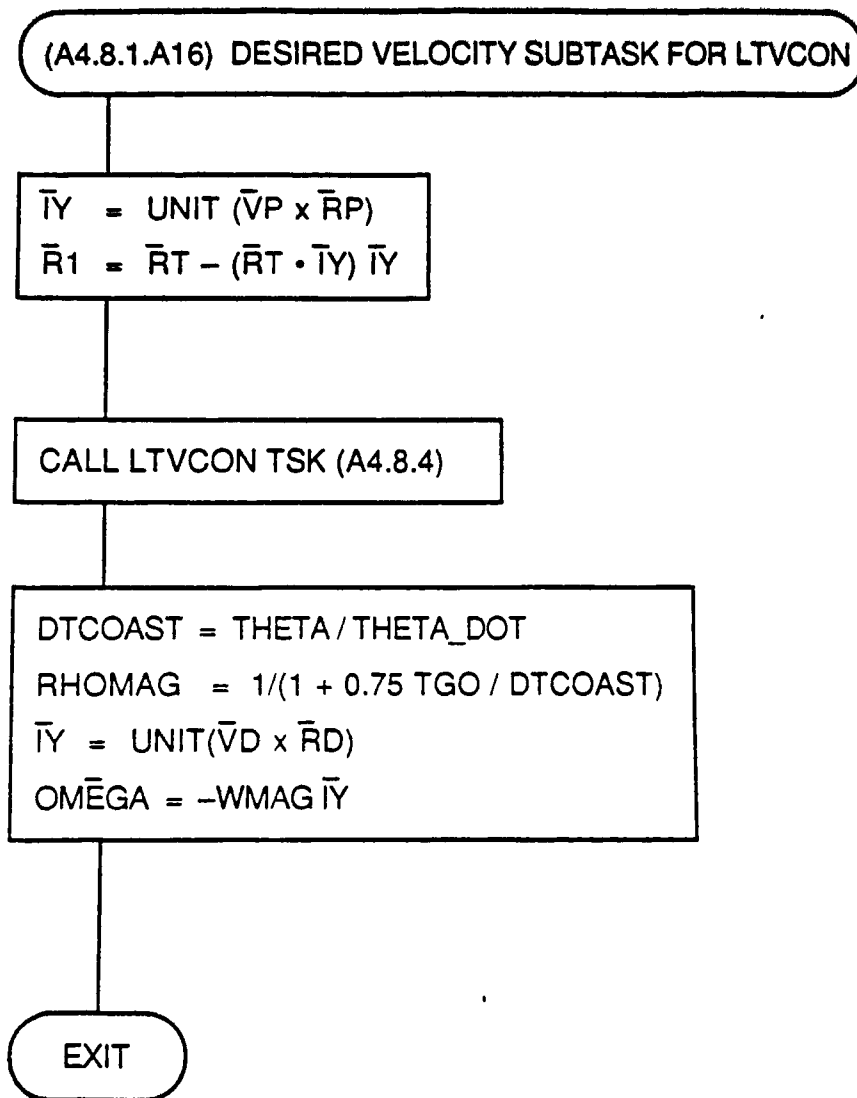


Figure A4.8.1.A16. PEG TSK (DESIRED VELOCITY SUBTASK FOR LTVCON) Flow Diagram

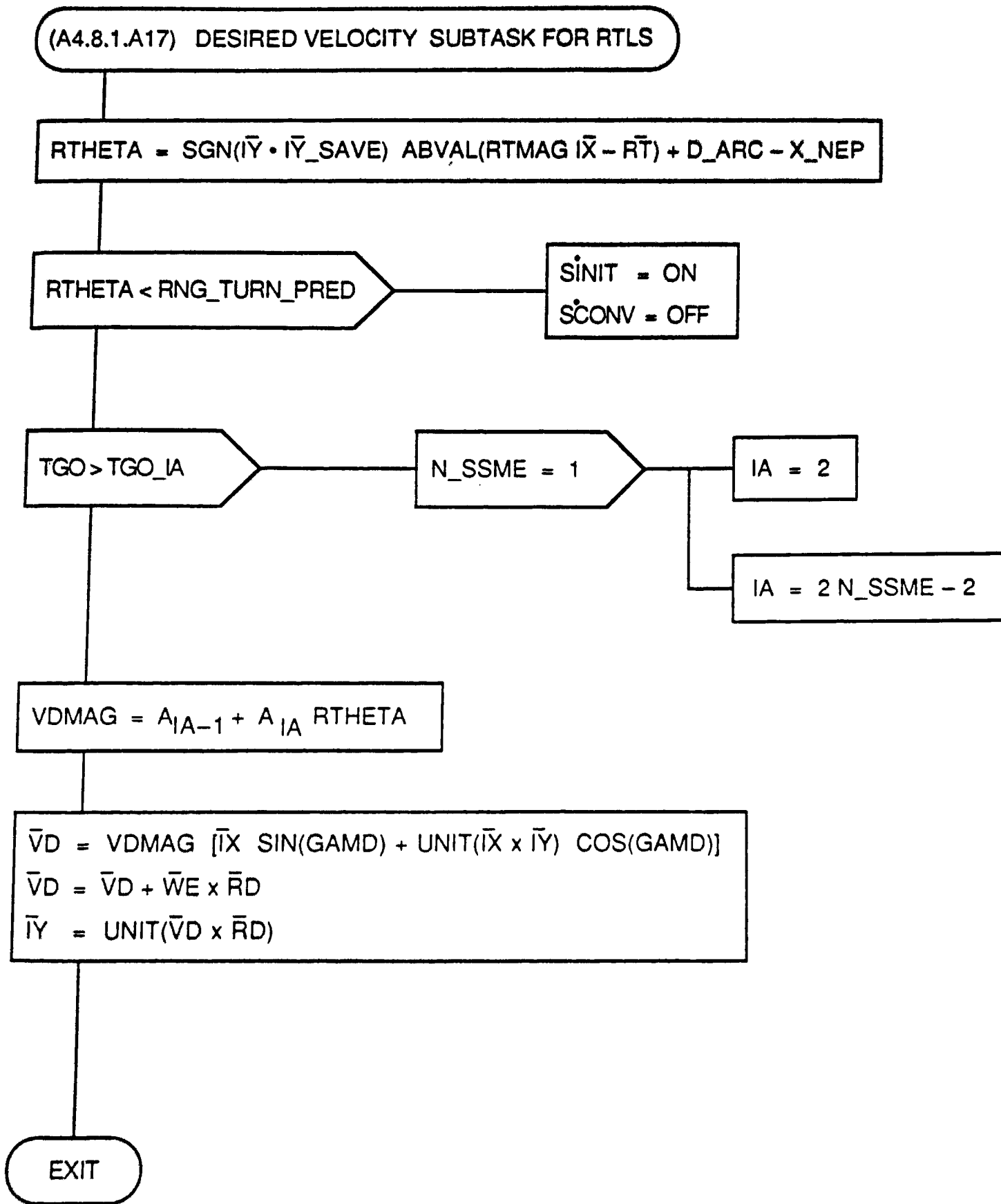


Figure A4.8.1.A17. PEG TSK (DESIRED VELOCITY SUBTASK FOR RTLS) Flow Diagram

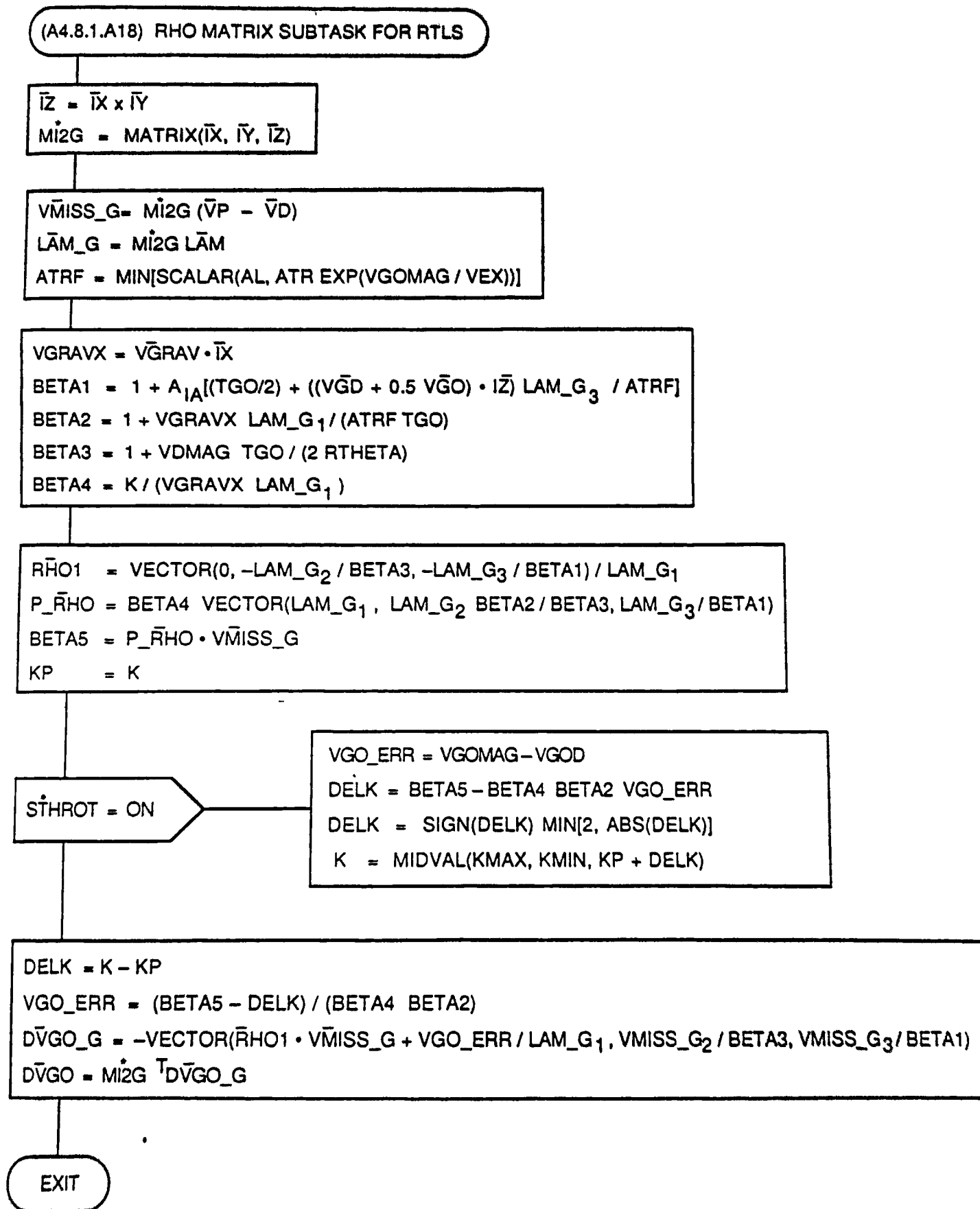


Figure A4.8.1.A18. PEG TSK (RHO MATRIX SUBTASK FOR RTLS) Flow Diagram

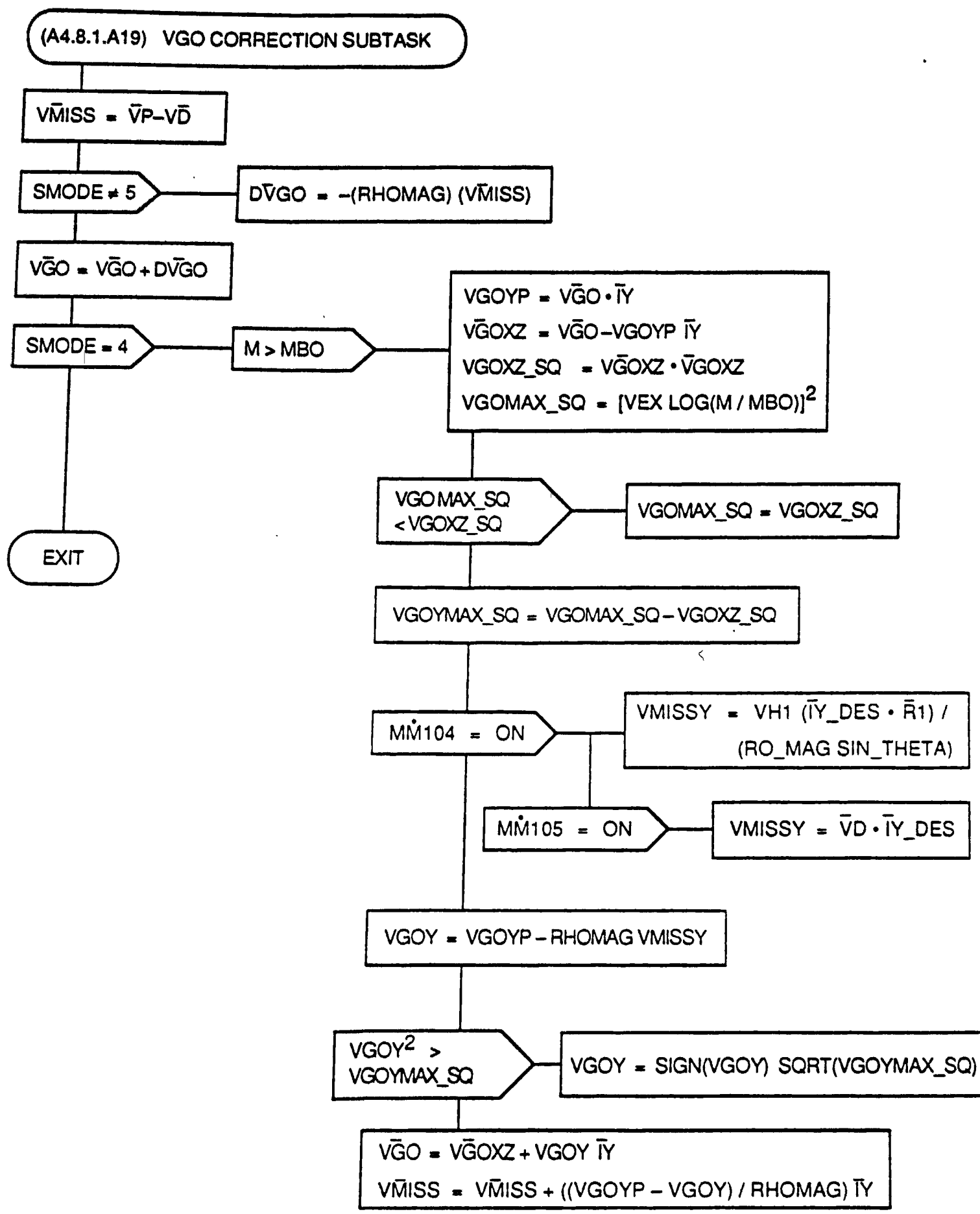


