

# Space Program Operations Contract

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## SPACE SHUTTLE ORBITER OPERATIONAL LEVEL C FUNCTIONAL SUBSYSTEM SOFTWARE REQUIREMENTS GUIDANCE, NAVIGATION AND CONTROL PART B

### ON-ORBIT NAVIGATION

PREPARED BY THE BOEING COMPANY  
Space Exploration

Under Subcontract 6000132079, PDRD P1433q

December 14, 2007

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**SPACE SHUTTLE ORBITER**  
**OPERATIONAL**  
**LEVEL C**  
**FUNCTIONAL SUBSYSTEM SOFTWARE REQUIREMENTS**  
**GUIDANCE, NAVIGATION, AND CONTROL**  
**PART B**  
**ON-ORBIT NAVIGATION**

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G4.22 ONORB UPP  
G4.198 ORB UPP SEQ  
G4.224 ONORB PRED

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G4.126 ONORB/RNDZ NAV  
G4.148 ORB/RNDZ NAV SEQ

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## **FOREWORD**

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

Level A CPDS – System-level constraints and capabilities

Level B CPDS – Functional requirements

Level C FSSR – Detailed-level requirements

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

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**DOCUMENT CHANGE RECORD**

The following tabulation summarizes the change activity associated with this document.

<b>DOCUMENT CHANGE RECORD</b>			
<b>Issue and Date</b>	<b>Change Summary/Effectivity</b>		
OI-34 Release December 14, 2007	This baseline release for effectivity OI-34 and subs includes:		
	<u>SCR</u>	<u>OI</u>	<u>Title</u>
	93017G	33	Baseline RSS99D0100 with Expanded Downlist

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**CHANGE REQUEST SUMMARY**

The following tabulation lists the paragraphs, tables (T), and figures (F) that have been changed as a result of approved change requests for this release. Changes incorporated prior to this release are listed in Appendix R. Changes from approved software change requests (SCRs) to this document are indicated by a change bar in the outer margin of the changed page.

<b>CHANGE REQUEST SUMMARY</b>			
<b>Paragraph</b>	<b>SCR No.</b>	<b>OI</b>	<b>SCR Title</b>
1.3-1.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.1.3-1.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.1.3-2.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.2.11-1.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.2.11-2.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.3.3-1.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.3.3-2.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.5.3-1.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.5.3-2.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist

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## 1.0 INTRODUCTION

### 1.1 PURPOSE

The purpose of the On-Orbit Navigation Level C document is to specify detailed software requirements in support of the on-orbit navigation Level B functional requirements.

### 1.2 SCOPE

This document provides Level C detailed requirements for the orbital operations computer loads, OPS 2 and OPS 8. These requirements represent the total software onorbit/rendezvous navigation baseline requirements for the following principal functions.

- A. Onorbit/rendezvous navigation sequencer
- B. Onorbit/rendezvous UPP sequencer
- C. Onorbit/rendezvous navigation
- D. Onorbit prediction
- E. Onorbit user parameter processing

### 1.3 ORGANIZATION

This document is organized into the following sections:

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

Section 1 defines the purpose, scope and organization of this document. Section 2 lists applicable references. Section 3 describes the general software system operations for the On-Orbit Navigation functions. Section 4 specifies detailed software requirements. It also contains applicable tables (IDD inputs/outputs, I-Loads, K-Loads and Constants) located at the end of each Principal Function. Section 5 provides supplemental material such as parameters and logic flow, coordinate systems, and variable lists.

The automated Interface Definition Document (IDD) tables provided herein define signal (parameter) interface requirements either between hardware (LRU) and software elements or between software elements and other software elements. A GN&C software element is either a sequenced principal function (PF), crew generated specialist/display function, or an OPS display function. In the event of a conflict between the IDD tables and other internal text input/output tables, the SASCB data base-controlled IDD tables take precedence.

The following table defines the data elements found in the IDD input/output, I-Load, K-Load, and Constant tables for each principal function.

Table 1.3-1. Parameter Element Description		
Title	Definition	Valid Entries
CAT	Category of the I-Load (**Note)	Three alphanumeric characters: the first character must be alphabetic.
D	Dependency of the I-Load	D = Design M = Mission L = LRU
DESCRIPTION	Parameter description of the K-Load or Constant.	A string of ≤ 64 characters.
DESTINATION	Destination of the output parameter	Abbreviated functional titles. (***)Note)
DT or DATA TYPE	Data Type	<ul style="list-style-type: none"> <li>* See reference (1) for valid I-Load, K-Load and Constant data types.</li> <li>* See reference (2) for valid IDD data types for parameters with destination TLM.</li> <li>* See reference (3) for valid IDD data types for all other parameters.</li> </ul>

Table 1.3-1. Parameter Element Description		
Title	Definition	Valid Entries
ENG UNITS or UNITS	Engineering Units	* See reference (1) for valid I-Load, K-Load and Constant units. * See reference (2) for valid IDD units for parameters with destination TLM. * See reference (3) for valid IDD units for all other parameters.
FSSR NAME	Requirements parameter name	A string (with no embedded blanks) of ≤ 32 characters consisting of alphanumerics, underscores, parenthesis, commas and slashes. Parenthesis are used for array elements. Commas separate the different indices of multidimensional arrays. Slashes are used to separate multiple names used for a single MSID.
LAST CR	The last CR affecting the parameter	5 digit number with an alphabetic revision letter.
MC	Memory Configuration	00=Generic                      05 = SM4 Orbit P/L 01=GN1 Ascent/GN6 RTLS    06 = P/L9 MMU 02=GN2 Orbit                 07 = Not Assigned 03=GN3 Entry                 08 = GN8 On-Orbit C/O 04=SM2 On-Orbit             09 = GN9 Preflight
MSID or M/S ID	Measurement/Stimulus Identification	Maximum of 10 alphanumeric characters. * See reference (3) for specifications
NOMENCLATURE	Parameter description of the IDD parameter.	String of ≤ 34 characters (including underscores and blank spaces).
PR or PREC	Precision	D, DP =Double                 S, SP = Single
SOURCE	Origin of the input parameter	Abbreviated functional titles.
S	Software Utilization	C = Common                    B = BFS Unique P = Primary                    X = BFS Derived A = BFS Converted
PR FCTN	Cross reference of the principal function identifiers that are applicable to this parameter.	See Level B GN&C CPDS SS-P-0002-510
VALUE	The value of the K-Load or Constant	* See reference (1) for valid value formats.
REV	Revision indicator	An asterisk (*) indicates changes for the current OI version

Table 1.3-1. Parameter Element Description		
Title	Definition	Valid Entries
* References:	(1) JSC 19350 I-Load Requirements Document Volume I (2) SS-P-0002-140 Level A SS Downlist/Uplink CPDS (3) JSC 18206 Shuttle Data Integration Plan Volume III MAST II/STAR Deliverable Products.	
** Note	For additional information on any I-Load, contact the I-Load owner defined in CR 98032, JSC, USA, and Boeing I-Load Owner Assignments	
*** Note	IDD output (source) tables which reflect parameters going to input (destination) "TLM" shall not be interpreted as a signal actually being downlisted. The parameter is only available for downlist in COMPOOL and does not appear in a downlist format. Parameters actually on the downlist will be designated with a destination denoting the downlist Format with a Rate Code. The Rate Code legend appears at the end of each FSSR data table. To complete the downlist information, Parent MSIDs (indicated by a 'P' in the 9 <sup>th</sup> character of the MSID) are now included in the software function output data tables in which a Child MSID already appears. A Parent MSID will have the same downlist destinations as its Child(ren) MSID(s).	

## 2.0 APPLICABLE DOCUMENTS

### 2.1 LEVEL A DOCUMENTS

- SS-P-0002-140 Shuttle Downlink/Uplink Software Requirements
- SS-P-0002-150 Shuttle Launch Data Bus Software Interface Requirements
- SS-P-0002-170 Shuttle Systems Level Requirements, Software

### 2.2 LEVEL B DOCUMENTS

- SS-P-0002-510 Shuttle Functional Level Requirements, GN&C
- SS-P-0002-550 Shuttle Functional Level Requirements, Vehicle Utility
- SS-P-0002-580 Shuttle 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

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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	Shuttle Flight Software Initialization Load <ul style="list-style-type: none"><li>• Volume I General Requirements</li><li>• Volume II Mission I-Load Requirements</li></ul>
JSC-19478	Payload Management, Level C Flight Software Requirements
JSC-19590	Systems Management, Level C Flight Software Requirements

**2.4 ICD DOCUMENTS**

ICD 3-1011-02	GPC/DEU ICD
ICD 2-1S001	Orbiter Primary Flight Software System and Backup Flight System Software Interface

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 NAVIGATION PROGRAM

For orbiter operations, the requirements for each operational navigation program (ONP) are specified at three levels: system level (A), functional level (B), and detailed level (C). In addition, the Level B and C requirements are specified in separate documents for guidance, navigation, and control (GN&C); system management (SM); vehicle utility (VU); and payloads (PL). This document is the onorbit and rendezvous navigation part of the GN&C Level C Operations ONP requirements for Release OI-8C.

### 3.2 GN&C SOFTWARE MAJOR FUNCTIONS

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

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

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

### 3.3 NAVIGATION SYSTEM OVERVIEW

The basic function of the orbiter navigation system is to provide and maintain an accurate current estimate of the orbiter navigation state, and when required as described below, to also provide and maintain an accurate current estimate of a target vehicle state. The orbiter navigation state consists of the three orbiter position components and the three orbiter velocity components expressed in the M50 inertial coordinate system. The time tag associated with this six dimensional navigation state defines the time of validity of its associated position and velocity estimate. The target vehicle state consists of the three target position components and the three target velocity components expressed in the M50 inertial coordinate system. The time tag associated with this six dimensional navigation state defines the time of validity of the associated target vehicle position and velocity estimate. The terms navigation state, state estimate and state vector are used interchangeably in this document.

On-orbit operations consists of two mission phases: non-rendezvous on-orbit operations, during which only the orbiter state is required to be maintained by the navigation system and rendezvous operations, during which both the orbiter and target states are required to be maintained.

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For non-rendezvous on-orbit operations, the orbiter navigation system performs its basic function by utilizing two independent navigation capabilities, each of which provides and maintains an accurate current estimate of the orbiter state.

The first navigation capability consists of those navigation principal function software elements which provide and maintain the orbiter state estimate also referred to as the navigation state estimate. These software elements perform the following functions: propagation of the orbiter state to current time using specified gravity and drag models and using orbiter IMU data when appropriate; and resetting or updating the state estimate to a ground uplink or the selected GPS navigation state, depending on the navigation system configuration.

This capability will be referred to as the baseline navigation capability.

The second navigation capability consists of the Global Positioning System (GPS) Line Replacement Units (LRUs) and those orbiter navigation principal function software elements which provide and maintain the GPS orbiter state estimates and the resulting selected GPS state estimate. The software elements perform the following functions: providing an aiding or reference state for each GPS receiver propagated to current time using orbiter IMU data, the aiding state being periodically reset to the orbiter navigation state estimate; propagation of the orbiter state estimates from the GPS LRUs to current time using orbiter IMU data; execution of a series of quality assessment checks on the propagated GPS state estimates; and selection of a single GPS state for use by the orbiter navigation system and for resetting of the navigation filter state estimates, depending on the navigation system configuration as specified by the crew. Up to three GPS LRUs can be installed on the orbiter, each LRU consisting of a receiver and its navigation function. The LRU receiver provides GPS measurements to its navigation Kalman filter for improving the accuracy of its orbiter state estimate. The state estimate from each of the GPS LRUs, along with its associated time tag, are then made available to the navigation system principal function software elements for processing.

Note that the GPS LRUs are not NAVAIDS. They do not provide sensor measurements for processing by a navigation principal function Kalman filter. The GPS LRUs provide complete state estimates (position, velocity) and associated time tag to the orbiter navigation system after processing GPS measurements in their Kalman filter. For the purposes of this document, the terms GPS LRU and GPS receiver will be used interchangeably and will refer to the orbiter GPS navigation capability.

Depending on the navigation system configuration, either the navigation state estimate or the selected GPS state estimate is used for calculating navigation state dependent parameters and for resetting the orbiter state estimate required by non-navigation functions. The selected GPS state estimate can also be used to reset the filter state estimate, and the navigation filter state can be used to initialize or restart the GPS LRU navigation process, again depending on the navigation system configuration.

For rendezvous mission operations, the basic function of the orbiter navigation system is to provide an estimate of both the orbiter and target vehicle states, such that the orbiter and target states accurately reflect the relative position and velocity that exists between the two vehicles. There are two capabilities provided for performing this rendezvous navigation function.

The first rendezvous navigation capability consists of those principal function software elements and rendezvous sensors which provide and maintain the orbiter and target filter state estimates. The software elements perform the following functions: propagation of the orbiter and target state estimates to current time, using gravity and orbiter and target drag models, along with IMU data when appropriate; resetting or updating the orbiter and target filter state estimates to a ground uplink; resetting the orbiter state to a



selected GPS navigation state, depending on the navigation system configuration and modifying the target state and rendezvous navigation filter covariance matrix as required to maintain the correct operation of the rendezvous navigation Kalman filter; processing rendezvous NAVAJD measurements, when available, in the principal function Kalman filter software to update the estimate of either the target or the orbiter state (depending on system configuration) relative to the other vehicle state, to improve the accuracy of the relative state estimate. The terms NAVAJD and sensor are used synonymously in this document and are used to describe the onboard relative navigation instruments which provide measurements for processing by the rendezvous navigation principal function Kalman filter. The rendezvous navigation instruments are associated with the following systems:

- Rendezvous Radar
- Two Star Trackers
- Crew Optical Alignment Sight (COAS)

During relative sensor rendezvous navigation the GPS LRUs continue to provide estimates of the orbiter inertial state. Depending on the configuration of the navigation system, the GPS state selected from the GPS LRU state estimates is used to automatically or manually reset the orbiter inertial state estimate. When this orbiter inertial state reset occurs: (1) the relative sensor navigation state estimate is preserved by adjusting the target inertial state and the prop state to reflect the relative position and velocity state estimates from the relative sensor rendezvous navigation; and (2) the rendezvous navigation Kalman filter covariance matrix is adjusted to correctly maintain the relative navigation covariance matrix state error statistics consistent with the relative navigation estimate.

The second rendezvous navigation capability provided by the orbiter navigation system uses the GPS navigation capability to provide a selected GPS orbiter state estimate for resetting the navigation system orbiter state estimate. The target state is maintained during this mode of operation by propagating the target state to current time, with a ground uplink of the target state as required. Onboard drag and gravity models, along with IMU data when appropriate, are used for orbiter and target state vector propagation.

If relative sensor measurements are being processed in this mode, providing a parallel rendezvous navigation capability, performing a reset of the orbiter state with the GPS state or uplinking a Target state from the ground to maintain its inertial accuracy, will cause a subsequent impact on crew operations. If the Orbiter filter state is reset to the selected GPS state, the target inertial state will automatically be adjusted to maintain the correct operation of the rendezvous navigation Kalman filter. If a target state is subsequently uplinked from the ground, however, no similar adjustment is automatically made to the orbiter state. In this case the relative state determined by the rendezvous navigation filter will have been changed without the filter being made aware of the change. A rendezvous navigation filter covariance reinitialization should be performed by the crew to restart relative sensor navigation with the new relative state conditions.

In summary:

#### Rendezvous Capability 1: Relative Sensor Rendezvous

- On-board environment models used for orbiter and target state propagation
- Inertial Measurement Unit (IMU) Data used for orbiter state propagation
- Relative sensor data used to update the inertial position and velocity of either the orbiter or the target state relative to the other one

- The non-updated vehicle state maintained by onboard propagation after initialization (from the ground or state vector transfer)
- Orbiter state resets with the selected GPS state (depending on system configuration) will automatically result in a modification to the target state to preserve the relative state consistent with the rendezvous covariance matrix.

#### Rendezvous Capability 2: GPS Rendezvous

- On-board environment models used for orbiter and target state propagation
- Inertial Measurement Unit (IMU) Data used for orbiter state propagation
- Orbiter state estimates from on-board GPS receivers
- Target state estimates updated by ground uplink
- Relative sensor rendezvous navigation in parallel, if desired
  - Resetting orbiter state to selected GPS state will automatically modify the target to maintain relative filter performance
  - Ground uplink of target state will change relative state. Rendezvous Covariance matrix no longer represents relative state and state error. Covariance matrix should be reinitialized to restart relative navigation.

This document provides detailed navigation software requirements for the on-orbit operational sequences. The navigation software requirements for rendezvous navigation with relative sensor measurement processing and for user parameter processing are detailed in this FSSR.

All requirements for the orbiter navigation system GPS receiver state processing principal function and the GPS reference state processing principal function can be found in STS 83-0004, Sections 4.3.3 and 4.6.4 respectively, using the release of that FSSR which corresponds to the same Flight Software release that this on-orbit/rendezvous NAVIGATION FSSR pertains. An overview of the associated requirements and assumptions for these GPS-related principal functions is located in STS 83-0004, Sections 3.3.4.3 and 3.3.4.4.

### 3.3.1 Navigation Functions

In general, the orbiter navigation system software can be divided into four parts: part (a) baseline navigation with IMU-NAVAID sensor processing; part (b) user parameter processing; part (c) GPS receiver state processing; and part (d) GPS reference state processing. The software requirements for parts (a) and (b) are presented in this document. The requirements for parts (c) and (d) are presented in STS 83-0004.

Part (a) is divided into the following major functions:

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

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

Data Handler. Prepares data for sensor measurement processing.

Navigation Reconfiguration. Initializes and resets the navigation system state estimate to ground uplinked states or the selected GPS receiver state estimate, depending on the configuration of the navigation system. Initializes and resets the navigation Kalman filter covariance matrix for rendezvous sensor measurement processing in response to navigation state initialization and ground resets. If executing relative sensor rendezvous navigation, this function also resets the target inertial state and adjusts the rendezvous navigation filter covariance matrix to preserve the relative state error and covariance state error statistics. The GPS state that is used for resetting the navigation state, either automatically or manually, is selected in the GPS receiver state processing principal function based on premission defined state quality assessment criteria and is subject to crew control. Navigation reconfiguration also reconfigures the rendezvous navigation filter for changing sensor types.

State and Covariance Propagation. Propagates the state and the covariance matrix for sensor measurement processing. Also propagates state for user parameter calculations.

State and Covariance Update. Determines and performs the state and the covariance matrix updates.

Execution of the GPS Receiver State Processing Function. Executes the GPS receiver state processing function to provide a selected GPS orbiter state estimate, associated time and IMU data, for use in resetting the navigation system orbiter state estimate and for use in resetting the user parameter state.

User Parameter State Reset. Provides a navigation state, associated time and IMU data for periodically resetting the user parameter state. This state is either a navigation filter state estimate or the selected GPS state, depending on configuration of the navigation system. This function also provides the baseline navigation state, associated time and IMU data for initializing and reanchoring the GPS reference state, maintained by the GPS reference state processing principal function.

The software functions for part (b) can be divided into the following major functions:

User Parameter State Propagation. Propagates the user parameter state provided by navigation at a faster rate than Nav for user parameter calculations. The user parameter state is updated with the most recent Nav state.

User Parameter Processing. Computes state related parameters for guidance and display and control.

In this document, the details are presented for the following functions:

1. Onorbit/Rendezvous Navigation Sequencer
2. Onorbit/Rendezvous Navigation
3. Onorbit Precision State Prediction
4. Onorbit User Parameter Processing Sequencer
5. Onorbit User Parameter Processing
6. Initialization of Specific OPS 2 Navigation Parameters
7. Downlist Requirements
8. Uplink Requirements
9. Coordinate Transformations

The details of each function are shown in Sections 5.2 through 5.5 in the form of flow charts of the modules comprising each function. The interconnection of the functions and component modules is shown by means of “block” diagrams in Section 5.6.

### **3.3.2 Deleted**

### **3.3.3 General Requirements**

This section discusses software requirements in the categories of service, single–use, or multiple–use that are not uniquely related to the navigation function.

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

- Coordinate transformations (this publication contains transformations required for navigation).
- Onorbit Prediction – This function provides the capability to propagate a state vector forward or backward in time over possibly large time intervals when requested by a user. Onorbit prediction is a Level B principal function.

Flow charts for the general requirements functions are contained in Section 5.3.

### **3.3.4 Requirements and Assumptions Overview**

The following sections present an overview of the requirements and assumptions of the STS Onorbit Rendezvous GN&C navigation system related software. The requirements and assumptions are presented according to the software functional breakdown discussed in Section 3.3.1: (1) navigation system functions which maintain the orbiter filter state estimates using orbiter IMU data, relative NAVaid measurement processing in the navigation principal function Kalman filter, and state resets using ground uplink data or the selected GPS state; (2) the user parameter processing functions; (3) the GPS reference state processing functions which initialize the GPS receiver state estimate, and maintain a reference state using selected IMU data; and (4) the GPS receiver state processing functions which select the GPS receiver state estimate

for use in resetting the navigation state and the user parameter state, depending on the configuration of the navigation system.

Sections 3.3.4.1 and 3.3.4.2 present the requirements and assumptions overview for the navigation system functions and the user parameter processing functions which provide the capabilities in (1) and (2) above. The requirements and assumptions overview for the orbiter navigation system GPS related software functions which provide the capabilities in (3) and (4) above can be found in STS 83-0004 Sections 3.3.4.3. and 3.3.4.4.

The following two sections present the requirements and assumptions overview for: (1) and (2) above.

### **3.3.4.1 Requirements for Baseline Navigation System and User Parameter Processing Software**

The following statements are navigation requirements that must not be violated. To illustrate the requirements, references are made to the flow charts in Section 5.2.

1. During the time that a state vector is being read by non–navigation application software, that state vector or portions thereof will not be updated by the navigation software. The reset equations in the user parameter propagator shall be so protected.
2. Statements that snap data upon entry into navigation shall be made so that a timewise consistent set of data is obtained before the set of data is used.
3. The navigation sensor read functions must not be interrupted by other programs until they are completed.
4. Since the acceleration models are to be used by both a navigation processing principal function (onorbit or rendezvous navigation) and the predictor principal function, execution of the model (for a given cycle) shall not be interrupted (ACCEL\_ONORBIT).
5. The specific display interface flags (PWRD\_FLT\_NAV, REND\_NAV\_FLAG, MEAS\_ENABLE, ANGLES\_AIF, RANGE\_AIF, RDOT\_AIF) shall not have their values changed by any source external to navigation during the execution of a navigation cycle.
6. The Onorbit/Rendezvous Sequencer principal function shall have the capability to execute at a maximum rate of one cycle each 1.92 seconds.
7. During any navigation phase, execution of the Onorbit/Rendezvous Sequencer and the Onorbit/Rendezvous Navigation principal function shall take precedence over the execution of the Onorbit Precision State Prediction principal function. This requirement is needed to assure that both the sequencer and navigation principal function executions will not be delayed by execution of the predictor principal function. This requirement shall not apply to the initialization procedures which take place upon entering OPS 2 or OPS 8.

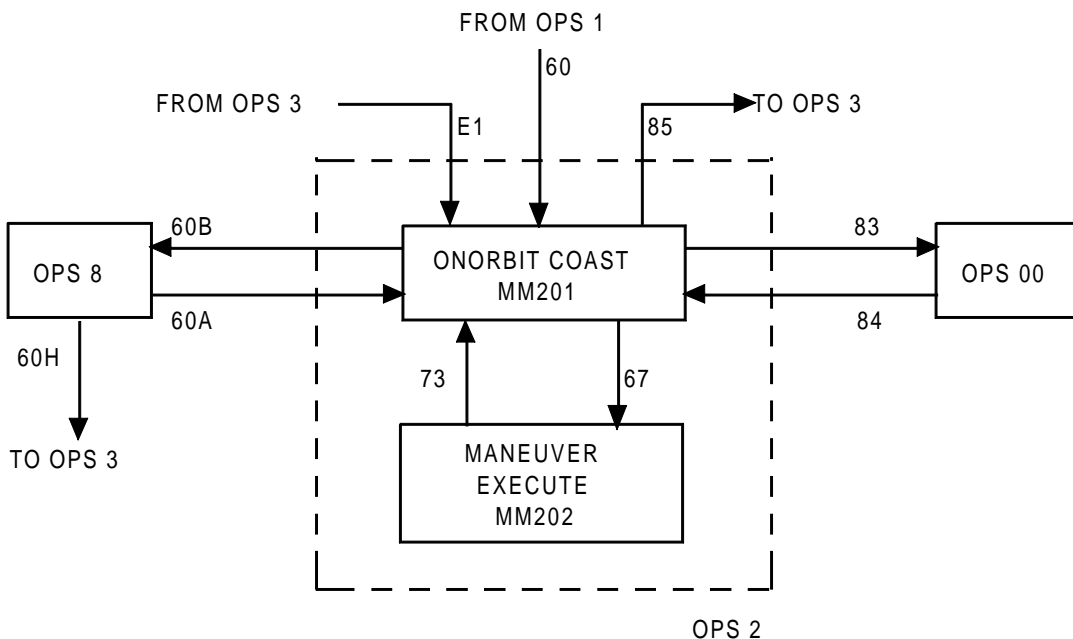
#### **3.3.4.1.1 General Requirements**

1. Figure 3.3–1 presents the assumed verified STS transitions for OPS 2 and OPS 8 and a summary of the events and major mode (MM) transitions that the Onorbit/Rendezvous Navigation Sequencer principal function must account for. The following list of assumptions applies to these verified transitions:

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2. There are four navigation phases: onorbit coast, rendezvous coast, onorbit powered flight, and rendezvous powered flight.
3. OPS 2 can be entered from OPS 1.
4. A flag, `REND_NAV_FLAG`, shall be set (and reset) external to the onorbit/ rendezvous navigation sequencer and onorbit/rendezvous navigation principal function. It is assumed that the crew will control this flag setting via the `REL_NAV` display. MSC may also control the flag for automatic transitions.
5. Once the onorbit navigation phase or the rendezvous navigation phase has been activated (while in Major Mode 201), the transition from one to the other can be controlled via crew resetting of the `REND_NAV_FLAG` via the `REL_NAV` display. This option is also available during Major Mode 202.
6. Entry into OPS 2 from OPS 3 can only occur when onorbit navigation is used (i.e., cannot begin OPS 2 with rendezvous navigation when coming from OPS 3).
7. Whenever reentering OPS 2 from OPS 00, entry is assumed to be made into Major Mode 201 with onorbit navigation active.
8. Transition to OPS 3 from OPS 2 (Major Mode 201) can occur while either onorbit or rendezvous navigation is active.
9. Transitions into OPS 2 and OPS 8 will initialize the `PWRD_FLT_NAV` flag to on.
10. It is assumed that OPS 2 and OPS 8 are separate memory loads in which all navigation software for the latter is contained within the former. A memory transition shall take place to transfer those OPS 2 principal functions needed for OPS 8, namely
  - a. Onorbit/Rendezvous Navigation Sequencer
  - b. Onorbit/Rendezvous Navigation
  - c. Onorbit/Rendezvous User Parameter Processing Sequencer
  - d. Onorbit User Parameter Processing
  - e. Onorbit Predictor

The navigation sequencer will currently indicate a cancellation and rescheduling of `ONORBIT_RENDEZVOUS_NAVIGATION` during the transition from OPS 8 to OPS 2 or OPS 2 to OPS 8, because of this assumption.



EVENT SUMMARY

<u>EVENT NO.</u>	<u>DESCRIPTION</u>	<u>CRITERIA</u>	<u>SOURCE</u>
60	106 → 201	OPS 201 PRO	CREW
60A	OPS 8 → 201	OPS 201 PRO	CREW
60B	201 → OPS 8	OPS 801 PRO	CREW
67	201 → 202	PRO OR OPS 202 PRO	CREW
73	202 → 201	PRO OR OPS 201 PRO	CREW
84	OPS 00 → 201	OPS 201 PRO	CREW
85	OPS 3 → 201	OPS 301 PRO	CREW
E1	OPS 8 → OPS 3	OPS 201 PRO	CREW
60H	OPS 2 → OPS 00	OPS 301 PRO	CREW
83		OPS 000 PRO	CREW/MSC

FIGURE 3.3-1. Verified STS Transitions

### 3.3.4.1.2 Deleted

### 3.3.4.2 Assumptions for Baseline Navigation System and User Parameter Processing Software

The following section presents the assumptions that were used in the development of the Level C Onorbit/Rendezvous requirements. The first section consists of those assumptions made that affect onorbit requirements as well as assumptions that affect both onorbit and rendezvous requirements. Section 3.3.4.2.2 contains only rendezvous related assumptions.

#### 3.3.4.2.1 Onorbit/Rendezvous Assumptions

1. Upon entering OPS 2 or OPS 8 the orbiter position and velocity vectors, obtained from the previous OPS, must be predicted to current time if the initialization time required is less than DT\_LIM (600 sec). Since this prediction is essential to the navigation task, the sequencer principal function execution must be dependent on the successful prediction of the orbiter state vectors. In order to minimize the delay due to the execution of the predictor principal function, the initial step size (PRED\_STEP\_OPS\_INIT), is set to ensure that only one prediction step will be taken by the predictor.
2. No onboard external data are processed during the nonrendezvous portion of operational sequence (OPS) 2 (i.e., onorbit coast and onorbit powered flight). One-way Doppler tracking and data relay satellite system (TDRSS) measurement incorporation is not currently planned for the STS program.
3. A six-dimensional state vector is maintained during nonrendezvous portions of OPS 2 and during OPS 8 (three position and three velocity components).
4. Prestored values for a nominal body contact force (due to venting and/or uncoupled thrusting, etc.) and vehicle/payload area configuration are required for acceleration models.
5. The inertial measurement unit subsystem operating program (IMU SOP) provides an estimate of the total accumulated IMU velocity at the time of a data snap in the presence of commfaults. The accumulated IMU velocity is provided to NAV from IMU RM, and is corrected to reference the orbiter CG instead of NAV-based CG.
6. OPS 2 and OPS 8 computational accuracy is assumed to be of AP101 double precision accuracy where mixed mode arithmetic is employed.
7. Incorporation of sensed velocity into the state propagation integrator is controlled by setting the PWRD\_FLT\_NAV flag in conjunction with an acceleration threshold. This flag is set by either moding, sequencing, and control (MSC), or by the crew via item entry on the REL\_NAV display (in OPS 2) or the FCS\_DIS\_C/O display (OPS 8). MSC will activate the PWRD\_FLT\_NAV flag upon entrance into Major Modes 201 and 202 and OPS 8. The crew can activate/deactivate the PWRD\_FLT\_NAV flag in Major Mode 201.
8. When the PWRD\_FLT\_NAV flag is ON, the use of sensed velocity in the navigation state propagator is triggered by testing accelerometer output versus prestored threshold levels. The threshold level, in micro g's, can be changed by crew input on the IMU\_ALIGN DISPLAY in OPS 2 only. The crew input threshold level will be preserved during OPS 2 and OPS 8 transitions.



9. Backward and forward integration capability is provided for state prediction and propagation.
10. Current attitude is used for propagation.
11. The precision state prediction function has accuracy comparable to that of the precision state propagation function and has the option of being executed in a faster (but less accurate) conic mode.
12. Acceleration models include both attitude-dependent and constant ballistic coefficient drag, a venting/RCS body contact force, and Earth gravity effects.
13. One orbiter and/or target state vector shall be maintained during all navigation phases in OPS 2.
  - a. During OPS 8, only the orbiter state vector shall be maintained.
  - b. During rendezvous, a backup state of the filtered vehicle's state shall be maintained.
14. The acceleration due to lift force is assumed to be negligible in the atmospheric drag acceleration model.
15. An automatic in-flight update capability will be provided by which the ground can uplink either an orbiter or a target state vector (M50) and associated time tag during any navigation phase (rendezvous or nonrendezvous). The following additional assumptions apply to this capability:
  - a. The ground shall uplink one vehicle state (three position and three velocity components, along with an associated time tag, and OP\_CODE) at a time.
  - b. The onboard software receiving these data (ground uplink high-rate special processing S/W processor) will set the DO\_OV\_UPLINK or DO\_TV\_UPLINK flag to ON to specify whether the uplinked data pertains to orbiter or target, and set up one of the following two variable sets depending on the results of this test:
 

Orbiter uplink	Target uplink
$\bar{R}_GND$	$\bar{R}_TV_GND$
	or
$\bar{V}_GND$	$\bar{V}_TV_GND$
T_GND	T_TV_GND
DO_OV_UPLINK = ON	DO_TV_UPLINK = ON
  - c. The navigation software has the capability of reinitializing the orbiter and/or target state vectors (and associated covariance matrix during rendezvous) in a single navigation cycle.
  - d. If a target vector is uplinked during a nonrendezvous navigation phase, it is stored for eventual use in a rendezvous phase.
  - e. There is no requirement to uplink a vehicle (either Shuttle or target) state vector to the propagation state vector.

- f. In predicting the Orbiter state ( $\bar{R}_{GND}$ ,  $\bar{V}_{GND}$ , and  $T_{GND}$ ) or target state ( $\bar{R}_{TV\_GND}$ ,  $\bar{V}_{TV\_GND}$ , and  $T_{TV\_GND}$ ) to within the hard-coded tolerance of current navigation time, it is required that only the initial state ( $\bar{R}_{PRED\_INIT}$ ,  $\bar{V}_{PRED\_INIT}$ , and  $T_{PRED\_INIT}$ ) and final state ( $\bar{R}_{PRED\_FINAL}$ ,  $\bar{V}_{PRED\_FINAL}$ , and  $T_{PRED\_FINAL}$ ) of the prediction be made available for the downlink processor. No intermediate states, in achieving the final state, are to be made available for the downlink processor.
16. A capability shall be provided for resetting the Orbiter navigation state to the selected GPS receiver state in OPS-2 and OPS-8, either automatically or manually, depending on the configuration of the navigation system as set by the crew.

Resetting the Orbiter navigation state to the selected GPS receiver state, should the appropriate checks be passed, must be completed before integrating the navigation state to the current time.

17. Propagation of orbiter and target position and velocity vectors will be performed by use of the super-G integration scheme during all navigation phases.
18. If the sensor (including IMU) SOP's are not in the same general-purpose computer (GPC) as the navigation filter software, then:
- a. Data and time tag must be preserved as a pair.
  - b. ICC transmission rate must be fast enough such that the data time tag and current time (in navigation GPC) difference shall not adversely affect navigation software performance.

If the sensor SOP's and navigation filter reside in the same GPC, then:

- a. Data must be time tagged.
  - b. Data must be the latest available at the time of the data snap.
19. The onorbit/rendezvous navigation sequencer will always snap IMU data and predict the last available state vector to current time when a memory transition has been performed:

OPS 1 to 2  
OPS 2 to 8  
OPS 3 to 2  
OPS 8 to 2  
OPS 0 to 2

20. The onorbit/rendezvous navigation sequencer is capable of responding to the following crew-controlled functions on the REL\_NAV and FCS\_DIS\_C/O displays:
- a. REL\_NAV
    - (1) Enable/disable onorbit and rendezvous navigation phases.
    - (2) Set flags for powered flight and coasting flight during Major Mode 201 (refer to Assumption 6).
    - (3) Allow measurement processing during rendezvous navigation, Major Mode 202.

- b. FCS\_DIS\_C/O display (OPS 8): Set positive feedback flags to display for indicating powered flight or coasting flight conditions.

### 3.3.4.2.2 Rendezvous-Only Assumptions

1. Entrance into the rendezvous navigation phase shall require target position and velocity vectors that have successfully been predicted to within a hard-coded tolerance of current navigation time. A flag, DOING\_REND\_NAV, shall be set to indicate to the crew as well as other software that the rendezvous navigation phase is active.

In predicting the target state ( $\bar{R}_{TV}$ ,  $\bar{V}_{TV}$ , and  $T_{TV}$ ) to within the hard-coded tolerance of current navigation time, it is required that only the initial state ( $\bar{R}_{PRED\_INIT}$ ,  $\bar{V}_{PRED\_INIT}$ , and  $T_{PRED\_INIT}$ ) and the final state ( $\bar{R}_{PRED\_FINAL}$ ,  $\bar{V}_{PRED\_FINAL}$ , and  $T_{PRED\_FINAL}$ ) of the prediction be made available for the downlink processor. No intermediate states, in achieving the final state, are to be made available for the downlink processor.

2. The onboard navigation software will store premission data for only one target vehicle.
3. It is assumed that one of the vehicles (either target or Shuttle) will have an accurately known position and velocity vector throughout the rendezvous navigation phase. The onboard navigation will carry a flag (SHUTTLE\_FILTER\_FLAG) which will determine whether the Shuttle or target state vector will be updated by the Kalman filter. The present design assumes that the SHUTTLE\_FILTER\_FLAG will be a mission-dependent (I-load) parameter; however, it is anticipated that future requirements may dictate that this flag be changed via uplink or crew display. Accordingly, any implementation should have the flexibility to allow for such a change with minimum impact.
4. The state vector maintained for rendezvous navigation will consist of 13 components.

Component no.	Description
1-3	Vehicle position (Shuttle or target)
4-6	Vehicle velocity (Shuttle or target)
7-9	Unmodeled acceleration estimates
10-13	Rendezvous tracker bias estimates

5. A capability shall be available to make the unmodeled acceleration states consider parameters only. In this mode, the unmodeled acceleration states are not updated by Kalman processing but the statistics are carried in the covariance matrix to act as state noise. An I-load parameter will determine if this capability is in operation or not and this parameter will not be changed throughout the mission.
6. There is no capability to uplink vents or thrusts for the target vehicle.
7. A 13 by 13 covariance matrix of Aries mean of 1950 position and velocity, unmodeled acceleration bias errors, and of (at most) four rendezvous tracker (instrument) biases is propagated during rendezvous coast and rendezvous powered flight navigation phases.

8. A valid or appropriate target vector shall always be I-loaded or uplinked prior to entry into the rendezvous navigation phase.
9. Upon entering rendezvous navigation, the covariance matrix is initialized to values stored in certain memory locations. These values are initialized through I-load and the position-velocity submatrix may be redefined with a ground uplink at any time.
10. The capability to load a premission determined set of known sensor biases (determined by calibration) into the bias slots of the navigated state vector shall be provided.
11. Both target and orbiter states shall be propagated but only one state will be updated by the Kalman filter.
12. During the rendezvous navigation phase, there will be a backup state vector associated with the vehicle state which is being filtered. Either the backup state or the filtered state will be sent to users according to crew input. The crew will have the capability to transfer the backup state to the filtered state, or the filtered state to the backup state.
13. The covariance propagation shall be done at a multiple (NCYCLE) of the state propagation rate to allow for slower measurement processing. The following subfunctions shall be done at the covariance propagation rate.
  - a. Sensor measurement selection
  - b. Measurement reconfiguration
  - c. Covariance matrix propagation
  - d. All measurement incorporation subfunctions
  - e. Measurement processing statistics
14. All rendezvous tracker bias variances are propagated as exponentially correlated random variables in the error covariance matrix propagation.
15. The unmodeled acceleration bias states are propagated as exponentially correlated random variables.
16. The covariance matrix can be reinitialized in any of five ways:
  - a. Execution of orbiter to target state transfer on the REL\_NAV display,
  - b. Execution of target to orbiter state transfer on the REL\_NAV display,
  - c. Execution of covariance matrix reinitialization on the REL\_NAV display,
  - d. Execution of backup to filtered state transfer on the REL\_NAV display, or
  - e. Auto inflight update of either the target or the orbiter.

In each of these cases the covariance matrix is set to the values contained in a specified set of memory locations. The position and velocity portions of the covariance matrix are computed using parameters that can be changed by ground uplink.

17. The following external data will be processed during the rendezvous coast navigation or during rendezvous powered flight when measurement processing is enabled and the acceleration level is below a predetermined threshold.
  - a. Rendezvous radar shaft angle, trunnion angle, range, and range rate
  - b. Star tracker horizontal and vertical angles
  - c. Crew optical alignment sight (COAS) horizontal and vertical angles
18. External measurement angle data are selected and processed mutually exclusively on an instrument basis. The rendezvous radar range and range rate may be processed with COAS, star tracker, or rendezvous radar angles. The display interface processor (DIP) will ensure this by activating the navigation sensor selection STATUS (DO\_ST\_RR\_COAS) flag for only the most recently crew-selected instrument.
19. External measurement data processing is inhibited for display and state vector updates whenever IMU sensed delta velocities are in excess of a design-dependent amount (MEAS\_THRESHOLD).
20. During Major Mode 202, when the MEAS\_ENABLE switch on the REL\_NAV display is set to OFF, the measurement statistics will be computed for display (assuming the data are valid), but the measurements will not be incorporated into the state vector update.
21. If a sensor AUTO/INHIBIT/FORCE (AIF) flag is switched to FORCE by the crew, this FORCE will be acknowledged by navigation for one navigation cycle only. After one cycle the flag must be reset to FORCE in order to force data. After the AIF flag has been processed, a copy of the AIF flag is communicated to the REL\_NAV display by navigation.
22. There shall be a bilevel edit criterion in the navigation filter. If the crew attempts to force data, the allowable residual ratio threshold shall be formulated as the larger of either the sum of the last residual ratio for the measurement type being processed and a design-dependent amount (DELTA\_RESID\_RATIO) or the number 1. For angle data the last residual ratio is equal to the greater of the two angle residual ratios from the previous cycle.
23. There shall be a data valid flag for rendezvous radar range and a data valid flag for rendezvous radar range rate. There will be a single data valid flag for each of the following angle sets: Rendezvous radar angles, star tracker angles, and COAS angles.
24. COAS processing is formulated such that data which is stale by more than a design-dependent amount (DELTA\_T\_COAS\_MAX) is considered invalid data and is not processed. Furthermore, the same data will not be incorporated twice by the filter.
25. The star tracker SOP shall supply a flag indicating that the star tracker is in the target tracking mode.

If the star tracker is not in the target tracking mode then the angle data are considered invalid and it is not processed by the filter.
26. The Rendezvous Radar SOP shall supply a flag indicating if the rendezvous radar is in the self test mode and, if it is, none of the rendezvous radar measurements (range, range rate, or angles) are processed by the filter.

- 27. Kalman filter statistics (residuals and residual ratios) will be calculated and displayed for each sensor type (range, range rate, angles) whenever rendezvous navigation is enabled and the sensor data are valid.
- 28. A capability shall be provided for resetting the orbiter state estimate to the selected GPS receiver state in OPS-2 and OPS-8, either automatically or manually, depending on the configuration of the navigation system as set by the crew.

Resetting the orbiter state to the selected GPS receiver state, should the appropriate checks be passed, must be completed before integrating the navigation state to the current time. If the reset occurs while processing relative sensor measurements, the target inertial state estimate must be changed to preserve the relative state estimate being maintained by the relative sensor processing and the rendezvous navigation Kalman filter covariance matrix shall be adjusted to correctly maintain the relative error statistics consistent with the new orbiter and target vehicle inertial states.

**3.4 OPERATIONAL SEQUENCES AND MAJOR MODES**

Table 3.4 identifies the OPS 2 and OPS 8 operation sequence major modes as referenced in Section 4, Detailed Requirements. Detailed descriptions may be found in the Level B CPDS.

Table 3.4. Operation Sequence Major Modes	
Major Mode No.	Onorbit/Rendezvous Phases
201	Onorbit powered flight Onorbit coast Rendezvous powered flight Rendezvous coast
202	Onorbit powered flight Rendezvous powered flight
OPS 8	Onorbit powered flight Onorbit coast

**3.5 IMPLEMENTATION CONSTRAINTS**

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

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

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

### **3.6 TIMING**

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

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## 4.0 DETAILED REQUIREMENTS

The various subsections of this section specify the detailed requirements for the Shuttle navigation system flight software package. This document contains operations detailed requirements for Navigation and User Parameter Processing principal functions for the orbit operations computer load (onorbit and rendezvous), Operational Sequence (OPS) 2. In addition, requirements dealing with other navigation software functions during OPS 8 and OPS 00 are also addressed.

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

Table 4.0-1 shows the traceability of the software paragraphs in this FSSR with respect to the corresponding principal function (PF) numbers defined in the Level B CPDS document. In addition, Table 4.0-2 shows the traceability of the PASS GN&C principal functions located in this FSSR with respect to the applicable BFS paragraphs in the Level C PRD specifications. These tables are provided for information only.

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.

The automated Interface Definition Document (IDD) tables define signal (parameter) interface requirements either between hardware (LRU) and software elements or between software elements and other software elements. In the event of a conflict between the IDD tables and other internal text input/output tables, the SASCB data base-controlled IDD tables take precedence. (MSID definitions per DIP JSC-18206, except 10th character use for multiple source reference.)<sup>F1</sup>

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

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

<sup>F1</sup> A GN&C software element is either a sequenced principal function, crew-generated specialist/display function, or an OPS display function.

Table 4.0-1. Level B to Level C Traceability		
Level B PF No.	Level B PF Name (Acronym)	Level C FSSR Section No.
4.148	Onorbit/Rendezvous Navigation Sequencer (ORB/RND NAV SEQ)	4.1
4.126	Onorbit/Rendezvous Navigation (ONORB RNDZ/NAV)	4.2
4.224	Onorbit Predictor (ONORB PRED)	4.3
4.198	Onorbit User Parameter Processing Sequencer (ORB UPP SEQ)	4.4
4.22	Onorbit User Parameter Processing (ONORB UPP)	4.5

Table 4.0-2. On-Orbit Navigation FSSR/PRD Correlation					
Principal Function	FSSR Paragraph	FSSR Title	BFS PRD	PRD Paragraph	BFS Title
G4.22	4.5	User Parameter Processing	N/A	N/A	N/A
G4.126	4.2	Onorbit/Rendezvous Navigation	N/A	N/A	N/A
G4.148	4.1	Onorbit/Rendezvous Navigation Sequencer	N/A	N/A	N/A
G4.198	4.4	Onorbit/Rendezvous User Parameter Processing Sequencer	N/A	N/A	N/A
G4.224	4.3	Onorbit Precision State Prediction	N/A	N/A	N/A

#### **4.1 ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER PRINCIPAL FUNCTION**

The Onorbit/Rendezvous Navigation Sequencer principal function must initialize and sequence the Onorbit/Rendezvous Navigation principal function during OPS 2 while the following major modes are active:

Major Mode 201 – Onorbit coast

Major Mode 202 – Maneuver execute

The Onorbit/Rendezvous Navigation Sequencer principal function must also initialize and sequence the Onorbit/Rendezvous Navigation principal function OPS 8 (orbital operation checkout).