Figure A4.8.1.A19. PEG TSK (VGO CORRECTION SUBTASK) Flow Diagram

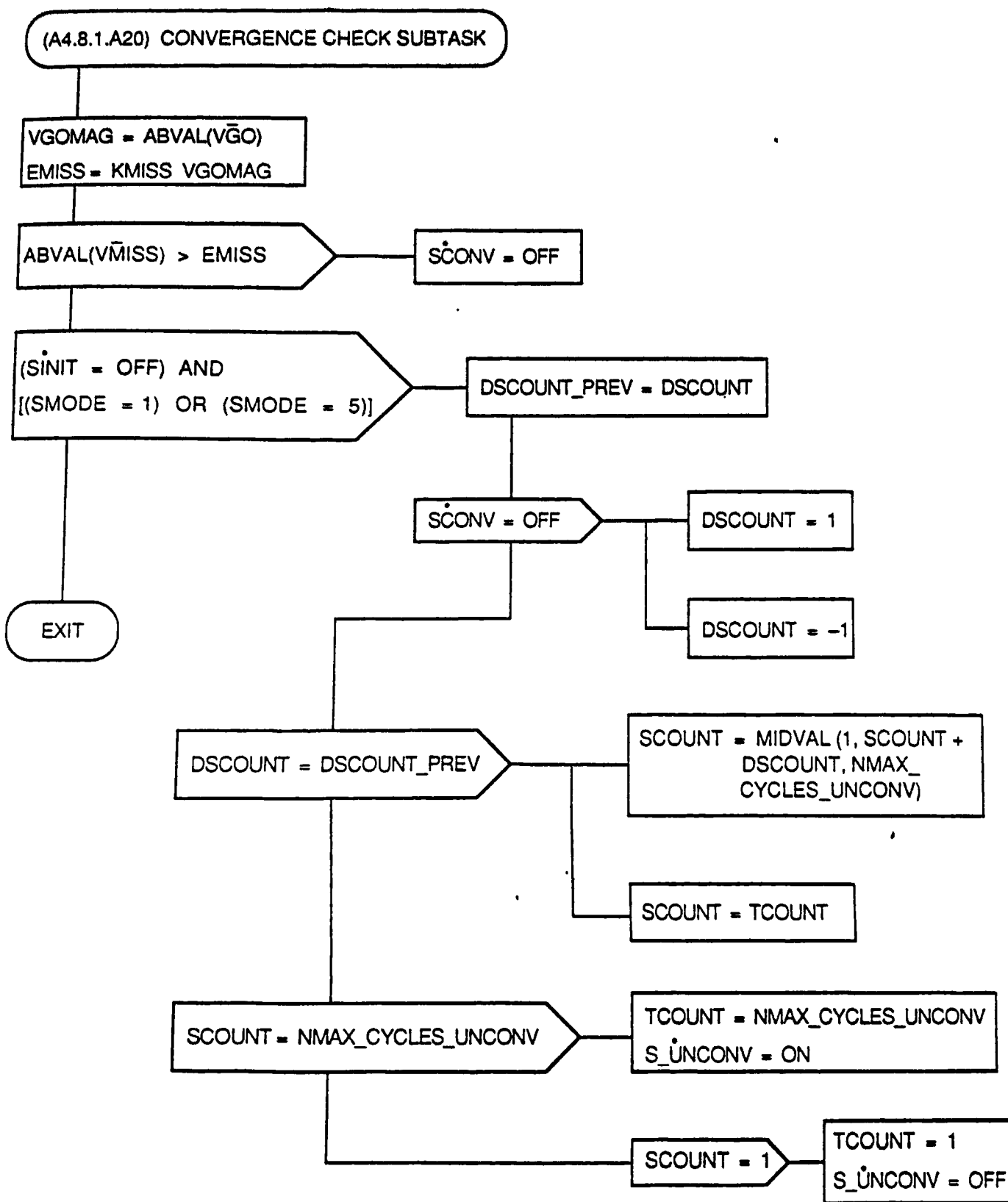


Figure A4.8.1.A20. PEG TSK (CONVERGENCE CHECK SUBTASK) Flow Diagram



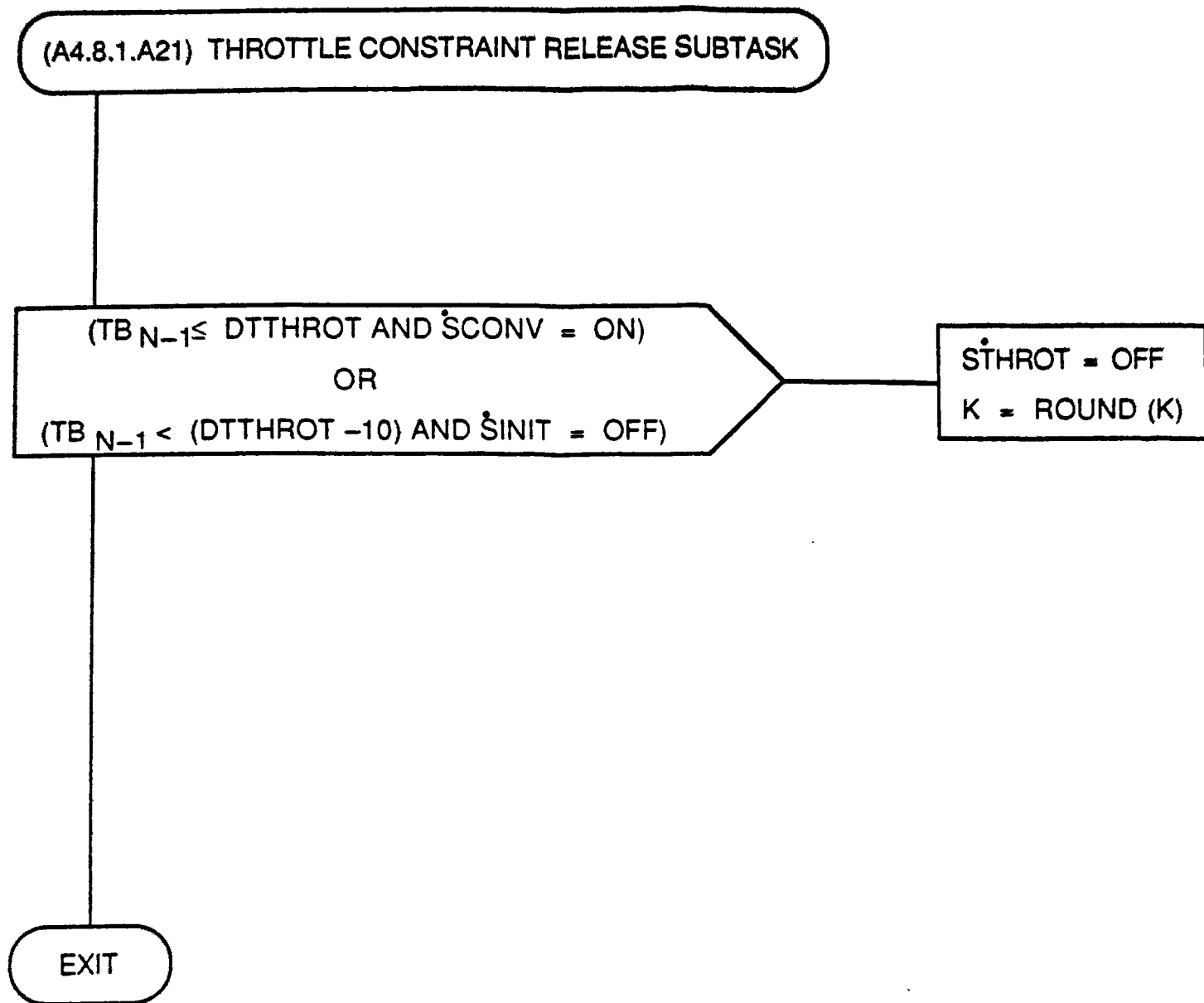


Figure A4.8.1.A21. PEG TSK (THROTTLE CONSTRAINT RELEASE SUBTASK) Flow Diagram

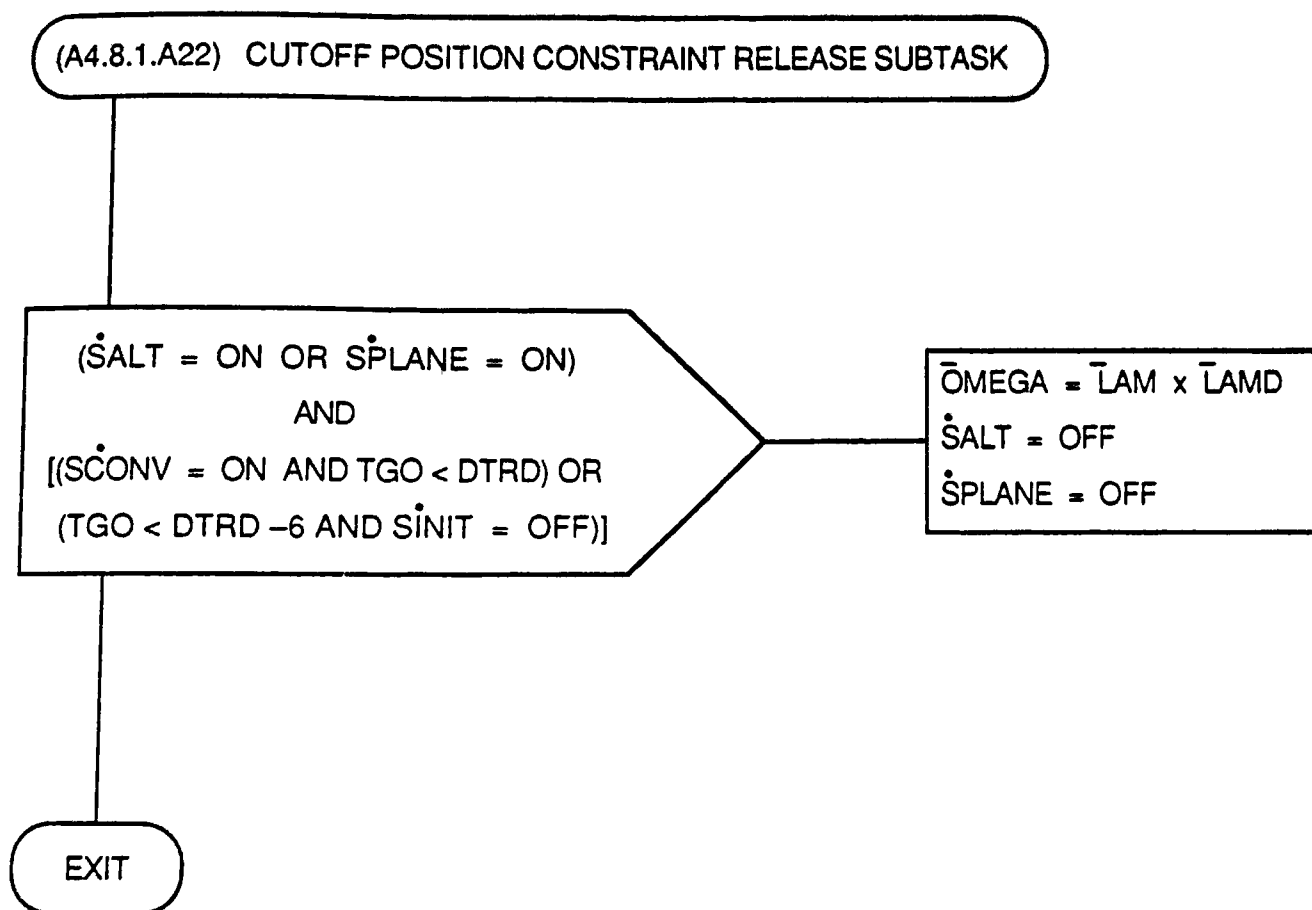


Figure A4.8.1.A22. PEG TSK (CUTOFF POSITION CONSTRAINT RELEASE SUBTASK)  
Flow Diagram

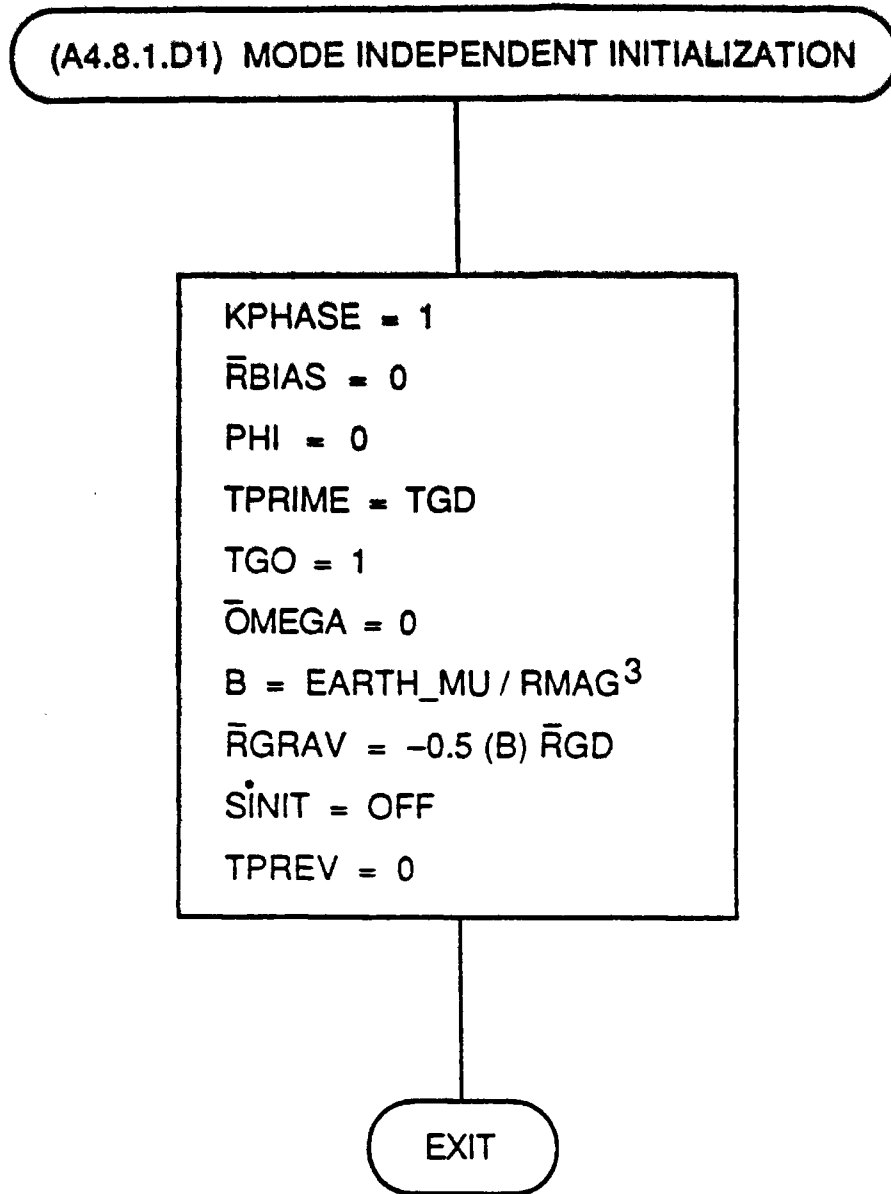


Figure A4.8.1.D1. PEG TSK (MODE INDEPENDENT INITIALIZATION) Flow Diagram

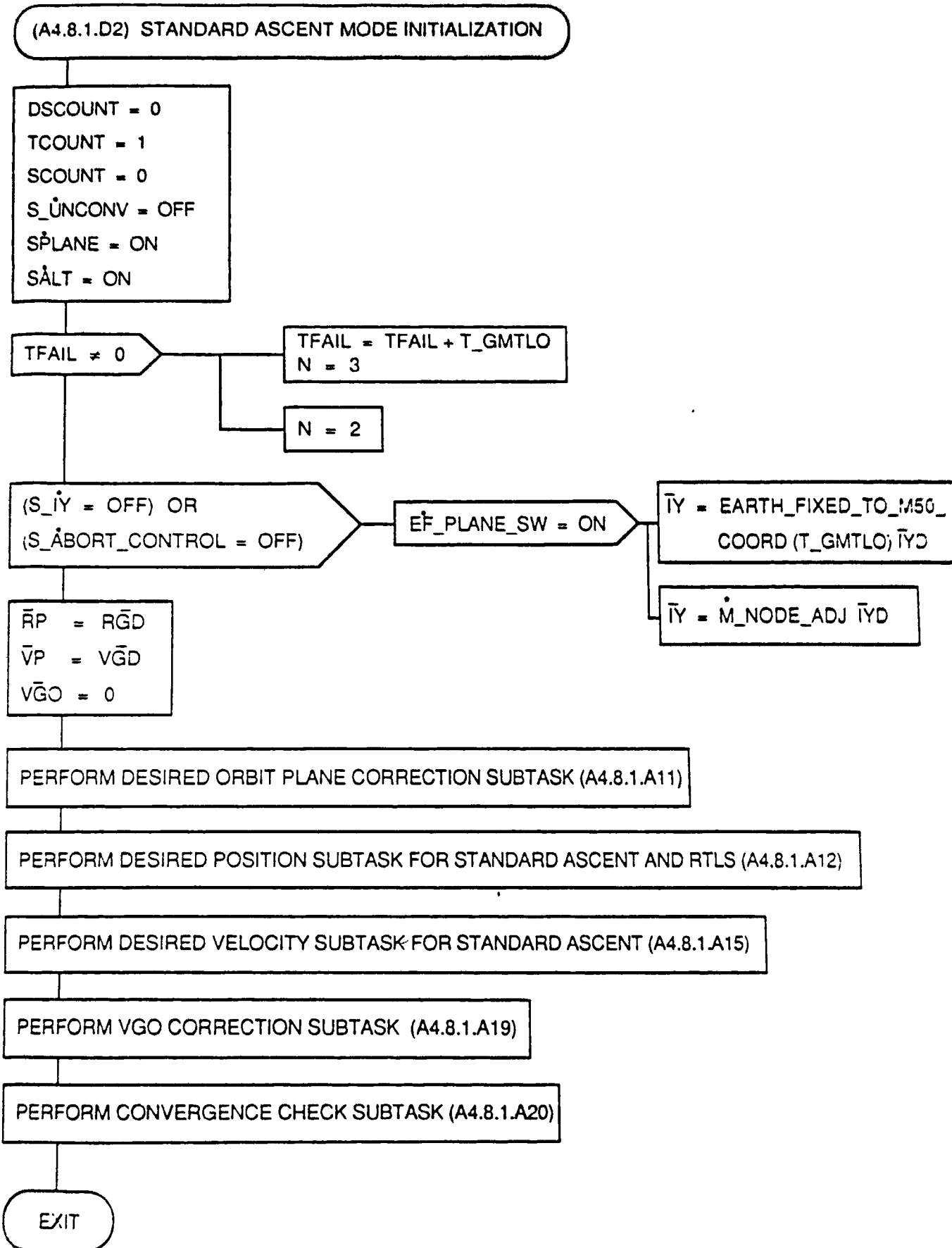


Figure A4.8.1.D2. PEG TSK (STANDARD ASCENT MODE INITIALIZATION) Flow Diagram

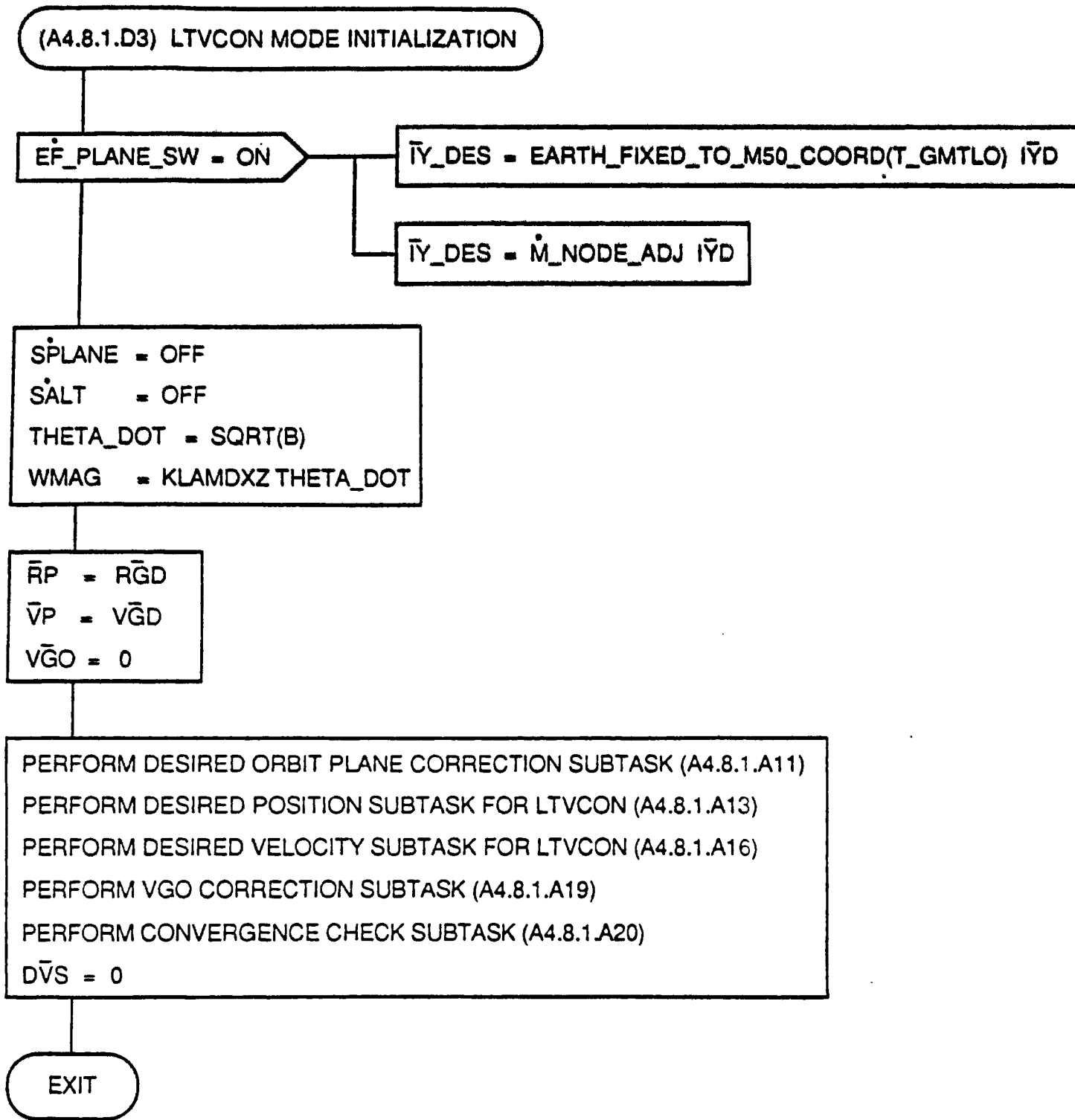


Figure A4.8.1.D3. PEG TSK (LTVCON MODE INITIALIZATION) Flow Diagram

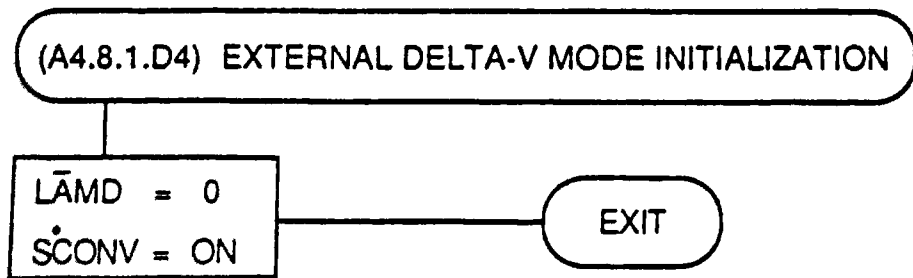


Figure A4.8.1.D4. PEG TSK (EXTERNAL DELTA-V MODE INITIALIZATION) Flow Diagram

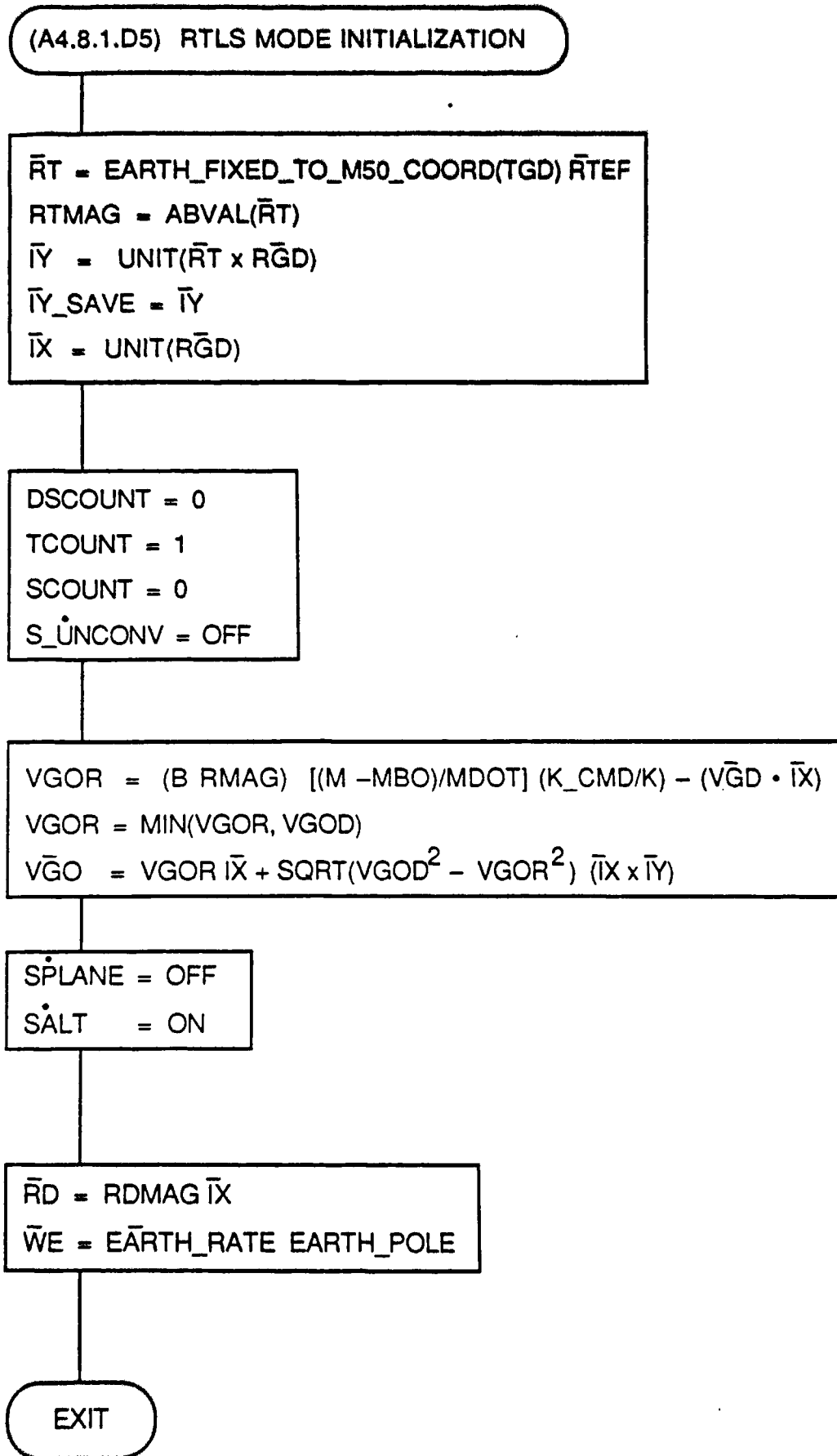


Figure A4.8.1.D5. PEG TSK (RTLS MODE INITIALIZATION) Flow Diagram

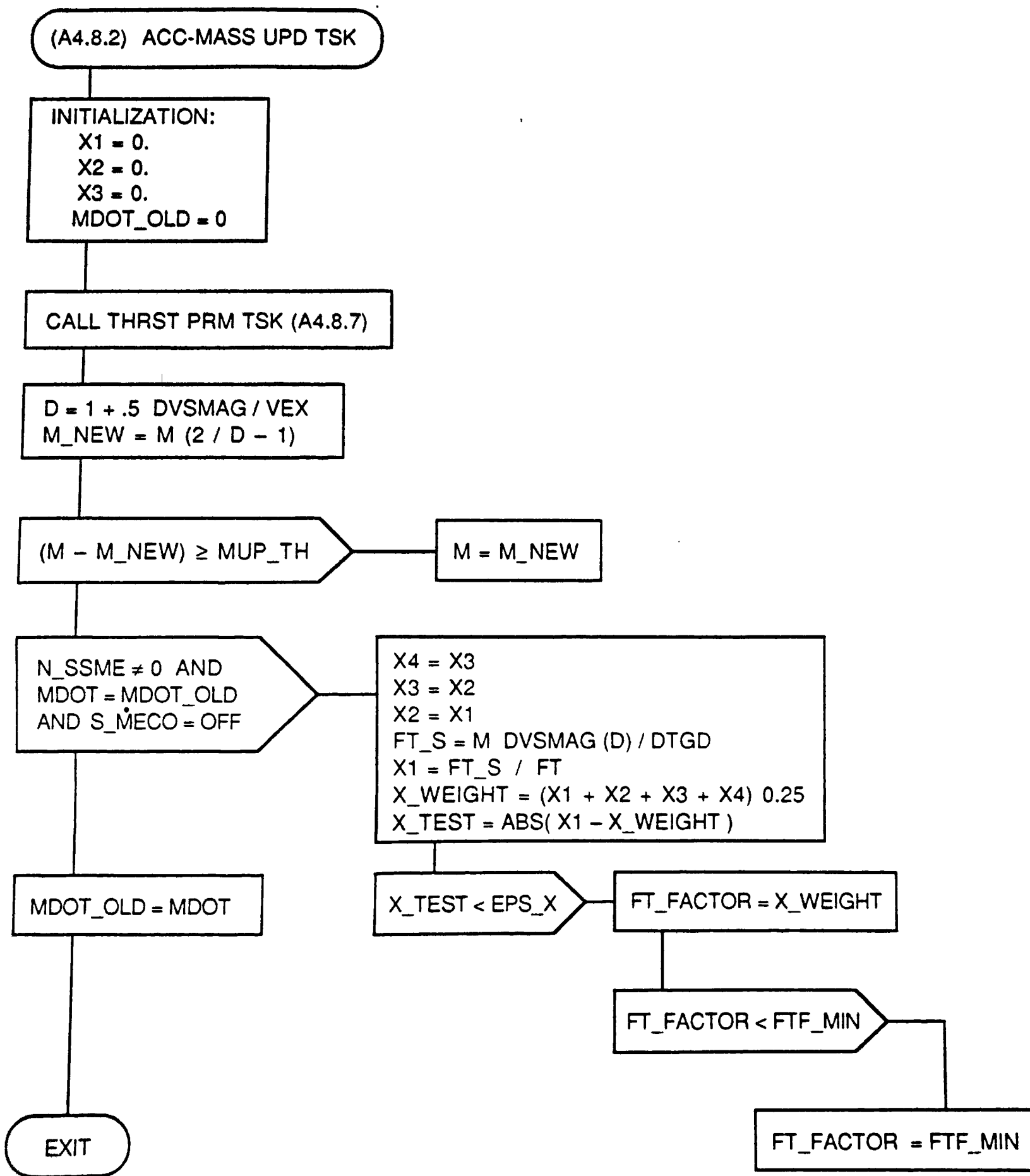
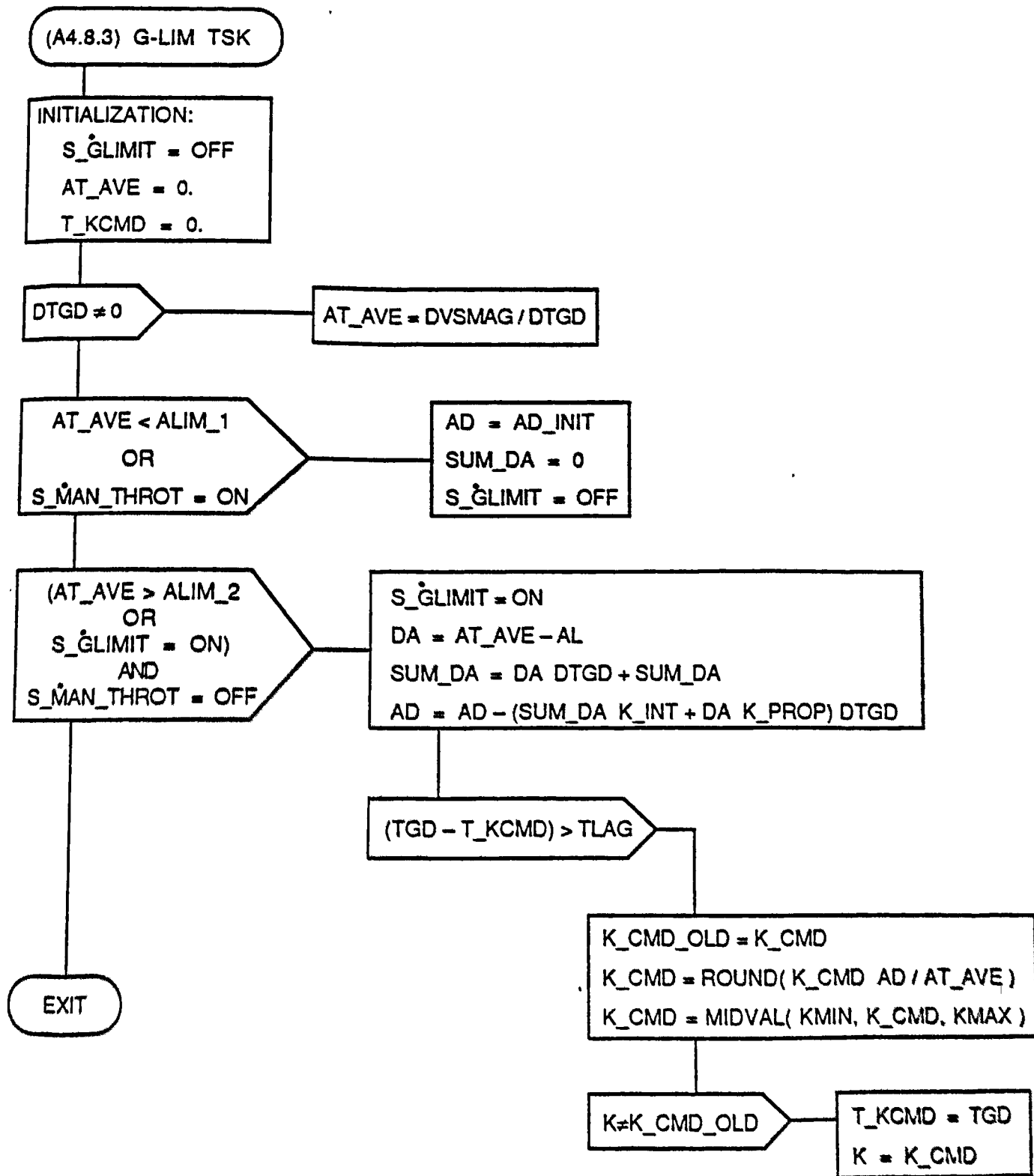