The Onorbit/Rendezvous Navigation Sequencer principal function must also interface with certain crew controls on the REL\_NAV and FDS DIS C/O displays relating to selection of rendezvous navigation (REND\_NAV\_FLAG), to selection of powered flight versus coasting flight navigation phases, and to selection of measurement processing in Major Mode 202 when in rendezvous navigation.

Detailed requirements for Onorbit/Rendezvous Navigation Processing principal function are identified in the specific principal function description in Section 4.2. Cues (events) for performing the proper navigation initialization and sequencing during OPS 2 and OPS 8 are defined in the Level B GN&C CPDS. The particular events and resulting navigation software actions pertaining to the Onorbit/Rendezvous Navigation Sequencer principal function are shown in Table 4.1-1. Table 4.1-2 presents the principal function parameter interface to the local modules. Dynamic parameter input/output data flow between the Onorbit/Rendezvous Navigation Sequencer principal function and other principal functions is shown in Table 4.1.3-1. Other available parameter tables include I-loads in Table 4.1.3-2, K-loads in Table 4.1.3-3, constants in Table 4.1.3-4, and a parameter cross-reference in Table 4.1.3-5.

Table 4.1-1. Onorbit/Rendezvous Navigation Sequencer Events			
Event No.	Description	Navigation Criteria	Navigation Action
THE FOLLOWING PERTAIN TO SEQUENCER FUNCTIONS DURING OPS 2.			
Begin coasting flight navigation phases (onorbit or rendezvous).			
60	Transition from OPS 1 to MM201 (begin OPS 2)	OPS 201 PRO	Entering into an onorbit coast navigation phase: SET: CURR_ORB_MASS = WT_DISP/G_2_FPS2  NAV_CURR_ORB_MASS = CURR_ORB_MASS  CALL: OPS_2_OR_8_INITIALIZE  SCHEDULE: NAV_ONORBIT_RENDEZVOUS, repeat every: DT_NAV_STATE_PROP
60A	Transition from OPS 8 to MM201 (begin OPS 2)	OPS 201 PRO	The REND_NAV_FLAG is assumed to be in the OFF state for this event:  Same action as EVENT_60 except current Orbiter mass is calculated as:  CURR_ORB_MASS = MASS_INIT
73	Transition from MM202 to MM201	OPS 201 PRO	SET: MEAS_ENABLE = OFF DOING_MEAS_ENABLE = OFF
E1	Transition from OPS 3 to MM201 (begin OPS 2)  Change in the REND_NAV_FLAG setting (i.e., REND_FLAG ≠ REND_NAV_FLAG_LAST)	OPS 201 PRO  Crew activates REL_NAV display control (RNDZ_NAV_ENA)	The rendezvous nav flag is assumed to be in the off state. Same action as EVENT_60.  If the REND_NAV_FLAG = OFF (i.e., entering an onorbit coasting navigation phase):  CALL: REND_NAV_EXIT  If REND_NAV_FLAG = ON (i.e., entering a rendezvous coast navigation phase):  CALL: REND_NAV_INIT
84	Transition from OPS 00 to MM201 (begin OPS 2)	OPS 201 PRO	If the transition to MM201 from OPS 00 resulted in a Major Function Base (MFB) overlay, execute the RNP MAT COMP function to initialize EARTH_POLE, M_M50TOEF_AT_EPOCH, and T_EPOCH.  CALL: RNP_MAT_COMP
Begin powered flight navigation phases (onorbit or rendezvous)			
67	Transition from MM201 to MM202	OPS 202 PRO	SET: PWRD_FLT_NAV = ON DOING_PWRD_FLT_NAV = ON

Table 4.1-1. Onorbit/Rendezvous Navigation Sequencer Events			
Event No.	Description	Navigation Criteria	Navigation Action
Perform special tasks upon termination of OPS 2.			
60B	Transition from MM201 to OPS 8 (terminate OPS 2)	OPS 801 PRO (refer to VU, Level B CPDS)	SET: PWRD_FLT_NAV = ON DOING_PWRD_FLT_NAV = ON  CALL: NAV_EXIT
85	Transition from MM201 to OPS 3 (terminate OPS 2)	OPS 301 PRO	CALL: NAV_EXIT
83	Transition from OPS 2 to OPS 00	OPS 000 PRO	CALL: NAV_EXIT
THE FOLLOWING PERTAIN TO SEQUENCER FUNCTIONS DURING OPS 8. Begin coasting flight navigation phase (OPS 8).			
60B	Transition from MM201 to OPS 8 (terminate OPS 2)	OPS 801 PRO (refer to VU, Level B CPDS)	SET: NAV_CURR_ORB_MASS = MASS_INIT  CALL: OPS_2_OR_8_INITIALIZE DOING_PWRD_FLT_NAV = ON  SCHEDULE: NAV_ONORBIT_RENDEZVOUS, repeat every: DT_NAV_STATE_PROP
Perform special tasks upon termination of OPS 8			
60A	Transition from OPS 8 to MM201	OPS 201 PRO	CALL: NAV_EXIT
60H	Transition from OPS 8 to OPS 3	MSC or OPS 301 PRO	CALL: NAV_EXIT

Table 4.1-2. Onorbit/Rendezvous Navigation Sequencer Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
ANGLES_AIF			Onorbit/Rend Nav	REND_NAV_EXIT, REND_NAV_INIT
ANGLES_AIF_DISPLAY			Rel Nav Disp	REND_NAV_EXIT, REND_NAV_INIT
ATMP			Onorbit Predictor, TLM	OPS_2_OR_8_ INITIALIZE, REND_NAV_INIT
CURR_ORB_MASS	Onorbit Guidance	NAV_EXIT	Onorbit/Rend Nav, Onorbit Guidance	ONORBIT_ REND_NAV_ SEQUENCER
COV_ACCEL_UVW_INIT			Onorbit/Rend Nav	REND_NAV_INIT
COV_COR_UPDATE	Ground Uplink	COVINIT_UVW		
COV_POS_SIG			TLM	COV_LAST_RESET
COV_PWRD_FLT			Onorbit/Rend Nav	REND_NAV_INIT
COV_PWRD_FLT_LAST			Onorbit/Rend Nav, TLM	REND_NAV_INIT
COV_VEL_SIG			TLM	COV_LAST_RESET
DMP			Onorbit Predictor	OPS_2_OR_8_ INITIALIZE, REND_NAV_INIT
DO_COAS_ANGLES_NAV_LAST			Onorbit/Rend Nav	REND_COV_INIT
DOING_MEAS_ENABLE			REL_NAV display, TLM	ONORBIT_REND_ NAV_SEQUENCER
DOING_PWRD_FLT_NAV			REL_NAV display, TLM, FCS_DIS_C/0 display	ONORBIT_REND_ NAV_SEQUENCER
DOING_REND_NAV			REL_NAV display, TLM, ONORBIT/REND NAV, ONORBIT/REND USER PARAMETER PROCESSING, ORB TGT, DISP, REL NAV SPEC FCTN	REND_NAV_INIT, REND_NAV_EXIT
DO_RR_ANGLES_NAV_LAST			Onorbit/Rend Nav	REND_COV_INIT

Table 4.1-2. Onorbit/Rendezvous Navigation Sequencer Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
DO_RRDOT_NAV_LAST			Onorbit/Rend Nav	REND_COV_INIT
DO_ST_ANGLES_NAV_LAST			Onorbit/Rend Nav	REND_COV_INIT
DT_FILT	Onorbit/Rend Nav	REND_COV_INIT		
$\bar{D}V_{COV}$			Onorbit/Rend Navigation, TLM	COV_LAST_RESET
$\bar{D}V_{FILT}$	Onorbit/Rend Nav	REND_COV_INIT		
E			Onorbit/Rend Navigation, TLM (diagonal element only)	COVINIT_UVW, U_A_BIAS_AND_COVINIT
EVENT_E1	Moding, Sequencing and Control	ONORBIT_REND_NAV_SEQUENCER		
EVENT_60	Moding, Sequencing and Control	ONORBIT_REND_NAV_SEQUENCER		
EVENT_60A	Moding, Sequencing and Control	ONORBIT_REND_NAV_SEQUENCER, NAV_EXIT		
EVENT_60B	Moding, Sequencing and Control	ONORBIT_REND_NAV_SEQUENCER, NAV_EXIT		
EVENT_60H	Moding, Sequencing and Control	ONORBIT_REND_NAV_SEQUENCER		
EVENT_67	Moding, Sequencing and Control	ONORBIT_REND_NAV_SEQUENCER		
EVENT_73	Moding, Sequencing and Control	ONORBIT_REND_NAV_SEQUENCER		
EVENT_83	Moding, Sequencing and Control	ONORBIT_REND_NAV_SEQUENCER, NAV_EXIT		
EVENT_84	Moding, Sequencing and Control	ONORBIT_REND_NAV_SEQUENCER		

Table 4.1-2. Onorbit/Rendezvous Navigation Sequencer Principal Function Parameter Interface to Local Modules					
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source	
EVENT_85	Moding, Sequencing and Control	ONORBIT_REND_NAV_SEQUENCER			
FILT_UPDATE			Onorbit/Rendezvous User Parameter Processing	OPS_2_OR_8_INITIALIZE	
GMDP			Onorbit Predictor	OPS_2_OR_8_INITIALIZE, REND_NAV_INIT	
GMOP			Onorbit Predictor	OPS_2_OR_8_INITIALIZE, REND_NAV_INIT	
GPS_AIF_RCVD*			NAV_ONORBIT_REND	GPS_RCVR_STATE_PROC	
GPS_DG_SF_PREV			NAV_ONORBIT_REND	GPS_RCVR_STATE_PROC	OPS_2_OR_8_INITIALIZE
GPS_REF_INIT_VALID				GPS_REF_STATE_PROC	OPS_2_OR_8_INITIALIZE
GPS_SV_SEL_AVAIL **			NAV_ONORBIT_REND	GPS_RCVR_STATE_PROC, ONORBIT/RENDEZVOUS	OPS_2_OR_8_INITIALIZE
G_TV_LAST				Onorbit/Rend Nav	REND_COV_INIT
L_CYCLE				Onorbit/Rend Nav, TLM	REND_COV_INIT
IDRAG			Onorbit/Rend Nav	REND_COV_INIT	
IGD			Onorbit/Rend Nav	REND_COV_INIT	
IGO			Onorbit/Rend Nav	REND_COV_INIT	
IVENT			Onorbit/Rend Nav	REND_COV_INIT	
MASS_INIT	Onorbit/Rend Nav Seq	ONORBIT_REND_NAV_SEQUENCER	Onorbit/Rend Nav Seq	NAV_EXIT	
MEAS_ENABLE			Onorbit/Rend Nav	ONORBIT_REND_NAV_SEQUENCER	
NAV_CURR_ORB_MASS			TLM	ONORBIT_REND_NAV_SEQUENCER	
N_ACCEPT			Onorbit/Rend Nav, TLM	DISPLAY_COUNT_INIT	
NOISY_NAV_MEAS			Onorbit/Rend Nav	REND_NAV_INIT	



Table 4.1-2. Onorbit/Rendezvous Navigation Sequencer Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
N_REJECT			Onorbit/Rend Nav, TLM	DISPLAY_COUNT_INIT
OPS_2_OR_8_INITIALIZE_COMPLETE			Onorbit/Rend User Parameter Processing Seq, MSC	OPS_2_OR_8_INITIALIZE
PRED_ENA_FLAG			Onorbit/Rend Nav, Onorbit Predictor	NAV_EXIT, OPS_2_OR_8_INITIALIZE
PRED_ORB_AREA			Onorbit Predictor, TLM	OPS_2_OR_8_INITIALIZE
PRED_ORB_CD			Onorbit Predictor, TLM	OPS_2_OR_8_INITIALIZE
PRED_ORB_MASS			Onorbit Predictor, TLM	OPS_2_OR_8_INITIALIZE
PRED_STEP			Onorbit Predictor, TLM	OPS_2_OR_8_INITIALIZE, REND_NAV_INIT
PRED_USE	Onorbit/Rend Nav	REND_NAV_INIT, STATE_VECTOR_PREDICT_TASK	Onorbit/Rend Nav, TLM	REND_NAV_INIT, STATE_VECTOR_PREDICT_TASK
PWRD_FLT_NAV			Onorbit/Rend NAV, ORB UPP	ONORBIT_REND_NAV_SEQUENCER, OPS_2_OR_8_INITIALIZE
RANGE_AIF			Onorbit/Rend NAV	REND_NAV_EXIT, REND_NAV_INIT
RANGE_AIF_DISPLAY			Rel Nav Disp	REND_NAV_EXIT, REND_NAV_INIT
RDOT_AIF			Onorbit/Rend NAV	REND_NAV_EXIT, REND_NAV_INIT
RDOT_AIF_DISPLAY			Rel Nav Disp	REND_NAV_EXIT, REND_NAV_INIT
REND_NAV_FLAG	REL_NAV display	ONORBIT_REND_NAV_SEQUENCER, REND_NAV_INIT	TLM	REND_NAV_INIT
R_FILT	Onorbit/Rend Nav	REND_COV_INIT, NAV_EXIT, COV_LAST_RESET, REND_NAV_INIT, SHUTTLE_RESET	Onorbit/Rend Nav	OPS_2_OR_8_INITIALIZE

Table 4.1-2. Onorbit/Rendezvous Navigation Sequencer Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
$\bar{R}$ _FILT_INIT	ASC NAV SEQ.,D/L NAV SEQ., Onorbit/Rend Nav Seq	OPS_2_OR_8_ INITIALIZE	D/L Nav Seq,Onorbit/Rend Nav Seq	NAV_EXIT
$\bar{R}$ _GPS_INIT		NAV_ONORBIT_REND	GPS_REF_STATE_PROC	OPS_2_OR_8_ INITIALIZE
$\bar{R}$ _LAST			Onorbit/Rend Nav	COV_LAST_RESET
$\bar{R}$ _PROP			Onorbit/Rend Nav	REND_NAV_INIT
$\bar{R}$ _PRED_FINAL	Onorbit Predictor	OPS_2_OR_8_ INITIALIZE, REND_NAV_INIT, STATE_VECTOR_PREDICT_TASK		
$\bar{R}$ _PRED_INIT			Onorbit Predictor, TLM	OPS_2_OR_8_ INITIALIZE, REND_NAV_INIT, STATE_VECTOR_PREDICT_TASK
$\bar{R}$ _RESET			Onorbit/Rend User Parameter Processing	SHUTTLE_RESET
$\bar{R}$ _TV	Onorbit/Rend Nav	REND_NAV_INIT, COV_LAST_RESET, REND_COV_INIT, TARGET_RESET	Onorbit/Rend Nav	REND_NAV_INIT
$\bar{R}$ _TV_LAST			Onorbit/Rend Nav	COV_LAST_RESET
$\bar{R}$ _TV_RESET			Onorbit/Rend User Parameter Processing	TARGET_RESET
$\bar{S}$ EL_V_M50_CG SEQ_ACCEPT	IMU RM	IMU DATA SNAP	Onorbit/Rend Nav, TLM	DISPLAY_COUNT_INIT
SEQ_REJECT			Onorbit/Rend Nav, TLM	DISPLAY_COUNT_INIT
SHUTTLE_FILTER_FLAG	REL_NAV display	REND_COV_INIT, REND_NAV_INIT		
SIG_UPDATE	Ground Uplink	COVINIT_UVW		
SQR_EMU			Onorbit/Rend Nav, Onorbit Predictor	OPS_2_OR_8_ INITIALIZE
SV_SOURCE_FOR_UPP			Onorbit/Rend Nav	REND_NAV_INIT

Table 4.1-2. Onorbit/Rendezvous Navigation Sequencer Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
TAU_UNMOD_ ACC_COV			Onorbit/Rend Nav	REND_NAV_INIT
T_COV_LAST			Onorbit/Rend Nav	COV_LAST_RESET
T_CURRENT_FILT			TLM	OPS_2_OR_8_ INITIALIZE
T_FILT_INIT	Deorbit/ Landing Nav Seq, Ascent Nav Seq, Onorbit/ Rend Nav Seq	OPS_2_OR_8_ INITIALIZE	D/L Nav Seq, Onorbit/Rend Nav Seq	NAV_EXIT
T_GPS_INIT			GPS_REF_STATE_ PROC	OPS_2_OR_8_ INITIALIZE
T_GPS_LAST_ UPDATE			GPS_RCVR_STATE PROC, Onorbit/Rend Nav, Ent Nav, Preland Nav	OPS_2_OR_8_ INITIALIZE
T_GPS_OFF			GPS_RCVR_STATE_ PROC	OPS_2_OR_8 INITIALIZE
T_IMUS	IMU INT PROC	IMU DATA SNAP		
T_LAST_FILT	Onorbit/Rend Nav	NAV_EXIT, REND_COV_INIT, COV_LAST_RESET, SHUTTLE_RESET	Onorbit/Rend Nav	OPS_2_OR_8_ INITIALIZE
TOT_ACC_LAST			Onorbit/Rend Nav	REND_COV_INIT
T_PRED_FINAL			Onorbit Predictor, TLM	OPS_2_OR_8_ INITIALIZE, STATE_VECTOR_ PREDICT_TASK
T_PRED_INIT			Onorbit Predictor, TLM	OPS_2_OR_8_ INITIALIZE, REND_NAV_INIT, STATE_VECTOR_ PREDICT_TASK
T_RESET	Onorbit/Rend Nav	STATE_VECTOR_ PREDICT_TASK	Onorbit/Rend User Parameter Processing, Onorbit/Rend Nav, GPS_RCVR_STATE_ PROC, Rel Nav Disp	SHUTTLE_RESET
T_TV	Onorbit/Rend Nav	REND_NAV_INIT, REND_COV_INIT	TLM, Onorbit/Rend Nav, Rel Nav Disp	REND_NAV_INIT

Table 4.1-2. Onorbit/Rendezvous Navigation Sequencer Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
TV_PREDICT_FAIL			TLM	REND_NAV_INIT
UNMOD_ACC_BIAS			Onorbit/Rend Nav	REND_NAV_EXIT, OPS_2_OR_8_INITIALIZE, U_A_BIAS_AND_COV_INIT
VAR_UNMOD_ACC_VMP			Onorbit/Rend Nav Onorbit Predictor	REND_NAV_INIT OPS_2_OR_8_INITIALIZE, REND_NAV_INIT
V_CURRENT_FILT			TLM	OPS_2_OR_8_INITIALIZE
V_FILT	Onorbit/Rend Nav	REND_COV_INIT, NAV_EXIT, COV_LAST_RESET, REND_NAV_INIT, SHUTTLE_RESET	Onorbit/Rend Nav	OPS_2_OR_8_INITIALIZE
V_FILT_INIT	Asc. Nav Seq, D/L Nav Seq, Onorbit/Rend Nav Sequencer	OPS_2_OR_8_INITIALIZE	D/L Nav Seq, Onorbit/Rend Nav Sequencer	NAV_EXIT
V_GPS_INIT		NAV_ONORBIT_REND	GPS_REF_STATE_PROC	OPS_2_OR_8_INITIALIZE
V_IMU_GPS_INIT		NAV_ONORBIT_REND	GPS_REF_STATE_PROC	OPS_2_OR_8_INITIALIZE
V_IMU_RESET			Onorbit/Rend User Parameter Processing, TLM	SHUTTLE_RESET
V_LAST			Onorbit/Rend Nav	COV_LAST_RESET
V_LAST_FILT			Onorbit/Rend Nav	OPS_2_OR_8_INITIALIZE
V_PRED_FINAL	Onorbit Predictor	REND_NAV_INIT, OPS_2_OR_8_INITIALIZE, STATE_VECTOR_PREDICT_TASK		
V_PRED_INIT			Onorbit Predictor, TLM	OPS_2_OR_8_INITIALIZE, REND_NAV_INIT, STATE_VECTOR_PREDICT_TASK

Table 4.1-2. Onorbit/Rendezvous Navigation Sequencer Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
$\bar{V}$ _PROP	Onorbit/Rend Nav	REND_NAV_INIT, COV_LAST_RESET, REND_COV_INIT, TARGET_RESET	Onorbit/Rend Nav	REND_NAV_INIT
$\bar{V}$ _RESET			Onorbit/Rend User Parameter Processing	SHUTTLE_RESET
$\bar{V}$ _TV			Onorbit/Rend Nav	REND_NAV_INIT
$\bar{V}$ _TV_LAST			Onorbit/Rend Nav	COV_LAST_RESET
$\bar{V}$ _TV_RESET	Deorbit maneuver dip; Ascent maneuver dip	ONORBIT_REND_ NAV_SEQUENCER	Onorbit/Rend User Parameter Processing	TARGET_RESET
WT_DISP				
* Initial value should be INHIBIT ** Initial value should be OFF				

#### 4.1.1 Sequencing Operations and Major Mode Transitions (ONORBIT\_REND\_NAV\_SEQUENCER)

The Onorbit/Rendezvous Navigation Sequencer principal function performs specific actions which control the execution of the Onorbit/Rendezvous Navigation principal function based on navigation phase and major mode transitions. These tasks are performed by the Sequencing Operations and Major Mode Transitions subfunction and include the following tasks for OPS 2 control:

- response to events for entering OPS 2
- response to events for exiting OPS 2
- response to events for major mode transitions within OPS 2
- response to crew entry on the REL NAV DISPLAY regarding selection of powered flight phase (both onorbit and rendezvous)
- response to crew entry (REL NAV DISPLAY) regarding selection of onorbit or rendezvous navigation phase (powered or coasting flight)

For OPS 8 control the following tasks are performed:

- response to events for entering OPS 8
- response to events for exiting OPS 8
- response to crew entry on the FCS/DED DISP C/O DISPLAY regarding selection of powered flight phase

The events for OPS 2 and OPS 8 navigation control are summarized below. Detailed requirements are specified separately below for OPS 2 and OPS 8.

- Events to enter OPS-2
  - 60 OPS-1 → OPS-2
  - 60A OPS-8 → OPS-2
  - E1 OPS-3 → OPS-2
  - 84 OPS-00 → OPS-2
- Events to exit OPS-2
  - 60B OPS-2 → OPS-8
  - 83 OPS-2 → OPS-00
  - 85 OPS-2 → OPS-3
- Events to enter OPS-8
  - 60B OPS-2 → OPS-8

- Events to exit OPS-8
  - 60A            OPS-8    →        OPS-2
  - 60H            OPS-8    →        OPS-3
- Events during OPS-2 and 8
  - 73             MM202    →        201
  - 67             MM201    →        202

A. Detailed requirements.

Part I.– OPS 2 Requirements

The detailed sequencing and major mode transition requirements for the OPS 2 portion of the Onorbit/Rendezvous Navigation Sequencer principal function are described as follows:

1. If an onorbit coast navigation phase is begun by entry into Major Mode 201 from OPS 1, OPS 3, OPS 8, or OPS 00 (EVENTS 60, E1, 60A, or 84), the Onorbit/Rendezvous Navigation Sequencer principal function shall provide the capability to initialize the orbiter state vector, mass, and other required navigation parameters on the basis of prestored computer locations unaffected by the computer program memory load reconfiguration. The following sequence should be followed:

- a. Compute the value for orbiter mass as follows:

If OPS 2 is to be entered from OPS 1 or OPS 3 the orbiter mass shall be calculated as:

$$\text{F3} \quad \text{CURR\_ORB\_MASS} = \text{WT\_DISP/G\_2\_FPS2} \quad \text{F3}$$

This equation shall be protected against division by zero (reference 3.5)

Otherwise, orbiter mass shall be reset to a saved value:

$$\text{CURR\_ORB\_MASS} = \text{MASS\_INIT}$$

- b. Store the computed mass value into a NAV slot for use by navigation.

$$\text{NAV\_CURR\_ORB\_MASS} = \text{CURR\_ORB\_MASS}$$

- c. An initialization operation shall now be performed to obtain current IMU data, predict the last saved OPS sequence orbiter position and velocity vectors to current time, reset parameters for user parameter state propagation, parameters for GPS reference state processing and initialize flags to OPS 2 or OPS 8 initial values (refer to Section 4.1.2 for detailed requirements):

$$\text{CALL: OPS\_2\_OR\_8\_INITIALIZE}$$

- d. After completion of initialization, the capability shall be provided for sequencing the Onorbit/Rendezvous Navigation principal function at the designated repetition rate, DT\_NAV\_STATE\_PROP.

2. If OPS 2 is not being entered, tests for detecting leaving OPS 2 to go to OPS 8 (EVENT 60B), OPS 00 (EVENT 83), or OPS 3 (EVENT 85) are made. If any of these 3 transitions is detected,

CALL: NAV\_EXIT

(Section 4.1.1.2) to store the necessary information into protected locations for the new OPS sequence.

3. If transitions into or out of OPS 2 have not been detected, tests for transitions in major mode in OPS 2 are made.
  - a. The test for transition from MM202 to MM201 (EVENT\_73) is made. If EVENT\_73 is ON, the MM202 measurement enable flag and the measurement enable positive feedback flag (for REL\_NAV\_DISPLAY) must be set to OFF.

MEAS\_ENABLE = OFF

DOING\_MEAS\_ENABLE = OFF

- b. If EVENT 73 is OFF, the test for transition from MM201 to MM202 (EVENT 67) is made. If EVENT\_67 is ON, the powered flight flag is set to ON.

PWRD\_FLT\_NAV = ON

In any event, the positive feedback flag for powered flight is set for the REL NAV display to the value of the powered flight navigation flag.

DOING\_PWRD\_FLT\_NAV = PWRD\_FLT\_NAV

4. A test is made to detect the following:
  - A transition into or out of the rendezvous navigation phase, or
  - the rendezvous navigation initialization target prediction task has been initiated but not completed.
  - a. If  $REND\_NAV\_FLAG \neq REND\_NAV\_FLAG\_LAST$ , a transition has occurred; or if  $REND\_NAV\_INIT\_PRED = ON$ , then the target prediction task has not been completed. Thus the  $REND\_NAV\_FLAG$  and  $REND\_NAV\_INIT\_FLAG$  are interrogated to determine the nature of the transition and the state of the target prediction.
    - (1) If  $REND\_NAV\_FLAG = ON$  or  $REND\_NAV\_INIT\_PRED = ON$  then the Rendezvous Navigation Initialization subfunction is invoked

CALL: REND\_NAV\_INIT

(See Section 4.1.2.2)

- (2) If  $REND\_NAV\_FLAG = OFF$  and  $REND\_NAV\_INIT\_PRED = OFF$ , the rendezvous navigation phase will be exited.



CALL: REND\_NAV\_EXIT

(See Section 4.1.1.1)

- b. If REND\_NAV\_FLAG = REND\_NAV\_FLAG\_LAST and REND\_NAV\_INIT\_PRED = OFF, then a transition has not occurred; and the rendezvous navigation initialization prediction task is not in progress. Thus the sequencer control logic has been completed for this navigation cycle.

Part II.– OPS 8 Requirements:

The detailed sequencing and major mode transition requirements for the OPS 8 portion of the Onorbit/Rendezvous Navigation Sequencer principal function are described as follows:

1. If the onorbit coast navigation phase is begun by entry into GN&C OPS 8 from OPS 2 (Event 60B), the Onorbit/Rendezvous Navigation Sequencer principal function shall provide the capability to initialize the orbiter state vector and other required navigation parameters on the basis of prestored data and OPS 2 data obtained from protected computer locations unaffected by the computer program memory load reconfiguration. A flag, REND\_NAV\_FLAG, will be maintained in the OFF state (by MSC) throughout OPS 8 as rendezvous navigation phase is not available in this OPS sequence. This following initialization sequence shall be performed:

- a. Initialize the current orbiter mass as saved from OPS 2:

NAV\_CURR\_ORB\_MASS = MASS\_INIT

- b. Perform an initialization operation to obtain current IMU data, predict the last saved OPS sequence orbiter position and velocity vectors to current time, reset parameters for user parameter state propagation, parameters for GPS reference state processing and initialize flags to OPS 2 or OPS 8 initial values (refer to Section 4.1.2 for detailed requirements):

CALL: OPS\_2\_OR\_8\_INITIALIZE

- c. After completion of this initialization, the capability shall be provided for sequencing the Onorbit/Rendezvous Navigation principal function at the designated repetition rate (DT\_NAV\_STATE\_PROP) during OPS 8.

2. If a transition for entering OPS 8 was not detected, tests are made to detect leaving OPS 8 to enter OPS 2 (EVENT 60A) or OPS 3 (EVENT 60H). If either event is “ON”,

CALL: NAV\_EXIT

to store necessary information into protected locations for the next OPS sequence.

3. If transitions into and out of OPS 8 have not been detected, the positive feedback flag for powered flight navigation is set (for the FCS/ DED DISP C/O DISPLAY) to the value of the powered flight navigation flag.

DOING\_PWRD\_FLT\_NAV = PWRD\_FLT\_NAV

- B. Interface Requirements. Input and output parameters are given in Table 4.1.1.

C. Processing Requirements. None

D. Constraints. The following additional constraints apply to the requirements presented in Section A:

1. The following flags are set by either REL\_NAV (via crew input) or FCS/DED DISP C/O DISPLAY (crew input):

REND\_NAV\_FLAG

PWRD\_FLT\_NAV

MEAS\_ENABLE

and should not be changed (in value) by these external functions during any given cycle of the Onorbit/Rendezvous Navigation principal function during any navigation phase since a timewise consistent set of navigation data is required (i.e., a completion of a navigation cycle) to perform the various navigation functions.

2. Memory transitions shall only be performed following the completion of a navigation cycle.
3. The maximum repetition rate for the Onorbit/Rendezvous Navigation Sequencer principal function shall be 1.92 seconds.

E. Supplemental Information. A suggested implementation of these requirements is illustrated in the Section 5.2 flow diagrams:

ONORBIT\_REND\_NAV\_SEQUENCER (OPS 2)

ONORBIT\_REND\_NAV\_SEQUENCER (OPS 8)

NAV\_EXIT

Table 4.1.1. ONORBIT\_REND\_NAV\_SEQUENCER Input/Output

Variable Name	Input Source	Output Destination
CURR_ORB_MASS		*
DOING_MEAS_ENABLE	**	*
DOING_PWRD_FLT_NAV	**	*
DT_NAV_STATE_PROP	**	
EVENT_E1	*,**	
EVENT_60	*,**	
EVENT_60A	*,**	
EVENT_60B	*,**	
EVENT_60H	*,**	
EVENT_67	*,**	
EVENT_73	*,**	
EVENT_83	*,**	
EVENT_84	*,**	
EVENT_85	*,**	
G_2_FPS2	**	
MASS_INIT	*,**, NAV_EXIT	
MEAS_ENABLE		*
NAV_CURR_ORB_MASS		*, ACCEL_ONORBIT, OPS_2_OR_8_INITIALIZE
PWRD_FLT_NAV	OPS_2_OR_8_INITIALIZE	*
REND_NAV_FLAG	*, REND_NAV_INIT, **	*
REND_NAV_FLAG_LAST	**, REND_NAV_INIT, REND_NAV_EXIT	
REND_NAV_INIT_PRED	**, REND_NAV_INIT	
WT_DISP	*,**	

\* See principal function input/output tables for the Onorbit/Rendezvous Navigation Sequencer (Table 4.1.3-1).  
\*\* See initialization parameters, Section 4.7.

#### 4.1.1.1 Rendezvous Navigation Phase Termination (REND\_NAV\_EXIT)

The purpose of the Rendezvous Navigation Phase Termination subfunction is to perform the necessary operations required when a rendezvous navigation phase is terminated in preparation for a transition to an onorbit navigation phase. This action occurs during OPS 2 when the crew or MSC changes the value of the REND\_NAV\_FLAG from a value of ON to OFF (crew control of the REND\_NAV\_FLAG is via the REL\_NAV display control, RNDZ\_NAV\_ENA). This subfunction is invoked by the Sequencing Operations and Major Mode Transitions subfunction (Section 4.1.1 ONORBIT\_REND\_NAV\_SEQUENCER).

A. Detailed Requirements. When called, this subfunction shall first set the unmodeled acceleration biases to zero. These bias terms were solved for by the rendezvous navigation filter and need to be set to zero for nonrendezvous navigation phases.

$$\overline{\text{UNMOD\_ACC\_BIAS}} = \overline{0}.$$

The Display Parameters Initialization subfunction shall now be executed to zero the ACCEPT/REJECT counters for display and measurement processing requirements:

CALL: DISPLAY\_COUNT\_INIT

Detailed requirements for the above subfunction are stated in Section 4.1.2.2.1.2.

The “last” flag is turned OFF to indicate the rendezvous navigation is no longer active.

REND\_NAV\_FLAG\_LAST = OFF

The positive feedback flag for the Rel Nav Display is set to OFF to indicate that rendezvous navigation is no longer active.

DOING\_REND\_NAV = OFF

Rendezvous filter measurement controls are re-initialized.

(a) AUTO/INHIBIT/FORCE crew command flags are inhibited.

ANGLES\_AIF = INHIBIT  
RANGE\_AIF = INHIBIT  
RDOT\_AIF = INHIBIT

(b) Display feedback flags associated with the crew command flags are also inhibited.

ANGLES\_AIF\_DISPLAY = INHIBIT  
RANGE\_AIF\_DISPLAY = INHIBIT  
RDOT\_AIF\_DISPLAY = INHIBIT

B. Interface Requirements. Input and output parameters for this subfunction may be found in Table 4.1.1.1.

C. Processing Requirements. This subfunction shall be called by the sequencing operations and major mode transitions subfunction (ONORBIT\_REND\_NAV\_SEQUENCER) when it is required to transition from rendezvous to onorbit navigation phases during OPS 2.

D. Constraints. None

E. Supplemental Information. A suggested implementation of this subfunction may be found in Section 5.2 flow diagrams:

REND\_NAV\_EXIT

Table 4.1.1.1.REND_NAV_EXIT Input/Output		
Variable Name	Input Source	Output Destination
ANGLES_AIF		*
ANGLES_AIF_DISPLAY		*
DOING_REND_NAV		*
RANGE_AIF		*
RANGE_AIF_DISPLAY		*
RDOT_AIF		*
RDOT_AIF_DISPLAY		*
REND_NAV_FLAG_LAST		ONORBIT_REND_NAV_SEQUENCER
UNMOD_ACC_BIAS		*
* See principal function input/output tables for the Onorbit/Rendezvous Navigation Sequencer (Tables 4.1.3-1 and 4.1.3-2).		

**4.1.1.2 Operation Sequencer Termination (NAV\_EXIT)**

Specific actions are required by the onboard navigation software when either the OPS 2 or OPS 8 operational sequence is terminated in preparation for transition to another OPS sequence. These actions are primarily concerned with protecting special memory locations to preserve data required for the next OPS sequence.

A. Detailed Requirements. The Operations Sequence Termination subfunction shall provide the capability to save off (in protected memory locations) certain navigation-related data sets for transmission across a memory transition from one operational sequence to another and, once the data has been saved, terminate the Onorbit/Rendezvous Navigation principal function. This subfunction shall perform these functions for the termination of OPS 2 and OPS 8 as follows:

1. If OPS 2 or OPS 8 is being terminated for a transition to either OPS 8 (from OPS 2, Event 60B), or to OPS 2 (from OPS 8, Event 60A), or to OPS 00 (from OPS 2, Event 83) the current orbiter mass must be saved prior to termination:

$$\text{MASS\_INIT} = \text{CURR\_ORB\_MASS}$$

2. In all cases where OPS 2 or OPS 8 is terminated, the following parameters shall be saved prior to termination:

$$\bar{R}_{\_FILT\_INIT} = \bar{R}_{\_FILT}$$

$$\bar{V}_{\_FILT\_INIT} = \bar{V}_{\_FILT}$$

$$T_{\_FILT\_INIT} = T_{\_LAST\_FILT}$$

Although the variable names with the `_INIT` have been designated as unique variables, this may not be required if the same physical core location can be used for  `$\bar{R}_{\_FILT}$`  (for example) in each memory load. The `_INIT` notation has been used for visibility purposes only. The IMU acceleration threshold `IMU_NAV_ACCEL_THRESH` is also preserved during OPS transitions.

3. A flag is set to cue the onorbit predictor to terminate any prediction task in progress.

$$PRED\_ENA\_FLAG = OFF$$

4. During OPS 2 and OPS 8 once the above data have been stored, execution of the Onorbit/Rendezvous Navigation principal function shall be canceled.

$$CANCEL: NAV\_ONORBIT\_RENDEZVOUS$$

B. Interface Requirements. Input and output requirements for this subfunction are defined in Table 4.1.1.2.

C. Processing Requirements. This subfunction is called by the following subfunction:

$$ONORBIT\_REND\_NAV\_SEQUENCER \text{ (Section 4.1.1)}$$

D. Constraints. None

E. Suggested Implementation. A suggested implementation in the form of a detailed flow chart may be found in Section 5.2 under the name `NAV_EXIT`.

Table 4.1.1.2. NAV_EXIT Input/Output		
Variable Name	Input Source	Output Destination
EVENT_60B	*,**	
EVENT_60A	*,**	
EVENT_83	*,**	
CURR_ORB_MASS	*	
$\bar{R}_{\_FILT}$	*, OPS_2_OR_8_INITIALIZE	
$\bar{V}_{\_FILT}$	*, OPS_2_OR_8_INITIALIZE	
T_LAST_FILT	*, OPS_2_OR_8_INITIALIZE	

Table 4.1.1.2. NAV_EXIT Input/Output		
Variable Name	Input Source	Output Destination
MASS_INIT		*
$\bar{R}$ _FILT_INIT		*
$\bar{V}$ _FILT_INIT		*
T_FILT_INIT		*
PRED_ENA_FLAG		*, STATE_VECTOR_PREDICT_TASK
<p>* See principal function I/O table for ONORBIT_REND_NAV_SEQUENCER (Table 4.1.3-1).  ** See initialization parameters, Section 4.7.</p>		

#### 4.1.2 Operation Sequence Initialization (OPS\_2\_OR\_8\_INITIALIZE)

The purpose of the Operation Sequence Initialization subfunction is to perform specific functions required when either operations sequence 2 (OPS 2) or 8 (OPS 8) is entered from another OPS sequence (i.e., OPS 1, OPS 3, OPS 00, OPS 2, or OPS 8).

##### A. Detailed Requirements.

1. The IMU data snap task shall provide the capability to obtain the selected sensed accumulated velocity and the GMT time tag associated with these data (Section 4.2.2.1). The IMU data is obtained as indicated by the following:

SNAP IMU\_DATA ( $\bar{V}$ \_CURRENT\_FILT, T\_CURRENT\_FILT)

The selected accumulated velocity is obtained from IMU RM and shall be that sensed at the orbiter center-of-mass. They shall be expressed in M50 coordinates.

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

$$\bar{V}_{LAST\_FILT} = \bar{V}_{CURRENT\_FILT}$$

$$T_{LAST\_FILT} = T_{CURRENT\_FILT}$$

2. Initialize the unmodeled acceleration biases solved for in the filter to zero. These bias terms are solved for by the rendezvous navigation filter and need to be zeroed for nonrendezvous navigation phases:

$$\bar{U}_{NMOD\_ACC\_BIAS} = \bar{0}.$$

Compute the square root of MU of the Earth for the precise predictor and precision state propagation:

$$SQR\_EMU = SQRT(EARTH\_MU)$$

3. Initialize the flag to enable use of the onorbit predictor for OPS 2 or OPS 8.

PRED\_ENA\_FLAG = ON

4. Set up the proper parameters to predict the stored orbiter state vector to current time (refer to Section 4.3 for predictor requirements; the following are unique COMPOOL locations for use by the predictor):

PRED\_ORB\_AREA = REF\_ORB\_AREA

PRED\_ORB\_MASS = NAV\_CURR\_ORB\_MASS

PRED\_ORB\_CD = REF\_ORB\_CD

GMDP = GM\_DEG

GMOP = GM\_ORD

DMP = DFL

VMP = VFLOV\_PRED

ATMP = 1

PRED\_STEP = PRED\_STEP\_OPS\_INIT

T\_PRED\_INIT = T\_FILT\_INIT

$\bar{R}$ \_PRED\_INIT =  $\bar{R}$ \_FILT\_INIT

$\bar{V}$ \_PRED\_INIT =  $\bar{V}$ \_FILT\_INIT

T\_PRED\_FINAL = T\_LAST\_FILT

5. Test the prediction time interval to determine if an OPS 0 to OPS 2 transition is in progress.
  - a. If  $|T\_PRED\_FINAL - T\_PRED\_INIT| > DT\_LIM$ , set the orbiter position and velocity to a premission hard-coded state vector rather than calling the predictor.

$\bar{R}$ \_FILT =  $\bar{R}$ \_TEMP

$\bar{V}$ \_FILT =  $\bar{V}$ \_TEMP

The parameter DT\_LIM is a K-load. (Although this operation will not result in an accurate orbiter state vector, it will allow the OPS 0 to OPS 2 transition to complete so that a state vector uplink can be made in OPS 2 to reinitialize the orbiter with a valid state vector.)

The time of the last GPS update is set equal to the last filter state time.

T\_GPS\_LAST\_UPDATE = T\_LAST\_FILT

Set the parameter GPS\_REF\_INIT\_VALID to OFF, indicating that the final predictor states were set to pre-mission hard-coded states. This prevents the GPS



Reference State Processing Principal Function from sending the pre-mission hard-coded state vector to a receiver if an announced reset is scheduled, or an initialization or filter restart of a receiver is commended, before a state vector uplink occurs.

GPS\_REF\_INIT\_VALID = OFF

- b. If  $|T\_PRED\_FINAL - T\_PRED\_INIT| \leq DT\_LIM$ ,  
call the Onorbit Precise Prediction principal function

CALL: ONORBIT\_PREDICT

Then reset the following onorbit navigation parameters:

$$\bar{R}\_FILT = \bar{R}\_PRED\_FINAL$$

$$\bar{V}\_FILT = \bar{V}\_PRED\_FINAL$$

6. Initialize those parameters required by the User Parameter State Propagation subfunction (Section 4.5.1) and GPS processing for the Orbiter vehicle only.

The reset state and time tag will be initialized to the filter state and time tag, and the reset IMU velocity counts will be set to the current IMU velocity counts.

$$\begin{aligned}\bar{R}\_RESET &= \bar{R}\_FILT \\ \bar{V}\_RESET &= \bar{V}\_FILT \\ T\_RESET &= T\_LAST\_FILT \\ \bar{V}\_IMU\_RESET &= \bar{V}\_LAST\_FILT\end{aligned}$$

The GPS reference state processing subfunction will be initialized with the reset orbiter states and associated data (i.e.  $\bar{R}\_RESET$ ,  $\bar{V}\_RESET$ , AND  $T\_RESET$ ) described above.

$$\begin{aligned}\bar{R}\_GPS\_INIT &= \bar{R}\_RESET \\ \bar{V}\_GPS\_INIT &= \bar{V}\_RESET \\ T\_GPS\_INIT &= T\_RESET\end{aligned}$$

A call is then made to the ACCEL\_ONORBIT function to obtain the gravity acceleration vector consistent with the GPS reference state processing principal function initialization states:

$$\bar{G}\_GPS\_INIT = ACCEL\_ONORBIT(GMDP, GMOP, DMP, VMP, ATMP, \bar{R}\_FILT, \bar{V}\_FILT, T\_LAST\_FILT)$$

For the three string GPS system, the current selected IMU accumulated velocities will be used to initialize the velocity counts for subsequent propagation of the GPS reference state. The initialization data for the GPS reference state processing principal function are initialized as follows:

$$\bar{V}\_IMU\_GPS\_INIT = \bar{V}\_CURRENT\_FILT$$

7. The flag which indicates that a GPS state has been selected by the GPS receiver state processing principal function in this operational sequence is initialized to OFF:

GPS\_SV\_SEL\_AVAIL = OFF

The data good indicators assigned to the previously selected GPS state are initialized to off at the OPS transition:

GPS\_DG\_SF\_PREV<sub>1</sub> = OFF

GPS\_DG\_SF\_PREV<sub>2</sub> = OFF

GPS\_DG\_SF\_PREV<sub>3</sub> = OFF

8. The time which indicates when a selected GPS state was last made available by the GPS receiver state processing principal function in this OPS sequence is initialized to the last filter state time at the OPS transition. This prevents the alarm, which indicates that the time since the last GPS state was selected by the GPS receiver state processing principal function has exceeded the pre-mission I-load constraint, from being issued at the OPS transition:

T\_GPS\_OFF = T\_LAST\_FILT

9. The value of the GPS lockout I-load parameter, GPS\_LOCKOUT, is then checked to determine if the flag to inhibit GPS GAX messages (NOOP\_GPS\_GAX\_MSGS) is to be set:

IF GPS\_LOCKOUT < 2 THEN  
NOOP\_GPS\_GAX\_MSGS = ON

Note that NOOP\_GPS\_GAX\_MSGS is set to OFF at OPS 2 transition so no explicit OFF assignment is necessary.

10. A flag indicating the use of the maneuvering flight state propagation algorithm is initialized to "ON." This flag can be turned off by the crew via CRT input.

PWRD\_FLT\_NAV = ON

11. Signal that the proper initialization has been accomplished to allow the Onorbit/Rendezvous User Parameter Processing Sequencer principal function to begin scheduling.

SET: OPS\_2\_OR\_8\_INITIALIZE COMPLETE = ON

12. Set the flag to indicate to the User Parameter State Propagation subfunction that a navigated state vector update has occurred.

FILT\_UPDATE = ON

B. Interface Requirements. The input and output requirements for this subfunction are described in Table 4.1.2.

C. Processing Requirements. This subfunction is called by the sequencing operations and major mode transitions subfunction, Section 4.1.1; ONORBIT\_REND\_NAV\_SEQUENCER.

D. Constraints. None

E. Supplemental Information. A suggested implementation of this module can be found in Section 5.2; OPS\_2\_OR\_8\_INITIALIZE.

T\_GPS\_LAST\_UPDATE shall be protected and carried across all GN&C OPS transitions.

GPS\_REF\_INIT\_VALID shall be initialized to “ON”, and shall be protected and carried across all GN&C OPS transitions.

Table 4.1.2. OPS_2_OR_8_INITIALIZE Input/Output		
Variable Name	Input Source	Output Destination
$\bar{V}$ _CURRENT_FILT	IMU DATA SNAP	*
T_CURRENT_FILT	IMU DATA SNAP	*
$\bar{V}$ _LAST_FILT		*
T_LAST_FILT		*
EARTH_MU	**	
SQR_EMU		*
REF_ORB_AREA	**	
REF_ORB_CD	**	
NAV_CURR_ORB_MASS	ONORBIT_REND_ NAV_SEQUENCER	*
GM_DEG	**	
GM_ORD	**	
DFL	**	
VFLOV_PRED	**	
PRED_STEP_OPS_INIT	**	
$\bar{R}$ _FILT_INIT	*,**	
$\bar{V}$ _FILT_INIT	*,**	
T_FILT_INIT	*,**	
$\bar{R}$ _FILT		*
$\bar{V}$ _FILT		*
T_PRED_INIT		*
FILT_UPDATE		*
GMDP		*
GMOP		*
DMP		*
VMP		*
ATMP		*
PRED_STEP		*
$\bar{R}$ _PRED_INIT		*
$\bar{V}$ _PRED_INIT		*
PWRD_FLT_NAV		*, ONORBIT_REND_NAV_ SEQUENCER
OPS_2_OR_8_INITIALIZE_COMPLETE		*

Table 4.1.2. OPS_2_OR_8_INITIALIZE Input/Output		
Variable Name	Input Source	Output Destination
$\bar{R}$ _PRED_FINAL	*	
$\bar{V}$ _PRED_FINAL	*	
$\bar{U}$ NMOD_ACC_BIAS		*
PRED_ORB_AREA		*
PRED_ORB_CD		*
PRED_ORB_MASS		*
T_PRED_FINAL		*
PRED_ENA_FLAG		STATE_VECTOR_PREDICT_TASK, *
$\bar{R}$ _TEMP	**	
$\bar{V}$ _TEMP	**	
DT_LIM	**	
GPS_DG_SF_PREV		*
GPS_LOCKOUT	**	
GPS_REF_INIT_VALID		SHUTTLE_RESET,*
GPS_SV_SEL_AVAIL		*
NOOP_GPS_GAX_MSGS		*
R_GPS_INIT		*
T_GPS_INIT		*
T_GPS_LAST_UPDATE		*
T_GPS_OFF		*
V_GPS_INIT		*
V_IMU_GPS_INIT		*

\* See principal function input/output tables for the Onorbit/Rendezvous Navigation Sequencer (Table 4.1.3-1).  
\*\* Initialization parameters, see Section 4.7.

4.1.2.1 Deleted

#### 4.1.2.2 Rendezvous Navigation Initialization (REND\_NAV\_INIT)

The Rendezvous Navigation Initialization subfunction is responsible for the proper initialization of selected rendezvous-related parameters whenever the Onorbit/Rendezvous Navigation Sequencer principal function has detected the following:

- (a) There is a request to initialize the rendezvous navigation phase, or
- (b) The prediction of the target vehicle has been initiated by the rendezvous navigation initialization subfunction but the prediction has not been completed.

This subfunction shall be responsible for the following tasks.

- Schedule the state vector prediction task in order to predict the target position and velocity vectors to current time.
- Set selected flags to OFF to insure the proper functioning of the Onorbit/Rendezvous Navigation principal function should the rendezvous navigation phase be canceled and then reentered.
- Set certain parameters for the unmodeled acceleration bias propagation to values used for coasting flight.
- Initialize the covariance matrix.
- Store the current target position and velocity vectors for use by the User Parameter Processing principal function.
- Initialize the backup state vector.

A. Detailed Requirements. This subfunction shall perform the following steps in the order indicated:

1. The prediction task indicator flag, PRED\_USE, is interrogated for a zero value to determine if the state vector prediction task is available for scheduling. If PRED\_USE = 0 then the following parameters are defined preceding the scheduling of the state vector prediction task.

```
REND_NAV_INIT_PRED = ON
PRED_USE = 4
TV_PREDICT_FAIL = OFF
GMDP = GM_DEG
GMOP = GM_ORD
DMP = DFL
VMP = VFLTV_PRED
ATMP = ATEL_TV
PRED_STEP = PREC_STEP_PRED
 $\bar{R}$ _PRED_INIT =  $\bar{R}$ _TV
 $\bar{V}$ _PRED_INIT =  $\bar{V}$ _TV
T_PRED_INIT = T_TV
```

The state vector prediction task is then scheduled.

SCHEDULE: STATE\_VECTOR\_PREDICT\_TASK

2. If the PRED\_USE flag is nonzero, it is tested for a value of 6, which indicates that the state vector prediction task has determined that the prediction interval is too large or an event to leave OPS 2 has been initiated; hence no prediction will take place.

If PRED\_USE = 6, then the following flags are set:

PRED\_USE = 0  
TV\_PREDICT\_FAIL = ON  
REND\_NAV\_INIT\_PRED = OFF  
REND\_NAV\_FLAG = OFF

The rendezvous navigation flag is set to OFF so that the rendezvous navigation initialization subfunction will not be invoked again until the REND\_NAV\_FLAG is reset to ON by the crew.

3. If the PRED\_USE flag is not set to 6, then it is tested for a value of 5 which indicates that the state vector prediction task has successfully predicted the target state vectors.

If PRED\_USE = 5 then the following actions are taken.

- (a) The predictor outputs are stored, and flags are set to free the predictor for other navigation users.

PRED\_USE = 0  
 $T_{TV} = T_{PRED\_FINAL}$   
 $R_{TV} = R_{PRED\_FINAL}$   
 $V_{TV} = V_{PRED\_FINAL}$   
REND\_NAV\_INIT\_PRED = OFF

- (b) Next, the REND\_NAV\_FLAG is tested for an ON value to determine if the crew request for activating the rendezvous navigation phase is still valid. If the REND\_NAV\_FLAG is on, the following actions are taken:

- (1) Flags are set to indicate that the unmodeled acceleration bias state statistics are to be initialized to their coast values.

NOISY\_NAV\_MEAS = OFF  
COV\_PWRD\_FLT = OFF  
COV\_PWRD\_FLT\_LAST = OFF

- (2) Unmodeled acceleration bias state statistical parameters are initialized to their coast values.

$TAU_{UNMOD\_ACC\_COV} = TAU_{U\_A\_COAST}$   
 $\overline{VAR}_{UNMOD\_ACC} = \overline{VAR}_{U\_A\_COAST}$   
 $\overline{COV}_{ACCEL\_UVW\_INIT} = \overline{COV}_{U\_A\_COAST}$

- (3) The rendezvous covariance initialization function is called to initialize the covariance matrix as described in Section 4.1.2.2.1.

CALL: REND\_COV\_INIT

- (4) The target state vector reset subfunction resets the user parameter processing state vectors as described in Section 4.1.2.2.2.

CALL: TARGET\_RESET

- (5) The flag is set to indicate that the backup propagated state vector (not the filtered state vector) is to be sent to user parameter processing.

SV\_SOURCE\_FOR\_UPP = PROP \*

\* In the event that NAV\_SV\_SOURCE\_FOR\_UPP is implemented as a discrete instead of as a character string, the following conventions should be followed:

PROP = 0

FILT = 1

- (6) The backup propagated state vector is initialized based on the setting of SHUTTLE\_FILTER\_FLAG. If SHUTTLE\_FILTER\_FLAG = ON, then initialize with the Shuttle state vector.

$$\begin{aligned}\bar{R}_{PROP} &= \bar{R}_{FILT} \\ \bar{V}_{PROP} &= \bar{V}_{FILT}\end{aligned}$$

If SHUTTLE\_FILTER\_FLAG = OFF, then initialize with the target state vector.

$$\begin{aligned}\bar{R}_{PROP} &= \bar{R}_{TV} \\ \bar{V}_{PROP} &= \bar{V}_{TV}\end{aligned}$$

- (7) The flags REND\_NAV\_FLAG\_LAST and DOING\_REND\_NAV are set to ON to indicate that the rendezvous navigation phase is now active.

REND\_NAV\_FLAG\_LAST = ON

DOING\_REND\_NAV = ON

- (8) Rendezvous filter measurement controls are initialized.

- (a) AUTO/INHIBIT/FORCE crew command flags are inhibited.

ANGLES\_AIF = INHIBIT

RANGE\_AIF = INHIBIT

RDOT\_AIF = INHIBIT

- (b) Display feedback flags associated with the crew command flags are also inhibited.

ANGLES\_AIF\_DISPLAY = INHIBIT

RANGE\_AIF\_DISPLAY = INHIBIT

RDOT\_AIF\_DISPLAY = INHIBIT

B. Interface Requirements. Input and output parameters are specified in Table 4.1.2.2.

C. Processing Requirements. The subfunction is called by ONORBIT\_REND\_NAV\_SEQUENCER (Section 4.1.1).

D. Constraints. None

E. Supplemental Information. A suggested implementation of these requirements is illustrated in Section 5.2 with REND\_NAV\_INIT.

Table 4.1.2.2. REND_NAV_INIT Input/Output		
Variable Name	Input Source	Output Destination
ANGLES_AIF		*
ANGLES_AIF_DISPLAY		*
ATFL_TV	**	
ATMP		*
$\bar{C}OV\_ACCEL\_UVW\_INIT$		U_A_BIAS_AND_COVINIT,*
COV_PWRD_FLT		*
COV_PWRD_FLT_LAST		*
$\bar{C}OV\_U\_A\_COAST$	**	
DFL	**	
DMP		*
DOING_REND_NAV		*
GM_DEG	**	
GMDP		*
GMOP		*
GM_ORD	**	
NOISY_NAV_MEAS		*
PREC_STEP_PRED	**	
PRED_STEP		*
PRED_USE	**,* STATE_VECTOR_ PREDICT_TASK	*, STATE_VECTOR_PREDICT_TASK
RANGE_AIF		*
RANGE_AIF_DISPLAY		*
RDOT_AIF		*
RDOT_AIF_DISPLAY		*
$\bar{R}\_PRED\_FINAL$	*	
$\bar{R}\_PRED\_INIT$		*
$\bar{R}\_FILT$	*	
$\bar{R}\_PROP$		*



Table 4.1.2.2. REND\_NAV\_INIT Input/Output

Variable Name	Input Source	Output Destination
$\bar{R}_{TV}$	**, *	*, REND_COV_INIT, TARGET_RESET, COV_LAST_RESET
REND_NAV_FLAG	*	*, ONORBIT_REND_NAV_SEQUENCER
REND_NAV_FLAG_LAST		ONORBIT_REND_NAV_SEQUENCER
REND_NAV_INIT_PRED		ONORBIT_REND_NAV_SEQUENCER
SHUTTLE_FILTER_FLAG	*	
SV_SOURCE_FOR_UPP		*
TAU_U_A_COAST	**	
TAU_UNMOD_ACC_COV		*
T_PRED_INIT		*, STATE_VECTOR_PREDICT_TASK
T_PRED_FINAL	STATE_VECTOR_PREDICT_TASK	
T_TV	**, *	*, REND_COV_INIT
TV_PREDICT_FAIL		*
$\bar{V}_{U\_A\_COAST}$	**	
$\bar{V}_{UNMOD\_ACC}$		*
$\bar{V}_{FILT}$	*	
VFLTV_PRED	**	
VMP		*
$\bar{V}_{PRED\_FINAL}$	*	
$\bar{V}_{PRED\_INIT}$		*
$\bar{V}_{PROP}$		*
$\bar{V}_{TV}$	*, **	*, REND_COV_INIT, TARGET_RESET, COV_LAST_RESET

\* Onorbit/Rendezvous Navigation Sequencer principal function, see Table 4.1.3-1/Table 4.1.3-2.  
\*\* Initialization parameters, see Section 4.7.

**4.1.2.2.1 Covariance Matrix Initialization (REND\_COV\_INIT)**

The Covariance Matrix Initialization subfunction shall perform the following tasks upon entering the rendezvous phase, whenever there is an automatic inflight update during the rendezvous phase, or whenever the crew requests a covariance matrix reinitialization or a state vector transfer.

1. Initialize the covariance matrix.
2. Zero the counter (I\_CYCLE) for the asynchronous covariance propagation.
3. Set certain flags to OFF so that the rendezvous sensor initialization subfunction will properly execute.
4. Zero measurement Accept/Reject counters used for display purposes.

A. Detailed Requirements. In circumstances in which the filter vehicle position and velocity elements of the on-board filter covariance matrix are to be initialized to UVW values, the following steps shall be performed (in the order indicated):

1. Zero the entire 13 by 13 dimensional covariance matrix

$$E_{1\text{ to }13, 1\text{ to }13} = 0.0$$

2. Test the SHUTTLE\_FILTER\_FLAG to determine if the Shuttle vehicle or the target vehicle state is being used by the Kalman filter.

- a. If the Shuttle vehicle is the filter vehicle

$$(\text{SHUTTLE\_FILTER\_FLAG} = \text{ON})$$

- (1) Call the UVW parameters initialization subfunction to initialize the position-velocity portion of the covariance matrix with the Shuttle state vector statistics (see Section 4.1.2.2.1.1)

$$\begin{aligned} \text{CALL: COVINIT\_UVW} \\ \text{IN LIST: } \bar{R}\_FILT, \bar{V}\_FILT \end{aligned}$$

- (2) Calculate the last acceleration vector for the Shuttle vehicle for use in the covariance matrix propagation subfunction.

$$\bar{TOT\_ACC\_LAST} = \bar{ACCEL\_ONORBIT}(\text{IGD}, \text{IGO}, \text{IDRAG}, \text{IVENT}, \text{ATFL\_OV}, \bar{R}\_FILT, \bar{V}\_FILT, \text{T\_LAST\_FILT})$$

$$+ \frac{\bar{DV}\_FILT}{DT\_FILT}$$

F3

F3 This equation shall be protected against division by zero (reference 3.5).

where IGD is the degree of the gravitational potential model, IGO is the order of the gravitational potential model, IDRAG is the drag model flag, IVENT is the vent model flag, all set by the state propagation, and ATFL\_OV is from I-load.

(For detailed requirements, see Section 4.2.4.1.1)

- b. If the target vehicle is the filter vehicle

(SHUTTLE\_FILTER\_FLAG = OFF)

- (1) Call the UVW parameters initialization subfunction to initialize the position–velocity portion of the covariance matrix with the target state vector statistics (see Section 4.1.2.2.1.1)

CALL: COVINIT\_UVW

IN LIST:  $\bar{R}_{TV}$ ,  $\bar{V}_{TV}$

- (2) Calculate the last acceleration vector for the target vehicle for use in the covariance matrix propagation subfunction,

$\bar{G}_{TV\_LAST} = \bar{ACCEL\_ONORBIT}(GM\_DEG, GM\_ORD, DFL, VFL\_TV,$   
 $ATFL\_TV, \bar{R}_{TV}, \bar{V}_{TV}, T\_TV)$

where GM\_DEG is the degree of the gravitational potential model, GM\_ORD is the order of the gravitational potential model, DFL is the drag model flag, VFL\_TV is the vent model flag, and ATFL\_TV is the attitude flag, all for the target vehicle.

(For detailed requirements, see Section 4.2.4.1.1)

3. The covariance matrix propagation cycle counter shall be reset

I\_CYCLE = 0

4. The covariance reset subfunction is called to store copies of the Shuttle state vector, the target state vector and their time tag, as well as to zero the covariance accumulated delta velocity.

CALL: COV\_LAST\_RESET

5. Reset the DO\_NAV\_LAST flags for all sensors so that the sensor bias portions of the covariance matrix will be reconfigured for active sensors

EXECUTE: DO\_NAV\_LAST\_SETUP CODE

DO\_COAS\_ANGLES\_NAV\_LAST = OFF

DO\_RR\_ANGLES\_NAV\_LAST = OFF

DO\_RRDOT\_NAV\_LAST = OFF

DO\_ST\_ANGLES\_NAV\_LAST = OFF

6. Reset the measurement ACCEPT/REJECT counters

(Refer to Section 4.1.2.2.1.2)

CALL: DISPLAY\_COUNT\_INIT

B. Interface Requirements. The input and output variables for this subfunction are defined in Table 4.1.2.2.1.

C. Processing Requirements. This subfunction is called by the following subfunctions:

ONORBIT\_REND\_AUTO\_INFLIGHT\_UPDATE (Section 4.2.3.1)

REL\_NAV\_DISPLAY\_UPDATES (Section 4.2.3.2)

REND\_NAV\_INIT (Section 4.1.2.2)

D. Constraints. None

E. Supplementary Information: A suggested implementation in the form of a detailed flow chart can be found in Section 5.2 under the name:

REND\_COV\_INIT

Table 4.1.2.2.1. REND_COV_INIT Input/Output		
Variable Name	Input Source	Output Destination
ATFL_OV	**	$\overline{\text{ACCEL\_ONORBIT}}$
ATFL_TV	**	$\overline{\text{ACCEL\_ONORBIT}}$
DFL	**	$\overline{\text{ACCEL\_ONORBIT}}$
DT_FILT	ONORBIT_REND_R_V_STATE_PROP, ***	
$\overline{\text{DV\_FILT}}$	ONORBIT_REND_R_V_STATE_PROP, ***	
GM_DEG	**	$\overline{\text{ACCEL\_ONORBIT}}$
GM_ORD	**	$\overline{\text{ACCEL\_ONORBIT}}$
IDRAG	ONORBIT_REND_R_V_STATE_PROP, ***	$\overline{\text{ACCEL\_ONORBIT}}$
IGD	ONORBIT_REND_R_V_STATE_PROP, ***	$\overline{\text{ACCEL\_ONORBIT}}$
IGO	ONORBIT_REND_R_V_STATE_PROP, ***	$\overline{\text{ACCEL\_ONORBIT}}$
IVENT	ONORBIT_REND_R_V_STATE_PROP, ***	$\overline{\text{ACCEL\_ONORBIT}}$
$\overline{\text{R\_FILT}}$	ONORBIT_REND_AUTO_INFLIGHT_ UPDATE, ONORBIT_REND_R_V_ STATE_PROP, REL_NAV_DISPLAY_ UPDATES, ***, REND_NAV_FILTER,*	$\overline{\text{ACCEL\_ONORBIT}}$ , COVINIT_UVW
$\overline{\text{R\_TV}}$	ONORBIT_REND_AUTO_INFLIGHT_ UPDATE, REND_NAV_INIT, ONORBIT_REND_R_V_STATE_PROP, REL_NAV_DISPLAY_UPDATES, REND_ NAV_FILTER,*	$\overline{\text{ACCEL\_ONORBIT}}$ , COVINIT_UVW
SHUTTLE_FILTER_FLAG	***	
T_LAST_FILT	ONORBIT_REND_AUTO_INFLIGHT_ UPDATE, ONORBIT_REND_R_V_ STATE_PROP, ***	
$\overline{\text{V\_FILT}}$	ONORBIT_REND_R_V_STATE_PROP, ONORBIT_REND_AUTO_INFLIGHT_ UPDATE, REL_NAV_DISPLAY_ UPDATES, ***, REND_NAV_FILTER,*	$\overline{\text{ACCEL\_ONORBIT}}$ , COVINIT_UVW
VFL_TV	**	$\overline{\text{ACCEL\_ONORBIT}}$
$\overline{\text{V\_TV}}$	ONORBIT_REND_R_V_STATE_PROP, REND_NAV_INIT, ONORBIT_REND_ AUTO_INFLIGHT_UPDATE, REL_NAV_ DISPLAY_UPDATES, REND_NAV_ FILTER,*	ACCEL_ONORBIT, COVINIT_UVW
†	ACCEL_ONORBIT	

Table 4.1.2.2.1. REND_COV_INIT Input/Output		
Variable Name	Input Source	Output Destination
DO_COAS_ANGLES_ NAV_LAST		REND_NAV_SENSOR_INIT, ***
DO_RR_ANGLES_NAV_ LAST		REND_NAV_SENSOR_INIT, ***
DO_RRDOT_NAV_LAST		REND_NAV_SENSOR_INIT, ***
DO_ST_ANGLES_ NAV_LAST		REND_NAV_SENSOR_INIT, ***
E		REND_BIAS_AND_COV_ PROP, REND_NAV_FILTER, COV_LAST_RESET, *, ***
$\bar{G}$ _TV_LAST		REND_BIAS_AND_COV_PROP , ***
I_CYCLE		NAV_ONORBIT_ RENDEZVOUS, ***,*
$\bar{T}$ TOT_ACC_LAST		REND_BIAS_AND_COV_PROP , ***
T_TV	ONORBIT_REND_R_V_STATE_PROP, ONORBIT_REND_AUTO_INFLIGHT_ UPDATE, REND_NAV_INIT,*	$\bar{A}$ CCEL_ONORBIT
†	Value returned from the function.	
*	Onorbit/Rendezvous principal function, see Table 4.2.11-1.	
**	Initialization parameters, see Section 4.7.	
***	Onorbit/Rendezvous Navigation Sequencer principal function, see Table 4.1.3-1.	

#### 4.1.2.2.1.1 UVW Parameters Initialization (COVINIT\_UVW)

The UVW Parameters Initialization subfunction initializes the covariance matrix when rendezvous navigation is initialized, or when an auto-flight update or REL\_NAV display update to the state vectors or covariance matrix is performed.

A. Detailed Requirements. This subfunction has an inlist with the following internal names

$$\text{INLIST: } \bar{\mathbf{R}}, \bar{\mathbf{V}}$$

where  $\bar{\mathbf{R}}$  is the filter vehicle position vector and  $\bar{\mathbf{V}}$  is the filter vehicle velocity vector.

This subfunction performs the following steps.

1. Initialize the first six diagonal elements of the covariance with the square of prestored standard deviations.

$$E_{I,I} = \text{SIG\_UPDATE}_I \text{ SIG\_UPDATE}_I \text{ for } I = 1 \text{ to } 6$$

2. Initialize the off-diagonal correlation terms of the covariance matrix in the upper left 6 by 6 portion using prestored correlation coefficients along with the prestored sigmas.

$$\begin{aligned} E_{1,2} &= \text{COV\_COR\_UPDATE}_1 \text{ SIG\_UPDATE}_1 \text{ SIG\_UPDATE}_2 \\ E_{1,4} &= \text{COV\_COR\_UPDATE}_2 \text{ SIG\_UPDATE}_1 \text{ SIG\_UPDATE}_4 \\ E_{1,5} &= \text{COV\_COR\_UPDATE}_3 \text{ SIG\_UPDATE}_1 \text{ SIG\_UPDATE}_5 \\ E_{2,4} &= \text{COV\_COR\_UPDATE}_4 \text{ SIG\_UPDATE}_2 \text{ SIG\_UPDATE}_4 \\ E_{2,5} &= \text{COV\_COR\_UPDATE}_5 \text{ SIG\_UPDATE}_2 \text{ SIG\_UPDATE}_5 \\ E_{3,6} &= \text{COV\_COR\_UPDATE}_6 \text{ SIG\_UPDATE}_3 \text{ SIG\_UPDATE}_6 \\ E_{4,5} &= \text{COV\_COR\_UPDATE}_7 \text{ SIG\_UPDATE}_4 \text{ SIG\_UPDATE}_5 \\ E_{2,1} &= E_{1,2} \\ E_{5,4} &= E_{4,5} \end{aligned}$$

3. Call the unmodeled acceleration bias and covariance initialization subfunction (Section 4.2.5.1) to initialize the unmodeled acceleration bias states and the unmodeled acceleration bias slots of the covariance matrix.

CALL: U\_A\_BIAS\_AND\_COVINIT

$$\text{INLIST: } \bar{\mathbf{R}}, \bar{\mathbf{V}}$$

4. Convert the upper left 6 by 6 portion of the covariance matrix from UVW to mean of '50 coordinates with the following equations:

$$E_{1to3, 1to3} = \mathbf{M\_UVW\_M50} E_{1to3, 1to3} \mathbf{M\_UVW\_M50}^T$$

$$E_{4to6, 4to6} = \mathbf{M\_UVW\_M50} E_{4to6, 4to6} \mathbf{M\_UVW\_M50}^T$$

$$E_{1to3, 4to6} = \mathbf{M\_UVW\_M50} E_{1to3, 4to6} \mathbf{M\_UVW\_M50}^T$$

$$E_{4to6, 1to3} = (E_{1to3, 4to6})^T$$

where the M\_UVW\_M50 transformation matrix was computed by U\_A\_BIAS\_AND\_COVINIT.

B. Interface Requirements. The inputs and outputs for this subfunction are given in Table 4.1.2.2.1.1.

C. Processing Requirements. This subfunction is called by

REND\_COV\_INIT (Section 4.1.2.2.1)

D. Constraints. None

E. Supplementary Information. A suggested implementation of this subfunction is given by the flow chart COVINIT\_UVW in Section 5.2.

Table 4.1.2.2.1.1. COVINIT_UVW Input/Output			
Inlist/Outlist			
Internal Name	External Name	Input Source	Output Destination
$\bar{R}$	$\bar{R}_{FILT}$	REND_COV_INIT	
$\bar{V}$	$\bar{V}_{FILT}$	REND_COV_INIT	
$\bar{R}$	$\bar{R}_{TV}$	REND_COV_INIT	
$\bar{V}$	$\bar{V}_{TV}$	REND_COV_INIT	
Variable Name		Input Source	Output Destination
COV_COR_UPDATE		** , *** , *	
E			* , *** , REND_BIAS_AND_COV_PROP, REND_NAV_FILTER, COV_LAST_RESET
M_UVW_M50		U_A_BIAS_AND_COVINIT	
R			U_A_BIAS_AND_COVINIT
SIG_UPDATE		** , *** , *	
V			U_A_BIAS_AND_COVINIT
* Onorbit/Rendezvous principal function, see Table 4.2.10-1. ** Initialization parameters, see Section 4.7. *** Onorbit/Rendezvous Navigation Sequencer principal function, see Table 4.1.3-1.			



#### 4.1.2.2.1.2 Display Parameter Initialization (DISPLAY\_COUNT\_INIT)

The Display Parameter Initialization subfunction shall reset measurement ACCEPT/REJECT counters whenever the covariance initialization subfunction is invoked, whenever exiting a rendezvous navigation phase, or whenever the magnitude of the IMU-sensed accelerations exceed a design-dependent threshold for measurement incorporation.

A. Detailed Requirements. The following steps shall be performed (in the order indicated):

Zero the ACCEPT/REJECT counters. N\_ACCEPT (N\_REJECT) is a 4x1 array which counts the total number of accepted (rejected) measurements during the current mark sequence. SEQ\_ACCEPT (SEQ\_REJECT) counts the number of sequential accepted (rejected) measurements during the current mark sequence.

N\_ACCEPT = 0  
 N\_REJECT = 0 (all are 4 x 1  
 SEQ\_ACCEPT = 0 dimensioned arrays)  
 SEQ\_REJECT = 0

B. Interface Requirements. The input and output data are shown in Table 4.1.2.2.1.2.

C. Processing Requirements. This subfunction is called by the following subfunctions:

REND\_COV\_INIT (Section 4.1.2.2.1)  
 REND\_NAV\_EXIT (Section 4.1.1.1)  
 REND\_BIAS\_AND\_COV\_PROP (Section 4.2.5)

D. Constraints. None

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart may be found in Section 5.2 under the name of DISPLAY\_COUNT\_INIT.

Table 4.1.2.2.1.2. DISPLAY_COUNT_INIT Input/Output		
Variable Name	Input Source	Output Destination
N_ACCEPT		MEAS_PROCESSING_STATISTICS_REND, *, ***
N_REJECT		MEAS_PROCESSING_STATISTICS_REND, *, ***
SEQ_ACCEPT		MEAS_PROCESSING_STATISTICS_REND, *, ***
SEQ_REJECT		MEAS_PROCESSING_STATISTICS_REND, *, ***
* Onorbit/Rendezvous principal function, see Table 4.2.10-1.		
*** Onorbit/Rendezvous Navigation Sequencer principal function, see Table 4.1.3-1.		

#### 4.1.2.2.1.3 Covariance Matrix Parameters Reset (COV\_LAST\_RESET)

The Covariance Matrix Parameters Reset subfunction saves certain navigation parameters at the end of a covariance matrix propagation subcycle for use in the next subcycle. These parameters include the orbiter and target position and velocity vectors as well as the current time. Also, a variable used for summing the IMU-sensed delta velocities over the subcycle interval is zeroed for use in the next subcycle.

A. Detailed Requirements. The following steps shall be performed:

Store the orbiter position and velocity vectors ( $\bar{R}_{FILT}$ ,  $\bar{V}_{FILT}$ ), the target position and velocity vectors ( $\bar{R}_{TV}$ ,  $\bar{V}_{TV}$ ), last filter time (T\_LAST\_FILT), and zero the delta velocity accumulator ( $\bar{DV}_{COV}$ ).

$$\bar{R}_{LAST} = \bar{R}_{FILT}$$

$$\bar{V}_{LAST} = \bar{V}_{FILT}$$

$$\bar{R}_{TV\_LAST} = \bar{R}_{TV}$$

$$\bar{V}_{TV\_LAST} = \bar{V}_{TV}$$

$$\bar{DV}_{COV} = \bar{0}.$$

$$T_{COV\_LAST} = T_{LAST\_FILT}$$

Calculate the square root of the sum of the position and velocity diagonals of the covariance matrix for downlist.

$$COV\_POS\_SIG = \text{SQRT}(E_{1,1} + E_{2,2} + E_{3,3})$$

$$COV\_VEL\_SIG = \text{SQRT}(E_{4,4} + E_{5,5} + E_{6,6})$$

B. Interface Requirements. The input and output data are shown in Table 4.1.2.2.1.3.

C. Processing Requirements. This subfunction is called by the following subfunctions:

NAV\_ONORBIT\_RENDEZVOUS (Section 4.2.1)

REND\_COV\_INIT (Section 4.1.2.2.1)

D. Constraints. None

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart may be found in Section 5.2 under the name COV\_LAST\_RESET.

Table 4.1.2.2.1.3. COV\_LAST\_RESET Input/Output

Variable Name	Input Source	Output Destination
$\bar{R}$ _FILT	REND_NAV_FILTER, ONORBIT_ REND_R_V_STATE_PROP, *, ***	
$\bar{R}$ _TV	REND_NAV_FILTER, ONORBIT_ REND_R_V_STATE_PROP, REND_NAV_INIT,***	
$\bar{V}$ _FILT	REND_NAV_FILTER, ONORBIT_ REND_R_V_STATE_PROP, *, ***	
$\bar{V}$ _TV	REND_NAV_FILTER, ONORBIT_ REND_R_V_STATE_PROP, REND_NAV_INIT,***	
$\bar{D}$ V_COV		NAV_ONORBIT_RENDEZVOUS, REND_BIAS_AND_COV_PROP, *, ***, REND_NAV_INTERP
$\bar{R}$ _LAST		REND_BIAS_AND_COV_PROP, REND_NAV_INTERP,*
$\bar{R}$ _TV_LAST		REND_BIAS_AND_COV_PROP, REND_NAV_INTERP,*
T_LAST_FILT	ONORBIT_REND_R_V_STATE_ PROP,*,***	
T_COV_LAST		REND_BIAS_AND_COV_PROP,*
$\bar{V}$ _LAST		REND_BIAS_AND_COV_PROP, REND_NAV_INTERP,*
$\bar{V}$ _TV_LAST		REND_BIAS_AND_COV_PROP, REND_NAV_INTERP,*
E	COV_INIT_UVW, GPS_RESYNCH, REND_BIAS_AND_COV_PROP, REND_COV_INIT, REND_NAV_FILTER, SETUP, U_A_BIAS_AND_COVINIT	
COV_POS_SIG		*,***
COV_VEL_SIG		*,***

\* Onorbit/Rendezvous Navigation Sequencer principal function, see Table 4.1.3-1.

\*\*\* Onorbit/Rendezvous Navigation principal function, see Table 4.2.11-1.

**4.1.2.2.2 Target State Vector Reset (TARGET\_RESET)**

Upon entering the rendezvous navigation phase, this subfunction is exercised to store the current target state vector (position and velocity) for user parameter processing. Thereafter, while still in the rendezvous navigation phase this subfunction is exercised at the end of each navigation cycle.

A. Detailed Requirements. This subfunction shall reset the user parameter processing (Section 4.5) copy of navigated target position and velocity:

$$\bar{R}_{TV\_RESET} = \bar{R}_{TV}$$

$$\bar{V}_{TV\_RESET} = \bar{V}_{TV}$$

B. Interface Requirements. The input and output parameters for this subfunction are found in Table 4.1.2.2.2.

C. Processing Requirements. This subfunction is called by the following subfunctions:

NAV\_ONORBIT\_RENDEZVOUS (Section 4.2.1)

REND\_NAV\_INIT (Section 4.1.2.2)

D. Constraints. None

E. Supplementary Information. A suggested implementation of this subfunction is found in Section 5.2, TARGET\_RESET.

Table 4.1.2.2.2. TARGET_RESET Input/Output		
Variable Name	Input Source	Output Destination
$\bar{R}_{TV}$	ONORBIT_REND_R_V_STATE_PROP, REND_NAV_FILTER, REND_NAV_INIT	
$\bar{V}_{TV}$	ONORBIT_REND_R_V_STATE_PROP, REND_NAV_FILTER, REND_NAV_INIT	
$\bar{R}_{TV\_RESET}$		*,***
$\bar{V}_{TV\_RESET}$		*,***
* Onorbit/Rendezvous principal function, see Table 4.2.10-1.		
** Onorbit/Rendezvous Navigation Sequencer principal function, see Table 4.1.3-1		

### 4.1.3 Onorbit/Rendezvous Navigation Sequencer Tables (4.148)

The IDD inputs and outputs are listed in Table 4.1.3-1 and 4.1.3-2 respectively. 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 4.1.3-3. K-loads are listed in Table 4.1.3-4. Constants are listed in Table 4.1.3-5, and a principal function cross-reference listing is presented in the table below.

Onorbit/Rendezvous Navigation Sequencer Principal Function (4.148) Cross-Reference Listing	
Local Name	Source Name
CURR_ORB_MASS	M
T_IMU	T_IMUS
$\bar{V}$ _CURRENT_FILT	SEL_V_M50_CG(1) SEL_V_M50_CG(2) SEL_V_M50_CG(3)

TABLE 4.1.3-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
COV_COR_UPDATE(1)	V96H1290C	UPLINKED ORB POS/VEL COR COEFF-1	UL					
COV_COR_UPDATE(2)	V96H1291C	UPLINKED ORB POS/VEL COR COEFF-2	UL					
COV_COR_UPDATE(3)	V96H1292C	UPLINKED ORB POS/VEL COR COEFF-3	UL					
COV_COR_UPDATE(4)	V96H1293C	UPLINKED ORB POS/VEL COR COEFF-4	UL					
COV_COR_UPDATE(5)	V96H1294C	UPLINKED ORB POS/VEL COR COEFF-5	UL					
COV_COR_UPDATE(6)	V96H1295C	UPLINKED ORB POS/VEL COR COEFF-6	UL					
COV_COR_UPDATE(7)	V96H1296C	UPLINKED ORB POS/VEL COR COEFF-7	UL					
DT_FILT	V90W4946C	DELTA TIME FOR NAV INTERVAL	ORB/RND NAV	S				
DV_FILT(1)	V90L4953C	ACCUM VELOCITY - X	ORB/RND NAV	FT/S			89648A	
DV_FILT(2)	V90L4954C	ACCUM VELOCITY - Y	ORB/RND NAV	FT/S			89648A	
DV_FILT(3)	V90L4955C	ACCUM VELOCITY - Z	ORB/RND NAV	FT/S			89648A	
EARTH_POLE(1)	V90U0190C	X-COMP UNIT VCTR ALONG EARTH AXIS	RNP MAT COMP	ND	DPL		93090E	
EARTH_POLE(2)	V90U0191C	Y-COMP UNIT VCTR ALONG EARTH AXIS	RNP MAT COMP	ND	DPL		93090E	
EARTH_POLE(3)	V90U0192C	Z-COMP UNIT VCTR ALONG EARTH AXIS	RNP MAT COMP	ND	DPL		93090E	
IDRAG	V90X4950X	DRAG FLAG FOR ACCEL MODEL	ORB/RND NAV					
IGD	V90J4947C	DEGREE OF ACCEL MODEL	ORB/RND NAV					
IGO	V90J4948C	ORDER OF ACCEL MODEL	ORB/RND NAV					
IVENT	V90X4951X	VENT FLAG FOR ACCEL MODEL	ORB/RND NAV					
M	V90U1961CD	CURRENT VEHICLE MASS	ORB GUID	SLUGS			89648A	
MASS_INIT	V90U4938C	ORBITER MASS SAVED ACROSS MEM TRAJ	ORB/RND NAV SEQ	SLUGS				
MM_CODE_201/MM_201	V90X8189X	MAJOR MODE 201 FLAG	MSC				92355B	
PRED_USE	V90J4768CA	PREDICTOR STATE INDICATOR	ORB/RND NAV				93017G	*
REND_NAV_FLAG	V93X6220XB	RENDEZVOUS NAV ENABLE CMD	REL NAV DISP		BD		93017G	*
R_FILT(1)	V90H0584CC	X-COMP OF FLTR'S CURR POS VECTOR	ORB/RND NAV	FT			91051K	
R_FILT(2)	V90H0585CC	Y-COMP OF FLTR'S CURR POS VECTOR	ORB/RND NAV	FT			91051K	
R_FILT(3)	V90H0586CC	Z-COMP OF FLTR'S CURR POS VECTOR	ORB/RND NAV	FT			91051K	
R_FILT_INIT(1)	V90H1276CA	X-COMP POS VCTR TO INIT NEXT OPS	D/L NAV SEQ					
R_FILT_INIT(1)	V90H1276CB	X-COMP POS VCTR TO INIT NEXT OPS	ORB/RND NAV SEQ	FT				
R_FILT_INIT(1)	V90H1276CC	X-COMP POS VCTR TO INIT NEXT OPS	ASC NAV SEQ	FT				
R_FILT_INIT(2)	V90H1277CA	Y-COMP POS VCTR TO INIT NEXT OPS	D/L NAV SEQ					
R_FILT_INIT(2)	V90H1277CB	Y-COMP POS VCTR TO INIT NEXT OPS	ORB/RND NAV SEQ	FT				
R_FILT_INIT(2)	V90H1277CC	Y-COMP POS VCTR TO INIT NEXT OPS	ASC NAV SEQ	FT				
R_FILT_INIT(3)	V90H1278CA	Z-COMP POS VCTR TO INIT NEXT OPS	D/L NAV SEQ					
R_FILT_INIT(3)	V90H1278CB	Z-COMP POS VCTR TO INIT NEXT OPS	ORB/RND NAV SEQ	FT				
R_FILT_INIT(3)	V90H1278CC	Z-COMP POS VCTR TO INIT NEXT OPS	ASC NAV SEQ	FT				
R_PRED_FINAL(1)	V95H0811C	X-COMP PRED SHUTTLE POS VECTOR	ORB PRED	FT	DPL		93017G	*
R_PRED_FINAL(2)	V95H0812C	Y-COMP PRED SHUTTLE POS VECTOR	ORB PRED	FT	DPL		93017G	*
R_PRED_FINAL(3)	V95H0813C	Z-COMP PRED SHUTTLE POS VECTOR	ORB PRED	FT	DPL		93017G	*
R_TV(1)	V90H0307CA	X-COMP TARGET VEH POS VCTR-M50	ORB/RND NAV	FT			89648A	
R_TV(2)	V90H0308CA	Y-COMP TARGET VEH POS VCTR-M50	ORB/RND NAV	FT			89648A	
R_TV(3)	V90H0309CA	Z-COMP TARGET VEH POS VCTR-M50	ORB/RND NAV	FT			89648A	
SEL_V_M50_CG(1)	V90L2607C	SEL TOTAL X VEL M50 AT CG	IMU RM	FT/S				
SEL_V_M50_CG(2)	V90L2608C	SEL TOTAL Y VEL M50 AT CG	IMU RM	FT/S				
SEL_V_M50_CG(3)	V90L2609C	SEL TOTAL Z VEL M50 AT CG	IMU RM	FT/S				
SHUTTLE_FILTER_FLAG	V90X4952X	VEHICLE STATE TO BE FILTERED	REL NAV DISP		BD		92067D	
SIG_UPDATE(1)	V96H1284C	UPLINKED ORB POS/VEL UVW STD DEV-1	UL	FT				

TABLE 4.1.3-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
SIG_UPDATE(2)	V96H1285C	UPLINKED ORB POS/VEL UVW STD DEV-2	UL	FT				
SIG_UPDATE(3)	V96H1286C	UPLINKED ORB POS/VEL UVW STD DEV-3	UL	FT				
SIG_UPDATE(4)	V96H1287C	UPLINKED ORB POS/VEL UVW STD DEV-4	UL	FT/S				
SIG_UPDATE(5)	V96H1288C	UPLINKED ORB POS/VEL UVW STD DEV-5	UL	FT/S				
SIG_UPDATE(6)	V96H1289C	UPLINKED ORB POS/VEL UVW STD DEV-6	UL	FT/S				
T_FILT_INIT	V90W1287CA	TIME TAG OF VCTR TO INIT NEXT OPS	D/L NAV SEQ	S				
T_FILT_INIT	V90W1287CB	TIME TAG OF VCTR TO INIT NEXT OPS	ORB/RND NAV SEQ	S				
T_FILT_INIT	V90W1287CC	TIME TAG OF VCTR TO INIT NEXT OPS	ASC NAV SEQ	S				
T_IMUS	V95W0002C	IMU INPUT TRANS TIME TAG	IMU INT PROC	S	DPL		93017G	*
T_LAST_FILT	V90W1252CA	TIME OF FILTER STATE VECTOR	ORB/RND NAV	S				
T_RESET	V90W0534CG	TIME OF FILTER STATE VCTR	ORB/RND NAV	S			92834C	
T_TV	V90W0315CA	TIME TAG OF TARGET VEH STATE VCTR	ORB/RND NAV	S			93017G	*
V_FILT(1)	V90L0624CC	X-COMP OF FLTR'S CURR VEL VECTOR	ORB/RND NAV	FT/S	SPL		91051K	
V_FILT(2)	V90L0625CC	Y-COMP OF FLTR'S CURR VEL VECTOR	ORB/RND NAV	FT/S	SPL		91051K	
V_FILT(3)	V90L0626CC	Z-COMP OF FLTR'S CURR VEL VECTOR	ORB/RND NAV	FT/S	SPL		91051K	
V_FILT_INIT(1)	V90L1279CA	X-COMP VEL VCTR TO INIT NEXT OPS	D/L NAV SEQ	FT/S				
V_FILT_INIT(1)	V90L1279CB	X-COMP VEL VCTR TO INIT NEXT OPS	ORB/RND NAV SEQ	FT/S				
V_FILT_INIT(1)	V90L1279CC	X-COMP VEL VCTR TO INIT NEXT OPS	ASC NAV SEQ	FT/S				
V_FILT_INIT(2)	V90L1280CA	Y-COMP VEL VCTR TO INIT NEXT OPS	D/L NAV SEQ	FT/S				
V_FILT_INIT(2)	V90L1280CB	Y-COMP VEL VCTR TO INIT NEXT OPS	ORB/RND NAV SEQ	FT/S				
V_FILT_INIT(2)	V90L1280CC	Y-COMP VEL VCTR TO INIT NEXT OPS	ASC NAV SEQ	FT/S			89648A	
V_FILT_INIT(3)	V90L1281CA	Z-COMP VEL VCTR TO INIT NEXT OPS	D/L NAV SEQ	FT/S				
V_FILT_INIT(3)	V90L1281CB	Z-COMP VEL VCTR TO INIT NEXT OPS	ORB/RND NAV SEQ	FT/S				
V_FILT_INIT(3)	V90L1281CC	Z-COMP VEL VCTR TO INIT NEXT OPS	ASC NAV SEQ	FT/S			89648A	
V_PRED_FINAL(1)	V95L0814C	X-COMP PRED SHUTTLE VEL VECTOR	ORB PRED	FT/S	DPL		93017G	*
V_PRED_FINAL(2)	V95L0815C	Y-COMP PRED SHUTTLE VEL VECTOR	ORB PRED	FT/S	DPL		93017G	*
V_PRED_FINAL(3)	V95L0816C	Z-COMP PRED SHUTTLE VEL VECTOR	ORB PRED	FT/S	DPL		93017G	*
V_TV(1)	V90L0310CA	X-COMP TARGET VEH VEL VCTR-M50	ORB/RND NAV	FT/S				
V_TV(2)	V90L0311CA	Y-COMP TARGET VEH VEL VCTR-M50	ORB/RND NAV	FT/S				
V_TV(3)	V90L0312CA	Z-COMP TARGET VEH VEL VCTR-M50	ORB/RND NAV	FT/S				
WT_DISP	V93G6940CB	VEHICLE WEIGHT	ASC MNVR DIP	LBS				
WT_DISP	V93G6940CE	VEHICLE WEIGHT	DEORB MNVR DIP	LBS				
	V90X8148X	MM 201 FROM OPS-00 FLAG	MSC				89599C	
	V90X8160X	MM 201 FROM MM 801 FLAG	MSC				89599C	
	V90X8164X	MM 201 FROM MM 301 FLAG	MSC				92354	
	V90X8180X	MM 301 FROM MM 201 FLAG	MSC				89599C	
	V90X8200X	TERMINATE POWERED FLIGHT MODE FLAG	MSC				89599C	
	V90X8644X	MM 301 FROM MM 801 FLAG	MSC				89599C	
	V90X8645X	MM 801 FROM MM 201 FLAG	MSC				92355B	
	V90X8646X	MM 202 FROM MM 201 FLAG	MSC				92355B	
	V90X8655X	MM201 TO OPS 00 TRANS EVENT FLAG	MSC				89599C	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.1.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
ANGLES_AIF	V93J6237CA	V/EL/Y EDIT OVRD-A/I/F	ORB/RND NAV		VAR		92834C	
ANGLES_AIF_DISPLAY	V90J1361CA	RNDZ NAV ANGLE AUT/INH/FOR FLAG	REL NAV DISP		HXS		92834C	
ATMP	V94J3999CD	ATTITUDE MODE FLAG	DL FMT 22/1 DL FMT 32/1 ORB PRED				93017G	*
COV_ACCEL_UVW_INIT(1)	V90H4930C	U-COMP UNMOD ACC BIAS	ORB/RND NAV	FT2/S4				
COV_ACCEL_UVW_INIT(2)	V90H4931C	V-COMP UNMOD ACC BIAS	ORB/RND NAV	FT2/S4				
COV_ACCEL_UVW_INIT(3)	V90H4932C	W-COMP UNMOD ACC BIAS	ORB/RND NAV	FT2/S4				
COV_POS_SIG	V90H0438CE	RSS OF COVARIANCE POS ELEMENTS	DL FMT 22/1	FT	SPL		93017G	*
COV_PWRD_FLT	V90X4936X	CURRENT COV PROP PWRD FLT	ORB/RND NAV				92297B	
COV_PWRD_FLT_LAST	V90X4845X	LAST VALUE OF PWRD FLT COV	ORB/RND NAV					
COV_VEL_SIG	V90L0439CE	RSS OF COVARIANCE VEL ELEMENTS	DL FMT 22/1	FT/S	SPL		93017G	*
DMP	V94X3969XD	PROPER DRAG MODEL FLAG	ORB PRED					
DOING_MEAS_ENABLE	V90X1417XA	NAV MEASUREMENT ENABLE IND	DL FMT 22/A DL FMT 32/A REL NAV DISP				93017G	*
DOING_PWRD_FLT_NAV	V90X1289X	PWR FLT NAV AVG G ON/OFF IND	DL FMT 22/A DL FMT 32/A FCS/DED DISP REL NAV DISP REL NAV SPEC		BD		93017G	*
DOING_REND_NAV	V90X4765X	RENDZ NAV ACTIVE FLAG	DL FMT 22/A DL FMT 32/A ORB TGTING DISP ORB UPP ORB/RND NAV REL NAV DISP REL NAV SPEC		BD		93017G	*
DO_COAS_ANGLES_NAV_LAST	V90X4725X	COAS ANGLES PROCESSING LAST FLAG	ORB/RND NAV					
DO_RRDOT_NAV_LAST	V90X4727X	RNG & RNG RATE PROCESSING LAST FLG	ORB/RND NAV					
DO_RR_ANGLES_NAV_LAST	V90X4726X	RR ANGLES PROCESSING LAST FLAG	ORB/RND NAV					
DO_ST_ANGLES_NAV_LAST	V90X4728X	ST ANGLES PROCESSING LAST FLAG	ORB/RND NAV					
DV_COV(1)	V90L4772CB	COV PROP DELTA V(1)	DL FMT 22/1 ORB/RND NAV	FT/S			93017G	*
DV_COV(2)	V90L4891CB	COV PROP DELTA V(2)	DL FMT 22/1 ORB/RND NAV	FT/S			93017G	*
DV_COV(3)	V90L4892CB	COV PROP DELTA V(3)	DL FMT 22/1 ORB/RND NAV	FT/S			93017G	*
E(1,1)	V90U4006CB	COVARIANCE MATRIX ELEMENT 1,1	ORB/RND NAV TLM					
E(1,10)	V90U4016CB	COVARIANCE MATRIX ELEMENT 1,10	ORB/RND NAV				89648A	
E(1,11)	V90U4017CB	COVARIANCE MATRIX ELEMENT 1,11	ORB/RND NAV				89648A	
E(1,12)	V90U4018CB	COVARIANCE MATRIX ELEMENT 1,12	ORB/RND NAV				89648A	
E(1,13)	V90U4019CB	COVARIANCE MATRIX ELEMENT 1,13	ORB/RND NAV				89648A	
E(1,2)	V90U4007CB	COVARIANCE MATRIX ELEMENT 1,2	ORB/RND NAV				89648A	
E(1,3)	V90U4008CB	COVARIANCE MATRIX ELEMENT 1,3	ORB/RND NAV				89648A	