Figure A4.8.2. ACC-MASS UPD TSK Flow Diagram



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Figure A4.8.3. G-LIM TSK Flow Diagram



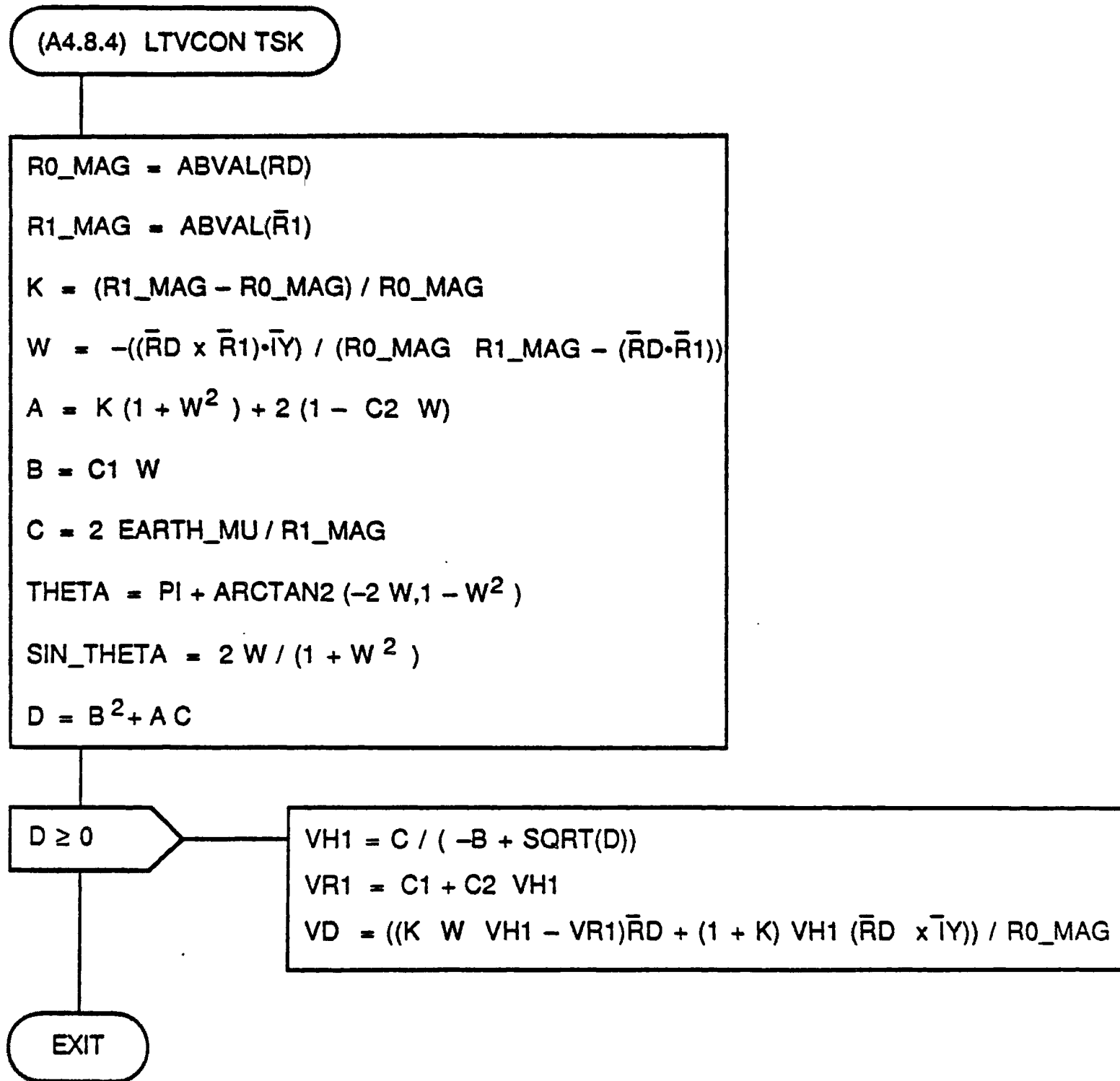


Figure A4.8.4. LTVCON TSK Flow Diagram

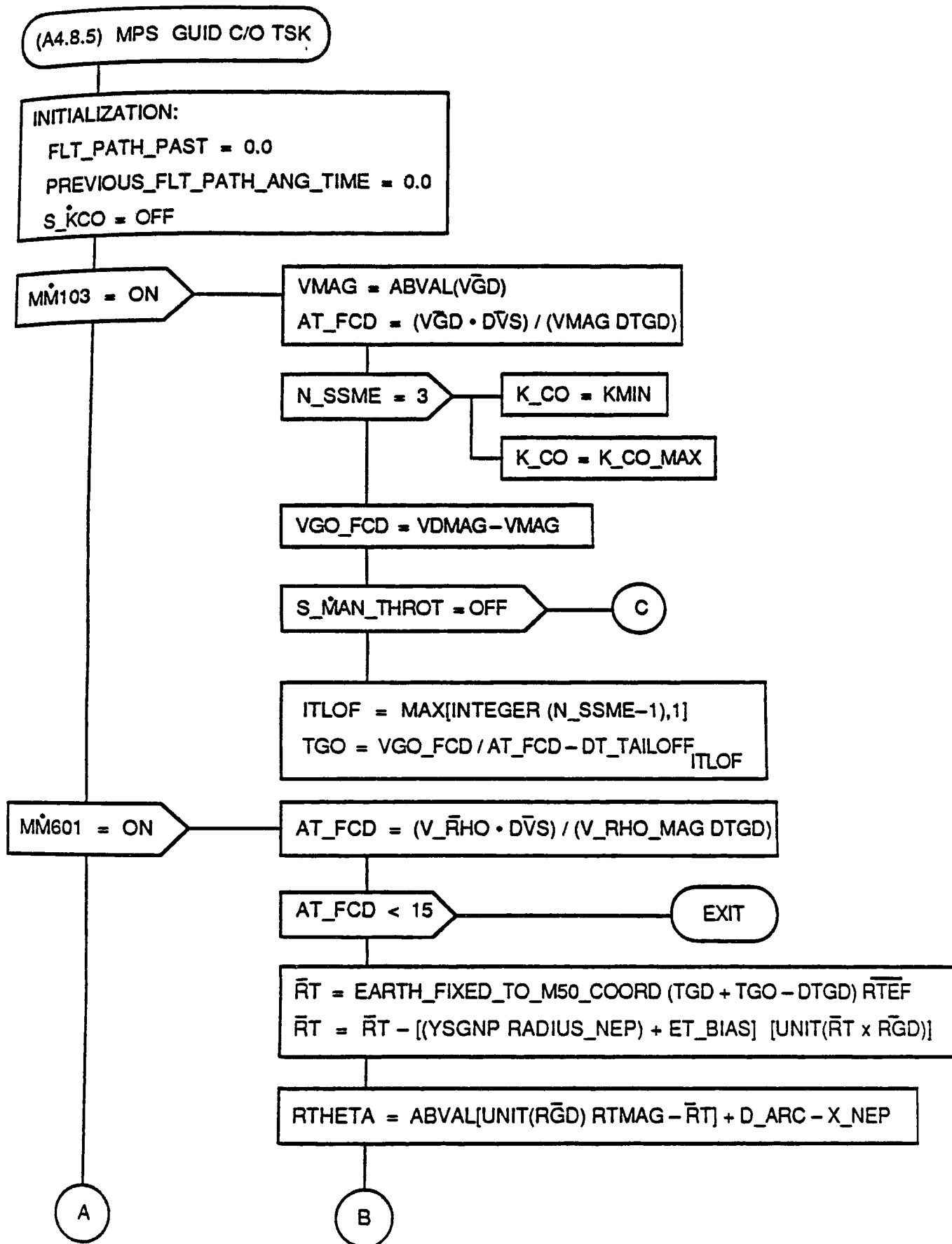


Figure A4.8.5 MPS GUID C/O TSK Flow Diagram (Sheet 1 of 3)

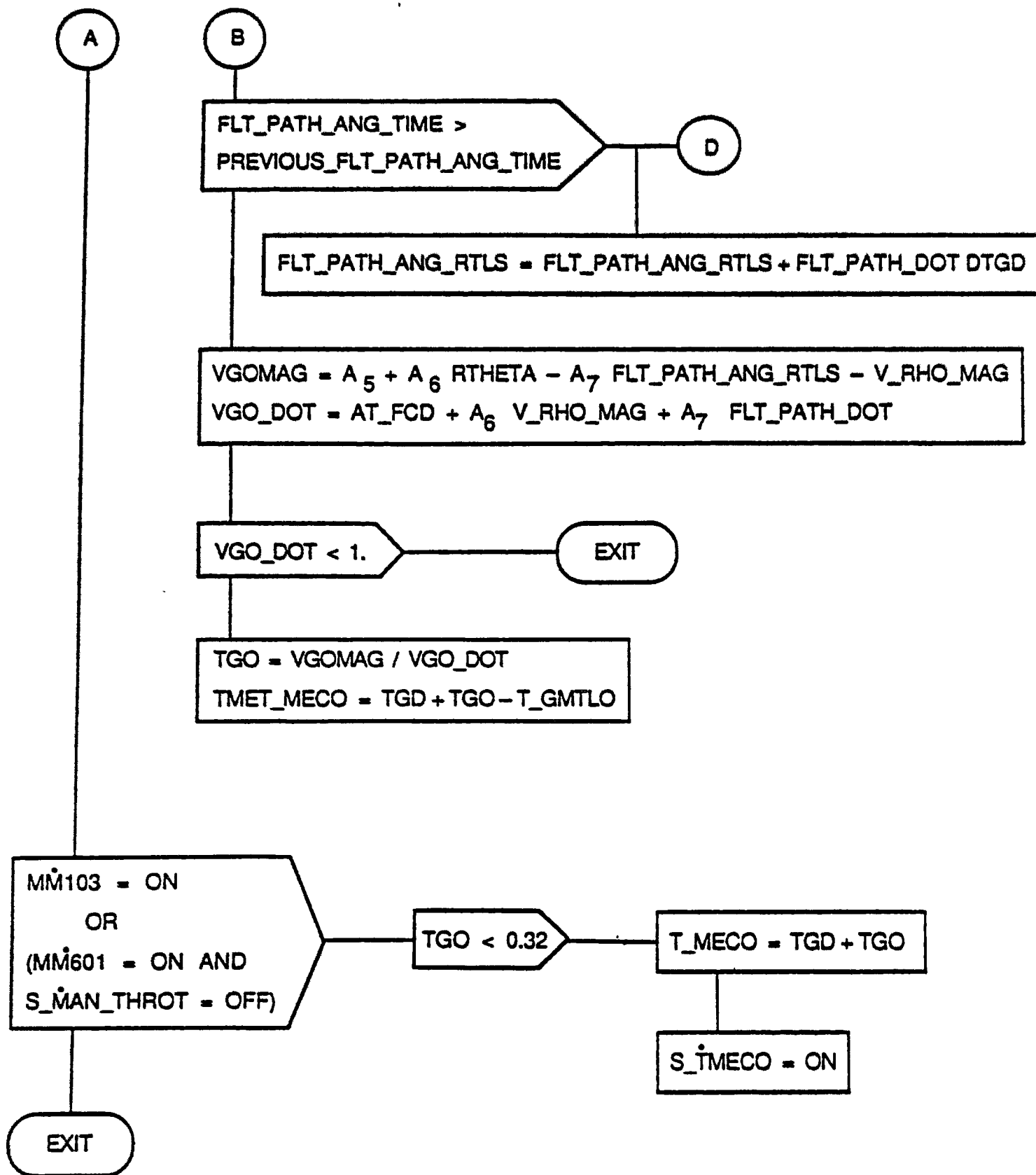


Figure A4.8.5. MPS GUID C/O TSK Flow Diagram (Sheet 2 of 3)

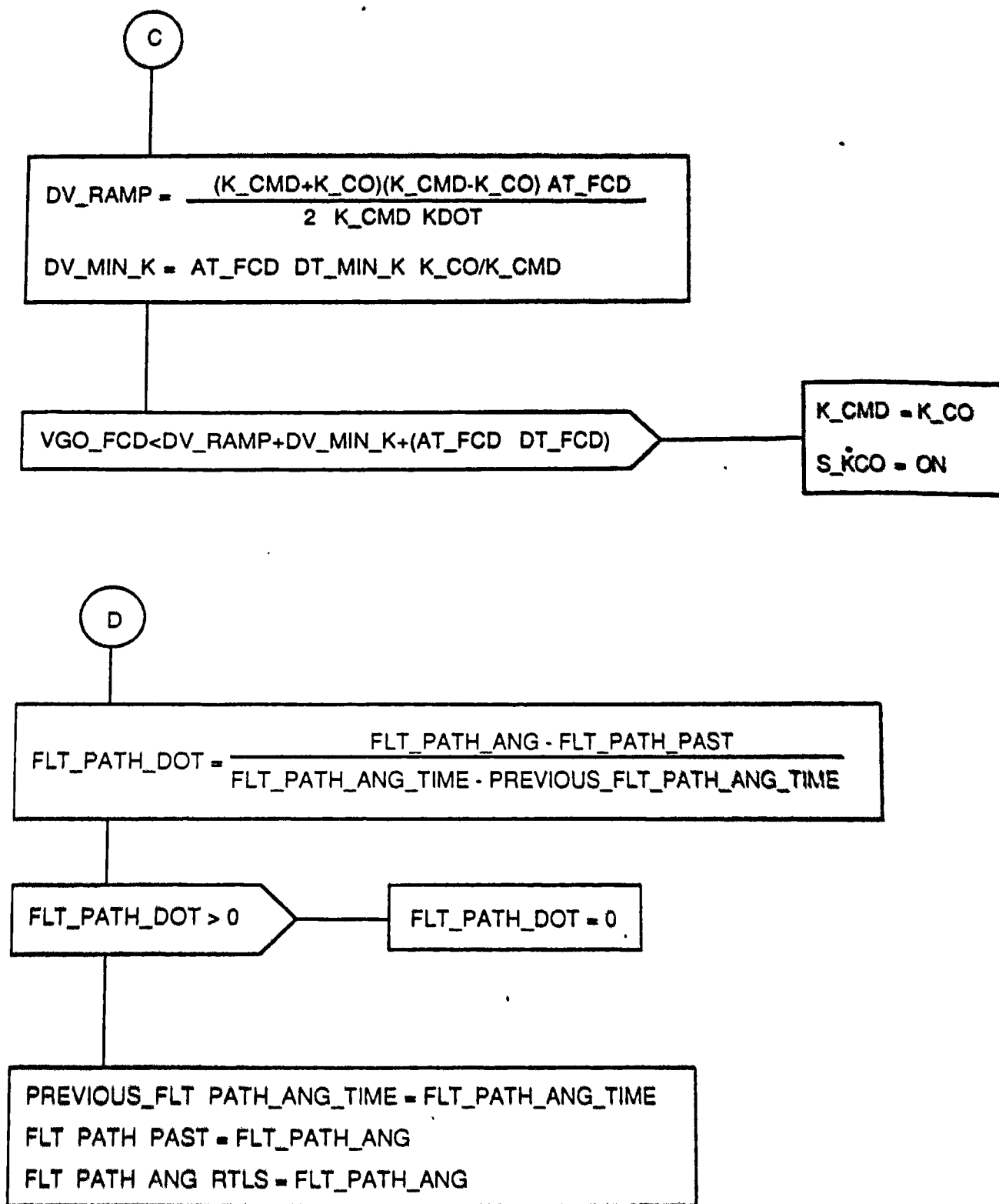


Figure A4.8.5. MPS GUID C/O TSK Flow Diagram (Sheet 3 of 3)