TABLE 4.1.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
E(1,4)	V90U4009CB	COVARIANCE MATRIX ELEMENT 1,4	ORB/RND NAV				89648A	
E(1,5)	V90U4011CB	COVARIANCE MATRIX ELEMENT 1,5	ORB/RND NAV				89648A	
E(1,6)	V90U4012CB	COVARIANCE MATRIX ELEMENT 1,6	ORB/RND NAV				89648A	
E(1,7)	V90U4013CB	COVARIANCE MATRIX ELEMENT 1,7	ORB/RND NAV				89648A	
E(1,8)	V90U4014CB	COVARIANCE MATRIX ELEMENT 1,8	ORB/RND NAV				89648A	
E(1,9)	V90U4015CB	COVARIANCE MATRIX ELEMENT 1,9	ORB/RND NAV				89648A	
E(10,1)	V90U4179C	COVARIANCE MATRIX ELEMENT 10,1	ORB/RND NAV					
E(10,10)	V90U4188CB	COVARIANCE MATRIX ELEMENT 10,10	ORB/RND NAV					
			TLM					
E(10,11)	V90U4189CB	COVARIANCE MATRIX ELEMENT 10,11	ORB/RND NAV				89648A	
E(10,12)	V90U4190CB	COVARIANCE MATRIX ELEMENT 10,12	ORB/RND NAV				89648A	
E(10,13)	V90U4191CB	COVARIANCE MATRIX ELEMENT 10,13	ORB/RND NAV				89648A	
E(10,2)	V90U4180C	COVARIANCE MATRIX ELEMENT 10,2	ORB/RND NAV					
E(10,3)	V90U4181C	COVARIANCE MATRIX ELEMENT 10,3	ORB/RND NAV					
E(10,4)	V90U4182C	COVARIANCE MATRIX ELEMENT 10,4	ORB/RND NAV					
E(10,5)	V90U4183C	COVARIANCE MATRIX ELEMENT 10,5	ORB/RND NAV					
E(10,6)	V90U4184C	COVARIANCE MATRIX ELEMENT 10,6	ORB/RND NAV					
E(10,7)	V90U4185C	COVARIANCE MATRIX ELEMENT 10,7	ORB/RND NAV					
E(10,8)	V90U4186C	COVARIANCE MATRIX ELEMENT 10,8	ORB/RND NAV					
E(10,9)	V90U4187C	COVARIANCE MATRIX ELEMENT 10,9	ORB/RND NAV					
E(11,1)	V90U4198C	COVARIANCE MATRIX ELEMENT 11,1	ORB/RND NAV					
E(11,10)	V90U4208C	COVARIANCE MATRIX ELEMENT 11,10	ORB/RND NAV					
E(11,11)	V90U4209CB	COVARIANCE MATRIX ELEMENT 11,11	ORB/RND NAV					
			TLM					
E(11,12)	V90U4210CB	COVARIANCE MATRIX ELEMENT 11,12	ORB/RND NAV				89648A	
E(11,13)	V90U4211CB	COVARIANCE MATRIX ELEMENT 11,13	ORB/RND NAV				89648A	
E(11,2)	V90U4199C	COVARIANCE MATRIX ELEMENT 11,2	ORB/RND NAV					
E(11,3)	V90U4200C	COVARIANCE MATRIX ELEMENT 11,3	ORB/RND NAV					
E(11,4)	V90U4202C	COVARIANCE MATRIX ELEMENT 11,4	ORB/RND NAV					
E(11,5)	V90U4203C	COVARIANCE MATRIX ELEMENT 11,5	ORB/RND NAV					
E(11,6)	V90U4204C	COVARIANCE MATRIX ELEMENT 11,6	ORB/RND NAV					
E(11,7)	V90U4205C	COVARIANCE MATRIX ELEMENT 11,7	ORB/RND NAV					
E(11,8)	V90U4206C	COVARIANCE MATRIX ELEMENT 11,8	ORB/RND NAV					
E(11,9)	V90U4207C	COVARIANCE MATRIX ELEMENT 11,9	ORB/RND NAV					
E(12,1)	V90U4218C	COVARIANCE MATRIX ELEMENT 12,1	ORB/RND NAV					
E(12,10)	V90U4227C	COVARIANCE MATRIX ELEMENT 12,10	ORB/RND NAV					
E(12,11)	V90U4228C	COVARIANCE MATRIX ELEMENT 12,11	ORB/RND NAV					
E(12,12)	V90U4229CB	COVARIANCE MATRIX ELEMENT 12,12	ORB/RND NAV					
			TLM					
E(12,13)	V90U4230CB	COVARIANCE MATRIX ELEMENT 12,13	ORB/RND NAV				89648A	
E(12,2)	V90U4219C	COVARIANCE MATRIX ELEMENT 12,2	ORB/RND NAV					
E(12,3)	V90U4220C	COVARIANCE MATRIX ELEMENT 12,3	ORB/RND NAV					
E(12,4)	V90U4221C	COVARIANCE MATRIX ELEMENT 12,4	ORB/RND NAV					
E(12,5)	V90U4222C	COVARIANCE MATRIX ELEMENT 12,5	ORB/RND NAV					
E(12,6)	V90U4223C	COVARIANCE MATRIX ELEMENT 12,6	ORB/RND NAV					
E(12,7)	V90U4224C	COVARIANCE MATRIX ELEMENT 12,7	ORB/RND NAV					

TABLE 4.1.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
E(12,8)	V90U4225C	COVARIANCE MATRIX ELEMENT 12,8	ORB/RND NAV					
E(12,9)	V90U4226C	COVARIANCE MATRIX ELEMENT 12,9	ORB/RND NAV					
E(13,1)	V90U4237C	COVARIANCE MATRIX ELEMENT 13,1	ORB/RND NAV					
E(13,10)	V90U4246C	COVARIANCE MATRIX ELEMENT 13,10	ORB/RND NAV					
E(13,11)	V90U4247C	COVARIANCE MATRIX ELEMENT 13,11	ORB/RND NAV					
E(13,12)	V90U4248C	COVARIANCE MATRIX ELEMENT 13,12	ORB/RND NAV					
E(13,13)	V90U4249CB	COVARIANCE MATRIX ELEMENT 13,13	ORB/RND NAV					
			TLM					
E(13,2)	V90U4238C	COVARIANCE MATRIX ELEMENT 13,2	ORB/RND NAV					
E(13,3)	V90U4239C	COVARIANCE MATRIX ELEMENT 13,3	ORB/RND NAV					
E(13,4)	V90U4240C	COVARIANCE MATRIX ELEMENT 13,4	ORB/RND NAV					
E(13,5)	V90U4241C	COVARIANCE MATRIX ELEMENT 13,5	ORB/RND NAV					
E(13,6)	V90U4242C	COVARIANCE MATRIX ELEMENT 13,6	ORB/RND NAV					
E(13,7)	V90U4243C	COVARIANCE MATRIX ELEMENT 13,7	ORB/RND NAV					
E(13,8)	V90U4244C	COVARIANCE MATRIX ELEMENT 13,8	ORB/RND NAV					
E(13,9)	V90U4245C	COVARIANCE MATRIX ELEMENT 13,9	ORB/RND NAV					
E(2,1)	V90U4026C	COVARIANCE MATRIX ELEMENT 2,1	ORB/RND NAV					
E(2,10)	V90U4035CB	COVARIANCE MATRIX ELEMENT 2,10	ORB/RND NAV				89648A	
E(2,11)	V90U4036CB	COVARIANCE MATRIX ELEMENT 2,11	ORB/RND NAV				89648A	
E(2,12)	V90U4037CB	COVARIANCE MATRIX ELEMENT 2,12	ORB/RND NAV				89648A	
E(2,13)	V90U4038CB	COVARIANCE MATRIX ELEMENT 2,13	ORB/RND NAV				89648A	
E(2,2)	V90U4027CB	COVARIANCE MATRIX ELEMENT 2,2	ORB/RND NAV					
			TLM					
E(2,3)	V90U4028CB	COVARIANCE MATRIX ELEMENT 2,3	ORB/RND NAV				89648A	
E(2,4)	V90U4029CB	COVARIANCE MATRIX ELEMENT 2,4	ORB/RND NAV				89648A	
E(2,5)	V90U4030CB	COVARIANCE MATRIX ELEMENT 2,5	ORB/RND NAV				89648A	
E(2,6)	V90U4031CB	COVARIANCE MATRIX ELEMENT 2,6	ORB/RND NAV				89648A	
E(2,7)	V90U4032CB	COVARIANCE MATRIX ELEMENT 2,7	ORB/RND NAV				89648A	
E(2,8)	V90U4033CB	COVARIANCE MATRIX ELEMENT 2,8	ORB/RND NAV				89648A	
E(2,9)	V90U4034CB	COVARIANCE MATRIX ELEMENT 2,9	ORB/RND NAV				89648A	
E(3,1)	V90U4045C	COVARIANCE MATRIX ELEMENT 3,1	ORB/RND NAV					
E(3,10)	V90U4054CB	COVARIANCE MATRIX ELEMENT 3,10	ORB/RND NAV				89648A	
E(3,11)	V90U4055CB	COVARIANCE MATRIX ELEMENT 3,11	ORB/RND NAV				89648A	
E(3,12)	V90U4056CB	COVARIANCE MATRIX ELEMENT 3,12	ORB/RND NAV				89648A	
E(3,13)	V90U4057CB	COVARIANCE MATRIX ELEMENT 3,13	ORB/RND NAV				89648A	
E(3,2)	V90U4046C	COVARIANCE MATRIX ELEMENT 3,2	ORB/RND NAV					
E(3,3)	V90U4047CB	COVARIANCE MATRIX ELEMENT 3,3	ORB/RND NAV					
			TLM					
E(3,4)	V90U4048CB	COVARIANCE MATRIX ELEMENT 3,4	ORB/RND NAV				89648A	
E(3,5)	V90U4049CB	COVARIANCE MATRIX ELEMENT 3,5	ORB/RND NAV				89648A	
E(3,6)	V90U4050CB	COVARIANCE MATRIX ELEMENT 3,6	ORB/RND NAV				89648A	
E(3,7)	V90U4051CB	COVARIANCE MATRIX ELEMENT 3,7	ORB/RND NAV				89648A	
E(3,8)	V90U4052CB	COVARIANCE MATRIX ELEMENT 3,8	ORB/RND NAV				89648A	
E(3,9)	V90U4053CB	COVARIANCE MATRIX ELEMENT 3,9	ORB/RND NAV				89648A	
E(4,1)	V90U4064C	COVARIANCE MATRIX ELEMENT 4,1	ORB/RND NAV					
E(4,10)	V90U4073CB	COVARIANCE MATRIX ELEMENT 4,10	ORB/RND NAV				89648A	

TABLE 4.1.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
E(4,11)	V90U4074CB	COVARIANCE MATRIX ELEMENT 4,11	ORB/RND NAV				89648A	
E(4,12)	V90U4075CB	COVARIANCE MATRIX ELEMENT 4,12	ORB/RND NAV				89648A	
E(4,13)	V90U4076CB	COVARIANCE MATRIX ELEMENT 4,13	ORB/RND NAV				89648A	
E(4,2)	V90U4065C	COVARIANCE MATRIX ELEMENT 4,2	ORB/RND NAV					
E(4,3)	V90U4066C	COVARIANCE MATRIX ELEMENT 4,3	ORB/RND NAV					
E(4,4)	V90U4067CB	COVARIANCE MATRIX ELEMENT 4,4	ORB/RND NAV					
			TLM					
E(4,5)	V90U4068CB	COVARIANCE MATRIX ELEMENT 4,5	ORB/RND NAV				89648A	
E(4,6)	V90U4069CB	COVARIANCE MATRIX ELEMENT 4,6	ORB/RND NAV				89648A	
E(4,7)	V90U4070CB	COVARIANCE MATRIX ELEMENT 4,7	ORB/RND NAV				89648A	
E(4,8)	V90U4071CB	COVARIANCE MATRIX ELEMENT 4,8	ORB/RND NAV				89648A	
E(4,9)	V90U4072CB	COVARIANCE MATRIX ELEMENT 4,9	ORB/RND NAV				89648A	
E(5,1)	V90U4083C	COVARIANCE MATRIX ELEMENT 5,1	ORB/RND NAV					
E(5,10)	V90U4092CB	COVARIANCE MATRIX ELEMENT 5,10	ORB/RND NAV				89648A	
E(5,11)	V90U4093CB	COVARIANCE MATRIX ELEMENT 5,11	ORB/RND NAV				89648A	
E(5,12)	V90U4094CB	COVARIANCE MATRIX ELEMENT 5,12	ORB/RND NAV				89648A	
E(5,13)	V90U4095CB	COVARIANCE MATRIX ELEMENT 5,13	ORB/RND NAV				89648A	
E(5,2)	V90U4084C	COVARIANCE MATRIX ELEMENT 5,2	ORB/RND NAV					
E(5,3)	V90U4085C	COVARIANCE MATRIX ELEMENT 5,3	ORB/RND NAV					
E(5,4)	V90U4086C	COVARIANCE MATRIX ELEMENT 5,4	ORB/RND NAV					
E(5,5)	V90U4087CB	COVARIANCE MATRIX ELEMENT 5,5	ORB/RND NAV					
			TLM					
E(5,6)	V90U4088CB	COVARIANCE MATRIX ELEMENT 5,6	ORB/RND NAV				89648A	
E(5,7)	V90U4089CB	COVARIANCE MATRIX ELEMENT 5,7	ORB/RND NAV				89648A	
E(5,8)	V90U4090CB	COVARIANCE MATRIX ELEMENT 5,8	ORB/RND NAV				89648A	
E(5,9)	V90U4091CB	COVARIANCE MATRIX ELEMENT 5,9	ORB/RND NAV				89648A	
E(6,1)	V90U4103C	COVARIANCE MATRIX ELEMENT 6,1	ORB/RND NAV					
E(6,10)	V90U4112CB	COVARIANCE MATRIX ELEMENT 6,10	ORB/RND NAV				89648A	
E(6,11)	V90U4113CB	COVARIANCE MATRIX ELEMENT 6,11	ORB/RND NAV				89648A	
E(6,12)	V90U4114CB	COVARIANCE MATRIX ELEMENT 6,12	ORB/RND NAV				89648A	
E(6,13)	V90U4115CB	COVARIANCE MATRIX ELEMENT 6,13	ORB/RND NAV				89648A	
E(6,2)	V90U4104C	COVARIANCE MATRIX ELEMENT 6,2	ORB/RND NAV					
E(6,3)	V90U4105C	COVARIANCE MATRIX ELEMENT 6,3	ORB/RND NAV					
E(6,4)	V90U4106C	COVARIANCE MATRIX ELEMENT 6,4	ORB/RND NAV					
E(6,5)	V90U4107C	COVARIANCE MATRIX ELEMENT 6,5	ORB/RND NAV					
E(6,6)	V90U4108CB	COVARIANCE MATRIX ELEMENT 6,6	ORB/RND NAV					
			TLM					
E(6,7)	V90U4109CB	COVARIANCE MATRIX ELEMENT 6,7	ORB/RND NAV				89648A	
E(6,8)	V90U4110CB	COVARIANCE MATRIX ELEMENT 6,8	ORB/RND NAV				89648A	
E(6,9)	V90U4111CB	COVARIANCE MATRIX ELEMENT 6,9	ORB/RND NAV				89648A	
E(7,1)	V90U4122C	COVARIANCE MATRIX ELEMENT 7,1	ORB/RND NAV					
E(7,10)	V90U4131CB	COVARIANCE MATRIX ELEMENT 7,10	ORB/RND NAV				89648A	
E(7,11)	V90U4132CB	COVARIANCE MATRIX ELEMENT 7,11	ORB/RND NAV				89648A	
E(7,12)	V90U4133CB	COVARIANCE MATRIX ELEMENT 7,12	ORB/RND NAV				89648A	
E(7,13)	V90U4134CB	COVARIANCE MATRIX ELEMENT 7,13	ORB/RND NAV				89648A	
E(7,2)	V90U4123C	COVARIANCE MATRIX ELEMENT 7,2	ORB/RND NAV					

TABLE 4.1.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
E(7,3)	V90U4124C	COVARIANCE MATRIX ELEMENT 7,3	ORB/RND NAV					
E(7,4)	V90U4125C	COVARIANCE MATRIX ELEMENT 7,4	ORB/RND NAV					
E(7,5)	V90U4126C	COVARIANCE MATRIX ELEMENT 7,5	ORB/RND NAV					
E(7,6)	V90U4127C	COVARIANCE MATRIX ELEMENT 7,6	ORB/RND NAV					
E(7,7)	V90U4128CB	COVARIANCE MATRIX ELEMENT 7,7	ORB/RND NAV TLM					
E(7,8)	V90U4129CB	COVARIANCE MATRIX ELEMENT 7,8	ORB/RND NAV				89648A	
E(7,9)	V90U4130CB	COVARIANCE MATRIX ELEMENT 7,9	ORB/RND NAV				89648A	
E(8,1)	V90U4141C	COVARIANCE MATRIX ELEMENT 8,1	ORB/RND NAV					
E(8,10)	V90U4150CB	COVARIANCE MATRIX ELEMENT 8,10	ORB/RND NAV				89648A	
E(8,11)	V90U4151CB	COVARIANCE MATRIX ELEMENT 8,11	ORB/RND NAV				89648A	
E(8,12)	V90U4152CB	COVARIANCE MATRIX ELEMENT 8,12	ORB/RND NAV				89648A	
E(8,13)	V90U4153CB	COVARIANCE MATRIX ELEMENT 8,13	ORB/RND NAV				89648A	
E(8,2)	V90U4142C	COVARIANCE MATRIX ELEMENT 8,2	ORB/RND NAV					
E(8,3)	V90U4143C	COVARIANCE MATRIX ELEMENT 8,3	ORB/RND NAV					
E(8,4)	V90U4144C	COVARIANCE MATRIX ELEMENT 8,4	ORB/RND NAV					
E(8,5)	V90U4145C	COVARIANCE MATRIX ELEMENT 8,5	ORB/RND NAV					
E(8,6)	V90U4146C	COVARIANCE MATRIX ELEMENT 8,6	ORB/RND NAV					
E(8,7)	V90U4147C	COVARIANCE MATRIX ELEMENT 8,7	ORB/RND NAV					
E(8,8)	V90U4148CB	COVARIANCE MATRIX ELEMENT 8,8	ORB/RND NAV TLM					
E(8,9)	V90U4149CB	COVARIANCE MATRIX ELEMENT 8,9	ORB/RND NAV				89648A	
E(9,1)	V90U4160C	COVARIANCE MATRIX ELEMENT 9,1	ORB/RND NAV					
E(9,10)	V90U4169CB	COVARIANCE MATRIX ELEMENT 9,10	ORB/RND NAV				89648A	
E(9,11)	V90U4170CB	COVARIANCE MATRIX ELEMENT 9,11	ORB/RND NAV				89648A	
E(9,12)	V90U4171CB	COVARIANCE MATRIX ELEMENT 9,12	ORB/RND NAV				89648A	
E(9,13)	V90U4172CB	COVARIANCE MATRIX ELEMENT 9,13	ORB/RND NAV				89648A	
E(9,2)	V90U4161C	COVARIANCE MATRIX ELEMENT 9,2	ORB/RND NAV					
E(9,3)	V90U4162C	COVARIANCE MATRIX ELEMENT 9,3	ORB/RND NAV					
E(9,4)	V90U4163C	COVARIANCE MATRIX ELEMENT 9,4	ORB/RND NAV					
E(9,5)	V90U4164C	COVARIANCE MATRIX ELEMENT 9,5	ORB/RND NAV					
E(9,6)	V90U4165C	COVARIANCE MATRIX ELEMENT 9,6	ORB/RND NAV					
E(9,7)	V90U4166C	COVARIANCE MATRIX ELEMENT 9,7	ORB/RND NAV					
E(9,8)	V90U4167C	COVARIANCE MATRIX ELEMENT 9,8	ORB/RND NAV					
E(9,9)	V90U4168CB	COVARIANCE MATRIX ELEMENT 9,9	ORB/RND NAV TLM					
FILT_UPDATE	V90X0224XI	FLAG IND NAV FILTER PROC COMPLETE	ORB UPP					
GMDP	V94J3975CD	GRAVITY MODEL DEGREE FLAG	ORB PRED					
GMOP	V94J3963CD	GRAVITY MODEL ORDER FLAG	ORB PRED					
GPS_DG_SF_PREV(1)	V90X3536XB	GPS 1 PREV DG SEL FILT	GPS RCVR STATE PROC		BD		91051K	
GPS_DG_SF_PREV(2)	V90X3537XB	GPS 2 PREV DG SEL FILT	GPS RCVR STATE PROC		BD		91051K	
GPS_DG_SF_PREV(3)	V90X3538XB	GPS 3 PREV DG SEL FILT	GPS RCVR STATE PROC		BD		91051K	
GPS_REF_INIT_VALID	V90X3642XD	GPS INIT REF STATE VALID FLAG	GPS REF STATE PROC		BD		92067D	
GPS_SV_SEL_AVAIL	V90X3081XB	GPS SEL STATE VCTR AVAIL FLAG	GPS RCVR STATE PROC ORB/RND NAV		BD		91051K	
G_GPS_INIT(1)	V90A2619CD	X GRAV ACC FOR GPS REF STATE INIT	GPS REF STATE PROC	FT/S2	SPL		92214A	

TABLE 4.1.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
G_GPS_INIT(2)	V90A2620CD	Y GRAV ACC FOR GPS REF STATE INIT	GPS REF STATE PROC	FT/S2	SPL		92214A	
G_GPS_INIT(3)	V90A2621CD	Z GRAV ACC FOR GPS REF STATE INIT	GPS REF STATE PROC	FT/S2	SPL		92214A	
G_TV_LAST(1)	V90A4796C	TARGET TOTAL X-COMP ACCEL VEC-M50	ORB/RND NAV	FT/S2				
G_TV_LAST(2)	V90A4797C	TARGET TOTAL Y-COMP ACCEL VEC-M50	ORB/RND NAV	FT/S2				
G_TV_LAST(3)	V90A4788C	TARGET TOTAL Z-COMP ACCEL VEC-M50	ORB/RND NAV	FT/S2				
I_CYCLE	V90J4889CB	COVARIANCE PROP COUNTER	DL FMT 22/1				93017G	*
M/CURR_ORB_MASS/WEIGHT	V90U1961CK	CURRENT VEHICLE MASS	ORB/RND NAV	SLUGS				
MASS_INIT	V90U4938C	ORBITER MASS SAVED ACROSS MEM TRAJ	ORB/RND NAV SEQ	SLUGS				
MEAS_ENABLE	V93X6232XB	NAV MEASUREMENT ENA CMD	ORB/RND NAV					
NAV_CURR_ORB_MASS	V90U4254CB	NAV CURRENT ORB MASS	DL FMT 22/1	SLUGS			93017G	*
NOISY_NAV_MEAS	V90X4937X	NAV MEAS PROC FLAG	ORB/RND NAV				92297B	
NOOP_GPS_GAX_MSGS	V90X3547XB	NOOP GPS GAX MSGS	GPS RCVR STATE PROC		BD		91051K	
N_ACCEPT(1)	V90J1402CB	H/X/AZ ANGULAR MARKS ACCEPTED	DL FMT 22/A				93017G	*
N_ACCEPT(2)	V90J1403CB	V/Y/EL ANGULAR MARKS ACCEPTED	DL FMT 22/A				93017G	*
N_ACCEPT(3)	V90J1400CB	RR RNG MARKS ACCEPTED	DL FMT 22/A				93017G	*
N_ACCEPT(4)	V90J1401CB	RR R DOT MARKS ACCEPTED	DL FMT 22/A				93017G	*
N_REJECT(1)	V90J1407CB	H/X/AZ ANGULAR MARKS REJECTED	DL FMT 22/A				93017G	*
N_REJECT(2)	V90J1408CB	V/Y/EL ANGULAR MARKS REJECTED	DL FMT 22/A				93017G	*
N_REJECT(3)	V90J1405CB	RR RNG MARKS REJECTED	DL FMT 22/A				93017G	*
N_REJECT(4)	V90J1406CB	RR RDOT MARKS REJECTED	DL FMT 22/A				93017G	*
OPS_2_OR_8_INITIALIZE_CPLT	V90X1242X	NAV INITIALIZATION COMPLETE FLAG	MSC				90885D	
PRED_ENA_FLAG	V90X4266X	PREDICTOR ENABLE FLAG	ORB UPP SEQ					
PRED_ORB_AREA	V93U6955CD	ORBITER REF AREA USED IN PRED	ORB PRED	FT2			93017G	*
PRED_ORB_CD	V93U6954CD	ORBITER DRAG COEFF USED IN PRED	DL FMT 22/1				93017G	*
PRED_ORB_MASS	V93U6953CD	ORBITER MASS USED IN PREDICTION	DL FMT 32/1	SLUGS			93017G	*

TABLE 4.1.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
PRED_STEP	V90W3964CD	INTEGRATION STEP SIZE	DL FMT 22/1 DL FMT 32/1 ORB PRED	S			93017G	*
PRED_USE	V90J4768CB	PREDICTOR STATE INDICATOR	DL FMT 22/1 DL FMT 32/1 ORB/RND NAV				93017G	*
PWRD_FLT_NAV	V93X5408XA	PWR FLT NAV AVG G ON/OFF CMD	ORB UPP ORB/RND NAV					
RANGE_AIF	V93J6241CA	RANGE EDIT OVRD-A/I/F	ORB/RND NAV		VAR		92834C	
RANGE_AIF_DISPLAY	V90J1362CA	RNDZ NAV RR RNG AUT/INH/FOR FLAG	REL NAV DISP		HXS		92834C	
RDOT_AIF	V93J6247CA	RR RANGE RATE EDIT OVRD-A/I/F	ORB/RND NAV		VAR		92834C	
RDOT_AIF_DISPLAY	V90J1368CA	RNDZ NAV RR R DOT AUT/INH/FOR FLAG	REL NAV DISP		HXS		92834C	
REND_NAV_FLAG	V93X6220XA	RENDEZVOUS NAV ENABLE CMD	DL FMT 22/1 DL FMT 32/1				93017G	*
R_FILT(1)	V90H0584CD	X-COMP OF FLTR'S CURR POS VECTOR	ORB/RND NAV	FT				
R_FILT(2)	V90H0585CD	Y-COMP OF FLTR'S CURR POS VECTOR	ORB/RND NAV	FT				
R_FILT(3)	V90H0586CD	Z-COMP OF FLTR'S CURR POS VECTOR	ORB/RND NAV	FT				
R_FILT_INIT(1)	V90H1276CB	X-COMP POS VCTR TO INIT NEXT OPS	D/L NAV SEQ ORB/RND NAV SEQ	FT				
R_FILT_INIT(2)	V90H1277CB	Y-COMP POS VCTR TO INIT NEXT OPS	D/L NAV SEQ ORB/RND NAV SEQ	FT				
R_FILT_INIT(3)	V90H1278CB	Z-COMP POS VCTR TO INIT NEXT OPS	D/L NAV SEQ ORB/RND NAV SEQ	FT				
R_GPS_INIT(1)	V90H3476CE	GPS INIT POS VECTOR X-COMP	GPS REF STATE PROC	FT	DPL		91051K	
R_GPS_INIT(2)	V90H3477CE	GPS INIT POS VECTOR Y-COMP	GPS REF STATE PROC	FT	DPL		91051K	
R_GPS_INIT(3)	V90H3478CE	GPS INIT POS VECTOR Z-COMP	GPS REF STATE PROC	FT	DPL		91051K	
R_LAST(1)	V90H4782C	CURR ORB X-POS FOR COV PROP	ORB/RND NAV	FT				
R_LAST(2)	V90H4783C	CURR ORB Y-POS FOR COV PROP	ORB/RND NAV	FT				
R_LAST(3)	V90H4784C	CURR ORB Z-POS FOR COV PROP	ORB/RND NAV	FT				
R_PRED_INIT(1)	V94H4002CD	X-COMP POS VEC AT INITIAL TIME	DL FMT 22/1 DL FMT 32/1 ORB PRED	FT			93017G	*
R_PRED_INIT(2)	V94H4003CD	Y-COMP POS VEC AT INITIAL TIME	DL FMT 22/1 DL FMT 32/1 ORB PRED	FT			93017G	*
R_PRED_INIT(3)	V94H4004CD	Z-COMP POS VEC AT INITIAL TIME	DL FMT 22/1 DL FMT 32/1 ORB PRED	FT			93017G	*
R_PROP(1)	V90H4991C	X-COMP OF BU POS VECTOR	ORB/RND NAV	FT				
R_PROP(2)	V90H4992C	Y-COMP OF BU POS VECTOR	ORB/RND NAV	FT				
R_PROP(3)	V90H4993C	Z-COMP OF BU POS VECTOR	ORB/RND NAV	FT				
R_RESET(1)	V90H0235CI	SEL X-COMP OF UPDATED POS VCTR RST	ORB UPP	FT	DPL			
R_RESET(2)	V90H0236CI	SEL Y-COMP OF UPDATED POS VCTR RST	ORB UPP	FT	DPL			
R_RESET(3)	V90H0237CI	SEL Z-COMP OF UPDATED POS VCTR RST	ORB UPP	FT	DPL			
R_TV(1)	V90H0307CB	X-COMP TARGET VEH POS VCTR-M50	ORB/RND NAV	FT				
R_TV(2)	V90H0308CB	Y-COMP TARGET VEH POS VCTR-M50	ORB/RND NAV	FT				

TABLE 4.1.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
R_TV(3)	V90H0309CB	Z-COMP TARGET VEH POS VCTR-M50	ORB/RND NAV	FT				
R_TV_LAST(1)	V90H4789C	TARGET X-POS FOR COV PROP	ORB/RND NAV	FT				
R_TV_LAST(2)	V90H4790C	TARGET Y-POS FOR COV PROP	ORB/RND NAV	FT				
R_TV_LAST(3)	V90H4791C	TARGET Z-POS FOR COV PROP	ORB/RND NAV	FT				
R_TV_RESET(1)	V90H1383CB	X-COMP OF CURR TARGET POS VCT RST	ORB UPP	FT	DPL			
R_TV_RESET(2)	V90H1384CB	Y-COMP OF CURR TARGET POS VCT RST	ORB UPP	FT	DPL			
R_TV_RESET(3)	V90H1385CB	Z-COMP OF CURR TARGET POS VCT RST	ORB UPP	FT	DPL			
SEQ_ACCEPT(1)	V90J4732CB	NUM SEQ MARKS ACCEPT-H/X/AZ	DL FMT 22/1 ORB/RND NAV				93017G	*
SEQ_ACCEPT(2)	V90J4733CB	NUM SEQ MARKS ACCEPT-V/Y/EL	DL FMT 22/1 ORB/RND NAV				93017G	*
SEQ_ACCEPT(3)	V90J4730CB	NUM SEQ MARKS ACCEPT-RNG	DL FMT 22/1 ORB/RND NAV				93017G	*
SEQ_ACCEPT(4)	V90J4731CB	NUM SEQ MARKS ACCEPT-RDOT	DL FMT 22/1 ORB/RND NAV				93017G	*
SEQ_REJECT(1)	V90J4737CB	NUM SEQ MARKS REJECT-H/X/AZ	DL FMT 22/1 ORB/RND NAV				93017G	*
SEQ_REJECT(2)	V90J4738CB	NUM SEQ MARKS REJECT-V/Y/EL	DL FMT 22/1 ORB/RND NAV				93017G	*
SEQ_REJECT(3)	V90J4735CB	NUM SEQ MARKS REJECT-RNG	DL FMT 22/1 ORB/RND NAV				93017G	*
SEQ_REJECT(4)	V90J4736CB	NUM SEQ MARKS REJECT-RDOT	DL FMT 22/1 ORB/RND NAV				93017G	*
SQR_EMU	V90U1241C	SQUARE ROOT OF EARTH MU	ORB PRED ORB/RND NAV	FT3/S2			89648A	
SV_SOURCE_FOR_UPP	V90X4989XA	USER STATE SELECTION FLAG	ORB/RND NAV					
TAU_UNMOD_ACC_COV	V90W4929C	CORR TIME CONST UNMOD ACC COV PROP	ORB/RND NAV	S			89648A	
TOT_ACC_LAST(1)	V90A1262C	LAST X-COMP OF TOTAL ORB ACCEL-M50	ORB/RND NAV	FT/S2				
TOT_ACC_LAST(2)	V90A1263C	LAST Y-COMP OF TOTAL ORB ACCEL-M50	ORB/RND NAV	FT/S2				
TOT_ACC_LAST(3)	V90A1264C	LAST Z-COMP OF TOTAL ORB ACCEL-M50	ORB/RND NAV	FT/S2				
TV_PREDICT_FAIL	V90X4769XB	TARGET PREDICTION FAILURE IND	DL FMT 22/1				93017G	*
T_COV_LAST	V90W4771C	TIME OF COV MATRIX	ORB/RND NAV	S				
T_CURRENT_FILT	V90W4749CA	SNAP TIME TAG CURR IMU/ATT DATA	DL FMT 22/1 DL FMT 32/1	S			93017G	*
T_FILT_INIT	V90W1287CB	TIME TAG OF VCTR TO INIT NEXT OPS	D/L NAV SEQ ORB/RND NAV SEQ	S				
T_GPS_INIT	V90W3482CE	GPS INIT STATE TIME TAG	GPS REF STATE PROC	S	DPL		92214A	
T_GPS_LAST_UPDATE	V90W3556CD	TIME OF NAV RESET WITH SEL GPS	ENT NAV GPS RCVR STATE PROC ORB/RND NAV PRELAND NAV	S	DPL		92369B	
T_GPS_OFF	V90W3543CB	TIME OF LAST SEL GPS BY SEL FILTER	GPS RCVR STATE PROC	S	DPL		91051K	
T_LAST_FILT	V90W1252CB	TIME OF FILTER STATE VECTOR	ORB/RND NAV	S				
T_PRED_FINAL	V94W3979CD	TIME AT WHICH STATE IS DESIRED	DL FMT 22/1 DL FMT 32/1 ORB PRED	S			93017G	*

TABLE 4.1.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
T_PRED_INIT	V94W3970CD	TIME AT BEGINNING OF PRED	DL FMT 22/1 DL FMT 32/1 ORB PRED	S			93017G	*
T_RESET	V90W0534CH	TIME OF FILTER STATE VCTR	GPS RCVR STATE PROC ORB UPP ORB/RND NAV REL NAV DISP	S			92834C	
T_TV	V90W0315CB	TIME TAG OF TARGET VEH STATE VCTR	DL FMT 22/1 ORB/RND NAV REL NAV DISP	S			93017G	*
UNMOD_ACC_BIAS(1)	V90U1265C	X-COMP OF UNMODELED ACCEL BIAS ERR	ORB/RND NAV	FT/S2				
UNMOD_ACC_BIAS(2)	V90U1266C	Y-COMP OF UNMODELED ACCEL BIAS ERR	ORB/RND NAV	FT/S2				
UNMOD_ACC_BIAS(3)	V90U1267C	Z-COMP OF UNMODELED ACCEL BIAS ERR	ORB/RND NAV	FT/S2				
VAR_UNMOD_ACC(1)	V90A4933C	VARIANCE OF UNMOD ACC-1	ORB/RND NAV	FT2/S4				
VAR_UNMOD_ACC(2)	V90A4934C	VARIANCE OF UNMOD ACC-2	ORB/RND NAV	FT2/S4				
VAR_UNMOD_ACC(3)	V90A4935C	VARIANCE OF UNMOD ACC-3	ORB/RND NAV	FT2/S4				
VMP	V94X3971XD	PROPER VENT MODEL FLAG	ORB PRED					
V_CURRENT_FILT(1)	V90L8927CC	SNAPPED SEL TOTAL X VEL M50	DL FMT 22/1 DL FMT 32/1	FT/S			93017G	*
V_CURRENT_FILT(2)	V90L8928CC	SNAPPED SEL TOTAL Y VEL M50	DL FMT 22/1 DL FMT 32/1	FT/S			93017G	*
V_CURRENT_FILT(3)	V90L8929CC	SNAPPED SEL TOTAL Z VEL M50	DL FMT 22/1 DL FMT 32/1	FT/S			93017G	*
V_FILT(1)	V90L0624CD	X-COMP OF FLTR'S CURR VEL VECTOR	ORB/RND NAV	FT/S	SPL			
V_FILT(2)	V90L0625CD	Y-COMP OF FLTR'S CURR VEL VECTOR	ORB/RND NAV	FT/S	SPL			
V_FILT(3)	V90L0626CD	Z-COMP OF FLTR'S CURR VEL VECTOR	ORB/RND NAV	FT/S	SPL			
V_FILT_INIT(1)	V90L1279CB	X-COMP VEL VCTR TO INIT NEXT OPS	D/L NAV SEQ ORB/RND NAV SEQ	FT/S				
V_FILT_INIT(2)	V90L1280CB	Y-COMP VEL VCTR TO INIT NEXT OPS	D/L NAV SEQ ORB/RND NAV SEQ	FT/S				
V_FILT_INIT(3)	V90L1281CB	Z-COMP VEL VCTR TO INIT NEXT OPS	D/L NAV SEQ ORB/RND NAV SEQ	FT/S				
V_GPS_INIT(1)	V90L3495CE	GPS INIT VEL VECTOR X-COMP	GPS REF STATE PROC	FT/S	SPL		91051K	
V_GPS_INIT(2)	V90L3496CE	GPS INIT VEL VECTOR Y-COMP	GPS REF STATE PROC	FT/S	SPL		91051K	
V_GPS_INIT(3)	V90L3497CE	GPS INIT VEL VECTOR Z-COMP	GPS REF STATE PROC	FT/S	SPL		91051K	
V_IMU_GPS_INIT(1)	V90L3506CE	IMU ACCUM X VEL FOR GPS INIT	GPS REF STATE PROC	FT/S	DPL		92369B	
V_IMU_GPS_INIT(2)	V90L3507CE	IMU ACCUM Y VEL FOR GPS INIT	GPS REF STATE PROC	FT/S	DPL		92369B	
V_IMU_GPS_INIT(3)	V90L3508CE	IMU ACCUM Z VEL FOR GPS INIT	GPS REF STATE PROC	FT/S	DPL		92369B	
V_IMU_RESET(1)	V90L0247CI	SEL X-COMP OF ACCUM SENSED VEL RST	DL FMT 22/1 DL FMT 32/1 ORB UPP	FT/S			93017G	*
V_IMU_RESET(2)	V90L0248CI	SEL Y-COMP OF ACCUM SENSED VEL RST	DL FMT 22/1 DL FMT 32/1 ORB UPP	FT/S			93017G	*



TABLE 4.1.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
V_IMU_RESET(3)	V90L0249CI	SEL Z-COMP OF ACCUM SENSED VEL RST	DL FMT 22/1 DL FMT 32/1 ORB UPP	FT/S			93017G	*
V_LAST(1)	V90L4785C	CURR ORB X-VEL FOR COV PROP	ORB/RND NAV	FT/S				
V_LAST(2)	V90L4786C	CURR ORB Y-VEL FOR COV PROP	ORB/RND NAV	FT/S				
V_LAST(3)	V90L4787C	CURR ORB Z-VEL FOR COV PROP	ORB/RND NAV	FT/S				
V_LAST_FILT(1)	V90L0621CD	X-COMP VEL W COV MTRX & FLTR UPDTE	ORB/RND NAV	FT/S				
V_LAST_FILT(2)	V90L0622CD	Y-COMP VEL W COV MTRX & FLTR UPDTE	ORB/RND NAV	FT/S				
V_LAST_FILT(3)	V90L0623CD	Z-COMP VEL W COV MTRX & FLTR UPDTE	ORB/RND NAV	FT/S				
V_PRED_INIT(1)	V94L4006CD	X-COMP VEL VEC AT INITIAL TIME	DL FMT 22/1 DL FMT 32/1 ORB PRED	FT/S			93017G	*
V_PRED_INIT(2)	V94L4007CD	Y-COMP VEL VEC AT INITIAL TIME	DL FMT 22/1 DL FMT 32/1 ORB PRED	FT/S			93017G	*
V_PRED_INIT(3)	V94L4008CD	Z-COMP VEL VEC AT INITIAL TIME	DL FMT 22/1 DL FMT 32/1 ORB PRED	FT/S			93017G	*
V_PROP(1)	V90L4994C	X-COMP OF BU VEL VECTOR	ORB/RND NAV	FT/S				
V_PROP(2)	V90L4995C	Y-COMP OF BU VEL VECTOR	ORB/RND NAV	FT/S				
V_PROP(3)	V90L4996C	Z-COMP OF BU VEL VECTOR	ORB/RND NAV	FT/S			89493B	
V_RESET(1)	V90L0239CI	SEL X-COMP OF UPDATED VEL VCTR RST	ORB UPP	FT/S				
V_RESET(2)	V90L0240CI	SEL Y-COMP OF UPDATED VEL VCTR RST	ORB UPP	FT/S				
V_RESET(3)	V90L0241CI	SEL Z-COMP OF UPDATED VEL VCTR RST	ORB UPP	FT/S				
V_TV(1)	V90L0310CB	X-COMP TARGET VEH VEL VCTR-M50	ORB/RND NAV	FT/S				
V_TV(2)	V90L0311CB	Y-COMP TARGET VEH VEL VCTR-M50	ORB/RND NAV	FT/S				
V_TV(3)	V90L0312CB	Z-COMP TARGET VEH VEL VCTR-M50	ORB/RND NAV	FT/S				
V_TV_LAST(1)	V90L4792C	TARGET X-VEL FOR COV PROP	ORB/RND NAV	FT/S				
V_TV_LAST(2)	V90L4793C	TARGET Y-VEL FOR COV PROP	ORB/RND NAV	FT/S				
V_TV_LAST(3)	V90L4794C	TARGET Z-VEL FOR COV PROP	ORB/RND NAV	FT/S				
V_TV_RESET(1)	V90L1380CB	X-COMP OF CURR TARGET VEL VCT RST	ORB UPP	FT/S				
V_TV_RESET(2)	V90L1381CB	Y-COMP OF CURR TARGET VEL VCT RST	ORB UPP	FT/S				
V_TV_RESET(3)	V90L1382CB	Z-COMP OF CURR TARGET VEL VCT RST	ORB UPP	FT/S				
	V90M3137PB	CGNB ORB NAV FLAG WD2	DL FMT 22/1				93017G	*
	V90M3138PA	CGNB POS FEEDBACK IND MFE	DL FMT 22/A DL FMT 32/A				93017G	*
	V93M0518PB	CGZB_REL_NAV_FLG_WD1_LFE	DL FMT 22/1 DL FMT 32/1				93017G	*

TABLE 4.1.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
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**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**

**Rate Codes: (HDR Only) 1 = 1 sample/sec 2 = 5 samples/sec 3 = 12.5 samples/sec 4 = 25 samples/sec 5 = 100 samples/sec  
(HDR and LDR) A = 1 sample/sec B = 5 samples/sec C = 12.5 samples/sec D = 25 samples/sec E = 100 samples/sec**

TABLE 4.1.3-3. ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
COV_COR_UPDATE (1)	V96H1290C	ND	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
COV_COR_UPDATE (2)	V96H1291C	ND	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
COV_COR_UPDATE (3)	V96H1292C	ND	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
COV_COR_UPDATE (4)	V96H1293C	ND	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
COV_COR_UPDATE (5)	V96H1294C	ND	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
COV_COR_UPDATE (6)	V96H1295C	ND	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
COV_COR_UPDATE (7)	V96H1296C	ND	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
COV_U_A_COAST (1)	V96U9095C	FT**2/SEC**4	F	S	D	P	G4.126 G4.148	00	ZPA	DC0617	
COV_U_A_COAST (2)	V96U9096C	FT**2/SEC**4	F	S	D	P	G4.126 G4.148	00	ZPA	DC0617	
COV_U_A_COAST (3)	V96U9097C	FT**2/SEC**4	F	S	D	P	G4.126 G4.148	00	ZPA	DC0617	
DT_NAV_STATE_PROP	V96U8683C	SEC	I	S	D	P	G4.148	00	ZFB	89622A	
GPS_LOCKOUT	V97U3563C	ND	I	S	M	P	G4.123 G4.139 G4.148 G6.11 G6.21 G6.51	00	GPI	92292B	
REF_ORB_AREA	V96U9160C	FT**2	F	S	D	P	G4.126 G4.148 G4.158	00	ZFB	89622A	
R_TV (1)	V90H0307C	FT	F	D	M	P	G4.148	00	RDZ	DC0617	
R_TV (2)	V90H0308C	FT	F	D	M	P	G4.148	00	RDZ	DC0617	
R_TV (3)	V90H0309C	FT	F	D	M	P	G4.148	00	RDZ	DC0617	
SIG_UPDATE (1)	V96H1284C	FT	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
SIG_UPDATE (2)	V96H1285C	FT	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
SIG_UPDATE (3)	V96H1286C	FT	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
SIG_UPDATE (4)	V96H1287C	FT/SEC	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
SIG_UPDATE (5)	V96H1288C	FT/SEC	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
SIG_UPDATE (6)	V96H1289C	FT/SEC	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
TAU_U_A_COAST	V96U9184C	SEC	F	S	D	P	G4.126 G4.148	00	ZPA	DC0617	

TABLE 4.1.3-3. ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
TFOFF	V96W8178C	SEC	F	D	M	P	G4.126 G4.148	00	ZFB	89622A	
TFON	V96W8177C	SEC	F	D	M	P	G4.126 G4.148	00	ZFB	89622A	
T_TV	V90W0315C	SEC	F	D	M	P	G4.148	00	RDZ	DC0617	
VAR_U_A_COAST(1)	V96U9208C	FT**2/SEC**4	F	S	D	P	G4.126 G4.148	00	ZPA	DC0617	
VAR_U_A_COAST(2)	V96U9209C	FT**2/SEC**4	F	S	D	P	G4.126 G4.148	00	ZPA	DC0617	
VAR_U_A_COAST(3)	V96U9210C	FT**2/SEC**4	F	S	D	P	G4.126 G4.148	00	ZPA	DC0617	
VFORCE(1)	V96U8174C	LBS	F	S	M	P	G4.126 G4.148	00	ZFB	89622A	
VFORCE(2)	V96U8175C	LBS	F	S	M	P	G4.126 G4.148	00	ZFB	89622A	
VFORCE(3)	V96U8176C	LBS	F	S	M	P	G4.126 G4.148	00	ZFB	89622A	
V_TV(1)	V90L0310C	FT/SEC	F	D	M	P	G4.148	00	RDZ	DC0617	
V_TV(2)	V90L0311C	FT/SEC	F	D	M	P	G4.148	00	RDZ	DC0617	
V_TV(3)	V90L0312C	FT/SEC	F	D	M	P	G4.148	00	RDZ	DC0617	

**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**

TABLE 4.1.3-4. ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148) K-LOADS

FSSR NAME DESCRIPTION	MSID	MC	KLOAD VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
DT_LIM	V96U9579C	00	+600	SEC	I	S	P	G4.123 G4.148	92080B	
GM_DEG	V96U9117C	00	+4	ND	I	S	P	G4.126 G4.148	59953	
GM_ORD	V96U9119C	00	+4	ND	I	S	P	G4.126 G4.148	59953	
MAX_TIME_TOL MAX ALLOWABLE TOTAL PREDICTION INTERVAL	V96U8685C	00	+5.4	E+04	SEC	F	S	P G4.126 G4.127 G4.148 G4.15 G6.11	92834C	
PREC_STEP_PRED	V98U8726C	00	+3.00	E+02	SEC	F	D	P G4.126 G4.148	89648A	
PRED_STEP_OPS_INIT	V96U8686C	00	+6.10	E+02	SEC	F	D	P G4.148	59953	
REF_ORB_CD	V96U9161C	00	+2.0	E+00	ND	F	S	P G4.126 G4.148 G4.158	89542A	
TARGET_AREA TARGET AREA FOR DRAG ACCELERATION	V96U9173C	00	+1.0	E+00	FT**2	F	S	P G4.126 G4.148	92545B	
TARGET_CD TARGET CD FOR DRAG ACCELERATION	V96U9174C	00	+2.0	E+00	ND	F	S	P G4.126 G4.148	92545B	
TARGET_MASS TARGET MASS FOR DRAG ACCELERATION	V96U9175C	00	+1.0	E+00	SLUGS	F	S	P G4.126 G4.148	92545B	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.1.3-5. ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
ATFL_OV CONTROLS USE OF CURRENT ORB ATTITUDE IN DRAG COMPUTE	V97U6102C	00	+0	ND	I		S	C G4.126 G4.148 G4.18 G4.21 G4.22	91051K	
ATFL_TV CONTROLS USE OF MASS, AREA & DC FOR TARGET	V97U6103C	00	+2	ND	I		S	C G4.126 G4.148	90374C	
C(01) TESSERAL HARMONIC COEFFICIENT ELEM 1	V97U6104C	00	-2.7635957	E-10	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
C(02) TESSERAL HARMONIC COEFFICIENT ELEM 2	V97U6105C	00	+1.5711423	E-06	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
C(03) TESSERAL HARMONIC COEFFICIENT ELEM 3	V97U6106C	00	+2.1907694	E-06	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
C(04) TESSERAL HARMONIC COEFFICIENT ELEM 4	V97U6107C	00	+3.0466825	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	

TABLE 4.1.3-5. ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
C(05) TESSERAL HARMONIC COEFFICIENT ELEM 5	V97U6108C	00	+9.7966803	E-08	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
C(06) TESSERAL HARMONIC COEFFICIENT ELEM 6	V97U6109C	00	-5.0552749	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
C(07) TESSERAL HARMONIC COEFFICIENT ELEM 7	V97U6110C	00	+7.8842515	E-08	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
C(08) TESSERAL HARMONIC COEFFICIENT ELEM 8	V97U6111C	00	+5.9073749	E-08	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
C(09) TESSERAL HARMONIC COEFFICIENT ELEM 9	V97U6112C	00	-4.1542493	E-09	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	

TABLE 4.1.3-5. ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
DFL INDICATES ACTIVATION (1) OF DRAG MODEL	V97U6114C	00	ON	ND	D		C	G4.126 G4.148	90374C	
EARTH_MU EARTH GRAVITATIONAL CONSTANT	V97U4378C	00	+1.40764487566E+16	FT**3/SEC**2	F	D	C	A6.9 G4.126 G4.127 G4.13 G4.139 G4.144 G4.148 G4.15 G4.158 G4.2 G4.205 G4.209 G4.210 G4.211 G4.224 G4.236 G4.3 G4.4 G5.10 G5.24 G5.26 G5.27	93090E	



TABLE 4.1.3-5. ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
EARTH_RADIUS_EQUATOR EARTH EQUATORIAL RADIUS	V97U5324C	00	+2.09257414698E+07	FT	F	D	C	A6.9 G4.126 G4.127 G4.13 G4.139 G4.144 G4.148 G4.15 G4.158 G4.19 G4.20 G4.205 G4.210 G4.211 G4.213 G4.23 G4.236 G4.238 G4.24 G4.25 G5.26 G5.27 V5.1.8	93090E	
EARTH_RADIUS_GRAV EARTH RADIUS(GRAV ACCEL)	V97U5325C	00	+2.09256561680E+07	FT	F	D	C	A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	

TABLE 4.1.3-5. ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
EARTH_RATE EARTH'S ROTATIONAL RATE	V97U4379C	00	+7.29211514646E-05	RAD/SEC	F		D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.17 G4.19 G4.20 G4.205 G4.21 G4.213 G4.22 G4.236 G4.237 G4.4 G5.26	93090E	
ELLIPT EARTH'S ELLIPTICITY CONSTANT	V97U5332C	00	+3.352329869 E-03	ND	F		D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.19 G4.20 G4.205 G4.213 G4.23 G4.236 G4.237 G4.238 G4.24 G4.25 G5.26 G5.27 V5.1.8	93090E	
G_2_FPS2 MASS-TO-WEIGHT CONVERSION	V97U4393C	00	+3.2174049 E+01	LB/SLUG	F		S	P A6.9 G4.13 G4.148 G4.158 G4.210 G4.211 G4.5	90374C	

TABLE 4.1.3-5. ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
R_TEMP(1) DEFAULT ORB POSITION OPS TRANSITION VECTOR TOO STALE	V97U6244C	00	+2.2166000	E+07	FT	F	S	P G4.123 G4.148	92080B	
R_TEMP(2) DEFAULT ORB POSITION OPS TRANSITION VECTOR TOO STALE	V97U6245C	00	+0.0	E+00	FT	F	S	P G4.123 G4.148	92080B	
R_TEMP(3) DEFAULT ORB POSITION OPS TRANSITION VECTOR TOO STALE	V97U6246C	00	+0.0	E+00	FT	F	S	P G4.123 G4.148	92080B	
S(01) TESSERAL HARMONIC COEFFICIENT ELEM 1	V97U5492C	00	-5.2357454	E-09	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
S(02) TESSERAL HARMONIC COEFFICIENT ELEM 2	V97U5493C	00	-9.0231337	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
S(03) TESSERAL HARMONIC COEFFICIENT ELEM 3	V97U5494C	00	+2.7267074	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
S(04) TESSERAL HARMONIC COEFFICIENT ELEM 4	V97U5495C	00	-2.1259298	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	

TABLE 4.1.3-5. ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
S(05) TESSERAL HARMONIC COEFFICIENT ELEM 5	V97U5496C	00	+1.9681077	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
S(06) TESSERAL HARMONIC COEFFICIENT ELEM 6	V97U5497C	00	-4.4125015	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
S(07) TESSERAL HARMONIC COEFFICIENT ELEM 7	V97U5498C	00	+1.4818958	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
S(08) TESSERAL HARMONIC COEFFICIENT ELEM 8	V97U5499C	00	-1.2140873	E-08	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
S(09) TESSERAL HARMONIC COEFFICIENT ELEM 9	V97U5500C	00	+6.3163541	E-09	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	

TABLE 4.1.3-5. ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
SV_TIME_TAG_DIFF	V97U6132C	01	+1.0	E+00	SEC	F	S	P G4.126	90374C	
TIME TOLERANCE FOR PREDICTION		02	+5.0	E-01				G4.127		
		03	+1.0	E+00				G4.148		
		08	+5.0	E-01				G4.15		
VFL_OV_PRED	V97U6135C	00	OFF		ND	D	P	G4.126	90374C	
DEACTIVATION(0) OF VENT FOR ORBITER PREDICTION								G4.148		
VFL_TV	V97U6136C	00	ON		ND	D	P	G4.126	90374C	
SPECIFIES(1) USE OF UNMODELED ACCEL FOR TARGET PROP								G4.148		
VFL_TV_PRED	V97U6139C	00	+0		ND	I	S	P G4.148	90374C	
VENTING FLAG FOR TARGET PREDICTION FOR UPP STATE PROPAGATION								G4.22		
VFL_TV_PROP	V97U6140C	00	OFF		ND	D	P	G4.126	90374C	
SPECIFIES(1) USE OF VENT IN BACKUP PROP FOR TARGET								G4.148		
V_TEMP(1)	V97U6247C	00	+0.0	E+00	FT/SEC	F	S	P G4.123	92080B	
DEFAULT ORB VEL WHEN OPS TRANSITION VECTOR TOO STALE								G4.148		
V_TEMP(2)	V97U6248C	00	+2.5270	E+04	FT/SEC	F	S	P G4.123	92080B	
DEFAULT ORB VEL WHEN OPS TRANSITION VECTOR TOO STALE								G4.148		
V_TEMP(3)	V97U6249C	00	+0.0	E+00	FT/SEC	F	S	P G4.123	92080B	
DEFAULT ORB VEL WHEN OPS TRANSITION VECTOR TOO STALE								G4.148		
ZONAL(01)	V97U5582C	00	+0.0	E+00	ND	F	D	C A6.9	90374C	
ZONAL HARMONICS COEFFICIENT ELEM 1								G4.126		
								G4.127		
								G4.139		
								G4.144		
								G4.148		
								G4.15		
								G4.205		
								G4.236		
ZONAL(02)	V97U5583C	00	+1.0826271	E-03	ND	F	D	C A6.9	90374C	
ZONAL HARMONICS COEFFICIENT ELEM 2								G4.126		
								G4.127		
								G4.139		
								G4.144		
								G4.148		
								G4.15		
								G4.205		
								G4.236		

TABLE 4.1.3-5. ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER (G4.148) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
ZONAL(03) ZONAL HARMONICS COEFFICIENT ELEM 3	V97U5584C	00	-2.5358868	E-06	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
ZONAL(04) ZONAL HARMONICS COEFFICIENT ELEM 4	V97U5585C	00	-1.6246180	E-06	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

## 4.2 ONORBIT/RENDEZVOUS NAVIGATION PRINCIPAL FUNCTION

The Onorbit/Rendezvous Navigation principal function is the name given to the collection of all subfunctions whose major task is to supply users of this principal function with accurate estimates of the orbiter and target state vectors. This section presents an overview of this principal function.

The Onorbit/Rendezvous Navigation principal function contains the following primary subfunctions.

- Navigation Control (Section 4.2.1)
- Navigation Data Snap (Section 4.2.2)
- State and Covariance Matrix Updates (Section 4.2.3)
- Position and Velocity State Propagation (Section 4.2.4)
- Unmodeled Acceleration State and Covariance Matrix Propagation (Section 4.2.5)
- Rendezvous Sensor Measurement Selection (Section 4.2.6)
- Sensor Measurement Initialization (Section 4.2.7)
- State and Covariance Measurement Incorporation (Section 4.2.8)
- Measurement Processing Statistics (Section 4.2.9)
- GPS Specific Subfunctions (Section 4.2.10)
- RNP Matrix Computation (STS 83-0005)
- GPS Receiver State Processing Principal Function (STS 83-0004)

As discussed in Section 3, on-orbit operations consist of two distinct phases: non-rendezvous on-orbit coast and rendezvous. During the on-orbit coast phase the orbiter navigation state (initialized at OPS transition) is propagated using drag and gravity models with IMU accumulated sensed velocity when required. The navigation state is periodically reset with either state uplinks from the ground, based on ground navigation of the orbiter, or with the selected GPS state vector from the GPS receiver state processing principal function, which is executed by the on-orbit/rendezvous navigation principal function.

During the rendezvous phase, two separate capabilities, controlled by the crew, are provided for maintaining both the orbiter and target states. The first capability utilizes onboard relative sensors to produce an accurate estimate of the position and velocity of the orbiter and target state. These sensors provide measurements which are processed in a thirteen element filter state rendezvous Kalman filter. The relative sensors consist of the rendezvous radar, the two star trackers and the Crew Optical Alignment Sight (COAS). The orbiter and target states are propagated using appropriately configured drag and gravity models. IMU data is used in the orbiter state propagation during translation maneuvers and when uncoupled attitude rotations exceed a threshold. The GPS receiver state processing principal function continues to execute during relative sensor processing, and, depending on the system configuration as set by the crew, can reset the Shuttle inertial state to the selected GPS orbiter state estimate. When this occurs, the target state and the rendezvous navigation Kalman filter covariance matrix are adjusted to maintain the relative error and relative error statistics in the orbiter-target relative frame. The orbiter navigation state

and the target state are provided to users through the Shuttle and Target reset subfunctions. The second rendezvous navigation capability utilizes the selected GPS orbiter state estimate obtained from processing the onboard GPS receiver's states in the GPS receiver processing principal function. The target state is maintained by the on-orbit/rendezvous navigation principal function, and can be periodically reset by ground uplink of the target state, based either on ground navigation of the target or using state vectors downlinked from the target vehicle navigation system. The selected orbiter GPS state and the target state are being sent to users through the Shuttle and target reset subfunctions.

The rendezvous navigation implementation in the on-orbit/rendezvous navigation principal function allows both relative navigation methods to be used at the same time. Thus relative sensor measurement processing can occur when the selected orbiter GPS state is being provided by the navigation principal function to software users. When the selected GPS state is also used to reset the orbiter navigation filter state, the software will automatically adjust the target state to maintain the correct inertial relative state so that relative sensor processing can proceed uninterrupted. The prop state is also adjusted to maintain the correct prop state to filter state relative information. If the target state is reset by ground uplink, no automatic adjustment is made to the orbiter state, causing the relative state to be changed. The rendezvous navigation filter covariance matrix no longer reflects the correct relative state error conditions and should be manually reinitialized.

The rendezvous navigation Kalman filter uses a thirteen component filter state which consists of the following:

- Orbiter or target position and velocity in the mean of 1950 coordinate system – six elements
- Orbiter or target unmodeled acceleration biases in mean of 1950 coordinates – three elements
- Systematic sensor biases – four elements

A flag (SHUTTLE\_FILTER\_FLAG) received from the REL NAV display determines whether the orbiter or the target position and velocity are to be updated with the Kalman filter. This same flag also indicates which vehicle is to be associated with the unmodeled acceleration bias states.

The Navigation Control subfunction supplies the navigation trunk logic, which sequences the other primary subfunctions in the proper order and at the proper rates. The covariance matrix propagation, sensor selection, sensor initialization, measurement incorporation and measurement processing statistics subfunctions can be performed at a rate slower than the data snap, state propagation and state and covariance matrix update subfunctions. This subrate is determined by an I-load, N\_CYCLE\_SUB. When the cycle counter, I\_CYCLE, reaches the value N\_CYCLE\_SUB, the subrate subfunctions are executed. This subrate capability is basically intended to be used when it is undesirable to perform the computationally complex covariance matrix propagation and measurement incorporation at the state vector propagation rate. The Navigation Control subfunction is scheduled by the Onorbit/Rendezvous Navigation Sequencer principal function at the proper rate for the active navigation phase and operational sequence.

All external flags input to NAV are snapped at the same time and stored into locations for use by NAV. The Navigation Data Snap subfunction copies frequently changing measurement data buffers into static memory locations local to the navigation processing. The RCS firing flag, DAP\_JET, is turned off after being copied into the local storage location, NAV\_DAP\_JET. During the rendezvous navigation phase, the IMU, the rendezvous radar, the star tracker, and the crew optical alignment sight (COAS) sensors are available to the navigation. During nonrendezvous, only IMU data are available.



If the RNP Matrix time parameters have been uplinked, the RNP MAT COMP function (G4.16) shall be called to recompute the RNP Matrix data.

The State and Covariance Matrix Updates subfunction implements ground updates to the orbiter or target state vector via uplink and performs state vector transfers and covariance matrix reinitialization when requested by the crew on the REL\_NAV display. All of these types of updates (except a transfer of the filtered state vector to the backup propagated state vector) require reinitialization of the covariance matrix. For ground updates the prediction task must be invoked to bring the Shuttle or target state vector to current time. Due to the priority of the Precise Predictor principal function in the onboard computer, the prediction can proceed only after navigation has completed a cycle. The prediction can possibly require more than one navigation interval to complete the prediction. The update to the navigation state vectors will not take place until the prediction has completed. With the state vector transfers, capabilities are provided which allow the target state to be moved to the Shuttle state or vice versa, or allow the filtered state to be moved to the backup state (maintaining the backup state with a current filter solution), or the backup state to be moved to the filtered state (reinitializing navigation with a stable vector).

The Position and Velocity State Propagation subfunction must maintain a current estimate of the orbiter position and velocity during rendezvous and nonrendezvous navigation phases and a current estimate of the target position and velocity during the rendezvous navigation phase only. The subfunction will provide a unit vector from the center of the Earth in the direction of the sun for use by the Universal Pointing Processor principal function at a frequency of once every navigation cycle. When the powered flight navigation phase is active and IMU-sensed acceleration exceeds a threshold, IMU-sensed delta velocities and a model of the Earth's gravitational acceleration are used to propagate the orbiter position and velocity to current time. When in the coasting flight navigation phase or IMU-sensed acceleration is below a threshold, models of the Earth's gravitational acceleration, aerodynamic drag, and venting or uncoupled RCS thrusting acceleration are used to propagate the orbiter. The target propagation uses models of the Earth's gravitational acceleration and aerodynamic drag during either powered flight or coasting flight. This subfunction must maintain a backup propagated state vector associated with the vehicle state being filtered during the rendezvous navigation phase. This backup state will be propagated only and will not be subjected to measurement incorporation or ground state vector uplinks.

The task of propagating the statistics of the state vector to current time as well as the propagation of the unmodeled acceleration bias states is performed by the Unmodeled Acceleration State and Covariance Matrix Propagation subfunction. The unmodeled acceleration bias state elements are propagated exponentially (the sensor bias state elements are assumed constant over the propagation interval) so this subfunction will determine the appropriate time constant and variances used for propagation dependent on whether or not IMU sensed delta velocities were used to propagate the position and velocity vectors for the orbiter.

The unmodeled acceleration bias states actually represent different quantities depending on whether the IMU-sensed delta velocities were used to propagate the state or not. In the former case the unmodeled acceleration biases represent the errors in the IMU accelerometers. In the latter case they represent unmodeled body forces such as drag, venting, and RCS uncoupled thrusting. In each case, a different time constant and variance are used for the exponentially correlated random variable statistics.

A 13-by-13 covariance matrix represents the statistics of the 13-element state vector. The position and velocity statistics are propagated using an analytic partial called the mean conic partial transition matrix. The unmodeled acceleration bias statistics and the sensor bias statistics are propagated as exponentially correlated random variables. A model of platform drift supplies state noise whenever the IMU-sensed delta velocities are used to propagate the state.

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The Sensor Measurement Selection subfunction must select a measurement set for processing by the Kalman filter. The following measurements are available:

- Rendezvous radar range and range rate
- Rendezvous radar shaft and trunnion angles
- Star tracker horizontal and vertical angles
- Crew optical alignment sight (COAS) horizontal and vertical angles

Up to four measurements can be chosen for processing – rendezvous radar range and range rate along with one pair of angles selected by the crew on the REL\_NAV display. When a measurement type is selected for the first time, statistical parameters associated with the newly selected measurement type must be initialized for use in the Kalman estimation of systematic sensor biases. This task is performed by the Navigation Sensor Initialization subfunction.

The State and Covariance Measurement Incorporation subfunction performs the final step in the Kalman processing, namely, the incorporation of the selected measurements. The covariance matrix is updated. The position and velocity vectors of the vehicle state selected for Kalman processing (determined by SHUTTLE\_FILTER\_FLAG) are updated. The sensor biases are updated. A flag from the ILOAD (UNMOD\_ACC\_UPDATE\_FLAG) determines whether the unmodeled acceleration states are to be updated or to be left zero, leaving only their statistical influence on the Kalman processing. Measurements can be incorporated into the state vector only when all the following criteria are satisfied.

- Rendezvous navigation phase is active (REND\_NAV\_FLAG = ON)
- The measurement type is selected
- The measurement data are valid
- The IMU-sensed acceleration is below a premission-specified threshold (MEAS\_THRESHOLD)
- The covariance matrix has been propagated on the current navigation cycle
- The estimated distance between the orbiter and the target is greater than a premission-specified distance
- The measurement is not in the INHIBIT mode as selected by the crew on the REL\_NAV display
- The measurement does not fail to pass the edit criteria which reject measurements which are not commensurate with the estimated measurement
- When in Major Mode 202 the MEAS\_ENABLE switch is set to ON by the crew

After Kalman processing has been completed, the Measurement Processing Statistics subfunction shall compute parameters to be displayed on the REL\_NAV display. The parameters calculated are the measurement residuals and residual ratios, the mark histories, and the edit status.

The GPS receiver state processing principal function is then executed prior to executing the Shuttle reset subfunction.

A direct user of the onorbit/rendezvous navigated state vector is the User Parameter Processing principal function. This principal function integrates the state vector using a high rate, less precise propagator (average-g) than that used by the navigation. The user parameter processing state vector is updated with the navigation state vector at the navigation rate. The user parameter processing state vector is updated by the backup navigation state, or the filtered navigation state, depending on crew item entry on the REL\_NAV display. Other principal functions which require state vectors get them from the User Parameter Processing principal function at the higher rate.

Another direct user of the onorbit/rendezvous navigated state vector is the GPS Reference State Processing principal function. The orbiter state is continuously provided to this principal function so that it is available for use when a GPS receiver is required to be initialized. The requirements for this principal function is provided in the Entry Through Landing Navigation FSSR STS 83-0004.

Table 4.2 contains the Onorbit/Rendezvous Navigation principal function parameter interface to local modules. There are some parameters in this table which are being output to telemetry (TLM) which were not set by NAV. For these situations, the local source is listed as "NONE."

Table 4.2. Onorbit/Rendezvous Navigation Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
ALT_SS			TLM	ACCEL_ONORBIT
ANGLES_AIF	REL_NAV display	NAV_ONORBIT_RENDEZVOUS		
ANGLES_AIF_DISPLAY			REL_NAV display, TLM	REND_SENSOR_SELECT
ANGLES_ENABLE_DISPLAY			REL_NAV display, TLM	REND_NAV_SENSOR_INIT
ATMP			Onorbit Predictor, TLM	ONORBIT_REND_AUTO_INFLIGHT_UPDATE
AXN	Star Tracker SOP		Sensor Data Snap	
COAS_DATA_GOOD			TLM	NAV_ONORBIT_RENDEZVOUS
COAS_HORIZ	Star Tracker SOP		Sensor Data Snap	
COAS_ID			TLM	NAV_ONORBIT_RENDEZVOUS
COAS_MARK_NUM			TLM	NAV_ONORBIT_RENDEZVOUS
COAS_VERT	Star Tracker SOP	Sensor Data Snap		
CONT_ACC			TLM	ONORBIT_REND_R_V_STATE_PROP
COV_ACCEL_UVW_INIT	Onorbit/Rendezvous Navigation Sequencer	U_A_BIAS_AND_COVINIT		
COV_COR_UPDATE	Uplink Processor	COVINIT_UVW		
COV_POS_SIG			TLM	COV_LAST_RESET
COV_VEL_SIG			TLM	COV_LAST_RESET

Table 4.2. Onorbit/Rendezvous Navigation Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
COV_PWRD_FLT	Onorbit/Rendezvous Navigation Sequencer	REND_BIAS_AND_COV_PROP		
COV_PWRD_FLT_LAST	Onorbit/Rendezvous Navigation Sequencer	REND_BIAS_AND_COV_PROP		
CURR_ORB_MASS	Onorbit/Rendezvous Navigation Sequencer, Onorbit Guidance	NAV_ONORBIT_RENDEZVOUS		
DA_THRESHOLD			TLM	NAV_ONORBIT_RENDEZVOUS
DAP_JET	ORB DAP	NAV_ONORBIT_RENDEZVOUS		
DATA_GOOD	Star Tracker SOP	Sensor Data Snap		
DID_COVAR_REINIT			REL_NAV display, TLM	REL_NAV_DISPLAY_UPDATES
DID_ORB_TO_TGT			REL_NAV display TLM	REL_NAV_DISPLAY_UPDATES, NAV_ONORBIT_RENDEZVOUS
DID_SV_SOURCE_FOR_UPP			REL_NAV display, TLM	NAV_ONORBIT_RENDEZVOUS
DID_FILTERED_TO_PROP			REL_NAV display, TLM	REL_NAV_DISPLAY_UPDATES
DID_PROP_TO_FILTERED			REL_NAV display, TLM	REL_NAV_DISPLAY_UPDATES
DID_TGT_TO_ORB			REL_NAV display, TLM	REL_NAV_DISPLAY_UPDATES
DISP_DELQ			REL_NAV display, TLM	MEAS_PROCESSING_STATISTICS_REND
DISP_EDIT			REL_NAV display, GN&C Communication Interface, TLM	MEAS_PROCESSING_STATISTICS_REND
DISP_SIG			REL_NAV display, TLM	MEAS_PROCESSING_STATISTICS_REND
DMP			Onorbit Predictor	ONORBIT_REND_AUTO_INFLIGHT_UPDATE
DO_COAS_ANGLES_NAV			TLM	REND_SENSOR_SELECT
DO_COAS_ANGLES_NAV_LAST	Onorbit/Rendezvous Navigation Sequencer	REND_NAV_SENSOR_INIT		
DO_COVAR_REINIT	REL_NAV display	NAV_ONORBIT_RENDEZVOUS		
DOING_REND_NAV	Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP, ONORBIT_REND_AUTO_INFLIGHT_UPDATE, NAV_ONORBIT_RENDEZVOUS		
DOING_MEAS_ENABLE			REL_NAV display, TLM	REND_SENSOR_SELECT
DOING_ST_RR_COAS			ORB ATT PROC, TLM	NAV_ONORBIT_RENDEZVOUS

Table 4.2. Onorbit/Rendezvous Navigation Principal Function Parameter Interface to Local Modules

Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
DO_FILTERED_TO_PROP	REL_NAV display	NAV_ONORBIT_RENDEZVOUS		
DO_ORB_TO_TGT	REL_NAV display	NAV_ONORBIT_RENDEZVOUS	REL_NAV display	NAV_ONORBIT_RENDEZVOUS, REL_NAV_DISPLAY UPDATES
DO_OV_UPLINK	Uplink Processor	NAV_ONORBIT_RENDEZVOUS	Uplink Processor	ONORBIT_REND_AUTO_INFLIGHT_UPDATE
DO_PROP_TO_FILTERED	REL_NAV display	NAV_ONORBIT_RENDEZVOUS		
DO_RR_ANGLES_NAV			TLM	REND_SENSOR_SELECT
DO_RR_ANGLES_NAV_LAST	Onorbit/Rendezvous Navigation Sequencer	REND_NAV_SENSOR_INIT		
DO_RRDOT_NAV_LAST	Onorbit/Rendezvous Navigation Sequencer	REND_NAV_SENSOR_INIT		
DO_ST_ANGLES_NAV			TLM	REND_SENSOR_SELECT
DO_ST_ANGLES_NAV_LAST	Onorbit/Rendezvous Navigation Sequencer	REND_NAV_SENSOR_INIT		
DO_ST_RR_COAS	REL_NAV display	NAV_ONORBIT_RENDEZVOUS		
DO_TV_UPLINK	Uplink Processor	NAV_ONORBIT_RENDEZVOUS	Uplink Processor	ONORBIT_REND_AUTO_INFLIGHT_UPDATE
DO_TGT_TO_ORB	REL_NAV display	NAV_ONORBIT_RENDEZVOUS		
$\bar{D}_{SS}$			TLM	$\bar{ACCEL\_ONORBIT}$
DT_COV			TLM	REND_BIAS_AND_COV_PROP
DV_COUNT			TLM	ONORBIT_REND_R_V_STATE_PROP
DV_DISP			TLM	ONORBIT_REND_R_V_STATE_PROP
$\bar{D}V_{COV}$	Onorbit/Rendezvous Navigation Sequencer	NAV_ONORBIT_RENDEZVOUS, REND_BIAS_AND_COV_PROP, REND_NAV_INTERP	TLM	NAV_ONORBIT_RENDEZVOUS, COV_LAST_RESET
DT_FILT			Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP
$\bar{D}V_{FILT}$			Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP
E	Onorbit/Rendezvous Navigation Sequencer	REND_BIAS_AND_COV_PROP, REND_NAV_FILTER	TLM (diagonal element only)	REND_BIAS_AND_COV_PROP, REND_NAV_FILTER, COVINIT_UVW, U_A_BIAS_AND_COVINIT, SETUP, REND_COV_INIT
FALSE_TARG	Star Tracker SOP	STAR_TRACKER_NAV	Star Tracker SOP	STAR_TRACKER_NAV

Table 4.2. Onorbit/Rendezvous Navigation Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
FILT_UPDATE			User Parameter Processing	NAV_ONORBIT_RENDEZVOUS
FOM <sub>I</sub> <sup>1</sup>			GPS_RCVR_STATE_PROC	NAV_ONORBIT_RENDEZVOUS
FOM_SOP <sub>I</sub> <sup>1</sup>	GPS_SOP	GPS data snap		
$\bar{G}_{NEW}$			TLM	ONORBIT_REND_R_V_STATE_PROP
$\bar{G}_{TV}$			TLM	ONORBIT_REND_R_V_STATE_PROP
$\bar{G}_{TV\_LAST}$	Onorbit/Rendezvous Navigation Sequencer	REND_BIAS_AND_COV_PROP		
GMDP			Onorbit Predictor	ONORBIT_REND_AUTO_INFLIGHT_UPDATE
GMOP			Onorbit Predictor	ONORBIT_REND_AUTO_INFLIGHT_UPDATE
GPS_AIF	REL_NAV Display	NAV_ONORBIT_RENDEZVOUS		
GPS_AIF_RCVD			GPS_RCVR_STATE_PROC, GPS_STATUS Display	NAV_ONORBIT_RENDEZVOUS
GPS_AIF_EXEC			GPS_STATUS DISPLAY	NAV_ONORBIT_RENDEZVOUS
GPS_DG <sub>I</sub> <sup>1</sup>			GPS_RCVR_STATE_PROC	NAV_ONORBIT_RENDEZVOUS
GPS_DG_SOP <sub>I</sub> <sup>1</sup>	GPS_SOP	GPS data snap		
GPS_FAIL_FOM <sub>I</sub> <sup>1</sup>			GPS_RCVR_STATE_PROC	NAV_ONORBIT_RENDEZVOUS
GPS_FAIL_FOM_SOP <sub>I</sub> <sup>1</sup>	GPS_SOP	GPS data snap		
GPS_NAV_AIF_EXEC			REL_NAV display, GPS_STATUS display	GPS_UPDATE
GPS_RATIO_FLAG	GPS_RCVR_STATE_PROC	GPS_UPDATE		
GPS_REF_INIT_VALID			GPS_REF_STATE_PROC	SHUTTLE_RESET
GPS_SV_SEL_AVAIL	GPS_RCVR_STATE_PROC	SHUTTLE_RESET		
GPS_TO_NAV_AI	GPS_STATUS Display	NAV_ONORBIT_RENDEZVOUS		
GPS_TO_NAV_FORCE	GPS_STATUS Display	NAV_ONORBIT_RENDEZVOUS		
GPS_TO_NAV_FORCE_RCVD			GPS_RCVR_STATE_PROC	NAV_ONORBIT_RENDEZVOUS
GPS_TO_NAV_RCVD			GPS_RCVR_STATE_PROC	NAV_ONORBIT_RENDEZVOUS

Table 4.2. Onorbit/Rendezvous Navigation Principal Function Parameter Interface to Local Modules

Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
GPS_TO_NAV_AIF			GPS_STATUS Display, GPS_RCVR_STATE_PROC, REL_NAV Display	GPS_UPDATE
H_NAV	Star Tracker SOP	Sensor Data Snap		
I_CYCLE	Onorbit/Rendezvous Navigation Sequencer	NAV_ONORBIT_RENDEZVOUS	TLM	NAV_ONORBIT_RENDEZVOUS REND_COV_INIT
IDRAG			Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP
IMU_NAV_ACCEL_THRESH	IMU align display	NAV_ONORBIT_RENDEZVOUS		
IVENT			Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP
IGD			Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP
IGO			Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP
KFACTOR	Uplink Processor	ACCEL_ONORBIT		
MEAS_ENABLE	REL_NAV display, Onorbit/Rendezvous Navigation Sequencer	NAV_ONORBIT_RENDEZVOUS		
M_M50_TO_BODY_COAS			TLM	NAV_ONORBIT_RENDEZVOUS
M_M50_TO_ST			TLM	NAV_ONORBIT_RENDEZVOUS
MM_CODE	MSC	NAV_ONORBIT_RENDEZVOUS		
N_ACCEPT	Onorbit/Rendezvous Navigation Sequencer	MEAS_PROCESSING_STATISTICS_REND	TLM, REL_NAV display	MEAS_PROCESSING_STATISTICS_REND, DISPLAY_COUNT_INIT, SETUP
NAV_MEAS			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_ANGLES_AIF			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_CURR_ORB_MASS			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_DAP_JET			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_DO_COVAR_REINIT			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_DO_FILTERED_TO_PROP			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_DO_ORB_TO_TGT			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_DO_OV_UPLINK			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_DO_PROP_TO_FILTERED			TLM	NAV_ONORBIT_RENDEZVOUS

Table 4.2. Onorbit/Rendezvous Navigation Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
NAV_DO_TGT_TO_ORB			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_DO_TV_UPLINK			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_FALSE_TARG			TLM, Star Tracker	STAR_TRACKER_NAV
NAV_MEAS_ENABLE			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_MM_CODE			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_PWRD_FLT_NAV			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_RANGE_AIF			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_RDOT_AIF			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_RR_ANGLES_ENABLE			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_ST_ENABLE			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_SIGHT	Star Tracker SOP	Sensor Data Snap		
NAV_SV_SOURCE_FOR_UPP			TLM	NAV_ONORBIT_RENDEZVOUS
NAV_TARGET	Star Tracker SOP	Sensor Data Snap		
NOISY_NAV_MEAS	Onorbit/Rendezvous Navigation Sequencer	REND_BIAS_AND_COV_PROP		
N_REJECT	Onorbit/Rendezvous Navigation Sequencer	MEAS_PROCESSING_STATISTICS_REND	TLM, REL_NAV display	MEAS_PROCESSING_STATISTICS_REND, DISPLAY_COUNT_INIT, SETUP
OV_PREDICT_FAIL			TLM	ONORBIT_REND_AUTO_INFLIGHT_UPDATE
PRED_ENA_FLAG	Onorbit/Rendezvous Navigation Sequencer	STATE_VECTOR_PREDICT_TASK		
PRED_ORB_AREA			Onorbit Predictor, TLM	ONORBIT_REND_AUTO_INFLIGHT_UPDATE
PRED_ORB_CD			Onorbit Predictor, TLM	ONORBIT_REND_AUTO_INFLIGHT_UPDATE
PRED_ORB_MASS			Onorbit Predictor, TLM	ONORBIT_REND_AUTO_INFLIGHT_UPDATE
PRED_STEP			Onorbit Predictor, TLM	ONORBIT_REND_AUTO_INFLIGHT_UPDATE
PRED_USE	Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_AUTO_INFLIGHT_UPDATE, STATE_VECTOR_PREDICT_TASK	Onorbit/Rendezvous Navigation Sequencer, TLM	ONORBIT_REND_AUTO_INFLIGHT_UPDATE, STATE_VECTOR_PREDICT_TASK



Table 4.2. Onorbit/Rendezvous Navigation Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
PWRD_FLT_NAV	REL_NAV display, Onorbit/Rendezvous Navigation Sequencer, FCS/DED DISP C/O Display	NAV_ONORBIT_RENDEZVOUS		
Q_BOD_M50	Onorbit Attitude Processing	IMU Data Snap		
Q_COAS_HORIZ			TLM	NAV_ONORBIT_RENDEZVOUS
Q_COAS_VERT			TLM	NAV_ONORBIT_RENDEZVOUS
Q_M50BODY_IMU			TLM	NAV_ONORBIT_RENDEZVOUS
Q_M50BODY_RR	Rendezvous Radar SOP	Sensor Data Snap	TLM	NAV_ONORBIT_RENDEZVOUS
Q_ST_HORIZ			TLM	NAV_ONORBIT_RENDEZVOUS
Q_ST_VERT			TLM	NAV_ONORBIT_RENDEZVOUS
Q_RR_RNG			TLM	NAV_ONORBIT_RENDEZVOUS
Q_RR_RNG_DOT			TLM	NAV_ONORBIT_RENDEZVOUS
Q_RR_ROLL			TLM	NAV_ONORBIT_RENDEZVOUS
Q_RR_PITCH			TLM	NAV_ONORBIT_RENDEZVOUS
RANGE_AIF	REL_NAV display	NAV_ONORBIT_RENDEZVOUS		
RANGE_AIF_DISPLAY			REL_NAV display, TLM	REND_SENSOR_SELECT
RDOT_AIF	REL_NAV display	NAV_ONORBIT_RENDEZVOUS		
RDOT_AIF_DISPLAY			REL_NAV display, TLM	REND_SENSOR_SELECT
RDOT_DATA_GOOD			TLM	NAV_ONORBIT_RENDEZVOUS
RNP_TIME_UL	Uplink Processor	NAV_ONORBIT_RENDEZVOUS		
R_FILT	Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP, COV_LAST_RESET, REND_COV_INIT, NAV_ONORBIT_RENDEZVOUS, REL_NAV_DISPLAY_UPDATE	Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP, REND_NAV_FILTER
R_FILT_DISP			ORBIT TGT DISPLAY	NAV_ONORBIT_RENDEZVOUS
R_FILT_TLM			TLM	NAV_ONORBIT_RENDEZVOUS
R_FMP_DISP			TLM, REL_NAV Display	NAV_ONORBIT_RENDEZVOUS

Table 4.2. Onorbit/Rendezvous Navigation Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
$\bar{R}$ _GPS_ECEF <sub>1</sub> <sup>†</sup>			GPS_RCVR_STATE_PROC	NAV_ONORBIT_RENDEZVOUSE
$\bar{R}$ _GPS_INIT			GPS_REF_STATE_PROC	SHUTTLE_RESET
$\bar{R}$ _GPS_SEL	GPS_RCVR_STATE_PROC	SHUTTLE_RESET, GPS_RESYNCH, GPS_UPDATE		
$\bar{R}$ _GPS_ECEF_SOP <sub>1</sub> <sup>†</sup>	GPS_SOP	GPS data snap		
$\bar{R}$ _GND	Uplink Processor	ONORBIT_REND_AUTO_INFLIGHT_UPDATE		
$\bar{R}$ _LAST	Onorbit/Rendezvous Navigation Sequencer	REND_BIAS_AND_COV_PROP, REND_NAV_INTERP		
R_MEAS_RSS			TLM, REL_NAV Display	MEAS_PROCESSING_STATISTICS_REND
RNG_DATA_GOOD			TLM	NAV_ONORBIT_RENDEZVOUS
$\bar{R}$ _PRED_FINAL	Onorbit Predictor	ONORBIT_REND_AUTO_INFLIGHT_UPDATE, STATE_VECTOR_PREDICT_TASK		
$\bar{R}$ _PRED_INIT			Onorbit Predictor, TLM	ONORBIT_REND_AUTO_INFLIGHT_UPDATE, STATE_VECTOR_PREDICT_TASK
$\bar{R}$ _PROP	Onorbit/Rendezvous Navigation Sequencer	REL_NAV_DISPLAY_UPDATES, ONORBIT_REND_R_V_STATE_PROP, NAV_ONORBIT_RENDEZVOUS		
$\bar{R}$ _PROP_TLM			TLM	NAV_ONORBIT_RENDEZVOUS
RR_ANG_DG	Rendezvous Radar SOP	Sensor Data Snap		
RR_ANGLE_DATA_GOOD			TLM	NAV_ONORBIT_RENDEZVOUS
RR_ANGLE_MARK_NUM			TLM	NAV_ONORBIT_RENDEZVOUS
RRDOT_MARK_NUM			TLM	NAV_ONORBIT_RENDEZVOUS
$\bar{R}$ _RESET			User Parameter Processing	SHUTTLE_RESET, NAV_ONORBIT_RENDEZVOUS
RR_PITCHO	Rendezvous Radar SOP	Sensor Data Snap		
RR_RANGEO	Rendezvous Radar SOP	Sensor Data Snap		
RR_RNG_DG	Rendezvous Radar SOP	Sensor Data Snap		
RR_RNGR_DG	Rendezvous Radar SOP	Sensor Data Snap		
RR_RNGRO	Rendezvous Radar SOP	Sensor Data Snap		

Table 4.2. Onorbit/Rendezvous Navigation Principal Function Parameter Interface to Local Modules

Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
RR_ROLLO	Rendezvous Radar SOP	Sensor Data Snap		
RR_SELF_TEST	Rendezvous Radar SOP	Sensor Data Snap		
RR_TIM	Rendezvous Radar SOP	Sensor Data Snap		
R_TV	Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP, REL_NAV_DISPLAY_UPDATES, COV_LAST_RESET, REND_COV_INIT, NAV_ONORBIT_RENDEZVOUS	Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP, REND_NAV_FILTER, NAV_ONORBIT_RENDEZVOUS
R_TV_GND	Uplink Processor	ONORBIT_REND_AUTO_INFLIGHT_UPDATE		
R_TV_LAST	Onorbit/Rendezvous Navigation Sequencer	REND_BIAS_AND_COV_PROP, REND_NAV_INTERP		
R_TV_RESET			User Parameter Processing	TARGET_RESET, NAV_ONORBIT_RENDEZVOUS
R_TV_TLM			TLM	NAV_ONORBIT_RENDEZVOUS
SENSOR_BIAS_TLM			TLM	NAV_ONORBIT_RENDEZVOUS
SENSOR_EDIT			TLM	REND_SENSOR_SELECT, RRDOT_NAV, RR_ANGLE_NAV, ANGLE_NAV
SELF_TEST_FLAG			TLM	NAV_ONORBIT_RENDEZVOUS
SEQ_ACCEPT	Onorbit/Rendezvous Navigation Sequencer	MEAS_PROCESSING_STATISTICS_REND	TLM	SETUP, MEAS_PROCESSING_STATISTICS_REND, DISPLAY_COUNT_INIT
SEQ_REJECT	Onorbit/Rendezvous Navigation Sequencer	MEAS_PROCESSING_STATISTICS_REND	TLM	SETUP, MEAS_PROCESSING_STATISTICS_REND, DISPLAY_COUNT_INIT
SEL_V_M50_CG	IMU Redundancy Management	IMU Data Snap		
SHUTTLE_FILTER_FLAG	REL_NAV display	NAV_ONORBIT_RENDEZVOUS, REL_NAV_DISPLAY_UPDATES, ONORBIT_REND_R_V_STATE_PROP, ACCEL_ONORBIT, REND_BIAS_AND_COV_PROP, REND_NAV_FILTER, GPS_RESYNCH		
SIG_UPDATE	Uplink Processor	COVINIT_UVW		