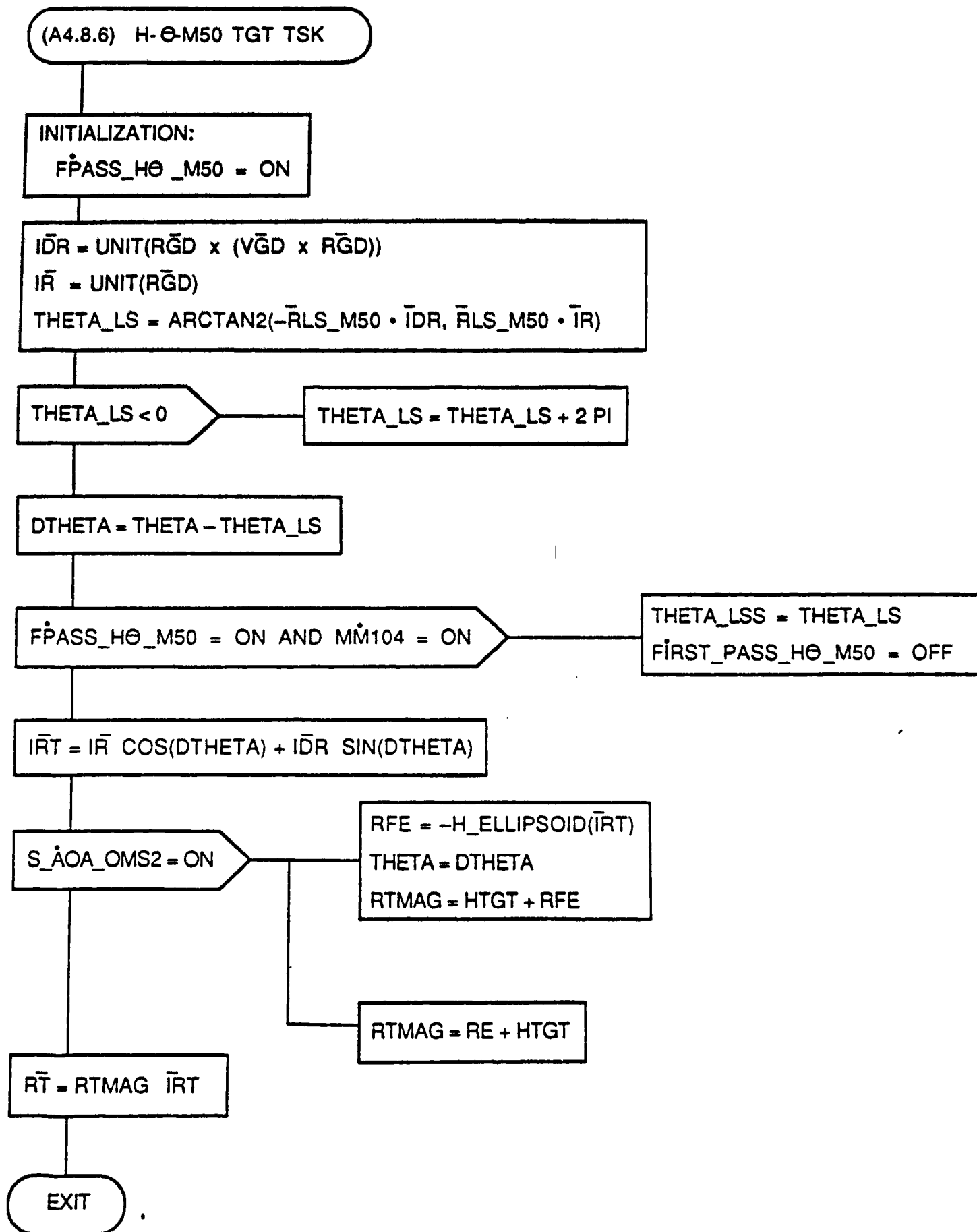


Figure A4.8.6. H-θ-M50 TGT TSK Flow Diagram

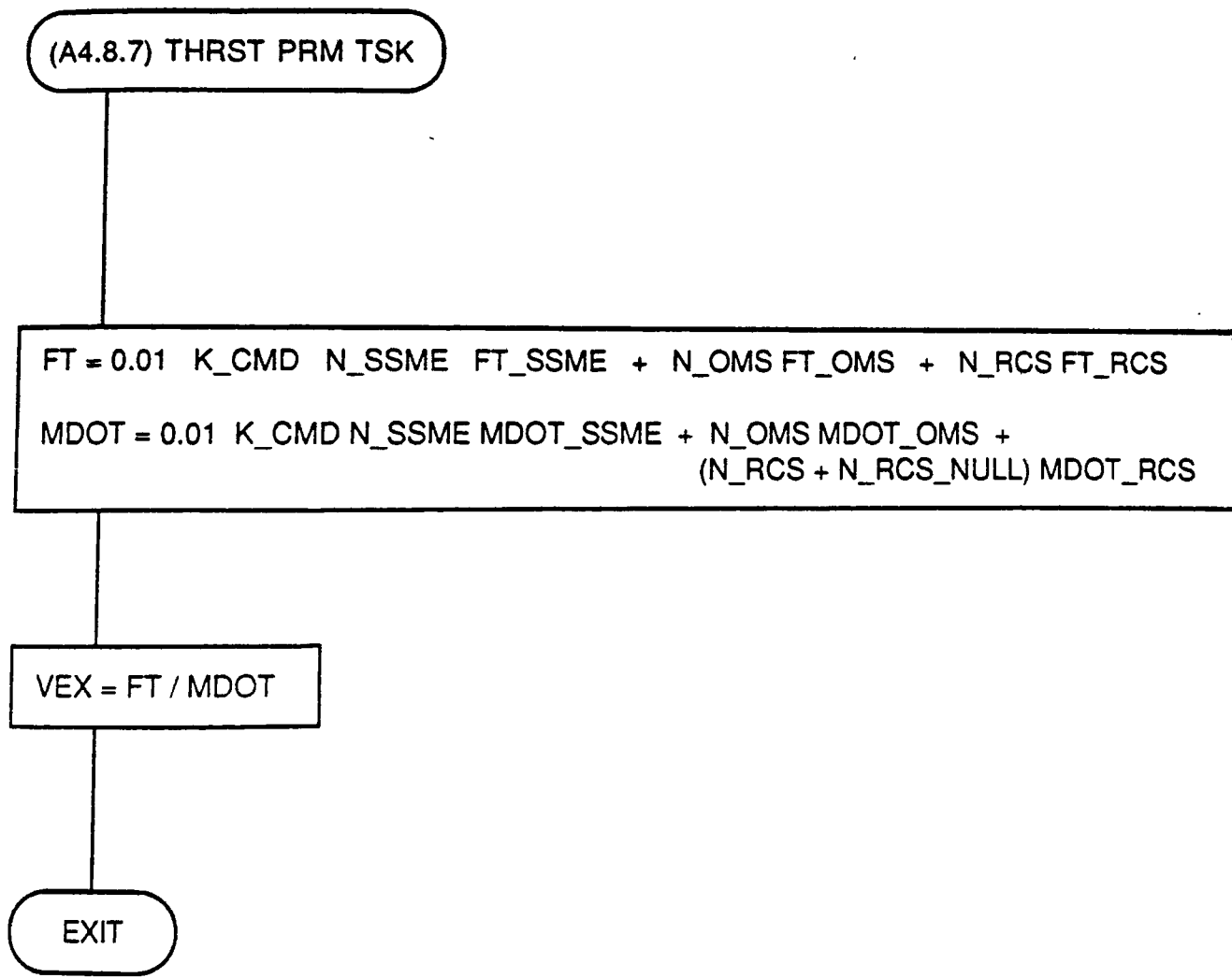


Figure A4.8.7. THRST PRM TSK Flow Diagram

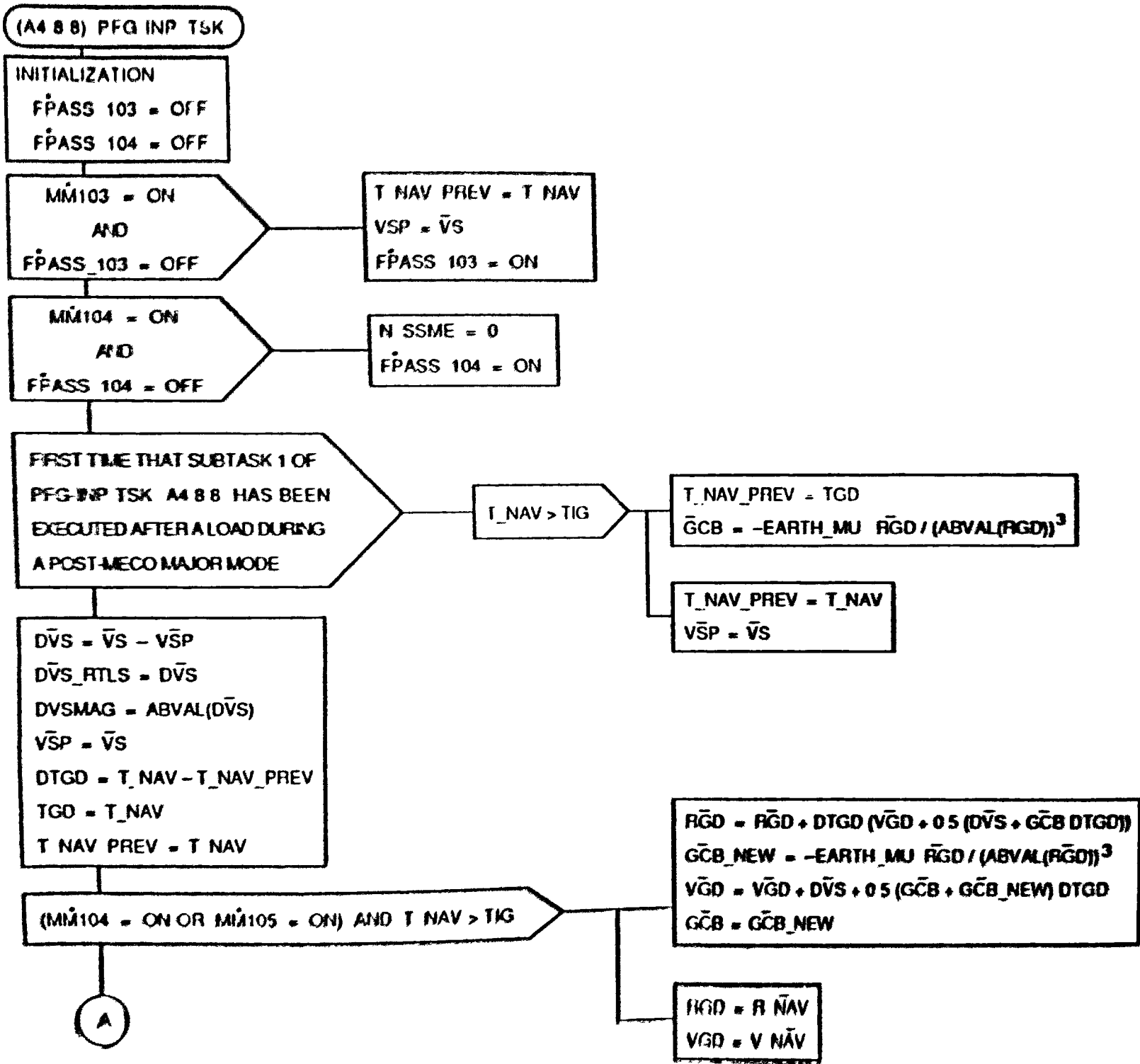
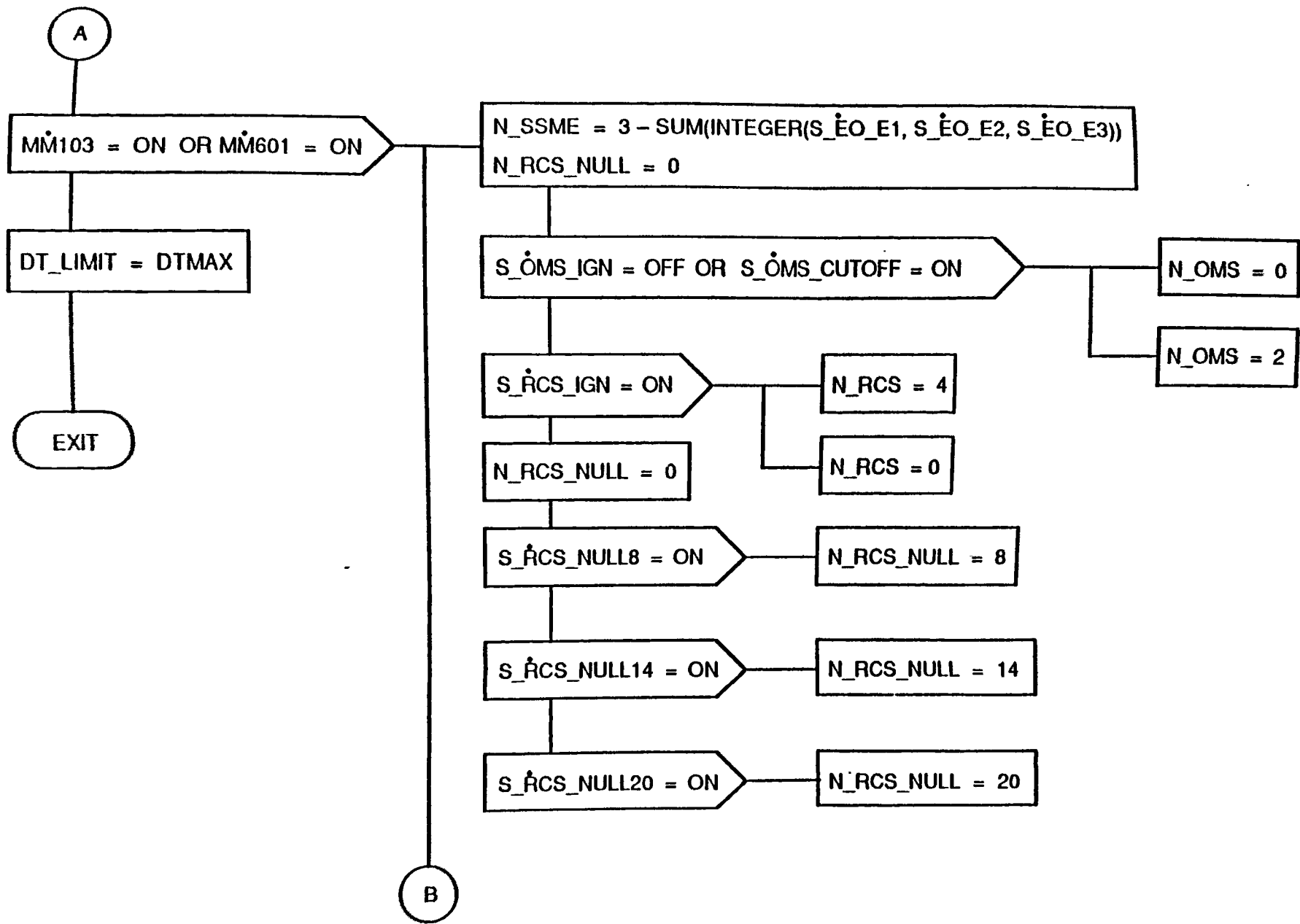


Fig 1 A4 8 8 PFG INP TSK Flow Diagram (Sheet 1 of 1)

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Figure A4.8.8. PPG INP TSK Flow Diagram (Sheet 2 of 3)