Table 4.2. Onorbit/Rendezvous Navigation Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
SQR_EMU	Onorbit/Rendezvous Navigation Sequencer	MEAN_CONIC_ PARTIAL_ TRANSITION_ MATRIX_6X6, ONORBIT_SV_INTERP		
ST_DATA_GOOD			TLM	NAV_ONORBIT_ RENDEZVOUS
ST_MARK_NUM			TLM	NAV_ONORBIT_ RENDEZVOUS
SV_SOURCE_FOR_UPP	REL_NAV display, Onorbit/Rendezvous Navigation Sequencer	NAV_ONORBIT_ RENDEZVOUS		
TARGET_KFACTOR	Uplink Processor	ACCEL_ONORBIT		
TAU_UNMOD_ACC_COV	Onorbit/Rendezvous Navigation Sequencer	REND_BIAS_AND_ COV_PROP		
T_COAS			TLM	NAV_ONORBIT_ RENDEZVOUS
T_COV_LAST	Onorbit/Rendezvous Navigation Sequencer	REND_BIAS_AND_ COV_PROP		
T_CURRENT_FILT			TLM	NAV_ONORBIT_ RENDEZVOUS
T_FILT_DAYS			ORBIT TGT display	NAV_ONORBIT_ RENDEZVOUS
T_FILT_HRS			ORBIT TGT display	NAV_ONORBIT_ RENDEZVOUS
T_FILT_MIN			ORBIT TGT display	NAV_ONORBIT_ RENDEZVOUS
T_FILT_SECS			ORBIT TGT display	NAV_ONORBIT_ RENDEZVOUS
T_GPS <sub>1</sub> <sup>†</sup>			GPS_RCVR_STATE_ PROC	NAV_ONORBIT_ RENDEZVOUS
T_GPS_INIT			GPS_REF_STATE_ PROC	SHUTTLE_RESET
T_GPS_LAST_UPDATE	Onorbit/Rendezvous Navigation Sequencer, Asc Nav Seq, D/L Nav Seq, Ent Nav	GPS_UPDATE	GPS_RCVR_STATE_ PROC, Ent Nav, Preland Nav	ONORB_REND_AUTO_ INFLIGHT_UPDATE, GPS_UPDATE
T_GPS_SOP <sub>1</sub> <sup>†</sup>	GPS_SOP	GPS data snap		
TFOFF	Uplink Processor	ACCEL_ONORBIT	TLM	none
TFON	Uplink Processor	ACCEL_ONORBIT	TLM	none
T_GND	Uplink Processor	ONORBIT_REND_ AUTO_INFLIGHT_ UPDATE		
T_IMU_SAVE_SOP <sub>1</sub> <sup>†</sup>	GPS_SOP	GPS data snap		
T_LAST_GPS <sub>1</sub> <sup>†</sup>			GPS_RCVR_STATE_ PROC	NAV_ONORBIT_ RENDEZVOUS
T_NAV	Star Tracker SOP	Sensor Data Snap		
T_IMUS	IMU Inertial Processing	IMU Data Snap		

Table 4.2. Onorbit/Rendezvous Navigation Principal Function Parameter Interface to Local Modules

Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
T_LAST_FILT	Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP, NAV_ONORBIT_RENDEZVOUS, COV_LAST_RESET, REND_COV_INIT	Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP
T_LAST_FILT_TLM			TLM	NAV_ONORBIT_RENDEZVOUS
T_M50_BODY	Star Tracker SOP	Sensor Data Snap		
T_M50_ST	Star Tracker SOP	Sensor Data Snap		
T_ORB_STATE_UPDATE			TLM	ONORBIT_REND_AUTO_INFLIGHT_UPDATE
TOT_ACC			TLM	REND_BIAS_AND_COV_PROP
TOT_ACC_LAST	Onorbit/Rendezvous Navigation Sequencer	REND_BIAS_AND_COV_PROP		
T_PRED_FINAL			Onorbit Predictor, TLM	STATE_VECTOR_PREDICT_TASK
T_PRED_INIT			Onorbit Predictor, TLM	ONORBIT_REND_AUTO_INFLIGHT_UPDATE, STATE_VECTOR_PREDICT_TASK
T_REND_RADAR			TLM	NAV_ONORBIT_RENDEZVOUS
T_RESET	Onorbit/Rendezvous Navigation Sequencer	STATE_VECTOR_PREDICT_TASK	User Parameter Processing, Onorbit/Rendezvous Navigation Sequencer, GPS_RCVR_STATE_PROC, Rel Nav Disp	SHUTTLE_RESET
TRG_TRK_MODE			TLM	NAV_ONORBIT_RENDEZVOUS
T_STAR_TRACKER			TLM	NAV_ONORBIT_RENDEZVOUS
T_TARLOS	Star Tracker SOP	Sensor Data Snap		
T_TV	Onorbit/Rendezvous Navigation Sequencer	REND_COV_INIT	TLM, Onorbit/Rendezvous Navigation Sequencer, Rel Nav Disp	ONORBIT_REND_R_V_STATE_PROP, ONORBIT_REND_AUTO_INFLIGHT_UPDATE (TLM only), NAV_ONORBIT_RENDEZVOUS
T_TV_GND	Uplink Processor	ONORBIT_REND_AUTO_INFLIGHT_UPDATE		
T_TV_STATE_UPDATE			TLM	ONORBIT_REND_AUTO_INFLIGHT_UPDATE

Table 4.2. Onorbit/Rendezvous Navigation Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
TV_PREDICT_FAIL			TLM	ONORBIT_REND_AUTO_INFLIGHT_UPDATE
$\bar{U}$ UNMOD_ACC_BIAS	Onorbit/Rendezvous Navigation Sequencer	$\bar{A}$ CCEL_ONORBIT, REND_BIAS_AND_COV_PROP, NAV_ONORBIT_RENDEZVOUS		
$\bar{U}$ UNMOD_ACC_BIAS_TLM			TLM	NAV_ONORBIT_RENDEZVOUS
$\bar{U}$ R_SUN			Universal Pointing Processing	ONORBIT_REND_R_V_STATE_PROP
USE_IMU_DATA			TLM	ONORBIT_REND_R_V_STATE_PROP
$\bar{V}$ AR_UNMOD_ACC	Onorbit/Rendezvous Navigation Sequencer	REND_BIAS_AND_COV_PROP		
$\bar{V}$ _CURRENT_FILT			GPS_RCVR_STATE_PROC, TLM	NAV_ONORBIT_RENDEZVOUS
$\bar{V}$ _GPS_ECEF <sub>i</sub> <sup>1</sup>			GPS_RCVR_STATE_PROC	NAV_ONORBIT_RENDEZVOUS
$\bar{V}$ _GPS_INIT			GPS_REF_STATE_PROC	SHUTTLE_RESET
$\bar{V}$ _GPS_SEL	GPS_RCVR_STATE_PROC	SHUTTLE_RESET, GPS_RESYNCH, GPS_UPDATE		
$\bar{V}$ _GPS_ECEF_SOP <sub>i</sub> <sup>1</sup>	GPS_SOP	GPS data snap		
$\bar{V}$ _IMU_GPS_INIT			GPS_REF_STATE_PROC	SHUTTLE_RESET
$\bar{V}$ _IMU_SAVE_SOP <sub>i</sub> <sup>1</sup>	GPS SOP	GPS Data Snap		
$\bar{V}$ _LAST_GPS <sub>i</sub> <sup>1</sup>			GPS_RCVR_STATE_PROC	NAV_ONORBIT_RENDEZVOUS
$\bar{V}$ ENT_SS			TLM	$\bar{A}$ CCEL_ONORBIT
$\bar{V}$ _FILT	Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP, REND_COV_INIT, NAV_ONORBIT_RENDEZVOUS, REL_NAV_DISPLAY_UPDATES	Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP, REND_NAV_FILTER
$\bar{V}$ _FILT_DISP			ORBIT TGT DISPLAY	NAV_ONORBIT_RENDEZVOUS
$\bar{V}$ _FILT_TLM			TLM	NAV_ONORBIT_RENDEZVOUS
$\bar{V}$ FORCE	Uplink Processor	ACCEL_ORBIT	TLM	none
V_FMP_DISP			TLM, REL_NAV Display	NAV_ONORBIT_RENDEZVOUS
$\bar{V}$ _GND	Uplink Processor	ONORBIT_REND_AUTO_INFLIGHT_UPDATE		
$\bar{V}$ _IMU_RESET			User Parameter Processing, TLM	SHUTTLE_RESET

Table 4.2. Onorbit/Rendezvous Navigation Principal Function Parameter Interface to Local Modules

Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
$\bar{V}$ _LAST	Onorbit/Rendezvous Navigation Sequencer	REND_BIAS_AND_COV_PROP, REND_NAV_INTERP		
$\bar{V}$ _LAST_FILTER	Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP		
VMP			Onorbit Predictor	ONORBIT_REND_AUTO_INFLIGHT_UPDATE
V_MEAS_RSS			TLM, REL_NAV Display	MEAS_PROCESSING_STATISTICS_REND
V_NAV	Star Tracker SOP	Sensor Data Snap		
$\bar{V}$ _PRED_FINAL	Onorbit Predictor	ONORBIT_REND_AUTO_INFLIGHT_UPDATE, STATE_VECTOR_PREDICT_TASK		
$\bar{V}$ _PRED_INIT			TLM, Onorbit Predictor	ONORBIT_REND_AUTO_INFLIGHT_UPDATE, STATE_VECTOR_PREDICT_TASK
$\bar{V}$ _PROP	Onorbit/Rendezvous Navigation Sequencer	REL_NAV_DISPLAY_UPDATES, ONORBIT_REND_R_V_STATE_PROP, NAV_ONORBIT_RENDEZVOUS		
$\bar{V}$ _PROP_TLM			TLM	NAV_ONORBIT_RENDEZVOUS
$\bar{V}$ _RESET			User Parameter Processing	SHUTTLE_RESET, NAV_ONORBIT_RENDEZVOUS
$\bar{V}$ _TV	Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP, REL_NAV_DISPLAY_UPDATES, COV_LAST_RESET, REND_COV_INIT, NAV_ONORBIT_RENDEZVOUS	Onorbit/Rendezvous Navigation Sequencer	ONORBIT_REND_R_V_STATE_PROP, REND_NAV_FILTER, NAV_ONORBIT_RENDEZVOUS
$\bar{V}$ _TV_GND	Uplink Processor	ONORBIT_REND_AUTO_INFLIGHT_UPDATE		
$\bar{V}$ _TV_LAST	Onorbit/Rendezvous Navigation Sequencer	REND_BIAS_AND_COV_PROP, REND_NAV_INTERP		
$\bar{V}$ _TV_RESET			User Parameter Processing	TARGET_RESET, NAV_ONORBIT_RENDEZVOUS
$\bar{V}$ _TV_TLM			TLM	NAV_ONORBIT_RENDEZVOUS

<sup>1</sup> I designates that there is a variable for each GPS receiver (I = 1 to GPS\_SW\_CAP)

Table 4.2. Onorbit/Rendezvous Navigation Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source

Tables 4.2.11-1 and 4.2.11-2 provide the input and output data flow between the Onorbit/Rendezvous Navigation principal function and other principal functions. Other available parameter tables include I-loads in Table 4.2.11-3, K-loads in Table 4.2.11-4, Constants in Table 4.2.11-5, and a parameter cross-reference listing in Section 4.2.11.



#### 4.2.1 Navigation Control (NAV\_ONORBIT\_RENDEZVOUS)

The Navigation Control subfunction is responsible for providing the executive logic for the proper execution of the Onorbit/Rendezvous Navigation principal function. This subfunction shall perform the following tasks.

- Store the orbiter and target state vectors from the previous navigation cycle into protected locations for downlist and display
- Snap all external flags input to NAV, the IMU data, and rendezvous sensor data (during rendezvous phase)
- Call the RNP matrix computation function in response to an RNP Matrix Time parameters uplink.
- Provide for possible automatic inflight updates of either the orbiter or target position and velocity vectors
- When in rendezvous phase, the Navigation Control subfunction will provide the capability to respond to crew requests, via the REL\_NAV display, to reinitialize the covariance matrix or to do state vector transfers between the orbiter position and velocity vectors and the target position and velocity vectors.
- Provide for the propagation of the position and velocity vectors for the orbiter and, when in rendezvous phase, propagate the target position and velocity vectors also
- Provide for the automatic or manual resetting of the orbiter navigation state to the selected GPS state from the GPS receiver state processing principal function execution on the previous navigation cycle. When in the rendezvous phase and processing relative sensor measurements perform the following: reset the target inertial state so that the relative state in inertial space reflects the relative state that existed prior to the update of the orbiter state; reset the prop state to preserve the prop to filter state relative information; adjust the rendezvous navigation filter covariance matrix so that the filter covariance matrix statistics correctly reflect the existing relative state and anticipated residual behavior.
- When in the rendezvous phase, the Navigation Control subfunction will provide the following functions:
  - Perform the scheduling of the asynchronous covariance propagation and invoke the Rendezvous Bias and Covariance Propagation subfunction when scheduled.
  - Provide the proper processing of the rendezvous sensor data. If the IMU-sensed acceleration magnitude falls below a design-dependent threshold, then the sensor data will be processed.
  - Store the backup propagation state vector for use by the User Parameter Processing principal function if it has been specified that the backup vector be used.
- This subfunction shall invoke the Shuttle Reset subfunction to store the updated Shuttle position and velocity vectors for the User Parameter Processing principal function, and provide values to GPS reference state processing principal function for GPS receiver reference state

initialization. When in rendezvous phase, the Target Reset subfunction is called to store the target position and velocity vectors.

- When in rendezvous phase, this subfunction will store the backup propagation state vector for use by the User Parameter Processing principal function if it has been specified that the backup vector be used.

A. Detailed Requirements. This subfunction shall perform the following steps in the order indicated.

1.0 Execute the SNAP\_INPUTS code which consists of the following tasks:

- a. Store the orbiter and target state vectors and time tag from the previous navigation cycle into protected locations for downlist.

$\overline{T\_LAST\_FILT\_TLM}$	=	$\overline{T\_LAST\_FILT}$
$\overline{R\_FILT\_TLM}$	=	$\overline{R\_FILT}$
$\overline{V\_FILT\_TLM}$	=	$\overline{V\_FILT}$
$\overline{R\_TV\_TLM}$	=	$\overline{R\_TV}$
$\overline{V\_TV\_TLM}$	=	$\overline{V\_TV}$
$\overline{SENSOR\_BIAS\_TLM}$	=	$\overline{SENSOR\_BIAS}$
$\overline{UNMOD\_ACC\_BIAS\_TLM}$	=	$\overline{UNMOD\_ACC\_BIAS}$

- b. Store the external flags input to NAV and the orbiter mass into protected locations for NAV and then turn the DAP\_JET flag off.

NAV_CURR_ORB_MASS	=	CURR_ORB_MASS
NAV_DO_OV_UPLINK	=	DO_OV_UPLINK
NAV_DO_TV_UPLINK	=	DO_TV_UPLINK
NAV_MM_CODE	=	MM_CODE
NAV_PWRD_FLT_NAV	=	PWRD_FLT_NAV
DA_THRESHOLD	=	IMU_NAV_ACCEL_THRESH
NAV_DAP_JET	=	DAP_JET
NAV_DO_ORB_TO_TGT	=	DO_ORB_TO_TGT
NAV_DO_FILTERED_TO_PROP	=	DO_FILTERED_TO_PROP
NAV_DO_PROP_TO_FILTERED	=	DO_PROP_TO_FILTERED
NAV_SV_SOURCE_FOR_UPP	=	SV_SOURCE_FOR_UPP
DAP_JET	=	OFF

- c. Snap the measurement data input to NAV, which consists of the following steps:

(1) Snap the IMU and GPS data as described in Section 4.2.2.1 and Section 4.2.2.2 respectively and perform the assignments of GPS related variables to navigation variables as shown.

- (a) Snap the selected IMU accumulated velocity, with the associated time tag, and the Mean of 50 to body quaternion as follows:

SNAP IMU\_DATA( $\overline{V\_CURRENT\_FILT}$ ,  $\overline{T\_CURRENT\_FILT}$ ,  
Q\_M50BODY\_IMU)

- (b) Collect and store a homogeneous set of GPS receiver data from the GPS SOP as shown. This data includes GPS state estimates, data good flags, figure-of-merit, and associated IMU data

SNAP GPS\_DATA ( $\bar{R}$ \_GPS\_ECEF,  $\bar{V}$ \_GPS\_ECEF, T\_GPS, GPS\_DG,  
GPS\_FAIL\_FOM, FOM,  $\bar{V}$ \_LAST\_GPS, T\_LAST\_GPS)

These GPS variables (vector, scalar arrays, character strings and discretely) correspond to data from up to three GPS receivers, which represents the maximum number of receivers for which the software is designed.

The snap statement implies the assignment of current GPS SOP data to the variables shown in parentheses. Time-homogeneous data for each GPS receiver must be provided to the appropriate subfunctions. The data between each receiver will not be time-homogenous.

- (c) The received values of the GPS control flags shall be stored for use by the navigation function:

GPS\_AIF\_RCVD = GPS\_TO\_GC\_AIF  
GPS\_TO\_NAV\_RCVD = GPS\_TO\_NAV\_AI  
GPS\_TO\_NAV\_FORCE\_RCVD = GPS\_TO\_NAV\_FORCE

The flag indicating that the navigation states have been set equal to the selected GPS state is set to OFF:

NAV\_RESET = OFF

The parameter which will indicate to the displays if the received GPS\_TO\_GC\_AIF command can be executed by the navigation software on this cycle is set to BLANK:

GPS\_AIF\_EXEC = BLANK

The blank refers to an OFF condition and the setting DOWN\_ARROW refers to an ON condition. Blank and DOWN\_ARROW are used for clarity of requirements with desired display formats.

- (2) Test the value of the DOING\_REND\_NAV flag to determine if the rendezvous phase is active. If the rendezvous phase is active (DOING\_REND\_NAV = ON), perform the following steps:

Snap the sensor measurement data as described in Section 4.2.2.3. For the rendezvous radar this includes the roll and pitch outputs, range and range rate measurements; the range, range rate, and angle data validity flags; the mean of 50 to body attitude quaternion at the time of the snap; the time tag for the measurements; and finally a self-test indicator.

SNAP REND\_RADAR (Q\_RR\_ROLL, Q\_RR\_PITCH, Q\_RR\_RNG,  
Q\_RR\_RNG\_DOT, RNG\_DATA\_GOOD, RDOT\_DATA\_GOOD,  
RR\_ANGLE\_DATA\_GOOD, Q\_M50BODY\_RR, T\_REND\_RADAR,  
SELF\_TEST\_FLAG)

For star tracker, snap the horizontal and vertical measurements, angle data validity flag, the mean of 50 to star tracker transformation matrix, the time tag for the star tracker measurements, and the target tracking mode indicator.

SNAP STAR\_TRACKER (Q\_ST\_HORIZ, Q\_ST\_VERT, ST\_DATA\_GOOD,  
M\_M50\_TO\_ST, T\_STAR\_TRACKER, TRG\_TRK\_MODE)

For COAS, snap the horizontal and vertical angle measurements, the data validity indicator, mean of 50 to body transformation matrix at the time of COAS data snap, the COAS identification, and the COAS time tag.

SNAP COAS (Q\_COAS\_HORIZ, Q\_COAS\_VERT, COAS\_DATA\_GOOD,  
M\_M50\_TO\_BODY\_COAS, COAS\_ID, T\_COAS)

Snap the rendezvous flags input to NAV.

NAV_ANGLES_AIF	= ANGLES_AIF
NAV_RANGE_AIF	= RANGE_AIF
NAV_RDOT_AIF	= RDOT_AIF
NAV_DO_COVAR_REINIT	= DO_COVAR_REINIT
NAV_DO_TGT_TO_ORB	= DO_TGT_TO_ORB
NAV_MEAS_ENABLE	= MEAS_ENABLE
DOING_ST_RR_COAS	= DO_ST_RR_COAS
NAV_ST_RR_COAS	= DO_ST_RR_COAS

If Star Tracker angles are selected (DO\_ST\_RR\_COAS = 1), then set  
NAV\_ST\_ENABLE = 1 and  
NAV\_RR\_ANGLES\_ENABLE = 0, else  
if Rendezvous Radar Angles are selected (DO\_ST\_RR\_COAS = 2), then set  
NAV\_RR\_ANGLES\_ENABLE = 1 and  
NAV\_ST\_ENABLE = 0, else  
set both NAV\_RR\_ANGLES\_ENABLE = 1 and  
NAV\_ST\_ENABLE = 1.

- d. Store the backup state vector into protected locations for downlist when the rendezvous phase is active.

$$\bar{R}_{PROP\_TLM} = \bar{R}_{PROP}$$

$$\bar{V}_{PROP\_TLM} = \bar{V}_{PROP}$$

- 2.0 As part of the SNAP\_INPUTS code, perform engineering units conversion on the downlisted orbiter state vector and store into protected locations for time-homogeneous onboard display.

$$\begin{aligned}
 T\_FILT\_DAYS &= TRUNCATE (T\_LAST\_FILT\_TLM/86,400) \\
 T\_FILT\_HRS &= TRUNCATE [(T\_LAST\_FILT\_TLM - 86,400 \\
 &\quad T\_FILT\_DAYS)/3,600] \\
 T\_FILT\_MIN &= TRUNCATE [(T\_LAST\_FILT\_TLM - 86,400 T\_FILT\_DAYS \\
 &\quad - 3,600 T\_FILT\_HRS)/60] \\
 T\_FILT\_SECS &= T\_LAST\_FILT\_TLM - 86,400 T\_FILT\_DAYS - 3,600 \\
 &\quad T\_FILT\_HRS - 60 T\_FILT\_MIN \\
 \bar{R}\_FILT\_DISP &= \bar{R}\_FILT\_TLM/1,000 \\
 \bar{V}\_FILT\_DISP &= \bar{V}\_FILT\_TLM/1,000
 \end{aligned}$$

- 3.0 Check the RNP Matrix Time Parameters uplink flag (RNP\_TIME\_UL) to determine if the RNP MAT COMP function (G4.16) should be called to recompute the RNP Matrix data (M\_M50TOEF\_AT\_EPOCH, T\_EPOCH, and EARTH\_POLE).

IF RNP\_TIME\_UL = ON, then  
 CALL: RNP\_MAT\_COMP  
 RNP\_TIME\_UL = OFF

- 4.0 Convert the mean of 50 to body quaternion from the IMU into a mean of 50 to body transformation matrix by calling the quaternion to matrix function described in Section 4.10.8.

Take the transpose of this matrix to generate a body to mean of 50 transformation matrix.

$$M\_BODYM50 = [QUAT\_TO\_MAT(Q\_M50BODY\_IMU)]^T$$

- 5.0 Test the value of the DOING\_REND\_NAV flag to determine if rendezvous phase is active.

- a. If the rendezvous phase is active (DOING\_REND\_NAV = ON), perform the following steps:

- (1) Subtract any known time bias from the measurement time for each sensor.

$$T\_REND\_RADAR = T\_REND\_RADAR - T\_BIAS\_REND\_RADAR$$

$$T\_STAR\_TRACKER = T\_STAR\_TRACKER - T\_BIAS\_ST$$

$$T\_COAS = T\_COAS - T\_BIAS\_COAS$$

- (2) Call the Onorbit Rendezvous Auto Inflight Updates subfunction to perform any required ground updates to the Shuttle or target state vectors as described in Section 4.2.3.1.

CALL: ONORBIT\_REND\_AUTO\_INFLIGHT\_UPDATE

- (3) Call the REL\_NAV Display Updates subfunction to perform any required updates to the state vectors or to the covariance matrix as selected by the crew as described in Section 4.2.3.2.

CALL: REL\_NAV\_DISPLAY\_UPDATES

- (4) Execute the GPS update function described in section 4.2.10. If a selected GPS state is available from the GPS receiver state processing principal function execution on the previous onorbit/rendezvous navigation cycle, and if other requisite criteria are satisfied, the orbiter navigation filter state will be reset to the selected GPS state. This function will copy GPS states generated on the previous navigation cycle, now time tagged to T\_LAST\_FILT, into  $\bar{R}$ \_FILT and  $\bar{V}$ \_FILT.

CALL: GPS\_UPDATE

- (5) Invoke the Onorbit Rendezvous State Propagation function described in Section 4.2.4 to propagate the position and velocity vectors to current time.

CALL: ONORBIT\_REND\_R\_V\_STATE\_PROP

- (6) Deleted.
- (7) Deleted.
- (8) Increment the covariance matrix propagation counter.

$I\_CYCLE = I\_CYCLE + 1$

Then execute the covariance propagation setup code,

EXECUTE: COV\_PROP\_SETUP\_CODE

which consists of the following tasks:

If IMU-sensed delta velocity was used by the State Propagation subfunction on the present navigation cycle (COV\_USE\_IMU\_DATA = ON), then accumulate the delta velocity into the total delta velocity for the covariance propagation interval and set the covariance powered flight indicator to ON.

$\bar{D}V\_COV = \bar{D}V\_COV + \bar{D}V\_FILT$

COV\_PWRD\_FLT = ON

If the contact acceleration (CONT\_ACC) for the Shuttle is greater than a design-dependent threshold for measurement processing (CONT\_ACC > MEAS\_THRESHOLD), then a flag is set to indicate that measurements will not be processed on the current covariance propagation subcycle.

NOISY\_NAV\_MEAS = ON

- (9) If the covariance matrix propagation cycle counter is greater than or equal to the covariance propagation subcycle count ( $I\_CYCLE \geq N\_CYCLE\_SUB$ ), then perform the following tasks:

Zero the cycle counter

I\_CYCLE = 0

Call the Rendezvous Bias and Covariance Matrix Propagation subfunction described in Section 4.2.5.

CALL: REND\_BIAS\_AND\_COV\_PROP

This subfunction propagates the covariance matrix and propagates the ECRV bias statistics and sets a flag (NAV\_MEAS) which determines whether sensor measurements will be incorporated into the state vector on the current covariance propagation cycle.

- (10) If the unmodeled Acceleration Bias and Covariance Propagation subfunction has set NAV\_MEAS = ON, i.e., NOISY\_NAV\_MEAS = OFF, and we are on a covariance propagation cycle, the measurements shall be processed on this cycle by performing the following tasks.

Call the Sensor Measurement Selection subfunction to select a measurement set for processing as described in Section 4.2.6.

CALL: REND\_SENSOR\_SELECT

Call the Sensor Measurement Initialization subfunction to initialize filter statistics and sensor bias states for newly selected measurement types as described in Section 4.2.7.

CALL: REND\_NAV\_SENSOR\_INIT

Call the Rendezvous Radar Range and Range Rate Measurement subfunction as described in Section 4.2.8.1.

CALL: RRDOT\_NAV

This subfunction incorporates the rendezvous radar range and range rate measurements using the Kalman filter update equations. Increment the mark counter for downlist.

RRDOT\_MARK\_NUM = RRDOT\_MARK\_NUM+1

If rendezvous radar angles have been selected for processing (DO\_RR\_ANGLES\_NAV = ON), then call the Rendezvous Radar Angles Measurement subfunction as described in Section 4.2.8.2.

CALL: RR\_ANGLE\_NAV

This subfunction incorporates the rendezvous radar shaft and trunnion measurements using the Kalman update.

Increment the mark counter for this measurement

RR\_ANGLE\_MARK\_NUM = RR\_ANGLE\_MARK\_NUM+1

Otherwise (DO\_RR\_ANGLES\_NAV = OFF), if star tracker angles have been selected (DO\_ST\_ANGLES\_NAV = ON), then call the Star Tracker Angles Measurement subfunction as described in Section 4.2.8.3.

CALL: STAR\_TRACKER\_NAV

This subfunction incorporates the horizontal and vertical star tracker measurements by using the Kalman filter update equations.

Increment the mark counter for this measurement

ST\_MARK\_NUM = ST\_MARK\_NUM+1

Otherwise (DO\_RR\_ANGLES\_NAV = OFF and DO\_ST\_ANGLES\_NAV = OFF), call the COAS Angles Measurement subfunction as described in Section 4.2.8.4.

CALL: COAS\_NAV

This subfunction incorporates the horizontal and vertical COAS measurements using the Kalman update equations.

Increment the mark counter for this measurement

COAS\_MARK\_NUM = COAS\_MARK\_NUM+1

Call Measurement Processing Statistics to calculate display parameters as described in Section 4.2.9.

CALL: MEAS\_PROCESSING\_STATISTICS\_REND

Set the measurement processing indicator to OFF

NAV\_MEAS = OFF

- (11) If the covariance matrix was propagated on this navigation cycle (I\_CYCLE = 0), then call the Covariance Matrix Parameters Reset subfunction.

CALL: COV\_LAST\_RESET

- (12) The GPS receiver state processing principal function shall now be executed.

CALL: GPS\_RCVR\_STATE\_PROC

- (13) Call the Target State Vector Reset subfunction to reset the user parameter processing state vector as described in Section 4.1.2.2.2.

CALL: TARGET\_RESET

- (14) Call the Orbiter State Vector Reset subfunction to reset the user parameter processing state vector as described in Section 4.2.1.1.

CALL: SHUTTLE\_RESET



- (15) Execute the STATE\_VECTOR\_MANAGEMENT code, which consists of the following:

Compute the RSS difference between the filtered position and velocity and the backup propagated position and velocity. If SHUTTLE\_FILTER\_FLAG = ON, then the Shuttle state is the filtered state, and the RSS difference is computed as follows:

$$R\_FMP\_DISP = |\bar{R}\_FILT - \bar{R}\_PROP|/1000.$$

$$V\_FMP\_DISP = |\bar{V}\_FILT - \bar{V}\_PROP|$$

If SHUTTLE\_FILTER\_FLAG = OFF, then the target state is the filtered state, and the RSS difference is computed as follows:

$$R\_FMP\_DISP = |\bar{R}\_TV - \bar{R}\_PROP|/1000.$$

$$V\_FMP\_DISP = |\bar{V}\_TV - \bar{V}\_PROP|$$

If the backup propagation vector has been selected for distribution to the User Parameter Processing principal function (NAV\_SV\_SOURCE\_FOR\_UPP = PROP\*), then the backup state vector is stored, based on the value of SHUTTLE\_FILTER\_FLAG. If SHUTTLE\_FILTER\_FLAG = ON and if the parameter GPS\_AIF\_RCVD is equal to INHIBIT, then the backup state vector is stored into the "RESET" locations for the Shuttle state vector.

- \* In the event that NAV\_SV\_SOURCE\_FOR\_UPP is implemented as a discrete instead of as a character string, the following convention should be followed:

$$PROP = 0$$

$$FILT = 1$$

$$\bar{R}\_RESET = \bar{R}\_PROP$$

$$\bar{V}\_RESET = \bar{V}\_PROP$$

If SHUTTLE\_FILTER\_FLAG = OFF, then the backup state vector is stored into the "RESET" locations for the target state vector.

$$\bar{R}\_TV\_RESET = \bar{R}\_PROP$$

$$\bar{V}\_TV\_RESET = \bar{V}\_PROP$$

Set the feedback flag for the REL\_NAV display to inform the crew that the appropriate state vector was sent to user parameter processing.

$$DID\_SV\_SOURCE\_FOR\_UPP = NAV\_SV\_SOURCE\_FOR\_UPP$$

- b. If the rendezvous phase is not active (DOING\_REND\_NAV = OFF) then the following steps shall be performed.
- (1) Repeat step (4) under Item a., that is call the GPS update function described in section 4.2.10. If a selected GPS state is available from the GPS receiver state processing principal function execution on the previous onorbit/rendezvous navigation cycle, and if other requisite criteria are satisfied, the navigation filter state will be reset to the selected GPS state. This function will copy GPS states generated on the previous navigation cycle, now time tagged to T\_LAST\_FILT, into  $\bar{R}$ \_FILT and  $\bar{V}$ \_FILT.

CALL: GPS\_UPDATE

- (2) Repeat step (2) under Item a, i.e., call the onorbit rendezvous auto inflight updates to perform any required ground updates to the Shuttle or target position and velocity vectors.

CALL: ONORBIT\_REND\_AUTO\_INFLIGHT\_UPDATE

- (3) Invoke the Onorbit Rendezvous State Propagation subfunction (see Section 4.2.4) to propagate the orbiter position and velocity vectors to current time.

CALL: ONORBIT\_REND\_R\_V\_STATE\_PROP

- (4) Repeat step (12) from a. The GPS receiver state processing principal function shall now be executed.

CALL: GPS\_RCVR\_STATE\_PROC

- (5) Repeat step (14) under Item a, i.e., call the Orbiter State Vector Reset subfunction to reset the user parameter processing orbiter state vector as described in Section 4.2.1.1.

CALL: SHUTTLE\_RESET

- (6) If an orbiter to target state transfer has been commanded by the crew, to support separation prior to the initiation of the relative navigation, the orbiter state vector is copied to the target state vector. The positive feedback (to the REL\_NAV display) is also set.

DID\_ORB\_TO\_TGT = OFF

If NAV\_DO\_ORB\_TO\_TGT = ON, then:

$T_{TV} = T_{LAST\_FILT}$

$\bar{R}_{TV} = \bar{R}_{FILT}$

$\bar{V}_{TV} = \bar{V}_{FILT}$

DO\_ORB\_TO\_TGT = OFF

DID\_ORB\_TO\_TGT = ON

6.0 Whether or not rendezvous phase is active, the flag is set to indicate to the user parameter state propagation subfunction that a navigated state vector update has occurred.

FILT\_UPDATE = ON

B. Interface Requirements. The inputs and outputs for this subfunction are listed in Table 4.2.1.

C. Processing Requirements. This subfunction is called by ONORBIT\_REND\_NAV\_SEQUENCER (Section 4.1.1).

D. Constraints. The following output variables must be implemented into a downlist time-homogeneous data set:

$\bar{R}$ \_FILT\_TLM,  $\bar{V}$ \_FILT\_TLM,  $\bar{R}$ \_PROP\_TLM,  $\bar{V}$ \_PROP\_TLM,  $\bar{R}$ \_TV\_TLM,  $\bar{V}$ \_TV\_TLM,  
T\_LAST\_FILT\_TLM.

DO\_ST\_RR\_COAS will always be 1, 2, or 3.

E. Supplementary Information. During OPS 8, rendezvous navigation cannot be active, hence it is not necessary to implement the DOING\_REND\_NAV = ON branch of the logic for the OPS 8 computer load.

A suggested implementation of this subfunction can be found in Section 5.2:

NAV\_ONORBIT\_RENDEZVOUS  
SNAP\_INPUTS CODE  
COV\_PROP\_SETUP CODE  
STATE\_VECTOR\_MANAGEMENT CODE

and the following from Section 5.3:

QUAT\_TO\_MAT FUNCTION

The navigation copy of the GPS to navigation auto/inhibit command signal, GPS\_TO\_NAV\_RCVD, has the values of AUTO, indicating an OFF (or 0) command, and INHIBIT, indicating an ON (or 1) command. The navigation copy of the GPS to navigation force signal, GPS\_TO\_NAV\_FORCE\_RCVD, has the values of NO FORCE, indicating an OFF (or 0) command, and FORCE, indicating an ON (or 1) command. The composite signal, GPS\_TO\_NAV\_AIF, constructed from the navigation copy of the GPS to navigation auto/inhibit command signal, GPS\_TO\_NAV\_RCVD, and the navigation copy of the GPS to navigation force signal, GPS\_TO\_NAV\_FORCE\_RCVD, takes on the following values: AUTO, indicating a 0 value, INHIBIT indicating a 1 value and FORCE indicating a value of 2.

Table 4.2.1. NAV\_ONORBIT\_RENDEZVOUS Input/Output

Variable Name	Input Source	Output Destination
ANGLES_AIF	*	
COAS_DATA_GOOD	Sensor Data Snap	COAS_NAV,*
COAS_ID	Sensor Data Snap	COAS_NAV,*
COAS_MARK_NUM	**	*
CONT_ACC	ONORBIT_REND_R_V_STATE_PROP	
COV_PWRD_FLT		REND_BIAS_AND_COV_PROP
COV_USE_IMU_DATA	ONORBIT_REND_R_V_STATE_PROP	
CURR_ORB_MASS	*	
DA_THRESHOLD		*, ONORBIT_REND_R_V_STATE_PROP
DAP_JET	*,**	
DID_ORB_TO_TGT		*
DID_SV_SOURCE_FOR_UPP		*
DO_COVAR_REINIT	*, REL_NAV_DISPLAY_UPDATES	
DO_FILTERED_TO_PROP	*,REL_NAV_DISPLAY_UPDATES	
DO_PROP_TO_FILTERED	*,REL_NAV_DISPLAY_UPDATES	
DO_ORB_TO_TGT	*,REL_NAV_DISPLAY_UPDATES	*
DO_OV_UPLINK	*,**	
DO_ST_RR_COAS	*	
DO_TGT_TO_ORB	*,REL_NAV_DISPLAY_UPDATES	
DO_TV_UPLINK	*,**	
DOING_ST_RR_COAS		*
DO_RR_ANGLES_NAV	REND_SENSOR_SELECT	
DO_ST_ANGLES_NAV	REND_SENSOR_SELECT	
DOING_REND_NAV	*,**	
$\overline{D}V\_COV$	*, COV_LAST_RESET	REND_BIAS_AND_COV_PROP, *, REND_NAV_INTERP
$\overline{D}V\_FLT$	ONORBIT_REND_R_V_STATE_PROP	
FILT_UPDATE		*
FOM <sub>1</sub> <sup>1</sup>	GPS DATA SNAP	*
GPS_AIF_RCVD		*, SHUTTLE_RESET
GPS_DG <sub>1</sub> <sup>1</sup>	GPS DATA SNAP	*
GPS_TO_NAV_RCVD		*, GPS_UPDATE
GPS_FAIL_FOM <sub>1</sub> <sup>1</sup>	GPS DATA SNAP	*
GPS_TO_NAV_FORCE_RCVD		*, GPS_UPDATE

Table 4.2.1. NAV\_ONORBIT\_RENDEZVOUS Input/Output

Variable Name	Input Source	Output Destination
I_CYCLE	*, REND_COV_INIT	
IMU_NAV_ACCEL_THRESH	*,**	
M_BODYM50		ACCEL_ONORBIT
MEAS_ENABLE	*,**	
MEAS_THRESHOLD	**	
M_M50_TO_BODY_COAS	Sensor Data Snap	*, COAS_NAV
M_M50_TO_ST	Sensor Data Snap	*, STAR_TRACKER_NAV
MM_CODE	*	
NAV_DAP_JET		*, ONORBIT_REND_R_V_STATE_PROP
NAV_MEAS	**, REND_BIAS_AND_COV_PROP	*
NAV_ANGLES_AIF		*, REND_SENSOR_SELECT
NAV_CURR_ORB_MASS		*, ACCEL_ONORBIT, ONORBIT_REND_AUTO_INFLIGHT_UPDATE
NAV_DO_COVAR_REINIT		*, REL_NAV_DISPLAY_UPDATES
NAV_DO_ORB_TO_TGT		*, REL_NAV_DISPLAY_UPDATES
NAV_DO_OV_UPLINK		*, ONORBIT_REND_AUTO_INFLIGHT_UPDATE
NAV_DO_TGT_TO_ORB		*, REL_NAV_DISPLAY_UPDATES
NAV_DO_TV_UPLINK		*, ONORBIT_REND_AUTO_INFLIGHT_UPDATE
NAV_MM_CODE		*, REND_SENSOR_SELECT, GPS_UPDATE
NAV_MEAS_ENABLE		*, REND_SENSOR_SELECT
NAV_PWRD_FLT_NAV		*, ONORBIT_REND_R_V_STATE_PROP
NAV_RR_ANGLES_ENABLE		
NAV_RANGE_AIF		*, REND_SENSOR_SELECT
NAV_RDOT_AIF		*, REND_SENSOR_SELECT
NAV_ST_ENABLE		
NAV_ST_RR_COAS		**, REND_SENSOR_SELECT
NAV_DO_FILTERED_TO_PROP		*, REL_NAV_DISPLAY_UPDATES
NAV_DO_PROP_TO_FILTERED		*, REL_NAV_DISPLAY_UPDATES
NAV_SV_SOURCE_FOR_UPP		*
NAV_RESET		SHUTTLE_RESET
N_CYCLE_SUB	**	

Table 4.2.1. NAV\_ONORBIT\_RENDEZVOUS Input/Output

Variable Name	Input Source	Output Destination
NOISY_NAV_MEAS	**	REND_BIAS_AND_COV_PROP
PWRD_FLT_NAV	*	
Q_COAS_HORIZ	Sensor Data Snap	COAS_NAV,*
Q_COAS_VERT	Sensor Data Snap	COAS_NAV,*
Q_M50BODY_IMU	IMU Data Snap	QUAT_TO_MAT,*
Q_M50BODY_RR	Sensor Data Snap	RR_ANGLE_NAV,*, REND_NAV_INTERP
Q_RR_RNG	Sensor Data Snap	RRDOT_NAV,*
Q_RR_RNG_DOT	Sensor Data Snap	RRDOT_NAV,*
Q_RR_ROLL	Sensor Data Snap	RR_ANGLE_NAV,*
Q_RR_PITCH	Sensor Data Snap	RR_ANGLE_NAV,*
Q_ST_HORIZ	Sensor Data Snap	STAR_TRACKER_NAV,*
Q_ST_VERT	Sensor Data Snap	STAR_TRACKER_NAV,*
***	QUAT_TO_MAT	
RNP_TIME_UL	Uplink Processor	
$\bar{R}$ _FILT	*, ONORBIT_REND_R_V_ STATE_PROP, REND_NAV_ FILTER	
R_FMP_DISP		*
$\bar{R}$ _PROP	ONORBIT_REND_R_V_STATE_ PROP,*	
$\bar{R}$ _PROP_TLM		*
$\bar{R}$ _RESET		*
$\bar{R}$ _TV_RESET		*
$\bar{R}$ _TV	**, *, ONORBIT_REND_R_V_ STATE_PROP, REND_NAV_ FILTER	*
$\bar{R}$ _FILT_TLM		*
$\bar{R}$ _GPS_ECEF <sup>1</sup>	GPS DATA SNAP	*
$\bar{R}$ _TV_TLM		*
RANGE_AIF	*	
RDOT_AIF	*	
RDOT_DATA_GOOD	Sensor Data Snap	RRDOT_NAV,*
RNG_DATA_GOOD	Sensor Data Snap	RRDOT_NAV,*
RR_ANGLE_DATA_GOOD	Sensor Data Snap	RR_ANGLE_NAV,*
RR_ANGLE_MARK_NUM	**	*
RRDOT_MARK_NUM	**	*
$\bar{R}$ _FILT_DISP		*
SELF_TEST_FLAG	Sensor Data Snap	RRDOT_NAV, RR_ANGLE_NAV,*
SENSOR_BIAS	Setup, REND_NAV_FILTER,**	

Table 4.2.1. NAV\_ONORBIT\_RENDEZVOUS Input/Output

Variable Name	Input Source	Output Destination
SENSOR_BIAS_TLM		*
SHUTTLE_FILTER_FLAG	*	
ST_DATA_GOOD	Sensor Data Snap	STAR_TRACKER_NAV,*
ST_MARK_NUM	**	*
SV_SOURCE_FOR_UPP	*	
T_BIAS_COAS	**	
T_BIAS_REND_RADAR	**	
T_BIAS_ST	**	
T_COAS	Sensor Data Snap	COAS_NAV,*
T_CURRENT_FILT	IMU Data Snap	*,ONORBIT_REND_R_V_STATE_PROP, ONORBIT_SV_INTERP, REND_BIAS_AND_COV_PROP, RRDOT_NAV, RR_ANGLE_NAV, STAR_TRACKER_NAV,COAS_NAV
T_GPS <sub>1</sub> <sup>1</sup>	GPS DATA SNAP	*
T_LAST_GPS <sub>1</sub> <sup>1</sup>	GPS DATA SNAP	*
T_LAST_FILT	ONORBIT_REND_R_V_STATE_PROP, *, ONORBIT_REND_AUTO_INFLIGHT_UPDATE	
T_LAST_FILT_TLM		*
T_REND_RADAR	Sensor Data Snap	RRDOT_NAV, RR_ANGLE_NAV,*
TRG_TRK_MODE	Sensor Data Snap	STAR_TRACKER_NAV,*
T_STAR_TRACKER	Sensor Data Snap	STAR_TRACKER_NAV,*
T_FILT_DAYS		*
T_FILT_HRS		*
T_FILT_MIN		*
T_FILT_SECS		*
T_TV		*
UNMOD_ACC_BIAS	*, U_A_BIAS_AND_COVINIT, REND_NAV_FILTER, REND_BIAS_AND_COV_PROP	
UNMOD_ACC_BIAS_TLM		*
USE_IMU_DATA	ONORBIT_REND_R_V_STATE_PROP	
V_CURRENT_FILT	IMU Data Snap	ONORBIT_REND_R_V_STATE_PROP, *, GPS_RCVR_STATE_PROC
V_FILT	*, ONORBIT_REND_R_V_STATE_PROP, REND_NAV_FILTER	
V_FMP_DISP		*
V_FILT_TLM		*

Table 4.2.1. NAV\_ONORBIT\_RENDEZVOUS Input/Output

Variable Name	Input Source	Output Destination
$\bar{V}$ _FILT_DISP		*
$\bar{V}$ _GPS_ECEF <sup>1</sup>	GPS DATA SNAP	*
$\bar{V}$ _LAST_GPS <sup>1</sup>	GPS DATA SNAP	*
$\bar{V}$ _PROP	ONORBIT_REND_R_V_STATE_	
	PROP, *	
$\bar{V}$ _PROP_TLM		*
$\bar{V}$ _RESET		*
$\bar{V}$ _TV_TLM		*
$\bar{V}$ _TV	**,*, ONORBIT_REND_R_V_	*
	STATE_PROP, REND_NAV_	
	FILTER	
$\bar{V}$ _TV_RESET		*
<p>* Onorbit/Rendezvous principal function, see Table 4.2.11-1 and Table 4.2.11-2.            ** Initialization parameters, see Section 4.7.            *** Value returned from the function.  <sup>1</sup>I designates that there is a variable for each GPS receiver (I=1,2,3)</p>		



#### 4.2.1.1 Orbiter State Vector Reset (SHUTTLE\_RESET)

The purpose of the Orbiter State Vector Reset Subfunction is to provide updated state vector associated parameters to the User Parameter State Propagation subfunction (Section 4.5.1) and the GPS Reference State Processing Principal Function (Entry Navigation FSSR, STS 83-0004) at the end of every navigation cycle.

A. Detailed Requirements. At the completion of a navigation cycle, the orbiter state vector reset subfunction shall be called:

CALL: SHUTTLE\_RESET

The Shuttle reset subfunction will store state data for use in resetting the orbiter state for the user parameter state propagator after all navigation updates have been completed for the current navigation cycle. Orbiter position, velocity, associated time tag, and velocity counts will be stored. It also will provide the GPS reference state processor principal function with the navigation filter state so that the GPS receiver states can be reinitialized as needed.

Either the navigation filter state or the navigation state will be stored, depending on the configuration of the navigation system as set by the crew. An indicator will be set to notify the crew if their commanded use of the selected GPS state was accomplished on this navigation cycle.

The user parameter propagator reset subfunction detailed requirements are as follows:

- 1.0 The availability of a selected GPS state is first determined by checking the condition of the GPS\_SV\_SEL\_AVAIL parameter. If a selected GPS state is not available, indicated by GPS\_SV\_SEL\_AVAIL = OFF, then the user parameter state is reset to the navigation filter state as shown in step 1.1. If a selected GPS state is available, indicated by GPS\_SV\_SEL\_AVAIL = ON, then step 1.2 is executed.
- 1.1 If a selected GPS state is not available, the user parameter reset state is set to the navigation filter state as follows:

$$\begin{aligned}\bar{R}_{\_RESET} &= \bar{R}_{\_FILT} \\ \bar{V}_{\_RESET} &= \bar{V}_{\_FILT}\end{aligned}$$

A check is then made to determine if the received GPS\_TO\_GC\_AIF flag, GPS\_AIF\_RCVD, is set to either AUTO or FORCE, that is not set to INHIBIT. If these conditions are satisfied, an indicator is set to notify the crew that the GPS\_TO\_GC\_AIF AUTO or FORCE command could not be executed on this navigation cycle. The steps are as follows:

```
IF GPS_AIF_RCVD not = INHIBIT THEN  
    GPS_AIF_EXEC = DOWN_ARROW
```

The setting of GPS\_AIF\_EXEC to DOWN\_ARROW indicates an ON condition and a setting of BLANK indicates an OFF condition. DOWN\_ARROW and BLANK are used for clarity of requirements with what is to be displayed to the crew.

- 1.2 If a selected GPS state is available, a check is made to determine if the received GPS Auto/Inhibit/Force command flag, GPS\_AIF\_RCVD, is set to 'INHIBIT'. If it is set to INHIBIT, the user parameter propagator reset data is set to navigation filter state data, otherwise is set to the selected GPS state data. This is accomplished as follows:

```
IF GPS_AIF_RCVD not = INHIBIT THEN
   $\overline{R\_RESET} = \overline{R\_GPS\_SEL}$ 
   $\overline{V\_RESET} = \overline{V\_GPS\_SEL}$ 
```

ELSE

```
 $\overline{R\_RESET} = \overline{R\_FILT}$ 
 $\overline{V\_RESET} = \overline{V\_FILT}$ 
```

- 2.0 The reset values for the accumulated IMU velocity counts and time tag associated with the reset state are stored as follows:

```
 $\overline{V\_IMU\_RESET} = \overline{V\_LAST\_FILT}$ 
T_RESET = T_LAST_FILT
```

- 3.0 The parameters for providing the GPS reference state processing principal function with GPS reference state initialization data will be set.

```
 $\overline{V\_IMU\_GPS\_INIT} = \overline{V\_CURRENT\_FILT}$ 
```

```
 $\overline{R\_GPS\_INIT} = \overline{R\_FILT}$ 
```

```
 $\overline{V\_GPS\_INIT} = \overline{V\_FILT}$ 
```

```
 $\overline{G\_GPS\_INIT} = \overline{G\_NEW}$ 
```

```
T_GPS_INIT = T_LAST_FILT
```

- 4.0 A check is made to determine if the flag which indicates to the GPS reference state processing principal function that a valid reference state has been obtained (GPS\_REF\_INIT\_VALID) should be set to ON. If this flag is OFF, and either a GPS to navigation state vector transfer or an orbiter state vector uplink has occurred, set this flag to ON.

```
IF ((GPS_REF_INIT_VALID = OFF) AND
    ((NAV_RESET = ON) OR (UPLINK_NAV_RESET = ON))) THEN
  GPS_REF_INIT_VALID = ON
```

B. Interface Requirements. The input and output requirements for this subfunction are shown in Table 4.2.1.1-1

C. Processing Requirements. This subfunction is called by the following module:

```
NAV_ONORBIT_RENDEZVOUS
```

D. Constraints. None

E. Supplemental Information. A suggested implementation of this subfunction can be found in Section 5.2 in the form of a flow diagram:

SHUTTLE\_RESET

Table 4.2.1.1-1. SHUTTLE_RESET Input/Output		
Variable Name	Input Source	Output Destination
$\bar{R}$ _FILT	ONORBIT_REND_R_V_STATE_PROP, REND_NAV_FILTER	
$\bar{V}$ _FILT	ONORBIT_REND_R_V_STATE_PROP, REND_NAV_FILTER	
T_LAST_FILT	ONORBIT_REND_R_V_STATE_PROP	
$\bar{V}$ _LAST_FILT	ONORBIT_REND_R_V_STATE_PROP	
$\bar{R}$ _RESET		*
$\bar{V}$ _RESET		*
$\bar{V}$ _IMU_RESET		*
T_RESET		*, STATE_VECTOR_PREDICT_TASK
$\bar{R}$ _GPS_INIT		*
$\bar{R}$ _GPS_SEL	*	
T_GPS_INIT		*
$\bar{V}$ _GPS_INIT		*
$\bar{V}$ _GPS_SEL	*	
$\bar{V}$ _IMU_GPS_INIT		*
GPS_SV_SEL_AVAIL	*	
GPS_AIF_EXEC		*
GPS_AIF_RCVD	NAV_ONORBIT_RENDEZVOUS	
$\bar{G}$ _GPS_INIT		*
$\bar{G}$ _NEW	ONORBIT_REND_R_V_STATE_PROP	
GPS_REF_INIT_VALID	OPS_2_OR_8_INITIALIZE	*
NAV_RESET	NAV_ONORBIT_RENDEZVOUS, GPS_UPDATE	
UPLINK_NAV_RESET	ONORBIT_REND_AUTO_INFLIGHT_UPDATE	

\*See Table 4.1.3-2 for the Onorbit/Rendezvous Navigation Sequencer outputs and Table 4.2.11-2 for the Onorbit/Rendezvous Navigation outputs.

#### 4.2.2 Navigation Data Snap

The Onorbit/Rendezvous navigation principal function shall accomplish the task of snapping navigation data to obtain orbiter IMU-sensed accumulated velocities, the current attitude quaternion, and sensor data from the rendezvous radar, the star tracker, the crew optical alignment sight (COAS) and GPS navigation state data. The selected IMU sensed velocity have been corrected in the IMU RM to reflect c.g.-sensed velocities instead of NAV-base velocities. (In this document, sensed velocity and c.g.-sensed velocity are used interchangeably) The total accumulated selected sensed velocity is required to account for non-gravitational accelerations during integration of the equations of motion in the navigation principal function.

The sensor data from the rendezvous radar, the star tracker, and the COAS are collected and stored for use in navigation processing during the rendezvous navigation phase. The state estimate data from the GPS receivers is collected for use by the GPS receiver state processing principal function, called from the Onorbit/Rendezvous navigation principal function, during both the onorbit (non-rendezvous) coast mission phase and the rendezvous mission phase.

##### 4.2.2.1 IMU and Attitude Data Snap

The IMU and attitude data snap task will provide the capability to obtain orbiter IMU-sensed accumulated velocities (expressed in M50 coordinates) and the current attitude quaternion, along with their associated GMT time tag. These data will be obtained through IMU RM and ATT PROC and stored for use in the Navigation and User Parameter Propagation subfunctions.

A. Detailed Requirements. The IMU and attitude data snap task shall provide the capability to obtain the selected sensed accumulated velocity and the GMT time tag associated with these data, and the mean of 50 to body attitude quaternion. The IMU data and attitude quaternion are obtained as indicated by the following:

$$\text{SNAP IMU\_DATA } (\bar{V}\_CURRENT\_FILT, T\_CURRENT\_FILT, \\ Q\_M50BODY\_IMU)$$

The selected IMU accumulated velocity will be that sensed at the Orbiter navbase modified to reflect the accumulated velocity at the Orbiter center of mass and shall be expressed in M50 coordinates. The selected IMU data is used in the onorbit/rendezvous navigation principal function by the state propagation subfunction, and it is used to propagate the rendezvous Kalman filter covariance matrix.

The snap statement above implies the assignment of current values of the IMU and attitude data from IMU RM and ATT PROC to the variable names shown in parentheses.

B. Interface Requirements. The parameter cross-reference table between IMU RM names and their copies of onorbit/rendezvous navigation variables is shown in the table of Section 4.2.11.

C. Processing Requirements. The data from IMU RM and ATT PROC (time tag, accumulated velocities, and attitude quaternions) must be made available for the collection and storage process. The collection rate is indicated by the onorbit/rendezvous navigation sequencer. However, this rate assumes that the available data are fresh. This implies that IMU RM and ATT PROC processing must be at a rate equal to or greater than the collection rate. This data snap is called by

NAV\_ONORBIT\_RENDEZVOUS (Section 4.2.1)

ONORBIT\_REND\_USER\_PARAM\_STATE\_PROP (Section 4.5.1)

OPS\_2\_OR\_8\_INITIALIZE (Section 4.1.2)

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

E. Supplementary Information. The snap statement above implies the assignment of current IMU RM and ATT PROC values to the variable names shown in parentheses. The suggested implementation of this subfunction is not described in this document because the discussion involves the processor level interface design concept, which is beyond the scope of this document. However, extreme care must be exercised to provide sequentially time-homogeneous data set to the appropriate subfunctions.

TABLE 4.2.2.1 DELETED

#### 4.2.2.2 GPS Data Snap

The GPS data snap task collects and stores homogeneous GPS receiver navigation data from the GPS SOP. The purpose of the GPS data snap is to properly save the data for use by the GPS receiver state vector processing principal function while the actual GPS data will continue to be refreshed by GPS LRU data readings and GPS SOP processing.

The homogeneous set of GPS receiver data shall be collected from the GPS SOP and stored. This data shall have the following characteristics: (1) it is the most current receiver navigation data from the GPS SOP that has been indicated by the receivers as valid (receiver data good is set on); (2) it is bracketed by IMU velocity counts which will be used in propagating these states to the current navigation filter time in the GPS Receiver State Processing principal function; (3) the velocity counts collected from the GPS SOP are from the IMU RM execution just prior to and closest to the GPS state time tag. The use of IMU accumulated velocity counts as close to the receiver state time tag minimizes the velocity transients introduced in the propagation of the GPS receiver states to current navigation filter time by providing the most accurate sensed velocity information across the GPS state propagation interval.

A. Detailed Requirements. A time homogeneous set of GPS data shall be collected from the GPS SOP and stored. Each set includes data from up to three receivers: GPS receiver state estimates, data good flags, figure-of-merit. Also included is the selected IMU velocity associated with each receiver.

The data snaps are as follows:

SNAP GPS\_DATA ( $\bar{R}$ \_GPS\_ECEF,  $\bar{V}$ \_GPS\_ECEF, T\_GPS, GPS\_DG,  
GPS\_FAIL\_FOM, FOM,  $\bar{V}$ \_LAST\_GPS, T\_LAST\_GPS)

These GPS variables (vector, scalar arrays, character strings and discretets) correspond to data from three GPS receivers, which represents the maximum number of receivers for which the software is designed. The first component of each array will be a time homogeneous set of data for GPS receiver 1, and likewise, array components 2 and 3 will be a consistent set of data for GPS receivers 2 and 3 respectively.

The IMU variables provided by the GPS SOP correspond to the values of the IMU counts closest to and just prior to each GPS state estimate time tag. They have been properly assigned to each receiver.

The snap statement implies the assignment of current GPS SOP data to the variables shown in parentheses. Time-homogeneous data for each GPS receiver must be provided to the appropriate subfunctions. The time homogeneous data from one receiver may have a different time tag than the time homogeneous data from another receiver.

Note that data shall be snapped for up to three receivers regardless of the number of receivers actually installed on the vehicle.

B. Interface Requirements. The parameter cross-reference table between the GPS SOP names and their navigation variable copies is shown in the table of Section 4.2.11.

C. Processing Requirements. It is required that the GPS data be made available by the GPS SOP for the collection and storage process. The collection rate is indicated by the Onorbit/Rendezvous sequencer rate. This rate assumes that the available GPS data are the most recent GPS data available.

D. Constraints. The GPS data collection should occur as close to the Onorbit/Rendezvous IMU data snap as possible.

E. Suggested Implementation. A suggested implementation of the onorbit GPS data snap subfunction, in the detailed flow chart NAV\_ONORBIT\_RENDEZVOUS, can be found in Section 5.2. The snap statement implies the assignment of current values to the variable names shown in parentheses. Time homogeneous data for up to three receivers must be provided to the appropriate subfunctions. The data between each receiver is not required to be time homogeneous.

#### **4.2.2.3 Rendezvous Sensor Data Snap**

During the rendezvous navigation phase, this subfunction collects and stores sensor data from the rendezvous radar, the star tracker, and the crew optical alignment sight (COAS).

The purpose of the rendezvous sensor data snap is to properly save the data sets used in navigation processing for use in the appropriate Rendezvous Sensor Navigation subfunction (Section 4.2.8) whereas the actual data may continue to be refreshed by hardware sensor reading and sensor SOP processing.

A. Detailed Requirements. During the rendezvous navigation phase, data from the external sensors, together with the corresponding data good flags, associated time tags, and the appropriate attitude information valid at those times shall be obtained. A premission-loaded time bias shall then be subtracted from the time tag for each sensor. The equations are:

1. For the rendezvous radar:

SNAP REND\_RADAR (Q\_RR\_ROLL, Q\_RR\_PITCH, Q\_RR\_RNG,  
Q\_RR\_RNG\_DOT, RNG\_DATA\_GOOD, RDOT\_DATA\_GOOD,  
RR\_ANGLE\_DATA\_GOOD, Q\_M50BODY\_RR, T\_REND\_RADAR,  
SELF\_TEST\_FLAG)

where:

Q\_RR\_ROLL is the roll angle output

Q\_RR\_PITCH is the pitch angle output

RR\_ANGLE\_DATA\_GOOD is the validity flag of the above outputs

Q\_RR\_RNG is the radar range measurement

RNG\_DATA\_GOOD is the respective data good flag

Q\_RR\_RNG\_DOT is the radar range rate reading

RDOT\_DATA\_GOOD is the respective validity indicator

T\_REND\_RADAR is the time at which these outputs are considered to have been effected

Q\_M50BODY\_RR is the gimbal angle quaternion array

SELF\_TEST\_FLAG is the flag indicating whether the rendezvous radar is operating in the self-test mode

$T\_REND\_RADAR = T\_REND\_RADAR - T\_BIAS\_REND\_RADAR$

2. For the star tracker,

SNAP STAR\_TRACKER (Q\_ST\_HORIZ, Q\_ST\_VERT, ST\_DATA\_GOOD,  
M\_M50\_TO\_ST, T\_STAR\_TRACKER, TRG\_TRK\_MODE)

where:

Q\_ST\_HORIZ is the horizontal angle measurement

Q\_ST\_VERT is the vertical angle measurement

ST\_DATA\_GOOD is the data good flag relative to these angle measurements

M\_M50\_TO\_ST is the M50 to star tracker sensor coordinate system rotation matrix at the time T\_STAR\_TRACKER

T\_STAR\_TRACKER is the time tag

TRG\_TRK\_MODE is the flag indicating whether the star tracker is in the target tracking mode

$T\_STAR\_TRACKER = T\_STAR\_TRACKER - T\_BIAS\_ST$

3. For the COAS,

SNAP COAS (Q\_COAS\_HORIZ, Q\_COAS\_VERT, COAS\_DATA\_GOOD,  
M\_M50\_TO\_BODY\_COAS, COAS\_ID, T\_COAS)

where:

Q\_COAS\_HORIZ is the horizontal angle measurement

Q\_COAS\_VERT is the vertical angle measurement

COAS\_DATA\_GOOD is the data good flag relative to these angle measurements

COAS\_ID is the COAS select indicator

T\_COAS is the time of the measurement

M\_M50\_TO\_BODY\_COAS is the M50 to COAS sensor coordinate system transformation matrix at the time T\_COAS

$$T\_COAS = T\_COAS - T\_BIAS\_COAS$$

B. Interface Requirements. The parameter name cross-reference between the rendezvous radar SOP and Onorbit/Rendezvous Navigation variables is shown in Table 4.2.10-5. The cross-reference table between star tracker SOP and Onorbit/Rendezvous Navigation variables is also given in Table 4.2.10-5.

C. Processing Requirements. The data from the sensors (measurements, ID's, validity flags, rotation matrices, quaternions, and time tags) must be made available for the collection and storage process. The collection rate (not necessarily equal to the rate of sensor interrogations) is indicated by the Onorbit/Rendezvous Navigation Sequencer. However, this rate assumes that the available data are fresh.

This implies that the SOP's processing must be at a rate equal to or greater than the collection rate. This subfunction is called by NAV\_ONORBIT\_RENDEZVOUS (Section 4.2.1).

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

E. Supplementary Information. The snap statement above implies the assignment of current SOP values to the variable names shown in parentheses. The suggested implementation of this subfunction is not described in this document because the discussion involves the processor level interface design concept which is beyond the scope of this document. However, extreme care must be exercised to provide sequentially time-homogeneous data sets to the appropriate subfunctions.

#### 4.2.2.4 Deleted

### 4.2.3 State and Covariance Matrix Updates

The Onorbit/Rendezvous Navigation principal function shall provide for the capability to perform automatic inflight updates of the orbiter and/or target position and velocities, crew requested covariance matrix reinitialization, and crew requested state vector transfers. The capability to perform the position-velocity update of either the orbiter or target will be handled by the automatic inflight updates subfunction, while the capability to handle crew requests for state vector transfers and covariance matrix reinitialization will be done by the REL\_NAV display updates subfunction.

#### 4.2.3.1 Auto Inflight Updates (ONORBIT\_REND\_AUTO\_INFLIGHT\_UPDATE)

The Automatic Inflight Updates subfunction shall determine when an update to the Shuttle or target state vector is required by the ground and then schedule the state vector prediction task to predict the uplinked state vectors to the time tag T\_RESET, established by the Orbiter State Vector Reset subfunction (see Section 4.1.2.1). If a state vector update has occurred during rendezvous navigation phase, the covariance matrix shall be reinitialized.

A. Detailed Requirements.



1. First, a local flag SV\_UPDATE, which indicates whether a state vector update has occurred, is set to OFF.
2. If the ground has indicated that the orbiter vector is uplinked (NAV\_DO\_OV\_UPLINK = ON), then the following tasks will be performed in the order indicated.
  - a. The prediction task indicator flag, PRED\_USE, is interrogated for a zero value to determine if the state vector prediction task is available for scheduling. If the state vector prediction task is available, then the following tasks are performed.

- (1) The following parameters are defined preceding the scheduling of the state vector prediction task:

```
PRED_USE = 1
OV_PREDICT_FAIL = OFF
PRED_ORB_MASS = NAV_CURR_ORB_MASS
PRED_ORB_AREA = REF_ORB_AREA
PRED_ORB_CD = REF_ORB_CD
GMDP = GM_DEG
GMOP = GM_ORD
DMP = DFL
VMP = VFLOV_PRED
ATMP = 1
PRED_STEP = PREC_STEP_PRED
R_PRED_INIT = R_GND
V_PRED_INIT = V_GND
T_PRED_INIT = T_GND
```

- (2) Next, the state vector prediction task is scheduled.

```
SCHEDULE: STATE_VECTOR_PREDICT_TASK
```

- b. If the PRED\_USE flag is nonzero, it is tested for a value of 3, which indicates that the state vector prediction task has determined that the prediction interval is too large or an event to leave OPS 2 or 8 has been initiated; hence, no prediction will take place. If PRED\_USE = 3, then the following flags are set.

```
PRED_USE = 0, indicating the state vector prediction task is available.
```

```
DO_OV_UPLINK = OFF
```

```
OV_PREDICT_FAIL = ON, indicating that no prediction will take place for the  
orbiter state vectors.
```

- c. If the PRED\_USE flag is not set to 0 or 3, then it is tested for a value of 2, which indicates that the state vector prediction task has successfully predicted the orbiter state vector. If PRED\_USE = 2, then the following actions are taken.

```
PRED_USE = 0, indicating that the state vector prediction task is available.
```

```
T_LAST_FILT = T_PRED_FINAL predicted orbiter vectors and time tag are stored.
```

$\bar{R}_{\text{FILT}} = \bar{R}_{\text{PRED\_FINAL}}$

$\bar{V}_{\text{FILT}} = \bar{V}_{\text{PRED\_FINAL}}$

SV\_UPDATE = ON, indicating that an inflight update has taken place.

T\_ORB\_STATE\_UPDATE = T\_LAST\_FILT, the time tag of the inflight update is saved for downlist.

DO\_OV\_UPLINK = OFF

UPLINK\_NAV\_RESET = ON, indicating that the navigation state has been reset with a ground uplink state.

T\_GPS\_LAST\_UPDATE = T\_LAST\_FILT, indicating that the QA2 (GPS minus navigation differences) thresholds should be reset to their minimum values.

3. If the ground has indicated that the target vector is uplinked (NAV\_DO\_TV\_UPLINK = ON), then the DOING\_REND\_NAV flag and the PRED\_USE flags are interrogated to determine if the uplinked target state vectors are to be stored or if the target state prediction logic should be exercised.

- a. If rendezvous navigation is active, DOING\_REND\_NAV = ON, or the target state prediction logic is in progress, PRED\_USE ≥ 7, then the PRED\_USE flag is tested to determine the appropriate action to follow.

- (1) If PRED\_USE = 0, target prediction is to be scheduled. The following actions are taken:

- The prediction parameters are initialized.

PRED\_USE = 7

TV\_PREDICT\_FAIL = OFF

GMDP = GM\_DEG

GMOP = GM\_ORD

DMP = DFL

VMP = VFLTV\_PRED

ATMP = ATFL\_TV

PRED\_STEP = PREC\_STEP\_PRED

$\bar{R}_{\text{PRED\_INIT}} = \bar{R}_{\text{TV\_GND}}$

$\bar{V}_{\text{PRED\_INIT}} = \bar{V}_{\text{TV\_GND}}$

$T_{\text{PRED\_INIT}} = T_{\text{TV\_GND}}$

- The state vector prediction task is scheduled.

SCHEDULE: STATE\_VECTOR\_PREDICT\_TASK

- (2) If the PRED\_USE flag is equal to 9, the state vector prediction task has determined that the prediction interval is too large; hence, no prediction will take place. The following flags are set.

PRED\_USE = 0 indicating the state vector prediction is available

DO\_TV\_UPLINK = OFF

TV\_PREDICT\_FAIL = ON indicating that no prediction will take place for the target state vectors.

- (3) If the PRED\_USE flag is equal to 8, the state vector prediction task has successfully predicted the target state vectors. The following actions are taken.

PRED\_USE = 0, indicating that the state vector prediction task is available.

T\_TV = T\_PRED\_FINAL predicted target vectors and time tag are stored.

$\bar{R}_{TV} = \bar{R}_{PRED\_FINAL}$

$\bar{V}_{TV} = \bar{V}_{PRED\_FINAL}$

SV\_UPDATE = ON, indicating that an inflight update has taken place.

T\_TV\_STATE\_UPDATE = T\_TV, the time tag of the inflight update is saved for downlist.

DO\_TV\_UPLINK = OFF

- b. If rendezvous navigation phase is not active, DOING\_REND\_NAV = OFF, and the target state prediction task is not in progress for an inflight update, PRED\_USE < 7, then the uplinked state vector and associated time tag are stored, the time of the uplink is stored, and the DO\_TV\_UPLINK flag is turned OFF.

T\_TV = T\_TV\_GND

$\bar{R}_{TV} = \bar{R}_{TV\_GND}$

$\bar{V}_{TV} = \bar{V}_{TV\_GND}$

T\_TV\_STATE\_UPDATE = T\_TV

DO\_TV\_UPLINK = OFF

4. Finally, the Covariance Initialization subfunction is invoked if the SV\_UPDATE flag is ON and DOING\_REND\_NAV = ON, indicating that the rendezvous navigation phase is active.

CALL: REND\_COV\_INIT

B. Interface Requirements. The inputs and outputs for this subfunction are given in Table 4.2.3.1.

C. Processing Requirements. This subfunction is called by

NAV\_ONORBIT\_RENDEZVOUS (Section 4.2.1)

D. Constraints. None

E. Supplementary Information. If a second state vector uplink (orbiter state vector in nonrendezvous phase or OPS 8 — orbiter or target state vector in rendezvous phase) is attempted for the same vehicle during the time period that PRED\_USE is nonzero, the second state vector uplink is ignored. A suggested implementation of this subfunction is given in Section 5.2:

ONORBIT\_REND\_AUTO\_INFLIGHT\_UPDATE

Table 4.2.3.1. ONORBIT_REND_AUTO_INFLIGHT_UPDATE Input/Output		
Variable Name	Input Source	Output Destination
ATFL_TV	**	
ATMP		*
DFL	**	*
DMP		*
DO_OV_UPLINK		*
DO_TV_UPLINK		*
DOING_REND_NAV	*,**	
GM_DEG	**	
GMDP		*
GMOP		*
GM_ORD	**	
NAV_CURR_ORB_MASS	NAV_ONORBIT_RENDEZVOUS	
NAV_DO_OV_UPLINK	NAV_ONORBIT_RENDEZVOUS	
NAV_DO_TV_UPLINK	NAV_ONORBIT_RENDEZVOUS	
OV_PREDICT_FAIL		*
PRED_ORB_AREA		*
PRED_ORB_CD		*
PRED_ORB_MASS		*
PRED_STEP		*
PRED_USE	*,**, STATE_VECTOR_PREDICT_TASK	*, STATE_VECTOR_PREDICT_TASK
PREC_STEP_PRED	**	
REF_ORB_AREA	**	
REF_ORB_CD	**	
$\bar{R}$ _FILT		REL_NAV_DISPLAY_UPDATES, REND_COV_INIT, ONORBIT_ REND_R_V_STATE_PROP, COV_LAST_RESET
$\bar{R}$ _GND	*	
$\bar{R}$ _PRED_FINAL	*	
$\bar{R}$ _PRED_INIT		*
$\bar{R}$ _TV		REL_NAV_DISPLAY_UPDATES, REND_COV_INIT, ONORBIT_ REND_R_V_STATE_PROP, COV_LAST_RESET
$\bar{R}$ _TV_GND	*	
T_GND	*	
T_GPS_LAST_UPDATE		*, GPS_UPDATE

Table 4.2.3.1. ONORBIT_REND_AUTO_INFLIGHT_UPDATE Input/Output		
Variable Name	Input Source	Output Destination
T_ORB_STATE_UPDATE		*
T_LAST_FILT		ONORBIT_REND_R_V_STATE_PROP, *, REND_COV_INIT
T_PRED_FINAL	STATE_VECTOR_PREDICT_TASK	
T_PRED_INIT		*, STATE_VECTOR_PREDICT_TASK
T_TV		*, REND_COV_INIT
T_TV_GND	*	
T_TV_STATE_UPDATE		*
TV_PREDICT_FAIL		*
UPLINK_NAV_RESET		SHUTTLE RESET
$\bar{V}$ _FILT		REL_NAV_DISPLAY_UPDATES, REND_COV_INIT, ONORBIT_REND_R_V_STATE_PROP, COV_LAST_RESET
VFLOV_PRED	**	
VFLTV_PRED	**	
$\bar{V}$ _GND	*	
VMP		*
$\bar{V}$ _PRED_FINAL	*	
$\bar{V}$ _PRED_INIT		*
$\bar{V}$ _TV		REL_NAV_DISPLAY_UPDATES, REND_COV_INIT, ONORBIT_REND_R_V_STATE_PROP, COV_LAST_RESET
$\bar{V}$ _TV_GND	*	
<p>* Onorbit/Rendezvous principal function, see Table 4.2.11-1.  ** Initialization parameters, see Section 4.7.</p>		

#### 4.2.3.1.1 State Vector Prediction Task (STATE\_VECTOR\_PREDICT\_TASK)

It is a requirement that the execution of either the Onorbit/Rendezvous Sequencer or the Onorbit/Rendezvous Navigation principal function has priority over the execution of the Onorbit Precision State Prediction principal function. The purpose of the state vector prediction task is to provide logic, to be executed at the same priority as the predictor, which will allow the navigation and sequencer principal functions to execute in a nominal manner despite delays in the predictor due to its low priority execution.

This task shall be scheduled by the Rendezvous Navigation Initialization (Section 4.1.2.2) subfunction and the Auto Inflight Updates subfunction to provide for the prediction of either the orbiter and/or target state vectors to the time tag specified by the Orbiter State Vector Reset subfunction. The state vector prediction task shall also test the prediction interval size against a gross reasonability design-dependent threshold to prevent the Onorbit Precision State Prediction principal function from predicting over inordinately large time intervals. Any prediction task in progress that was scheduled by the STATE\_VECTOR\_PREDICT\_TASK is terminated when an event to leave OPS 2 or OPS 8 is initiated. The state vector prediction task shall also set the value of the PRED\_USE flag, which indicates the status of prediction to the scheduling subfunction. The PRED\_USE flag has the following values.

<u>Value of PRED USE</u>	<u>Definition</u>
0	Prediction task is available for scheduling
1	Prediction task scheduled for orbiter inflight update
2	Prediction task completed for orbiter inflight update
3	Prediction task failed for orbiter inflight update
4	Prediction task scheduled for rendezvous navigation initialize
5	Prediction task completed for rendezvous navigation initialize
6	Prediction task failed for rendezvous navigation initialize
7	Prediction task scheduled for target inflight update
8	Prediction task completed for target inflight update
9	Prediction task failed for target inflight update

The scheduling subfunction will set PRED\_USE to the values of 0, 1, 4, or 7. All other values are set by the prediction task.

#### A. Detailed Requirements.

1. A local flag, PRED\_TASK\_COMPLETE, which signals when the prediction task is completed, is initialized to OFF upon entering the state vector prediction task.

PRED\_TASK\_COMPLETE = OFF

2. Next, the absolute value of the differences between the initial prediction time tag, T\_PREDICT\_INIT, and the time tag T\_RESET is tested against a gross reasonability (design dependent) threshold in order to prevent the Onorbit Precision State Prediction principal function from predicting over excessively large time intervals.

$$|T\_PRED\_INIT - T\_RESET| > MAX\_TIME\_TOL$$

- a. If the time threshold is exceeded or an event to leave OPS 2 or 8 has been initiated, then the flag PRED\_USE is incremented by 2 in order to communicate to the invoking subfunction that the prediction task has failed.

$$\text{PRED\_USE} = \text{PRED\_USE} + 2$$

- b. If the maximum time tolerance MAX\_TIME\_TOL is not exceeded, then the following logic [steps (1), (2), (3), (4), and (5)] is executed in a cyclic fashion until the PREDICT\_TASK\_COMPLETE flag is turned ON.

DO UNTIL

$$\text{PREDICT\_TASK\_COMPLETE} = \text{ON}$$

- (1) The PRED\_ENA\_FLAG is tested for an OFF value to determine if an event has been initiated to leave OPS 2 or OPS 8.

If PRED\_ENA\_FLAG = OFF, a flag is set to terminate the current execution of the state vector prediction task, and the PRED\_USE flag is incremented to show the incompleteness of the prediction task.

$$\begin{aligned} \text{PRED\_TASK\_COMPLETE} &= \text{ON} \\ \text{PRED\_USE} &= \text{PRED\_USE} + 2 \end{aligned}$$

If PRED\_ENA\_FLAG = ON, the logic proceeds to execute steps (2) through (5).

- (2) The time tag for the final predicted state vectors is set to the current value of T\_RESET as defined by the navigation task.

$$\text{T\_PRED\_FINAL} = \text{T\_RESET}$$

- (3) Next, the Onorbit Precision State Prediction principal function is invoked.

CALL: ONORBIT\_PREDICT

- (4) The predicted state vectors and time tag are saved for the next state vector prediction task cycle.

$$\begin{aligned} \bar{\mathbf{R}}_{\text{PRED\_INIT}} &= \bar{\mathbf{R}}_{\text{PRED\_FINAL}} \\ \bar{\mathbf{V}}_{\text{PRED\_INIT}} &= \bar{\mathbf{V}}_{\text{PRED\_FINAL}} \\ \text{T\_PRED\_INIT} &= \text{T\_PRED\_FINAL} \end{aligned}$$

- (5) Using NAV's current value for T\_RESET, the prediction interval magnitude is tested against a hard-coded time tolerance SV\_TIME\_TAG\_DIFF to determine if the predicted vectors are close to the time tag T\_RESET.

$$|\text{T\_PRED\_INIT} - \text{T\_RESET}| \leq \text{SV\_TIME\_TAG\_DIFF}$$

[It should be noted that any value for SV\_TIME\_TAG\_DIFF which is smaller than the length of a single navigation cycle will cause the predictor task to predict to current time (T\_RESET).]

If the predicted state vector time tag is close to the current reset time tag (i.e., less than or equal to SV\_TIME\_TAG\_DIFF), then the prediction complete flag is set to ON and the PRED\_USE flag is incremented by one to indicate to the proper navigation subfunction that the prediction task is completed and predicted state vectors are available.

PRED\_TASK\_COMPLETE = ON  
PRED\_USE = PRED\_USE + 1

Steps (1), (2), (3), (4) and (5) are repeated until PRED\_TASK\_COMPLETE is ON as specified in step b.

B. Interface Requirements. Input and output parameters for the state vector prediction task are specified in Table 4.2.3.1.1. Since the STATE\_VECTOR\_PREDICT\_TASK (SVPT) executes in parallel to the navigation task, the value of T\_RESET can update in NAV while the SVPT is in process. The SVPT makes cyclic use of T\_RESET in two places in its logic and should be provided NAV's current value of T\_RESET each time it uses the parameter.

C. Processing Requirements. The following subfunctions schedule the state vector prediction task.

Rendezvous Navigation Initialization  
(REND\_NAV\_INIT, Section 4.1.2.2)  
Auto Inflight Updates  
(ONORBIT\_REND\_AUTO\_INFLIGHT\_UPDATE, Section 4.2.3.1)

D. Constraints. The STATE\_VECTOR\_PREDICT\_TASK is one of several users of the onorbit predictor. Since the same compool locations are used by all users of this principal function for setup and output and since the use of the predictor by the STATE\_VECTOR\_PREDICT\_TASK may be interrupted by other users, it is required that its predictor parameters be protected from alternation by other users during execution of this principal function.

If more than one execution of steps (1), (2), (3), (4), and (5) is needed to complete the prediction of a state to within the time tolerance of T\_RESET, it is not required that intermediate states (in step (4)) be made available for the downlink processor.

E. Supplemental Information. A suggested implementation of the state vector prediction task may be found in the Section 5.2 flow chart STATE\_VECTOR\_PREDICT\_TASK.



Table 4.2.3.1.1. STATE\_VECTOR\_PREDICT\_TASK Input/Output

Variable Name	Input Source	Output Destination
MAX_TIME_TOL	**	
PRED_ENA_FLAG	OPS_2_OR_8_INITIALIZE, NAV_EXIT, *	
PRED_USE	ONORBIT_REND_AUTO_ INFLIGHT_UPDATE, REND_NAV_INIT, *, **	ONORBIT_REND_AUTO_ INFLIGHT_UPDATE, REND_NAV_INIT, *, **
$\bar{R}$ _PRED_INIT		*, **
$\bar{R}$ _PRED_FINAL	*, **	
SV_TIME_TAG_DIFF	**	
T_PRED_INIT	ONORBIT_REND_AUTO_ INFLIGHT_UPDATE, REND_NAV_INIT	*, **
T_PRED_FINAL		*, **, REND_NAV_INIT, ONORBIT_REND_AUTO_ INFLIGHT_UPDATE
T_RESET	SHUTTLE_RESET, *, **	
$\bar{V}$ _PRED_INIT		*, **
$\bar{V}$ _PRED_FINAL	*, **	
<p>* Onorbit/Rendezvous principal function, see Table 4.2.11-1.  ** Initialization parameters, see Section 4.7.  *** Onorbit/Rendezvous Navigation Sequencer principal function, see Table 4.1.3-1.</p>		

#### 4.2.3.2 REL\_NAV Display Updates (REL\_NAV\_DISPLAY\_UPDATES)

This subfunction is required to respond to crew request, made via item entries on the REL\_NAV display, to reinitialize the covariance matrix to perform a state vector transfer from the orbiter state vector to the target state vector or vice versa, or to perform a state vector transfer from the filtered state to the backup propagated state or vice versa. This subfunction is exercised on each state vector propagation cycle by the NAV control logic.

A. Detailed Requirements. The following steps shall be performed (in the order indicated) in response to crew request while rendezvous navigation is active:

1. Turn off the positive feedback flags to the REL\_NAV display.

DID\_COVAR\_REINIT = OFF

DID\_ORB\_TO\_TGT = OFF

DID\_TGT\_TO\_ORB = OFF

DID\_FILTERED\_TO\_PROP = OFF

DID\_PROP\_TO\_FILTERED = OFF

2. Test the NAV\_DO\_COVAR\_REINIT flag to determine if the crew has requested that the covariance matrix be reinitialized. If NAV\_DO\_COVAR\_REINIT = ON, perform the following steps:
  - a. Call the Covariance Matrix Initialization subfunction to reinitialize the covariance matrix, to zero the unmodeled acceleration states, and compute the total filter vehicle acceleration vector see Section 4.1.2.2.1):

CALL: REND\_COV\_INIT

- b. Reset the covariance matrix initialization indicator flag and the positive feedback flag (to the REL\_NAV display) as follows:

DO\_COVAR\_REINIT = OFF

DID\_COVAR\_REINIT = ON

3. Test the NAV\_DO\_ORB\_TO\_TGT flag to determine if the crew has requested a state vector transfer (orbiter to target).

- a. If NAV\_DO\_ORB\_TO\_TGT = ON, the following steps are taken:

- (1) The target state vectors are set equal to the orbiter state vectors:

$$\bar{\mathbf{R}}_{TV} = \bar{\mathbf{R}}_{FILT}$$
$$\bar{\mathbf{V}}_{TV} = \bar{\mathbf{V}}_{FILT}$$

- (2) The Covariance Matrix Initialization subfunction is called to reinitialize the covariance matrix, to zero the unmodeled acceleration states, and compute the total filter vehicle acceleration vector (see Section 4.1.2.2.1):

CALL: REND\_COV\_INIT

- (3) The flags indicating the orbiter-to-target state vector transfer and the positive feedback (to the REL\_NAV display) shall be set:

DO\_ORB\_TO\_TGT = OFF

DID\_ORB\_TO\_TGT = ON

- b. If the NAV\_DO\_ORB\_TO\_TGT flag is off, test the NAV\_DO\_TGT\_TO\_ORB flag to determine if the crew has requested a state vector transfer (target to orbiter). If NAV\_DO\_TGT\_TO\_ORB = ON, the following steps are taken:

- (1) The orbiter state vector shall be set equal to the target state vector:

$$\bar{R}_{\text{FILT}} = \bar{R}_{\text{TV}}$$

$$\bar{V}_{\text{FILT}} = \bar{V}_{\text{TV}}$$

- (2) The Covariance Matrix Initialization subfunction is called to reinitialize the covariance matrix, to zero the unmodeled acceleration state, and compute the total filter vehicle acceleration vector (see Section 4.1.2.2.1):

CALL: REND\_COV\_INIT

- (3) The flags indicating target-to-orbiter state vector transfer and the positive feedback (to the REL\_NAV display) shall be set:

DO\_TGT\_TO\_ORB = OFF

DID\_TGT\_TO\_ORB = ON

4. Test the NAV\_DO\_FILTERED\_TO\_PROP flag to determine if the crew has requested that the backup propagated state vector be updated with the filtered state vector.

- a. If NAV\_DO\_FILTERED\_TO\_PROP = ON, the following steps are taken:

- (1) The backup propagated state vector is reset based on the value of the SHUTTLE\_FILTER\_FLAG. If the Shuttle vector is the filtered factor (SHUTTLE\_FILTER\_FLAG = ON), then the Shuttle vector is used.

$$\bar{R}_{\text{PROP}} = \bar{R}_{\text{FILT}}$$

$$\bar{V}_{\text{PROP}} = \bar{V}_{\text{FILT}}$$

If the target vector is the filtered vector (SHUTTLE\_FILTER\_FLAG = OFF), then the target vector is used.

$$\begin{aligned}\bar{R}_{PROP} &= \bar{R}_{TV} \\ \bar{V}_{PROP} &= \bar{V}_{TV}\end{aligned}$$

- (2) The flags indicating the filtered vector to backup vector transfer and the positive feedback (to the REL\_NAV display) shall be set:

$$\begin{aligned}DO\_FILTERED\_TO\_PROP &= OFF \\ DID\_FILTERED\_TO\_PROP &= ON\end{aligned}$$

- b. If the NAV\_DO\_FILTERED\_TO\_PROP flag is off, test the NAV\_DO\_PROP\_TO\_FILTERED flag to determine if the crew has requested that the filtered state be reset with the backup propagated state. If NAV\_DO\_PROP\_TO\_FILTERED = ON, the following steps are taken:
- (1) The backup propagated state vector is used to reset the filtered state based on the value of the SHUTTLE\_FILTER\_FLAG. If the Shuttle vector is the filtered vector (SHUTTLE\_FILTER\_FLAG = ON), then the Shuttle vector is reset.

$$\begin{aligned}\bar{R}_{FILT} &= \bar{R}_{PROP} \\ \bar{V}_{FILT} &= \bar{V}_{PROP}\end{aligned}$$

If the target vector is the filtered vector (SHUTTLE\_FILTER\_FLAG = OFF) then the target vector is reset.

$$\begin{aligned}\bar{R}_{TV} &= \bar{R}_{PROP} \\ \bar{V}_{TV} &= \bar{V}_{PROP}\end{aligned}$$

- (2) The Covariance Matrix Initialization subfunction is called to reinitialize the covariance matrix, to zero the unmodeled acceleration state, and compute the total filter vehicle acceleration vector (see Section 4.1.2.2.1):

CALL: REND\_COV\_INIT

- (3) The flags indicating the reset of the filtered vector with the backup vector and the positive feedback (to the REL\_NAV display) shall be set:

$$\begin{aligned}DO\_PROP\_TO\_FILTERED &= OFF \\ DID\_PROP\_TO\_FILTERED &= ON\end{aligned}$$

B. Interface Requirements. Input and output parameters are listed in Table 4.2.3.2.

C. Processing Requirements. This subfunction is called by

NAV\_ONORBIT\_RENDEZVOUS (Section 4.2.1)

D. Constraints. Covariance matrix reinitialization as well as the state vector transfer and backup vector/filtered vector transfer must be activated via crew input to the REL\_NAV display and only while the Rendezvous Navigation principal function is active.

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart can be found in Section 5.2 under the name:

REL\_NAV\_DISPLAY\_UPDATES

Table 4.2.3.2. REL\_NAV\_DISPLAY\_UPDATES Input/Output

Variable Name	Input Source	Output Destination
DID_COVAR_REINIT		*
DID_FILTERED_TO_PROP		*
DID_ORB_TO_TGT		*
DID_PROP_TO_FILTERED		*
DID_TGT_TO_ORB		*
DO_COVAR_REINIT		NAV_ONORBIT_RENDEZVOUS
DO_FILTERED_TO_PROP		NAV_ONORBIT_RENDEZVOUS
DO_ORB_TO_TGT		NAV_ONORBIT_RENDEZVOUS
DO_PROP_TO_FILTERED		NAV_ONORBIT_RENDEZVOUS
DO_TGT_TO_ORB		NAV_ONORBIT_RENDEZVOUS
NAV_DO_COVAR_REINIT	NAV_ONORBIT_RENDEZVOUS	
NAV_DO_FILTERED_TO_PROP	NAV_ONORBIT_RENDEZVOUS	
NAV_DO_ORB_TO_TGT	NAV_ONORBIT_RENDEZVOUS	
NAV_DO_PROP_TO_FILTERED	NAV_ONORBIT_RENDEZVOUS	
NAV_DO_TGT_TO_ORB	NAV_ONORBIT_RENDEZVOUS	
$\bar{R}$ _FILT	ONORBIT_REND_R_V_STATE_PROP, ONORBIT_REND_AUTO_INFLIGHT_UPDATE, REND_NAV_FILTER, *	REND_COV_INIT, COV_LAST_RESET, ONORBIT_REND_R_V_STATE_PROP
$\bar{R}$ _PROP	ONORBIT_REND_R_V_STATE_PROP, *	ONORBIT_REND_R_V_STATE_PROP
$\bar{R}$ _TV	ONORBIT_REND_R_V_STATE_PROP, ONORBIT_REND_AUTO_INFLIGHT_UPDATE, *, REND_NAV_FILTER, **	REND_COV_INIT, COV_LAST_RESET, ONORBIT_REND_R_V_STATE_PROP
SHUTTLE_FILTER_FLAG	*	
$\bar{V}$ _FILT	ONORBIT_REND_R_V_STATE_PROP, ONORBIT_REND_AUTO_INFLIGHT_UPDATE, REND_NAV_FILTER, *	REND_COV_INIT, COV_LAST_RESET, ONORBIT_REND_R_V_STATE_PROP
$\bar{V}$ _PROP	ONORBIT_REND_R_V_STATE_PROP, *	ONORBIT_REND_R_V_STATE_PROP
$\bar{V}$ _TV	ONORBIT_REND_R_V_STATE_PROP, ONORBIT_REND_AUTO_INFLIGHT_UPDATE, *, REND_NAV_FILTER, **	REND_COV_INIT, COV_LAST_RESET, ONORBIT_REND_R_V_STATE_PROP

\* Onorbit/Rendezvous principal function, see Table 4.2.11-1.  
\*\* Initialization parameters, see Section 4.7.

#### 4.2.4 Position and Velocity State Propagation (ONORBIT\_REND\_R\_V\_STATE\_PROP)

The Position and Velocity State Propagation subfunction is contained within the Onorbit/Rendezvous Navigation principal function and is used to perform a number of tasks related to the propagation of the orbiter and target vehicle state vectors. The subfunction will be employed to propagate the orbiter and target vehicle state vectors from the time of the previous navigation cycle to the current navigation cycle time.

Prior to state vector propagation, the task of snapping IMU and attitude data shall be performed to obtain the current time (T\_CURRENT\_FILT), accumulated IMU-sensed velocity ( $\bar{V}$ \_CURRENT\_FILT), and an attitude quaternion (Q\_M50BODY\_IMU). This accumulated IMU-sensed velocity has been corrected in the IMU RM to reference the orbiter center of gravity. For detailed requirements of these data snaps, see IMU and Attitude Data Snap, Section 4.2.2.1.

During vehicle state propagation, various acceleration models are available for use in the determination of perturbing acceleration values and include gravitational accelerations (always used) and nongravitational accelerations (drag, and a limited venting and uncoupled RCS thrusting model). The nongravitational acceleration models shall be used only when the vehicle-sensed acceleration ( $\bar{D}V$ \_FILT), obtained from the IMU accumulated sensed velocity ( $\bar{V}$ \_CURRENT\_FILT), is judged to be insignificant; that is, below a predetermined value (DA\_THRESHOLD TEST). A detailed description of the acceleration models may be found in Section 4.2.4.1.1.