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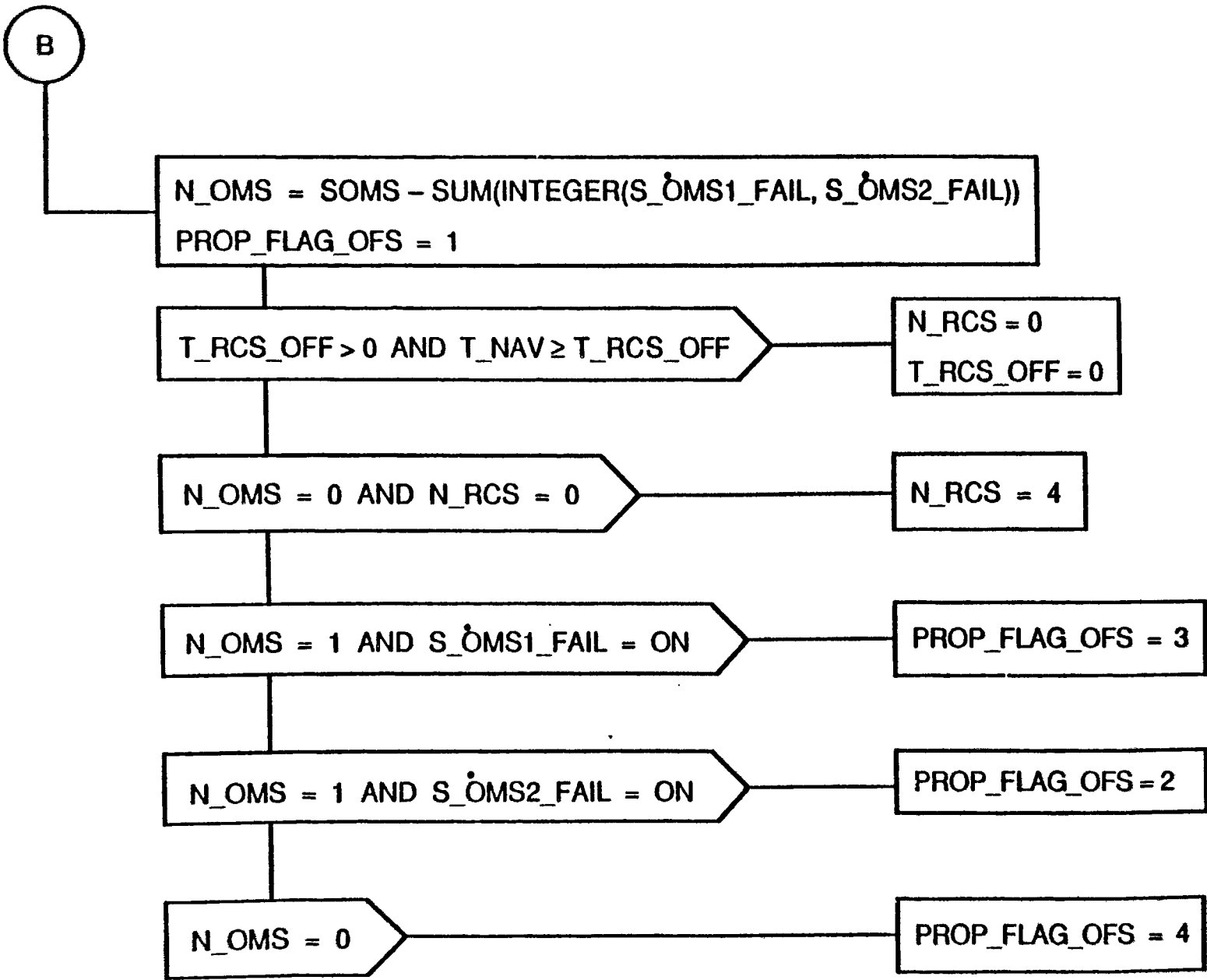


Figure A4.8.8. PFG INP TSK Flow Diagram (Sheet 3 of 3)

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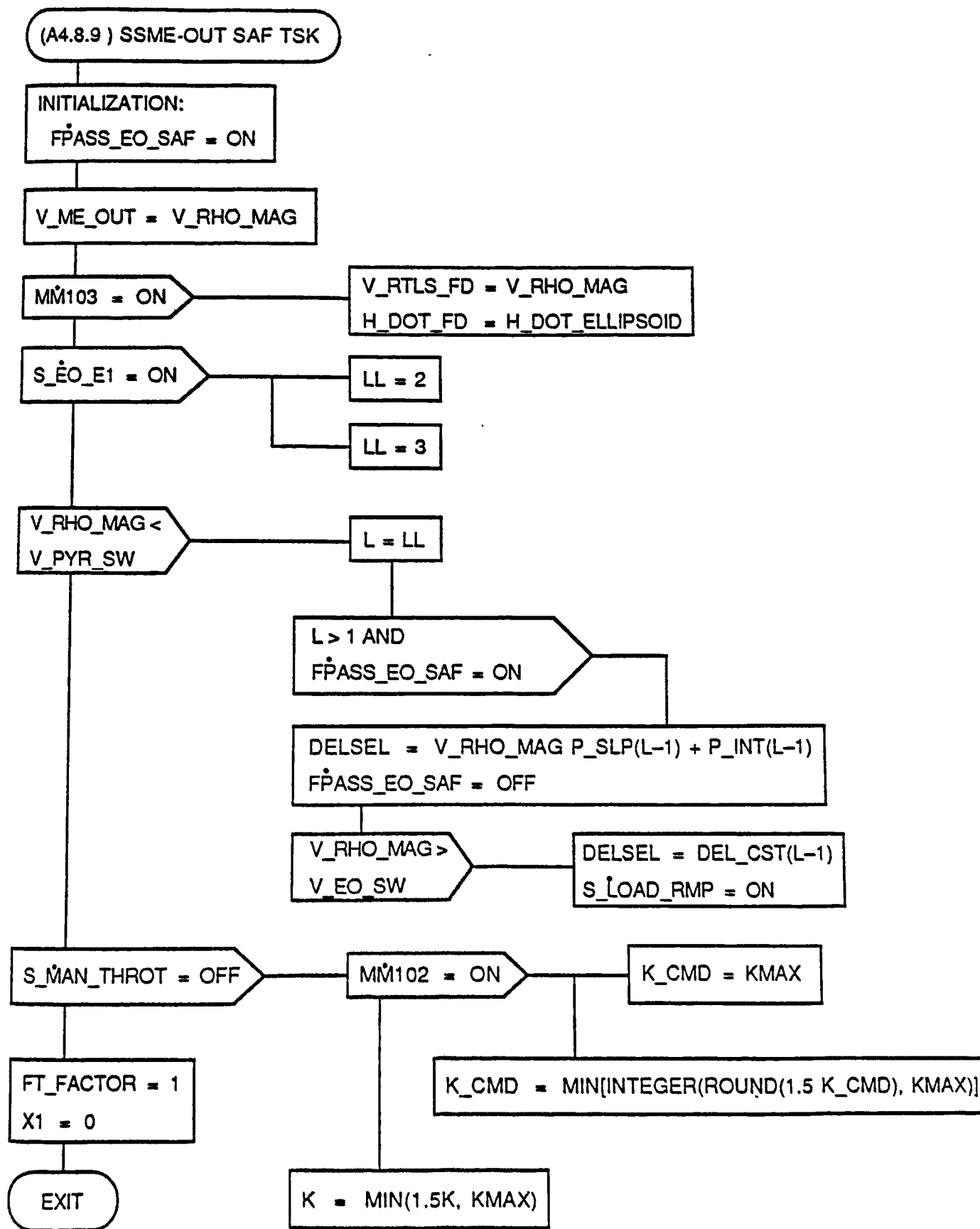


Figure A4.8.9. SSME-OUT SAF TSK Flow Diagram

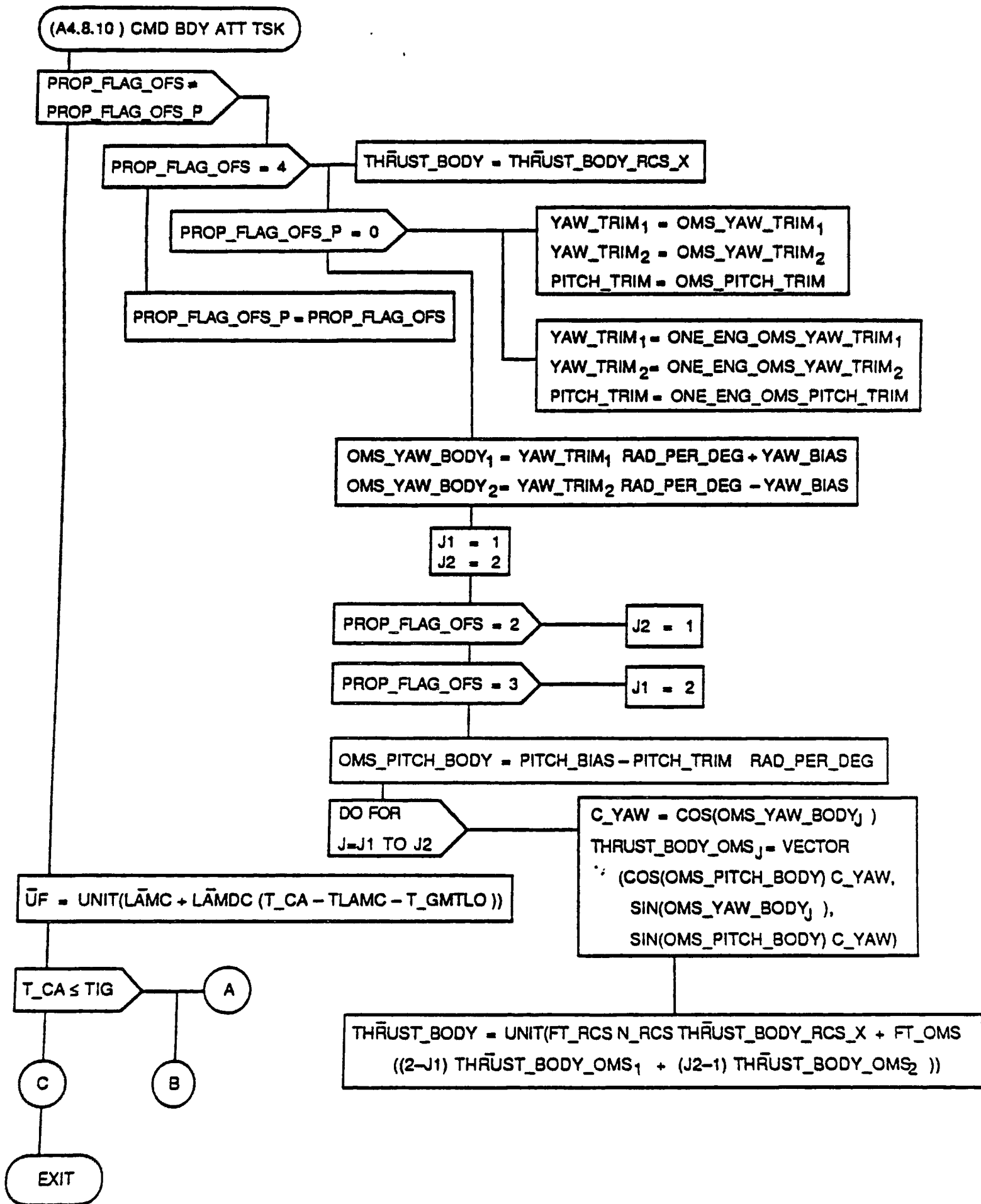


Figure A4.8.10. CMD BDY ATT TSK Flow Diagram (Sheet 1 of 4)

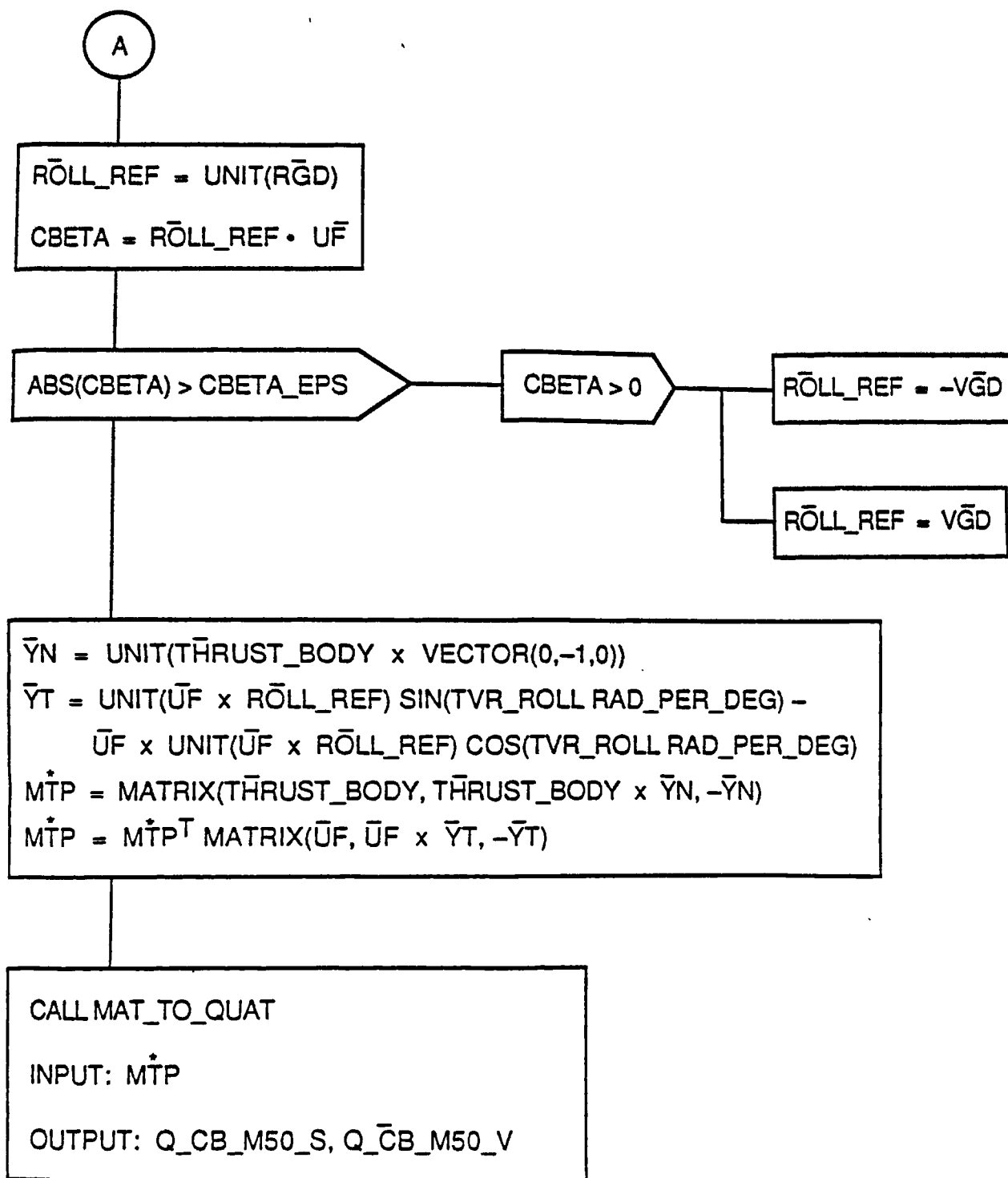


Figure A4.8.10. CMD BDY ATT TSK Flow Diagram (Sheet 2 of 4)



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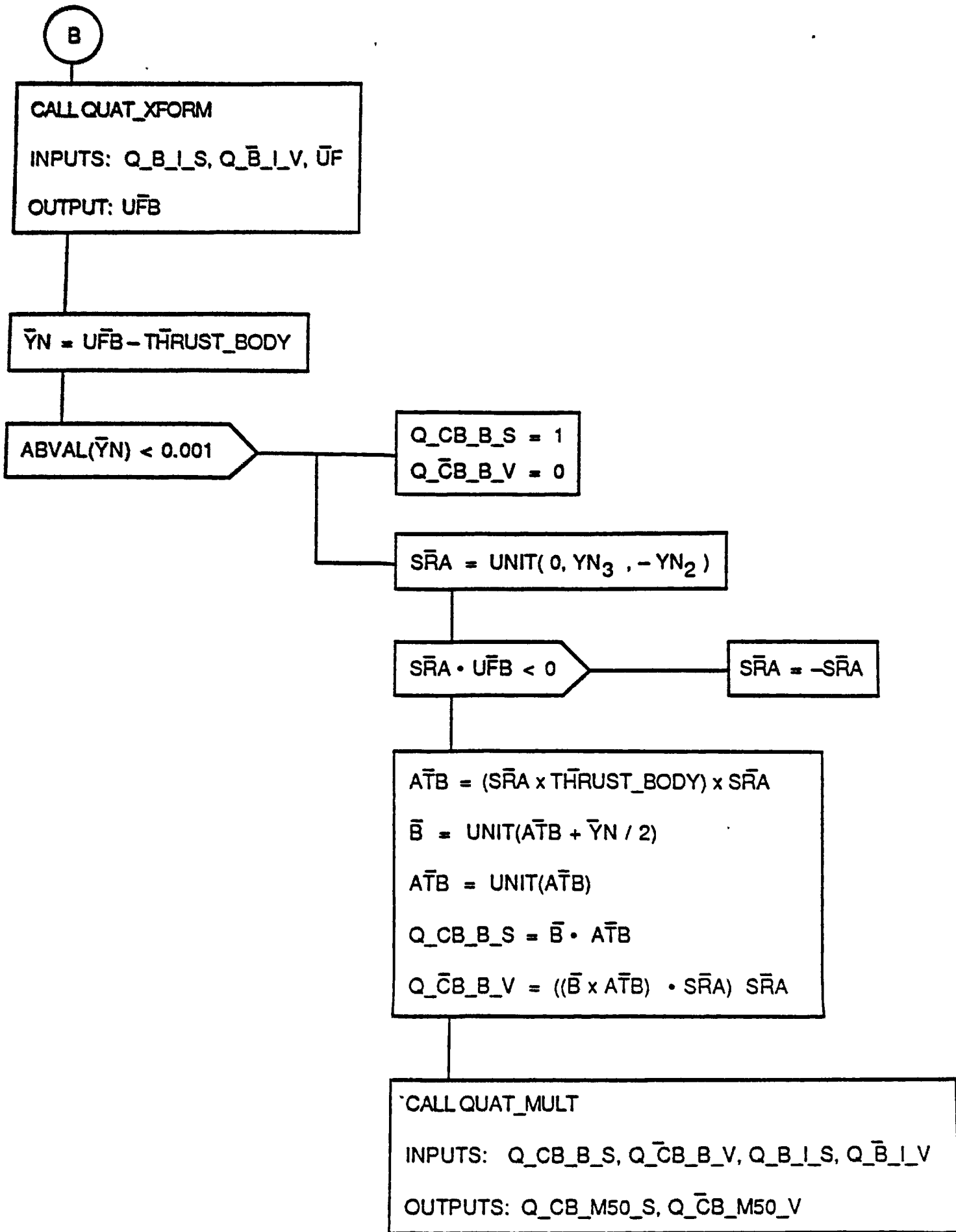


Figure A4.8.10. CMD BDY ATT TSK Flow Diagram (Sheet 3 of 4)

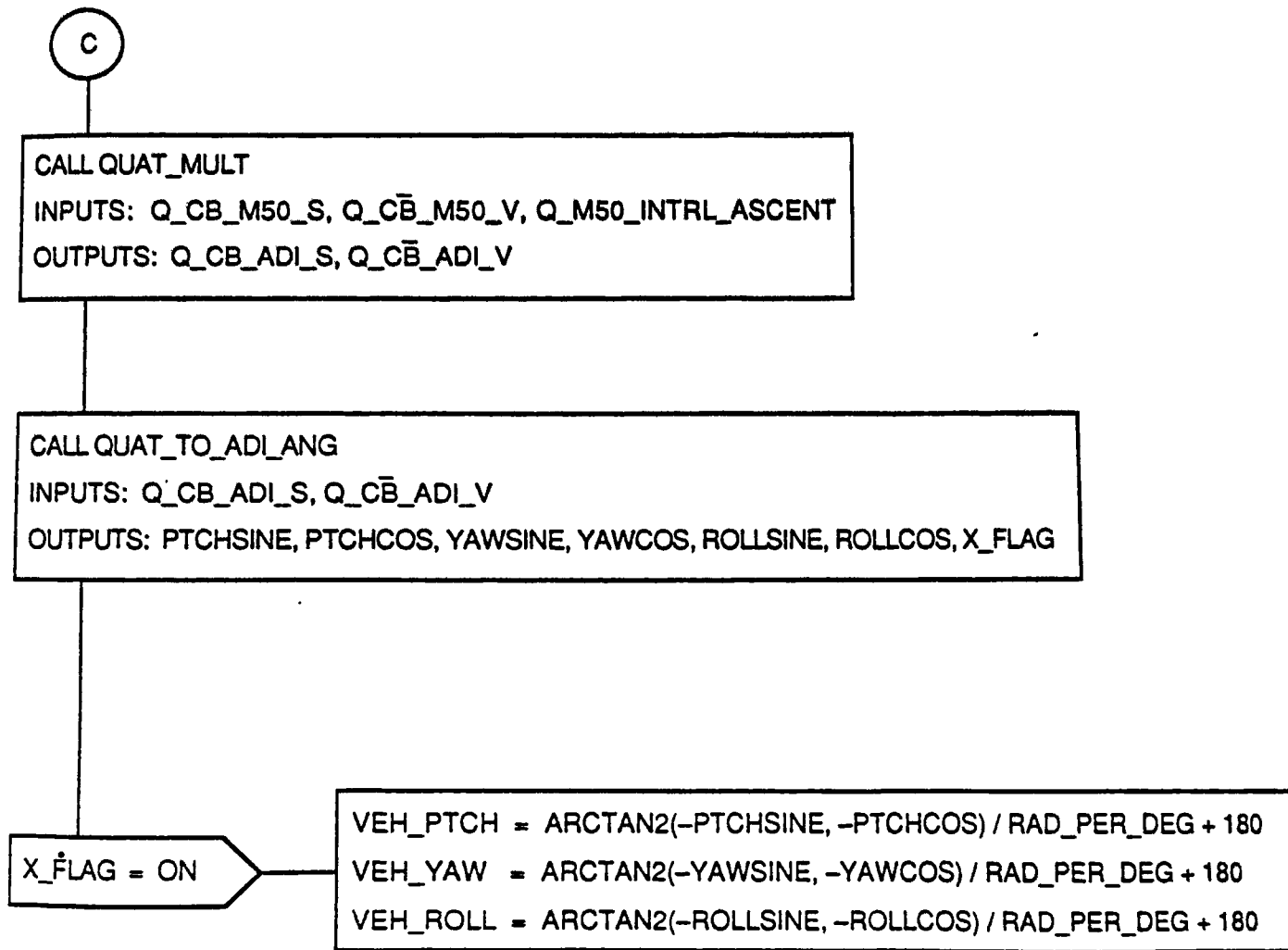


Figure A4.8.10. CMD BDY ATT TSK Flow Diagram (Sheet 4 of 4)

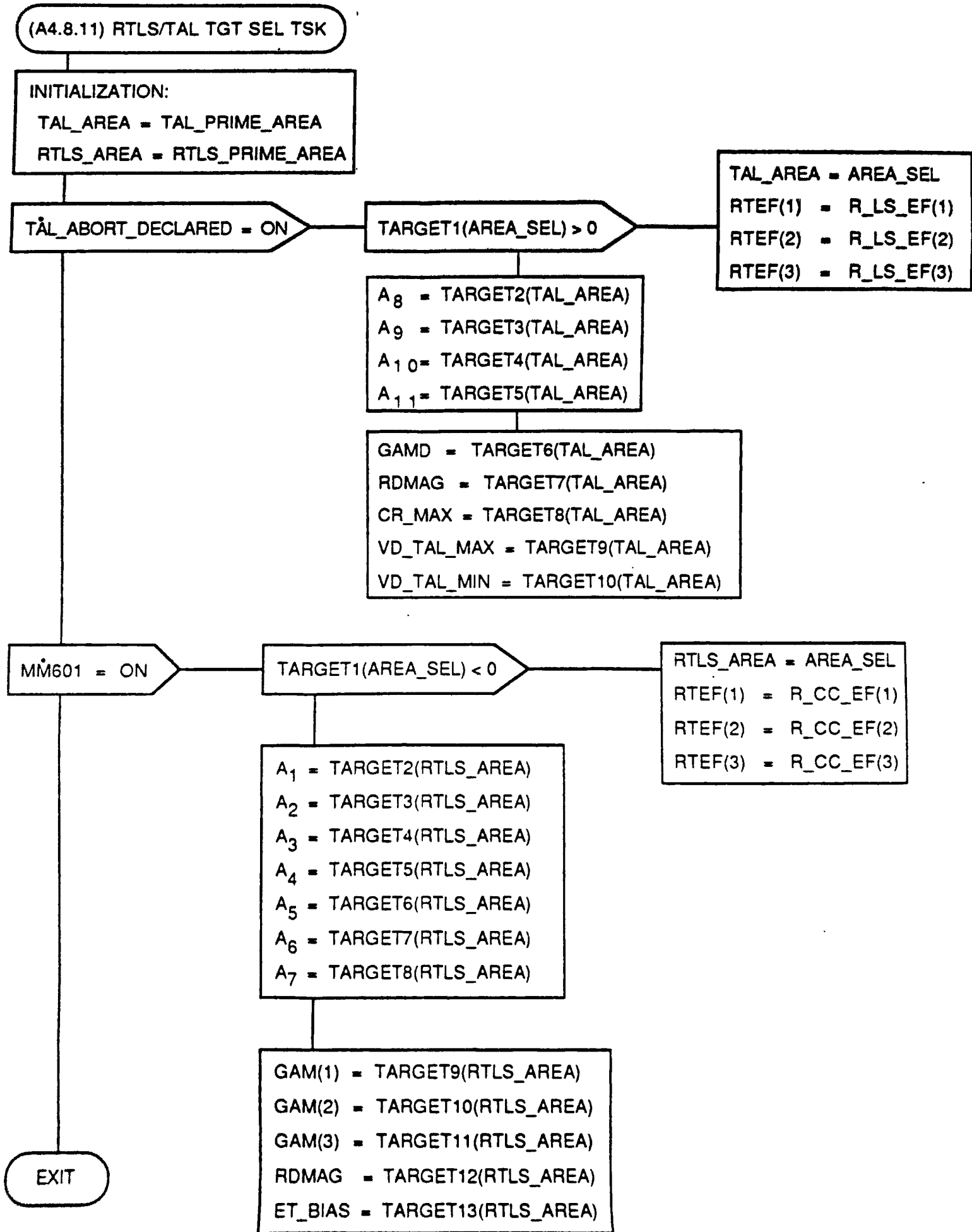


Figure A4.8.11. RTLS/TAL TGT SEL TSK Flow Diagram

APPENDIX B. TEMPORARY VARIABLES





APPENDIX B

TEMPORARY VARIABLES

The following table lists the temporary variables used within the various tasks of Section 4. The variable HAL name, definition, required precision, units, and FSSR reference are given.

Table B-1. Task Internal Variables

Symbol	Definition	Prec	Units	FSSR Ref
TGD	Time of navigated state	DP	sec	4.2.2
DTGD	Difference between previous and current values of TGD	SP	sec	4.2.2
DENOM	Interval between adjacent tabulated values of PPOLY	SP	fps	4.2.3
THETP	Interval between adjacent tabulated values of THET	SP	fps <sup>-1</sup>	4.2.3
PSIP	Interval between adjacent tabulated values of PSI	SP	fps <sup>-1</sup>	4.2.3
PHIP	Interval between adjacent tabulated values of PHI	SP	fps <sup>-1</sup>	4.2.3
DELT	Interval between V_RHO_MAG and greatest value of PPOLY < V_RHO_MAG	SP	fps	4.2.3
THETC	Interpolated value of THET	SP	ND	4.2.3
PSIC	Interpolated value of PSI	SP	ND	4.2.3
PHIC	Interpolated value of PHI	SP	ND	4.2.3
CTHET	Cosine of THETC	SP	ND	4.2.3
ST ET	Sine of THETC	SP	ND	4.2.3
C SI	Cosine of PSIC	SP	ND	4.2.3
SPS	Sine of PSIC	SP	ND	4.2.3
CPHI	Cosine of PHIC	SP	ND	4.2.3
SP I	Sine of PHIC	SP	ND	4.2.3

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Table B-1. Task Internal Variables (Cont)

Symbol	Definition	Prec	Units	PSSR Ref
I	Linear interpolation segment index for first-stage attitude tables	I	N/A	4.2.3
L	Engine out index: L = 1, all ME's operating; ME No. 1 out, L = 2; otherwise L = 3	I	N/A	4.2.3
K_RAMP	Load relief ramping switch	I	N/A	4.2.3
DELPT_BIAS	Engine-out pitch command bias	SP	rad	4.2.3
S_THRT_INIT	Discrete to ensure a one-time computation of TDEL_ADJUST	D	N/A	4.2.3
J	Boost throttling segment index	I	N/A	4.2.4
DM_PREMECO	OMS and RCS propellant mass burned pre-MECO	SP	slugs	4.5.4
DV_OMS	Delta V obtainable from OMS propellant remaining	SP	fps	4.5.4
DV_EXCESS	OMS excess delta V capability	SP	fps	4.5.4
MASS_OMS_PREOMS1	OMS propellant available before OMS-1 burn	SP	slugs	4.5.4
MASS_OMS_PREOMS2	OMS propellant available before OMS-2 burn	SP	slugs	4.5.4
DH_OMS1	OMS propellant burned during OMS-1	SP	slugs	4.5.4
KDELTA	Cosine of angle defining flyback thrust constraint	SP	ND	4.6.3
MF	Predicted vehicle mass at MECO during RTLS fuel dissipation	SP	slugs	4.6.3
UFZ	Unit normal to fuel dissipation thrust direction	SP	ND	4.6.3

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Table B-1. Task Internal Variables (Cont)

Symbol	Definition	Prec	Units	PSSR Ref
THETA	RTLS turnaround turn angle	SP	rad	4.6.3
UF_PEG	Unit desired initial flyback direction	SP	ND	4.6.3
AT_EST	Estimated thrust acceleration during RTLS	SP	fps <sup>2</sup>	4.6.3, 4.6.4
Q_M50_VR	Relative velocity axes to M50 quaternion	SP	ND	4.6.5
ALPHA_Q	Desired half angle of attack during RTLS powered pitchdown	SP	rad	4.6.5
Q_CB_VR	Relative velocity axes to commanded body quaternion	SP	ND	4.6.5
AZ	RTLS azimuth	SP	rad	4.6.6
THETA_C	Thrust vector commanded pitch angle during initial RTLS phase	SP	rad	4.6.6
$\bar{V}_{RHO\_BR}$	Vehicle's earth relative velocity in boost reference coordinates	SP	fps	4.6.6
$\bar{R}_{CNIG\_TGT}$	RTLS launch site heading vector	DP	ft	4.6.7
SRCS	Assumed number of active RCS jets	I	N/A	4.7.7
T_CUR	Current elapsed time in seconds	DP	sec	4.7.8
T_C_DAY	Current time within the current day	SP	sec	4.7.8
T_DAYS	Elapsed time to start of the current day	SP	sec	4.7.8
$\bar{R}_{J2}, \bar{V}_{J2}$	Contribution of J <sub>2</sub> gravity term to burnout state	SP	ft, fps	4.7.8
RMAC	Magnitude of position vector	SP	ft	4.7.9, 4.8.1

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Table B-1. Task Internal Variables (Cont)

Symbol	Definition	Prec	Units	FSSR Ref
R_UNIT	Unit $\bar{R}$	SP	ND	4.7.9
RDOT	Altitude rate	SP	fps	4.7.9
AM	Orbit semimajor axis	SP	ft	4.7.9
P	Orbit semilatus rectum	SP	ft	4.7.9
K	Orbit parameter related to $J_2$	SP	ft	4.7.9
MM	Sine of geocentric latitude	SP	ND	4.7.9
NN	Polar component of unit horizontal velocity	SP	ND	4.7.9
S_INC	Sine squared of orbit inclination	SP	ND	4.7.9
NU	Inverse of mean orbital rate	SP	sec	4.7.9
M	$e \sin E$	SP	ND	4.7.9
N	$e \cos E$	SP	ND	4.7.9
E	Eccentricity	SP	ND	4.7.9
DELTA	$J_2$ correction term	SP	ft	4.7.9
SW	Sign of RDOT		ND	4.7.9
KK	Time to apsis correction factor	SP	ft	4.7.9
DELTB	Sine of 2 x argument of perigee	SP	ft	4.7.9
OMS_YAW_BODY <sub>I</sub> (I=1,2)	OMS engine yaw angles	SP	rad	4.7.10

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Table B-1. Task Internal Variables (Cont)

Symbol	Definition	Prec	Units	FSSR Ref
THRUST_BODY_OMS <sub>1</sub> (I=1,2)	OMS unit thrust vector	SP	ND	4.7.10
OMS_PITCH_BODY <sub>1</sub> (I=1,2)	OMS engine pitch angles	SP	rad	4.7.10
C_YAW	Cos (OMS_YAW_BODY <sub>1</sub> )	SP	ND	4.7.10
THRUST_BODY	Resultant unit thrust vector of both OMS engines	SP	ND	4.7.10
UF	Unit thrust vector at TIC	SP	ND	4.7.10
ROLL_REF	Unit angular momentum vector at TIC	SP	ND	4.7.10
CBETA	ROLL_REF • UF	SP	ND	4.7.10
YN, YT	Unit vectors used in computing preburn attitude matrix	SP	ND	4.7.10
TFAIL	Earliest engine-out time of GMT for an AOA	DP	sec	4.8.1
TB <sub>1</sub> (I=1,3)*	Burn time of Ith thrust phase	DP	sec	4.8.1
TGOA <sub>1</sub> (I=1,3)	Time to end of Ith thrust phase	DP	sec	4.8.1
TAU <sub>1</sub> (I=1,3)	Hypothetical time until total vehicle mass is consumed, Ith thrust phase	DP	sec	4.8.1
VEXA <sub>1</sub> (I=1,3)	Average exhaust velocity, Ith thrust phase	SP	fps	4.8.1
IA <sub>1</sub> (I=1,3), SA <sub>1</sub> (I=1,3), QA <sub>1</sub> (I=1,3)	Thrust integrals for Ith thrust phase	DP	fps to ft-sec <sup>2</sup>	4.8.1
TPRIME	Previous value at TIC	DP	sec	4.8.1

\*Number in parentheses indicates number of values.



Table B-1. Task Internal Variables (Cont)

Symbol	Definition	Prec	Units	FSSR Ref
LREM	Remaining velocity to be gained	DP	fps	4.8.1
TGOP	Previous value of TGO	SP	sec	4.8.1
TGOB	Time to start of lth thrust phase	SP	sec	4.8.1
L, J, S, Q	Total thrust integrals	DP	fps to ft-sec <sup>2</sup>	4.8.1
JOL	Time interval to TLAM	DP	sec	4.8.1
QPRIME	Q-S JOL	DP	ft-sec	4.8.1
$\bar{R}GRAV$	Position contribution of gravity	SP	ft	4.8.1
$\bar{R}GO$	Desired position change due to thrust	DP	ft	4.8.1
$\bar{R}GOPRIME$	Predicted value of $\bar{R}GO$	SP	ft	4.8.1
$\bar{R}GOX, \bar{R}GOY, \bar{R}GOZ$	X, Y and Z components of $\bar{R}GO$ in PEG coordinates	DP	ft	4.8.1
$\bar{R}GOXY$	X-Y plane projection of $\bar{R}GO$	DP	ft	4.8.1
LAMDY	Y component of $\bar{L}AMD$	SP	rad/sec	4.8.1
TPREV	Previous value of TP	DP	sec	4.8.1
$\bar{V}GRAV$	Velocity contribution of gravity	SP	fps	4.8.1
$\bar{V}THRUST$	Velocity change due to thrust	SP	fps	4.8.1
TB_EST	Initial estimate of burn time	SP	sec	4.8.1
$\bar{R}P$	Predicted cutoff position vector	DP	ft	4.8.1
$\bar{V}P$	Predicted cutoff velocity vector	SP	fps	4.8.1

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Table B-1. Task Internal Variables (Cont)

Symbol	Definition	Prec	Units	FSSR Ref
B	Circular orbit rate squared	SP	sec <sup>-2</sup>	4.8.1
$\bar{W}E$	Earth rotation vector	SP	rad/sec	4.8.1
DTCOAST	Estimated coast time to target	SP	sec	4.8.1
RIIOMAG	$\bar{V}GO$ correction factor for Mode 4	SP	ND	4.8.1
RTHETA	Range to target in RTLS	SP	ft	4.8.1, 4.8.5
VDMAG	Desired cutoff velocity magnitude	SP	fps	4.8.1
VRATIO <sub>I</sub> (I=1,2)	LA <sub>I</sub> (6VEXA <sub>I</sub> )	SP	ND	4.8.1
ATRF	Predicted final thrust acceleration	SP	fps	4.8.1
$\bar{O}MEGA$	Thrust turning rate vector	SP	sec <sup>-1</sup>	4.8.1
THETA_DOT	Orbital rate	SP	sec <sup>-1</sup>	4.8.1
$\bar{V}MISS\_G$	$\bar{V}MISS$ in PEG coordinates	SP	fps	4.8.1
M12G*	M50 to PEG coordinates matrix	SP	ND	4.8.1
SPPLANE	Orbital plane constrained discrete	D	N/A	4.8.1
SALT	Cutoff altitude constrained discrete	D	N/A	4.8.1
$\bar{V}MISS$	Cutoff velocity error	SP	fps	4.8.1
DVGO	$\bar{V}GO$ correction	SP	fps	4.8.1
WMAG	Desired turning rate of thrust	SP	sec <sup>-1</sup>	4.8.1
DELK	Desired change in throttle command	SP	pct	4.8.1

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Table B-1. Task Internal Variables

Symbol	Definition	Prec	Units	FSSR Ref
KP	Desired throttle setting	SP	pct	4.8.1
EMISS	Maximum value of $\bar{V}$ MISS magnitude for PEG convergence	SP	fps	4.8.1
VGOD	Desired velocity-to-be-gained for RTLS	SP	fps	4.8.1
LAMDMAX	Maximum allowable value of LAMDAG	SP	sec <sup>-1</sup>	4.8.1
LAMDYJOL		SP	rad	4.8.1
$\bar{R}$ T_AIM	TAL M50 aim point	DP	ft	4.8.1
T_CA	Time of closest approach to the TAL aim point	SP	sec	4.8.1
CRNG_D	Current TAL MECO crossrange	SP	ft	4.8.1
$\bar{I}$ Y_SAVE	Previous value of $\bar{I}$ Y used in RTLS initialization	DP	ND	4.8.1
$\bar{I}$ Y_DES	Unit normal to the desired orbital plane	DP	ND	4.8.1
IA	Index of coefficients used in RTLS range velocity line	I	N/A	4.8.1
DSCOUNT, SCOUNT, TCOUNT	Counters used in monitoring the number of successive converged and unconverged PEG cycles	I	N/A	4.8.1
DSCOUNT_PREV	Previous value of DSCOUNT	I	N/A	4.8.1
VGOR	Velocity-to-be-gained in the radial direction for RTLS	SP	fps	4.8.1
$\bar{L}$ AM_G	$\bar{L}$ AM in PEG coordinates	SP	fps	4.8.1

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Table B-1. Task Internal Variables (Cont)

Symbol	Definition	Prec	Units	FSSR Ref
VGRAVX	Radial component of VGRAV	SP	fps	4.8.1
BETA1-BETA3	} Variables used in $\bar{VCO}$ and K updates for RTLS	SP	ND	4.8.1
BETA4		SP	pct/fps	4.8.1
BETA5		SP	pct	4.8.1
RHO1		Vector used in $\bar{VCO}$ update for RTLS	SP	ND
VCO ERR	Error in VCOMAG for RTLS	SP	fps	4.8.1
P RHO	Vector used in K update for RTLS	SP	pct/fps	4.8.1
DVCO G	$\bar{DVCO}$ in PEC coordinates	SP	fps	4.8.1
VCOYP	Y component of $\bar{VCO}$	SP	fps	4.8.1
VCOXZ	Inplane component of $\bar{VCO}$	SP	fps	4.8.1
VCOXZ SQ	Magnitude squared of $\bar{VCOXZ}$	SP	fps <sup>2</sup>	4.8.1
VCOMAX SQ	Square of maximum VCOMAG	SP	fps <sup>2</sup>	4.8.1
VCOYMAX SQ	Square of maximum VCOY	SP	fps <sup>2</sup>	4.8.1
VMISSY	Y component of velocity error	SP	fps	4.8.1
VCOY	Desired out of plane velocity component	SP	fps	4.8.1
RTHRUST	Position change due to thrust	DP	ft	4.8.1
RBIAS	Difference between RCO and RTHRUST	DP	ft	4.8.1
PHI	Thrust turn angle	SP	rad	4.8.1



Table B-1. Task Internal Variables (Cont)

Symbol	Definition	Prec	Units	FSSR Ref
TI	Value of (t-JOL) at start of thrust phase	DP	sec	4.8.1
TF	Value of (t-JOL) at end of thrust phase	DP	sec	4.8.1
TFMEANSQ	Value of (t-JOL) used to compute mean linear tangent vector for small thrust arcs	DP	sec	4.8.1
SMA_GAIN	Inverse of mean linear tangent vector magnitude for small thrust arcs	DP	ND	4.8.1
IF_MAG_I	Magnitude of linear tangent vector at start of thrust phase	DP	ND	4.8.1
IF_MAG_F	Magnitude of linear tangent vector at end of thrust phase	DP	ND	4.8.1
A	Constant coefficient of the quadratic acceleration profile	DP	fps <sup>2</sup>	4.8.1
B	Linear coefficient of the quadratic acceleration profile	DP	fps <sup>2</sup>	4.8.1
C	Quadratic coefficient of the quadratic acceleration profile	DP	fps <sup>2</sup>	4.8.1
y(5), M(3)	Elements along $\bar{L}AM$ and $\bar{L}AMD$ of the position and velocity changes due to thrust	DP	fps <sup>2</sup>	4.8.1
D	Denominator in mass update equation	SP	ND	4.8.2
X2, X3, X4	Prior values of sensed/computed thrust force	SP	ND	4.8.2
X_WEIGHT	Weighted average of X1, ..., X4	SP	ND	4.8.2

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Table B-1. Task Internal Variables (Cont)

Symbol	Definition	Prec	Units	FSSR Ref
X_TEST	X-weight convergence criterion	SP	ND	4.8.2
MDOT_OLD	Previous value of MDOT	SP	slug/sec	4.8.2
M_NEW	Current estimate of the vehicle mass	SP	slugs	4.8.2
FT_S	Sensed thrust force	SP	lbf	4.8.2
AT_AVE	Sensed acceleration magnitude	SP	fps <sup>2</sup>	4.8.3
AD	Desired thrust acceleration	SP	fps <sup>2</sup>	4.8.3
DA	AT_AVE-AL	SP	fps <sup>2</sup>	4.8.3
SUM_DA	Integral of DA	SP	fps	4.8.3
T_KCMD	Time of last throttle change	DP	sec	4.8.3
RO_MAG	Current position vector magnitude	DP	ft	4.8.4
RI_MAG	Target position vector magnitude	DP	ft	4.8.4
K, W	Dimensionless variable used in LTVCON task	SP	ND	4.8.4
A, B, C	Coefficients in equation for VHI	SP	ND-fps <sup>2</sup>	4.8.4
D	$B^2 + 4AC$	SP	fps <sup>2</sup>	4.8.4
AT_FCD	Sensed acceleration component along $\bar{VGD}$	SP	fps <sup>2</sup>	4.8.5
VMAG	Magnitude of $\bar{VGD}$	SP	fps	4.8.5
DV_RAMP	Velocity gain during ramp down to KMIN	SP	fps	4.8.5
DV_MIN_K	Velocity gain at KMIN	SP	fps	4.8.5

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Table B-1. Task Internal Variables (Cont)

Symbol	Definition	Prec	Units	FSSR Ref
VGO_FCD	Remaining velocity to be gained	SP	fps	4.8.5
FLT_PATH_DOT	Flight path angle rate, RTLS	SP	rad/sec	4.8.5
FLT_PATH_PAST	Past value of flight path angle	SP	rad	4.8.5
K_CO	MECO throttle setting	I	pct	4.8.5
ITLOF	Index for tailoff time at minimum power level	I	N/A	4.8.5
RT	Position of the RTLS landing site at the estimated time of MECO	DP	ft	4.8.5
PREVIOUS_FLT_PATH_ANG_TIME	Previous value of time of computing of FLT_PATH_ANG	DP	sec	4.8.5
FLT_PATH_ANG_RTLS	Predicted current flight path angle	SP	rad	4.8.5
VGOMAG	Magnitude of velocity-to-be-gained	SP	fps	4.8.5
VGODOT	Time rate of change of the velocity-to-be-gained	SP	fps <sup>2</sup>	4.8.5
$\bar{I}DR, \bar{I}R$	Downrange and radial unit vectors	DP	ND	4.8.6
$\bar{I}RT$	Unit target position vector, PEG 4	DP	ND	4.8.6
RTMAG	Magnitude of PEG 4 target vector	DP	ft	4.8.6
THETA_LS	Downrange angle from launch site	SP	rad	4.8.6
DTHETA	Remaining downrange angle to target	SP	rad	4.8.6
RPE	Earth radius along $\bar{I}RT$ direction	DP	ft	4.8.6
$\bar{V}SP$	Total sensed velocity	DP	fps	4.8.8

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Table B-1. Task Internal Variables (Cont)

Symbol	Definition	Prec	Units	FSSR Ref
T_NAV_PREV	Previous value of T_NAV	DP	sec	4.8.8
GCB_NEW	Current gravity acceleration	SP	fps <sup>2</sup>	4.8.8
GCB	Prior value of GCB_NEW	SP	fps <sup>2</sup>	4.8.8
MTP	M50 to commanded body matrix	SP	ND	4.8.10
TAL_AREA	Index used in selecting TAL abort targets	I	N/A	4.8.11
RTLS_AREA	Index used in selecting RTLS abort targets	I	N/A	4.8.11

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APPENDIX C. OPS-1 UTILITY ROUTINES



APPENDIX C

This appendix describes the required inputs and outputs of the utility routines and functions used by powered flight guidance.

1. A/E PREC PRED

Inputs: ( $\bar{R}_{INIT}$ ,  $\bar{V}_{INIT}$ ,  $T_{INIT}$ ,  $T_{FINAL}$ ,  $DT_{MAX}$ ,  $GMD_{PRED}$ ,  $GMO_{PRED}$ )

- 1, 2, and 3. Initial state and time (GMT seconds).
- 4. Time at which final state is required in GMT (sec).
- 5. Upper bound for the integration step size (sec).
- 6 and 7. Degree and order indicators where

	GMD_PRED	GMO_PRED
Full precision + drag	4	4
Central body + J2	2	0
Central body	0	0

Note: When  $D < 4$ , drag effects are not included.

Outputs: ( $\bar{R}_{FINAL}$ ,  $\bar{V}_{FINAL}$ ,  $\bar{G}_{FINAL}$ ) 1. Position, 2. velocity, and 3. gravity vectors at  $T_{FINAL}$ .

Ref: OFT Level C Ascent/RTLS Navigation FSSR, STS 83-0005A.

2. EARTH\_FIXED\_TO\_M50\_COORD (T\_EPOCH)

Direction cosine matrix which will transform a vector from the earth-fixed system to M50 at  $T_{EPOCH}$  (GMT seconds).

Ref: OFT Level C Ascent/RTLS Navigation FSSR, STS 83-0005A.

3. H\_ELLIPSOID ( $\bar{R}$ )

Output is height above the Fisher ellipsoid of a point described by the position vector,  $\bar{R}$ .





Information:

$$H\_ELLIPSOID (\bar{R}) = |\bar{R}| - (1\_ELLIPT) \text{ EARTH\_RADIUS\_EQUATOR}/$$

$$\sqrt{1 + [(1-ELLIPT)^2 - 1] [1 - (\text{UNIT}(\bar{R}) \cdot \text{EARTH\_POLE})^2]}$$

Ref: OFT Level C Ascent/RTLS Navigation FSSR, STS 83-0005A.

#### 4. MAT\_TO\_QUAT

Inputs: (M\_CB\_I) Direction cosine matrix CB frame with reference to I frame.

Outputs: (Q\_CB\_I\_S, Q\_CB\_I\_V) scalar and vector parts of the quaternion.

Information: The matrix will transform a vector from Frame I to Frame CB. The output quaternion does this equivalently.

Ref: OFT Level C Ascent Flight Control FSSR, STS 83-0008A.

#### 5. QUAT\_XFORM

Inputs: (Q\_B\_A\_S, Q\_B\_A\_V, W\_A)

1. Scalar part of the quaternion in Frame B with reference to Frame A.

2. Vector part of the quaternion.

3. Vector in Frame A.

Outputs: (W\_B)

1. Vector in Frame B.

Information:  $\bar{W}^B = Q_A^B \bar{W}^A (Q_A^B)^*$

Ref: OFT Level C Ascent Flight Control FSSR, STS 83-0008A.

#### 6. RV\_TO\_QLVLH

Input: (XR, XV)

1. Vehicle position in M50.

2. Vehicle velocity in M50.

Output: (XO\_M50\_LVLHS, XO\_M50\_LVLHV)



1. LVLH-to-M50 quaternion, scalar and vector parts.

Information:  $X\bar{Z} = \text{UNIT}(-\bar{X}R)$

$XY = \text{UNIT}(\bar{X}V \times \bar{X}R)$

$XX = \text{UNIT}(\bar{X}Y \times \bar{X}Z)$

$^*XM = \text{Matrix}(X\bar{X}, X\bar{Y}, X\bar{Z})^T$

The LVLH\_TO\_M50 quaternion is formed by operating on the  $^*XM$  matrix using the function MAT\_TO\_QUAT.

Ref: OFT Level C Ascent Flight Control FSSR, STS 83-0008A.

7. QUAT\_MULT

Inputs: (Q1S, Q1V, Q2S, Q2V)

1. Scalar and vector parts of the left quaternion.

2. Scalar and vector parts of the right quaternion.

Outputs: (Q3S, Q3V)

1. Scalar and vector parts of the output quaternion.

Information:  $Q_A^C = Q_B^C Q_A^B$

Ref: OFT Level C Ascent Flight Control FSSR, STS 83-0008A.

8. QUAT\_TO\_ADI\_ANG

Input: (XQS, XQV)

Scalar and vector part of the input quaternion.

Output: (XPTCHSINE, XPTCHCOS, XYAWSINE, XYAWCOS, XROLLSINE, XROLLCOS, XFLAG)

Pitch, yaw, and roll sine and cosine values in above order. XFLAG is flag indicating that pitch and roll functions have been updated.

Information: Order of rotation is pitch, yaw, then roll.

Ref: OFT Level C Ascent Flight Control FSSR, STS 83-0008A.

IDENTIFICATION NUMBER SE-694D DOCUMENT NUMBER STS83-0002

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