If the orbiter acceleration exceeds a predetermined value (DA\_THRESHOLD\_TEST), or if the accumulated c.g.-sensed velocity over an attitude control maneuver exceeds an I-loaded threshold (VEL\_THRESH), then the IMU-sensed velocities will be incorporated into NAV.

State vector propagation will employ only one scheme for integration of the equations of motion, the SUPER\_G algorithm (see Section 4.2.4.1). This algorithm will be used for propagating both the orbiter and target state vectors in both coasting and powered flight. This subfunction also propagates the backup propagated state with the same SUPER\_G algorithm.

A. Detailed Requirements. The computations that shall be performed for propagation of the position and velocity vectors are initiated by a call to the Onorbit/Rendezvous Position and Velocity State Propagation subfunction (ONORBIT\_REND\_R\_V\_STATE\_PROP) in the following form:

CALL: ONORBIT\_REND\_R\_V\_STATE\_PROP

The following will be performed in the order indicated.

1. The acceleration model flags shall be set up for orbiter coasting flight propagation:

IGD = GM\_DEG

IGO = GM\_ORD

IDRAG = 1

IVENT = 1

2. Next the change in velocity ( $\overline{DV\_FILT}$ ) and the corresponding time interval ( $DT\_FILT$ ) used in the advancement of both orbiter and target state vectors shall be calculated by subtraction of the previous cycle values ( $\overline{V\_LAST\_FILT}$  and  $T\_LAST\_FILT$ ) from the current IMU snapped values.

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

$$DT\_FILT = T\_CURRENT\_FILT - T\_LAST\_FILT$$

3. An acceleration averaged over the desired interval is next determined by:

$$CONT\_ACC = |\overline{DV\_FILT}| / DT\_FILT \quad F3$$

F3 This equation shall be protected against division by zero (reference 3.5).

4. Next the powered flight navigation flag,  $NAV\_PWRD\_FLT\_NAV$ , shall be tested, and flags specifying the acceleration models to be used to propagate the orbiter state vector on this navigation cycle shall be defined.
- a. If the  $NAV\_PWRD\_FLT\_NAV$  flag is found to be ON, acceleration threshold tests must be made to determine the acceleration models to be used in propagating the orbiter state vector. The procedure is as follows:

- (1) Convert the  $DA\_THRESHOLD$  value from micro-g's to feet/sec<sup>2</sup>, normalize according to the propagation time interval ( $DT\_FILT$ ), and store the new value into  $DA\_THRESHOLD\_TEST$ .

$$DA\_THRESHOLD\_TEST = DA\_THRESHOLD (GO) (10^{-6})/DT\_FILT \quad F3$$

F3 This equation shall be protected against division by zero (reference 3.5).

("GO" is the g's to feet/sec<sup>2</sup> conversion factor.)

- (2) Initialize the thrust flag to OFF.

$$THRUST = OFF$$

- (3) Test the acceleration value ( $CONT\_ACC$ ) against the converted threshold value,  $DA\_THRESHOLD\_TEST$ .

If  $CONT\_ACC > DA\_THRESHOLD\_TEST$ , turn the  $COV\_USE\_IMU\_DATA$  flag ON and set the flags for modeling drag and vent forces to 0 (OFF) and the thrust flag to ON.

$$\begin{aligned} COV\_USE\_IMU\_DATA &= ON \\ IDRAG &= 0 \\ IVENT &= 0 \\ THRUST &= ON \end{aligned}$$

Otherwise, set the  $COV\_USE\_IMU\_DATA$  flag to OFF.

$$COV\_USE\_IMU\_DATA = OFF$$

- (4) Test the NAV\_DAP\_JET flag for an ON condition. If NAV\_DAP\_JET = ON, turn the thrust flag to ON.

$$\text{THRUST} = \text{ON}$$

- (5) Test the thrust flag or the USE\_IMU\_DATA\_LAST flag for an ON condition.

If either THRUST = ON or USE\_IMU\_DATA\_LAST = ON, set the accumulated thrust value,  $\overline{DV\_SUM}$ , equal to  $\overline{DV\_SUM} + \text{IMU-sensed velocity } (\overline{DV\_FILT})$ , and set the flag USE\_IMU\_DATA to ON.

$$\begin{aligned}\overline{DV\_SUM} &= \overline{DV\_SUM} + \overline{DV\_FILT} \\ \text{USE\_IMU\_DATA} &= \text{ON}\end{aligned}$$

Otherwise, set the flag USE\_IMU\_DATA to OFF, and set  $\overline{DV\_FILT}$  to zero.

$$\begin{aligned}\text{USE\_IMU\_DATA} &= \text{OFF} \\ \overline{DV\_FILT} &= 0.\end{aligned}$$

- (6) Set the USE\_IMU\_DATA\_LAST flag to the present value of the USE\_IMU\_DATA flag.

$$\text{USE\_IMU\_DATA\_LAST} = \text{USE\_IMU\_DATA}$$

- (7) Test if the USE\_IMU\_DATA flag (USE\_IMU\_DATA) is ON, and the THRUST flag (THRUST) is OFF.

If USE\_IMU\_DATA = ON and THRUST = OFF, then do the following:

- (a) If the magnitude of the accumulated thrust velocity ( $|\overline{DV\_SUM}|$ ) is less than the I-loaded value (VEL\_THRESH), remove all the accumulated velocity that was added to NAV during the maneuver interval:

$$\overline{DV\_FILT} = \overline{DV\_FILT} - \overline{DV\_SUM}$$

Otherwise, increment the total to date accumulated velocity accepted by NAV (and the number of times NAV has accepted such velocities), and store into the downlist parameter  $\overline{DV\_DISP}$  (and DV\_COUNT).

$$\begin{aligned}\overline{DV\_DISP} &= \overline{DV\_DISP} + \overline{DV\_SUM} \\ \text{DV\_COUNT} &= \text{DV\_COUNT} + 1\end{aligned}$$

- (b) Set the flag USE\_IMU\_DATA\_LAST to OFF and zero out the accumulated sensed velocity.

$$\begin{aligned}\text{USE\_IMU\_DATA\_LAST} &= \text{OFF} \\ \overline{DV\_SUM} &= 0\end{aligned}$$

- b. In the situation where the NAV\_PWRD\_FLT\_NAV is found to be OFF, the orbiter sensed acceleration is not used in propagating the orbiter state vector. Therefore, set



$\bar{D}_{\text{FILT}} = \bar{0}$ .  
USE\_IMU\_DATA = OFF

5. Next the SUPER\_G algorithm is called to propagate the orbiter state vector, using the acceleration models computed above.

CALL: SUPER\_G  
IN LIST: IGD, IGO, IDRAG, IVENT, ATFL\_OV,  $\bar{R}_{\text{FILT}}$ ,  $\bar{V}_{\text{FILT}}$ ,  
T\_LAST\_FILT, T\_CURRENT\_FILT, DT\_FILT,  $\bar{D}\bar{V}_{\text{FILT}}$   
OUT LIST:  $\bar{R}_{\text{FILT}}$ ,  $\bar{V}_{\text{FILT}}$ ,  $\bar{G}_{\text{NEW}}$

The values of  $\bar{R}_{\text{FILT}}$  and  $\bar{V}_{\text{FILT}}$  output by SUPER\_G are the required propagated position and velocity vectors of the orbiter during a powered or coasting flight mode. The vector  $\bar{G}_{\text{NEW}}$  is a modeled total acceleration vector obtained according to the specified flag settings and corresponding to  $\bar{R}_{\text{FILT}}$ ,  $\bar{V}_{\text{FILT}}$  and T\_CURRENT\_FILT.

6. Once the orbiter state vector has been propagated, the DOING\_REND\_NAV flag will be tested to determine if propagation of the target vehicle state and the backup propagated state is required.



If the DOING\_REND\_NAV flag is ON, the following steps will be performed:

- a. The target vehicle state vector will be propagated to time T\_CURRENT\_FILT from time T\_TV using the SUPER\_G algorithm.

CALL: SUPER\_G  
IN LIST: GM\_DEG, GM\_ORD, DFL, VFL\_TV, ATFL\_TV,  $\bar{R}_{\text{TV}}$ ,  
 $\bar{V}_{\text{TV}}$ , T\_TV, T\_CURRENT\_FILT, DT\_FILT,  $\bar{T}\bar{D}\bar{V}_{\text{FILT}}$   
OUT LIST:  $\bar{R}_{\text{TV}}$ ,  $\bar{V}_{\text{TV}}$ ,  $\bar{G}_{\text{TV}}$

The out list variables represent the required advanced target vehicle state vector and total target acceleration vector. Here  $\bar{R}_{\text{TV}}$  is the target position vector,  $\bar{V}_{\text{TV}}$  the target velocity vector, and  $\bar{G}_{\text{TV}}$  the corresponding acceleration vector, all determined for the time T\_CURRENT\_FILT.

- b. The backup propagated state vector will be propagated to time T\_CURRENT\_FILT using the SUPER\_G algorithm. The arguments to SUPER\_G are based on which vehicle state vector is the filtered state as follows:

- (1) If the Shuttle state is the filtered state (SHUTTLE\_FILTER\_FLAG = ON), set the flag to indicate that it is the Shuttle backup state (and not the filtered state) that is being propagated

ORB\_PROP\_SV = ON

and call the SUPER\_G subfunction to propagate the backup state using arguments appropriate to the propagation of a Shuttle vector.

CALL: SUPER\_G  
IN LIST: IGD, IGO, IDRAG, IVENT, ATFL\_OV,  $\bar{R}$ \_PROP,  $\bar{V}$ \_PROP,  
T\_LAST\_FILT, T\_CURRENT\_FILT, DT\_FILT,  $\bar{D}$ V\_FILT  
OUT LIST:  $\bar{R}$ \_PROP,  $\bar{V}$ \_PROP,  $\bar{G}$ \_PROP

Reset the flag to signal the completion of the propagation of the Shuttle backup propagated state vector.

ORB\_PROP\_SV = OFF

- (2) If the target state is the filtered state (SHUTTLE\_FILTER\_FLAG = OFF), call the SUPER\_G subfunction to propagate the backup state using arguments appropriate to the propagation of a target state vector.

CALL: SUPER\_G  
IN LIST: GM\_DEG, GM\_ORD, DFL, VFL\_TV\_PROP,  
ATFL\_TV,  $\bar{R}$ \_PROP,  $\bar{V}$ \_PROP, T\_TV,  
T\_CURRENT\_FILT, DT\_FILT,  $\bar{T}$ DV\_FILT  
OUT LIST:  $\bar{R}$ \_PROP,  $\bar{V}$ \_PROP,  $\bar{G}$ \_PROP

- c. The time T\_CURRENT\_FILT is saved as T\_TV.  
T\_TV = T\_CURRENT\_FILT

7. After satisfaction of the operations caused by the DOING\_REND\_NAV flag value, T\_LAST\_FILT and  $\bar{V}$ \_LAST\_FILT will be updated to T\_CURRENT\_FILT and  $\bar{V}$ \_CURRENT\_FILT in preparation for the next cycle through ONORBIT\_REND\_R\_V\_STATE\_PROP.

$T\_LAST\_FILT = T\_CURRENT\_FILT$   
 $\bar{V}\_LAST\_FILT = \bar{V}\_CURRENT\_FILT$

8. A call to the solar ephemeris subfunction will provide sine and cosine functions of the sun's current position preparatory to calculation of the Earth-sun unit vector. The unit vector will be constructed as follows:

- (a) CALL: SOLAR\_EPHEM  
IN LIST: T\_CURRENT\_FILT  
OUT LIST: SDEC, CDEC1, COS\_SOL\_RA, SIN\_SOL\_RA  
(b) UR\_SUN<sub>1</sub> = COS\_SOL\_RA CDEC1  
UR\_SUN<sub>2</sub> = SIN\_SOL\_RA CDEC1  
UR\_SUN<sub>3</sub> = SDEC

The solar unit vector is required by the Universal Pointing Processing principal function.

B. Interface Requirements. Input and output parameters for the Position and Velocity State Propagation subfunction trunk logic are given in Table 4.2.4.

C. Processing Requirements. This subfunction shall be called by the Onorbit/ Rendezvous Navigation principal function (NAV\_ONORBIT\_RENDEZVOUS).

D. Constraints. The following constraints apply:

1. The acceleration models task is needed not only by the Navigation State Propagation subfunction, but also by the Onorbit Precision State Prediction principal function and by the User Parameter State Propagation subfunction. Each user of acceleration models shall set its own flags and therefore requires a different calculation. To protect against interference in the acceleration computations, it is important that these computations not be interrupted.
2. The current orbiter mass (CURR\_ORB\_MASS) will be initialized for use by NAV by the Onorbit/Rendezvous Navigation Sequencer principal function and will be maintained for NAV by the Onorbit Guidance principal function.

E. Supplementary Information. A suggested implementation of this subfunction in the form of detailed flow diagrams may be found in Section 5.2 under the following:

ONORBIT\_REND\_R\_V\_STATE\_PROP

Table 4.2.4. ONORBIT_REND_R_V_STATE_PROP Input/Output		
Variable Name	Input Source	Output Destination
ATFL_OV	**	SUPER_G
ATFL_TV	**	SUPER_G
CDEC1	SOLAR_EPHEM	
COS_SOL_RA	SOLAR_EPHEM	
CONT_ACC		NAV_ONORBIT_RENDEZVOUS,*
COV_USE_IMU_DATA		NAV_ONORBIT_RENDEZVOUS
DFL	**	SUPER_G
DA_THRESHOLD	NAV_ONORBIT_RENDEZVOUS	
DOING_REND_NAV	*, **	
DT_FILT		REND_COV_INIT, *, SUPER_G
DV_COUNT	**	*
$\bar{D}V\_DISP$	**	*
$\bar{D}V\_FILT$		REND_COV_INIT, SUPER_G, NAV_ONORBIT_RENDEZVOUS,*
$\bar{D}V\_SUM$	**	
GM_DEG	**	SUPER_G
GM_ORD	**	SUPER_G
$\bar{G}\_NEW$	SUPER_G	REND_BIAS_AND_COV_PROP, *
$\bar{G}\_TV$	SUPER_G	REND_BIAS_AND_COV_PROP, REND_NAV_INTERP, *
IDRAG		SUPER_G, REND_COV_INIT, REND_NAV_INTERP, *
IGD		SUPER_G, REND_COV_INIT, REND_NAV_INTERP, *
IGO		SUPER_G, REND_COV_INIT, REND_NAV_INTERP, *
IVENT		SUPER_G, REND_COV_INIT, REND_NAV_INTERP, *
NAV_PWRD_FLT_NAV	NAV_ONORBIT_RENDEZVOUS	
ORB_PROP_SV		$\bar{A}CCEL\_ONORBIT$
$\bar{R}\_FILT$	SUPER_G, ONORBIT_REND_ AUTO_INFLIGHT_UPDATE, REL_NAV_DISPLAY_UPDATES, REND_NAV_FILTER, *	SUPER_G, REND_COV_INIT, COV_LAST_RESET, REND_ NAV_FILTER, REND_NAV_ INTERP, REL_NAV_DISPLAY_ UPDATES, REND_BIAS_AND_ COV_PROP, *, SHUTTLE_RESET, NAV_ONORBIT_RENDEZVOUS

Table 4.2.4. ONORBIT_REND_R_V_STATE_PROP Input/Output		
Variable Name	Input Source	Output Destination
$\bar{R}_{TV}$	ONORBIT_REND_AUTO_INFLIGHT_UPDATE, REL_NAV_DISPLAY_UPDATES, REND_NAV_FILTER, *, SUPER_G	COV_LAST_RESET, REND_COV_INIT, TARGET_RESET, REND_NAV_FILTER, REND_BIAS_AND_COV_PROP, REL_NAV_DISPLAY_UPDATES, REND_NAV_INTERP, *, SUPER_G, NAV_ONORBIT_RENDEZVOUS
SDEC	SOLAR_EPHEM	
SIN_SOL_RA	SOLAR_EPHEM	
SHUTTLE_FILTER_FLAG	*	
T_CURRENT_FILT	NAV_ONORBIT_RENDEZVOUS	SUPER_G, SOLAR_EPHEM
T_LAST_FILT	*,ONORBIT_REND_AUTO_INFLIGHT_UPDATE	SUPER_G,*, SHUTTLE_RESET, COV_LAST_RESET, REND_COV_INIT, NAV_ONORBIT_RENDEZVOUS,*
T_TV	ONORBIT_REND_AUTO_INFLIGHT_UPDATE	*, REND_COV_INIT, SUPER_G
$\bar{U}_R_{SUN}$		*
$\bar{T}DV_{FILT}$	**	SUPER_G
USE_IMU_DATA		*
NAV_DAP_JET	NAV_ONORBIT_RENDEZVOUS	
USE_IMU_DATA_LAST	**	
$\bar{R}_{PROP}$	*, REL_NAV_DISPLAY_UPDATES, SUPER_G	REL_NAV_DISPLAY_UPDATES, NAV_ONORBIT_RENDEZVOUS, SUPER_G
$\bar{V}_{CURRENT\_FILT}$	NAV_ONORBIT_RENDEZVOUS	
$\bar{V}_{FILT}$	SUPER_G, REND_NAV_FILTER, ONORBIT_REND_AUTO_INFLIGHT_UPDATE,REL_NAV_DISPLAY_UPDATES,*	SUPER_G, REND_COV_INIT, COV_LAST_RESET, SHUTTLE_RESET, REND_BIAS_AND_COV_PROP, REND_NAV_FILTER, REND_NAV_INTERP, REL_NAV_DISPLAY_UPDATES, *, NAV_ONORBIT_RENDEZVOUS
VFL_TV_PROP	**	SUPER_G
VFL_TV	**	SUPER_G
$\bar{V}_{LAST\_FILT}$	*	SHUTTLE_RESET

Table 4.2.4. ONORBIT_REND_R_V_STATE_PROP Input/Output		
Variable Name	Input Source	Output Destination
$\bar{V}_{TV}$	ONORBIT_REND_AUTO_ INFLIGHT_UPDATE, REL_NAV_DISPLAY_UPDATES, REND_NAV_FILTER, *, SUPER_G	COV_LAST_RESET, REL_ NAV_DISPLAY_UPDATES, REND_COV_INIT, TARGET_ RESET, REND_NAV_INTERP, REND_NAV_FILTER,*, SUPER_G, REND_BIAS_AND_COV_PROP, NAV_ONORBIT_RENDEZVOUS
$\bar{V}_{PROP}$	*, REL_NAV_DISPLAY_UPDATES, SUPER_G	REL_NAV_DISPLAY_UPDATES, NAV_ONORBIT_RENDEZVOUS, SUPER_G
VEL_THRESH	**	
* Onorbit/Rendezvous principal function, see Table 4.2.11-1. ** Initialization parameters, see Section 4.7.		

#### 4.2.4.1 Position and Velocity Propagation (SUPER\_G)

During powered flight navigation phases, the equations of motion used for orbiter state propagation have the form of a Taylor series truncated at the term in  $h^3$ , where  $h$  is the step size. The integration scheme used, called SUPER\_G, is an improved version of the AVERAGE\_G method, containing a correction cycle.

During orbiter powered flight conditions, nongravitational accelerations sensed by the IMU's are incorporated into the state vector in the SUPER\_G state propagation algorithm when above a preset threshold. For orbiter coasting flight or target state vector propagation, the accelerations are always modeled in the SUPER\_G algorithm.

##### A. Detailed Requirements.

The SUPER\_G subfunction shall be invoked whenever the following statement is encountered:

CALL: SUPER\_G

IN LIST: GMD, GMO, DM, VM, ATM,  $\bar{R}_{IN}$ ,  $\bar{V}_{IN}$ , T\_IN, T\_FIN, DT\_FILT,  $\bar{D}V_{IN}$

OUT LIST:  $\bar{R}_{FIN}$ ,  $\bar{V}_{FIN}$ ,  $\bar{G}_{OUT}$

1. Upon initiation of SUPER\_G, an initial total acceleration,  $\bar{G}_{INT}$ , will be calculated by the ACCEL\_ONORBIT function as:

$$\bar{G}_{INT} = \text{ACCEL\_ONORBIT}(\text{GMD}, \text{GMO}, \text{DM}, \text{VM}, \text{ATM}, \bar{R}_{IN}, \bar{V}_{IN}, T_{IN})$$

where the function arguments are the appropriate flag settings (that is, the degree and order of the gravitational potential model, drag mode, vent mode, and attitude mode flag settings), current position vector, current velocity vector, and previous time.

2. Next the position vector is advanced using the current position and velocity vectors, the time interval DT\_FILT, initial acceleration vector  $\bar{G}_{INT}$  calculated in the previous step, and the value of  $\bar{D}V_{IN}$ :

$$\bar{R}_{FIN} = \bar{R}_{IN} + DT\_FILT [\bar{V}_{IN} + .5 (\bar{D}V_{IN} + DT\_FILT \bar{G}_{INT})]$$

3. Find a new value of the total acceleration vector, based on the advanced position vector, velocity vector, and time tag:

$$\bar{G}_{OUT} = \text{ACCEL\_ONORBIT}(\text{GMD}, \text{GMO}, \text{DM}, \text{VM}, \text{ATM}, \bar{R}_{FIN}, \bar{V}_{IN}, T_{FIN})$$

4. The vehicle velocity vector is corrected using an average total acceleration difference.

$$\bar{V}_{FIN} = \bar{V}_{IN} + \bar{D}V_{IN} + .5 DT\_FILT (\bar{G}_{INT} + \bar{G}_{OUT})$$

5. Finally, the vehicle position vector is corrected by:

$$\bar{R}_{FIN} = \bar{R}_{FIN} + [(\bar{G}_{OUT} - \bar{G}_{INT}) DT\_FILT^2]/6.$$

The velocity and position vectors calculated in Steps 4 and 5 constitute the required propagated state.

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B. Interface Requirements. The input and output required for the SUPER\_G subfunction are listed in Table 4.2.4.1. Required inputs for use of the ACCEL\_ONORBIT function are given in Section 4.2.4.1.1.

C. Processing Requirements. The SUPER\_G subfunction is called by the following:

ONORBIT\_REND\_R\_V\_STATE\_PROP

D. Constraints. The SUPER\_G subroutine will be called to integrate the orbiter and target state vectors during coasting and powered flight.

E. Supplementary Information. A suggested implementation of the SUPER\_G subroutine, in the form of a detailed flow chart, is presented in Section 5.2 under:

SUPER\_G



Table 4.2.4.1. SUPER_G Input/Output			
Inlist/outlist		Input Source	Output Destination
Internal Name	External Name		
GMD	IGD	ONORBIT_REND_R_V_ STATE_PROP	
GMO	IGO	ONORBIT_REND_R_V_ STATE_PROP	
DM	IDRAG	ONORBIT_REND_R_V_ STATE_PROP	
VM	IVENT	ONORBIT_REND_R_V_ STATE_PROP	
ATM	ATFL_OV	ONORBIT_REND_R_V_ STATE_PROP	
$\bar{R}$ _IN	$\bar{R}$ _FILT	ONORBIT_REND_R_V_ STATE_PROP	
$\bar{V}$ _IN	$\bar{V}$ _FILT	ONORBIT_REND_R_V_ STATE_PROP	
T_IN	T_LAST_FILT	ONORBIT_REND_R_V_ STATE_PROP	
T_FIN	T_CURRENT_FILT	ONORBIT_REND_R_V_ STATE_PROP	
DT_FILT	DT_FILT	ONORBIT_REND_R_V_ STATE_PROP	
$\bar{D}$ V_IN	$\bar{D}$ V_FILT	ONORBIT_REND_R_V_ STATE_PROP	
GMD	GM_DEG	ONORBIT_REND_R_V_ STATE_PROP	
GMO	GM_ORD	ONORBIT_REND_R_V_ STATE_PROP	
DM	DLF	ONORBIT_REND_R_V_ STATE_PROP	
VM	VFL_TV	ONORBIT_REND_R_V_ STATE_PROP	
ATM	ATFL_TV	ONORBIT_REND_R_V_ STATE_PROP	
$\bar{R}$ _IN	$\bar{R}$ _TV	ONORBIT_REND_R_V_ STATE_PROP	
$\bar{V}$ _IN	$\bar{V}$ _TV	ONORBIT_REND_R_V_ STATE_PROP	
T_IN	T_TV	ONORBIT_REND_R_V_ STATE_PROP	
$\bar{D}$ V_IN	$\bar{D}$ V_FILT	ONORBIT_REND_R_V_ STATE_PROP	
$\bar{R}$ _IN	$\bar{R}$ _PROP	ONORBIT_REND_R_V_ STATE_PROP	

Table 4.2.4.1. SUPER\_G Input/Output

Inlist/outlist		Input Source	Output Destination
Internal Name	External Name		
$\bar{V}_{IN}$	$\bar{V}_{PROP}$	ONORBIT_REND_R_V_ STATE_PROP	
VM	VFL_TV_PROP	ONORBIT_REND_R_V_ STATE_PROP	
$\bar{R}_{FIN}$	$\bar{R}_{FILT}$		ONORBIT_REND_R_V_ STATE_PROP
$\bar{V}_{FIN}$	$\bar{V}_{FILT}$		ONORBIT_REND_R_V_ STATE_PROP
$\bar{G}_{OUT}$	$\bar{G}_{NEW}$		ONORBIT_REND_R_V_ STATE_PROP
$\bar{R}_{FIN}$	$\bar{R}_{TV}$		ONORBIT_REND_R_V_ STATE_PROP
$\bar{V}_{FIN}$	$\bar{V}_{TV}$		ONORBIT_REND_R_V_ STATE_PROP
$\bar{G}_{OUT}$	$\bar{G}_{TV}$		ONORBIT_REND_R_V_ STATE_PROP
$\bar{R}_{FIN}$	$\bar{R}_{PROP}$		ONORBIT_REND_R_V_ STATE_PROP
$\bar{V}_{FIN}$	$\bar{V}_{PROP}$		ONORBIT_REND_R_V_ STATE_PROP
$\bar{G}_{OUT}$	$\bar{G}_{PROP}$		ONORBIT_REND_R_V_ STATE_PROP
GMD			$\bar{ACCEL\_ONORBIT}$
GMO			$\bar{ACCEL\_ONORBIT}$
DM			$\bar{ACCEL\_ONORBIT}$
VM			$\bar{ACCEL\_ONORBIT}$
ATM			$\bar{ACCEL\_ONORBIT}$
$\bar{R}_{IN}$			$\bar{ACCEL\_ONORBIT}$
$\bar{R}_{FIN}$			$\bar{ACCEL\_ONORBIT}$
$\bar{V}_{IN}$			$\bar{ACCEL\_ONORBIT}$
T_IN			$\bar{ACCEL\_ONORBIT}$
T_FIN			$\bar{ACCEL\_ONORBIT}$
$\Delta$		$\bar{ACCEL\_ONORBIT}$	

$\Delta$  Only the value of  $\bar{ACCEL\_ONORBIT}$  is passed.

#### 4.2.4.1.1 Acceleration Models (ACCEL\_ONORBIT)

During orbital operations, models to account for gravitational, vent and thrust, and vehicle aerodynamic drag accelerations shall be available. These models are to be used in the orbiter state vector propagation whenever the IMU-sensed acceleration magnitude is below a given threshold level. When the sensed acceleration magnitude is above the threshold level, the gravitational acceleration model only will be used. In the orbiter state prediction mode, only the gravitational and drag acceleration models may be used. During propagation or prediction of a target vehicle state, the gravitational and drag acceleration models may be used. Additionally, during both the orbiter and the target state propagation modes, capability exists to incorporate the unmodeled acceleration biases as determined by the Kalman filter in REND\_NAV\_FILTER. The backup propagated state vector is propagated in the same way as its associated filtered vector except that the unmodeled acceleration bias states are not incorporated.

A. Detailed Requirements. This function is activated whenever the statement  $\overline{\text{ACCEL\_ONORBIT}}$  (GMD, GMO, DM, VM, ATM,  $\overline{\text{R}}$ ,  $\overline{\text{V}}$ , T) is encountered, where:

GMD	input degree of Earth gravitational potential model (ACCEL_EARTH_GRAV)
GMO	input order of Earth gravitational potential model (ACCEL_EARTH_GRAV)
DM	flag indicating use (1) or nonuse (0) of vehicle drag acceleration model (ACCEL_ONORBIT_DRAG)
VM	flag indicating use (1) or nonuse (0) of vent and thrust model (ACCEL_ONORBIT_VENT_AND_THRUST)
ATM	attitude mode flag (used when DM and/or VM are set to 1.)
$\overline{\text{R}}$	position vector of vehicle in M50 coordinates
$\overline{\text{V}}$	velocity vector of vehicle in M50 coordinates
T	position and velocity vectors time tag

The following steps will be performed (in the order indicated) whenever the  $\overline{\text{ACCEL\_ONORBIT}}$  function is activated.

1. The values of  $\overline{\text{G}}$ , the gravitational acceleration due to the Earth's nonspherical shape,  $\overline{\text{D}}$ , the drag model acceleration vector, and  $\overline{\text{VENT}}$ , the acceleration due to vent and thrusting shall be initially nulled.

$$\begin{aligned}\overline{\text{G}} &= \overline{\mathbf{0}}. \\ \overline{\text{D}} &= \overline{\mathbf{0}}. \\ \overline{\text{VENT}} &= \overline{\mathbf{0}}.\end{aligned}$$

The current Earth-fixed to M50 transformation FIFTY will be constructed.

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

Here, the EARTH\_FIXED\_TO\_M50\_COORD function is defined in Section 4.10.2.

Next the input M50 position vector will be transformed to Earth-fixed coordinates.

$$\bar{R}_{EF} = \text{FIFTY}^T \bar{R}$$

Components of the Earth-fixed position unit vector will be determined by the following:

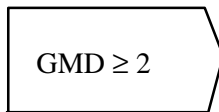
$$R\_INV = 1./|\bar{R}| \quad \text{F3} \quad \text{This equation shall be protected against division by zero (reference 3.5).}$$

$$\bar{U}R = R\_INV \bar{R}_{EF}$$

The acceleration vector due to the Earth's gravitational attraction as a point mass will be determined by:

$$\bar{G}_{CENTRAL} = - \text{EARTH\_MU} R\_INV^3 \bar{R}$$

2. Next the value of GMD shall be tested to determine if the gravitational acceleration vector due to the Earth's nonsphericity (G) shall be determined.



- a. If GMD is equal to or greater than 2, the ACCEL\_EARTH\_GRAV code will be executed, which is a model formulated using S. Pines' spherical harmonics development.

- (1) The following variables are to be set up to serve as starting values for recursive relations used in the Pines formulation:

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

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

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

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

$$L = 1$$

$$\text{AUXILIARY} = 0.$$

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

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

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

- (2) Recursive calculations shall then proceed, using as many components of the one-column arrays ZETA\_REAL and ZETA\_IMAG as required to account for the effects of tesseral harmonics. ZETA\_REAL and ZETA\_IMAG are the only terms that depend on the vehicle's longitude.

Do for I = 1 to GMO:

$$\text{ZETA\_REAL}_{I+1} = \text{UR}_1 \text{ZETA\_REAL}_I - \text{UR}_2 \text{ZETA\_IMAG}_I$$

$$\text{ZETA\_IMAG}_{I+1} = \text{UR}_1 \text{ZETA\_IMAG}_I + \text{UR}_2 \text{ZETA\_REAL}_I$$

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

Do for N = 2 to GMD the following steps:

(a)  $A_{N+1,1} = 0.$   
 $A_{N+1,2} = (2. N + 1.) A_{N,2}$   
 $A_{N,1} = A_{N,2}$   
 $A_{N,2} = \text{UR}_3 A_{N+1,2}$

(b) Do for J = 2 to N:

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

$$A_{N-J+1,2} = (\text{UR}_3 A_{N-J+2,2} - A_{N-J+2,1})/J$$

(c)  $F1 = 0.$   
 $F2 = 0.$   
 $F3 = -A_{1,1} \text{ZONAL}_N$   
 $F4 = -A_{1,2} \text{ZONAL}_N$

(These account for the zonal harmonics contributions.)

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

$$F1 = F1 + N1 A_{N1,1} (C_L \text{ZETA\_REAL}_{N1} + S_L \text{ZETA\_IMAG}_{N1})$$

$$F2 = F2 + N1 A_{N1,1} (S_L \text{ZETA\_REAL}_{N1} - C_L \text{ZETA\_IMAG}_{N1})$$

$$\text{DNM} = C_L \text{ZETA\_REAL}_{N1+1} + S_L \text{ZETA\_IMAG}_{N1+1}$$

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

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

$$L = L + 1$$

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

(e)  $\text{RO\_N} = \text{RO\_N} \text{RO\_ZERO}$   
 $G_1 = G_1 + \text{RO\_N} F1$   
 $G_2 = G_2 + \text{RO\_N} F2$   
 $G_3 = G_3 + \text{RO\_N} F3$   
 $\text{AUXILIARY} = \text{AUXILIARY} + \text{RO\_N} F4$

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

- (4) Once these calculations have been completed ( $N = GMD$ ) and stored, the Earth-fixed acceleration vector shall be obtained and rotated to the M50 coordinate system.

$$\bar{G} = \bar{G} - \text{AUXILIARY} \bar{UR}$$

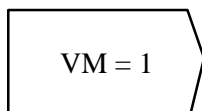
$$\bar{G} = \text{FIFTY} \bar{G}$$

This is the gravitational acceleration vector needed for equations of motion of the Shuttle. Values of GMD and of GMO may be set by the user independently. However, it is necessary that  $GMO \leq GMD$ . A maximum value of 4 for GMD shall be used, which will make the array ZONAL have 4 components, the arrays C and S have 9 components each, ZETA\_REAL and ZETA\_IMAG have 5 each, and A has a maximum dimension of 5 by 2.

Terms shown in Earth's gravity calculations as  $C_L$  and  $S_L$  are usually represented by  $C_{n,m}$ , and  $S_{n,m}$ , respectively, but were renumbered for single subscript utilization; the terms called  $ZONAL_N$  correspond to  $J_N = -C_{N,0}$ .

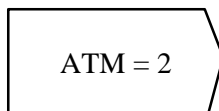
The S. Pines formulation of gravitational potential may be found, in condensed form, in the paper "Uniform Representation of the Gravitational Potential and its Derivatives," AIAA Journal, Vol. II, No. 11, November 1973. In expanded form, and with an earlier draft of the computer program herein presented, it is contained in MDC Report W0013, NASA CR 14/478, of February 9, 1976, Pines' Nonsingular Gravitational Potential: Derivation, Description, and Implementation.

3. Next a test will be performed to determine if vent and thrust accelerations are to be modeled. It should be noted that the vent and thrust acceleration model is used only during state propagation (i.e., this model is not used for orbiter or target vehicle state prediction).



- a. If VM is equal to 1, vent and thrust accelerations are to be modeled for use during orbiter or target vehicle propagations. The ACCEL\_ONORBIT\_VENT\_AND\_THRUST CODE will be executed as follows:

A check of the ATM flag will be made to determine if the modeled vent and thrust acceleration will apply to the orbiter state propagation ( $ATM = 0$ ), or target vehicle propagation ( $ATM = 2$ ).



- (1) If ATM is equal to 2, the vent and thrust acceleration is for the target vehicle. A check of the SHUTTLE\_FILTER\_FLAG will be made to determine if the unmodeled acceleration bias ( $\overline{UNMOD\_ACC\_BIAS}$ ) applies to the orbiter (SHUTTLE\_FILTER\_FLAG = ON), or the target vehicle (SHUTTLE\_FILTER\_FLAG = OFF).

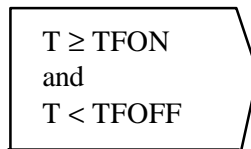


If the Shuttle filter flag is OFF, the target vehicle vent and thrust vector ( $\overline{VENT}$ ) will be set equal to the unmodeled acceleration bias; otherwise the value of  $\overline{VENT}$  will remain at its initialized value. The value of  $\overline{UNMOD\_ACC\_BIAS}$  is determined in the Onorbit/Rendezvous Navigation principal function by the Kalman filter. The bias acceleration is applicable to either the Shuttle or target vehicle as indicated by setting of the SHUTTLE\_FILTER\_FLAG as mentioned above.

- (2) If the value of ATM does not equal 2 in Step 3a, the vent and thrust modeled acceleration will be for the orbiter.

The following steps will be performed:

The value of time (T) is tested to determine if it lies within the vent and thrust model action time span as specified by the values of TFON and TFOFF,

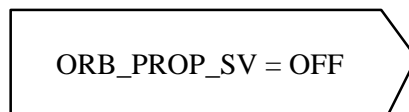


and if so, a body contact force vector ( $\overline{VFORCE}$ ) and the current orbiter mass (NAV\_CURR\_ORB\_MASS) will be used to construct the orbiter venting and acceleration vector. A multiplication by M\_BODYM50 transforms the vector from body to M50 coordinates. This acceleration vector is then stored in  $\overline{VENT}$ .

$$\overline{VENT} = M\_BODYM50 (\overline{VFORCE}/NAV\_CURR\_ORB\_MASS) \quad F3$$

F3 This equation shall be protected against division by zero (reference 3.5).

The ORB\_PROP\_SV flag is tested



and if the Shuttle primary state (not the backup state) is being propagated (ORB\_PROP\_SV = OFF), then the following steps will be performed:

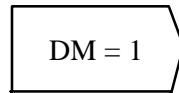
- i. The value of the SHUTTLE\_FILTER\_FLAG will be checked



and if on (orbiter is filtered state), the unmodeled acceleration bias is added to the vent and thrust acceleration vector

$$\overline{V}_{ENT} = \overline{U}NMOD\_ACC\_BIAS + \overline{V}_{ENT}$$

- ii. The value  $\overline{V}_{ENT}$ , the orbiter vent and thrust modeled acceleration vector, is stored as  $\overline{V}_{ENT\_SS}$  to be available for downlist.
4. After the ACCEL\_ONORBIT\_VENT\_AND\_THRUST logic has been satisfied, the drag model flag (DM) shall be tested



and if true (DM = 1), the vehicle drag acceleration vector shall be determined.

- a. The first step to be performed in the vehicle drag computational flow will be to exercise the SOLAR\_EPHEM (Section 4.2.4.1.1.3) subfunction by the following:

CALL: SOLAR\_EPHEM

IN LIST: T

OUTLIST: SDEC, CDEC1, COS\_SOL\_RA, SIN\_SOL\_RA

where:

CDEC1 = cosine of the solar declination

COS\_SOL\_RA = cosine of the solar right ascension

SDEC = sine of the solar declination

SIN\_SOL\_RA = sine of the solar right ascension

T = time of desired computation

- b. Next the ONORBIT\_DENSITY code will be exercised to provide the atmospheric density value associated with the vehicle position. This section of code is initiated with determination of the vehicle altitude (ALT) above the reference ellipsoid through use of the H\_ELLIPSOID function (see Section 4.2.4.1.1.1).

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

where  $\overline{R}$  is the vehicle M50 position vector.

- (1) The next series of expressions will be performed to determine GDI, one of the Babb\_Mueller atmospheric density diurnal factors.

CDEC1 = CDEC1 R\_INV

SDEC = SDEC R\_INV R<sub>3</sub>

CSFST = R<sub>1</sub> COS\_SOL\_RA COS\_LAG

CSSND = R<sub>1</sub> SIN\_SOL\_RA SIN\_LAG

SIFST = R<sub>2</sub> SIN\_SOL\_RA COS\_LAG

SSND = R<sub>2</sub> COS\_SOL\_RA SIN\_LAG



$$\text{COS\_PSI} = \text{SDEC} + \text{CDEC1} (\text{CSFST} - \text{CSSND} + \text{SIFST} + \text{SSND})$$

$$\text{GDI} = [(1.0 + \text{COS\_PSI})/2.0]^{\text{GDIE}}$$

where COS\_LAG, SIN\_LAG and GDIE are design-dependent parameters (see Section 4.7).

- (2) A check of the vehicle altitude above the reference ellipsoid (ALT) will be made to see if it is greater than ALT\_L (the Babb–Mueller density layer altitude).

$$\text{ALT} > \text{ALT\_L}$$

If the statement is true, the layering index integer K will be set to 2; otherwise K will be set to 1.

- (3) The nighttime vertical density profile factor (AFH) will be determined

$$\text{AFH} = \text{ABM}_{1,K} + \text{ABM}_{2,K} \text{ALT} + \text{ABM}_{3,K}/\text{ALT} \quad \text{F3}$$

where  $\text{ABM}_{1 \text{ TO } 3,K}$  are mission-dependent calibration coefficient (see Section 4.7). The diurnal density effect will be determined next.

$$\text{BFH} = (\text{BM}_1 + \text{BM}_2 \text{ALT} + \text{BM}_3/\text{ALT}) \text{GDI} \quad \text{F3}$$

F3 This equation shall be protected against division by zero (reference 3.5).

The  $\text{BM}_{1 \text{ TO } 3}$  are mission-dependent calibration coefficients (see Section 4.7). A seasonal–latitudinal term will be determined as follows,

$$\text{CBM1} = \text{ALT} - \text{C\_DENSEA}$$

$$\text{CBM1} = [\text{CBD1}(\text{R\_INV})^2 \text{ABS}(\text{R}_3)\text{R}_3] \text{CBM1} \text{EXP}(\text{CBD2} \text{CBM1})$$

C\_DENSEA, CBD1 and CBD2 are design-dependent parameters (see Section 4.7).

- (4) The atmospheric density will now be determined as

$$\text{RHO} = \text{RREF} \text{EXP}(\text{AFH} + \text{BFH} + \text{CBM1} \text{CBM2})$$

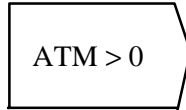
Here RREF is a design-dependent parameter and CBM2 is a seasonal–latitudinal mission-dependent parameter (see Section 4.7).

- c. Next the ACCEL\_ONORBIT\_DRAG code will be executed using the atmospheric density value of (RHO) previously determined. The code will begin with calculation of the vehicle velocity vector in Earth–relative M50 coordinates as determined by

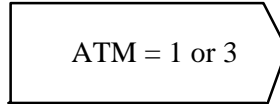
$$\bar{\mathbf{V}}_R = \bar{\mathbf{V}}_{\text{REL}}(\bar{\mathbf{V}}, \bar{\mathbf{R}})$$

where  $\bar{\mathbf{V}}_{\text{REL}}(\bar{\mathbf{V}}, \bar{\mathbf{R}})$  is the Earth relative velocity function (see Section 4.2.4.1.1.2), and  $\bar{\mathbf{V}}, \bar{\mathbf{R}}$  are the vehicle velocity and position vectors in M50 coordinates.

- (1) A test to determine if ATM is greater than 0 is performed:



If ATM is greater than 0, a second test will be performed to determine if ATM is equal to 1 or 3.



If ATM is equal to 1 or 3, the drag computation will be for orbiter state prediction and will use the following configuration parameters:

VEH\_MASS = PRED\_ORB\_MASS  
CD = PRED\_ORB\_CD  
AREA = PRED\_ORB\_AREA

The values of PRED\_ORB\_MASS, PRED\_ORB\_CD and PRED\_ORB\_AREA to be used will be determined by that principal function which initiates a call to the onorbit predictor.

If in the test of ATM, ATM does not equal 1 or 3, the ensuing drag computation will be used for a target vehicle state propagation or prediction mode. The following configuration parameters will be set:

VEH\_MASS = TARGET\_MASS  
CD = TARGET\_CD TARGET\_KFACTOR  
AREA = TARGET\_AREA

Here TARGET\_MASS, TARGET\_CD and TARGET\_AREA are K-Loads (See Section 4.7) and TARGET\_KFACTOR is an uplinkable scale factor, whose nominal value is 1.0. The TARGET\_KFACTOR parameter and uplink are provided to allow adjustments to the target vehicle drag coefficient to handle uncertainties in target drag characteristics, multiple targets, atmospheric density variations, and other sources of drag variation during target state propagation and prediction.

- (2) If in the test of ATM, ATM is not greater than 0, the computation of drag will be used for orbiter state propagation.

In the above event, VEH\_MASS and AREA will be designated by:

VEH\_MASS = NAV\_CURR\_ORB\_MASS  
AREA = REF\_ORB\_AREA

where NAV\_CURR\_ORB\_MASS was set by NAV\_ONORBIT\_RENDEZVOUS and REF\_ORB\_AREA is a design-dependent parameter (see Section 4.7).

The coefficient of drag, CD, shall be determined as follows for orbiter state propagation.

First,  $\bar{V}_{REL\_BODY}$ , the vehicle velocity vector relative to the atmosphere, but expressed in body coordinates, is determined as:

$$\bar{V}_{REL\_BODY} = (M\_BODYM50)^T \bar{V}_R$$

where  $M\_BODYM50$  is the transformation matrix of body to M50 coordinates and  $\bar{V}_R$  has been determined in c.

Next the square of the sine of the vehicle angle of attack (SA) will be determined as:

$$SA = (V\_REL\_BODY_3)^2 / (V\_REL\_BODY_1^2 + V\_REL\_BODY_3^2) \quad F3$$

The sine of the vehicle sideslip angle, SB, will be determined by the following:

$$SB = |V\_REL\_BODY_2| / |\bar{V}_R| \quad F3$$

F3 This equation shall be protected against division by zero (reference 3.5)

The sine of twice the sideslip angle S2B will be determined by:

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

F4 This equation shall be protected against square roots of a negative number (reference 3.5).

The orbiter coefficient of drag CD may now be determined as:

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

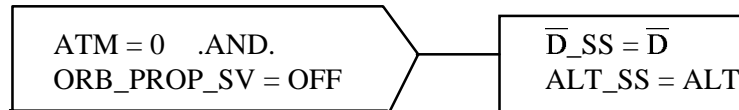
The vehicle configuration constants CDF, CDN, EXP\_SHAPE\_FACTOR, CDS, and CDA are design-dependent parameters (see Section 4.7). KFACTOR is the orbiter drag model scale factor and is mission dependent (see Section 4.7). The parameter KFACTOR is included as an uplink parameter (see Section 4.9) to allow adjustments to the orbiter drag coefficient due to configuration parameter uncertainties, atmospheric density model deviations, or other causes during orbiter state propagation.

- (3) After vehicle parameters VEH\_MASS, AREA and CD have been determined by one of the logic paths of 4c(1) or of 4c(2) as dictated by the value of the ATM flag, a vehicle drag acceleration vector  $\bar{D}$  in M50 coordinates will be determined by:

$$\bar{D} = -0.5 CD RHO AREA |\bar{V}_R| \bar{V}_R / VEH\_MASS \quad F3$$

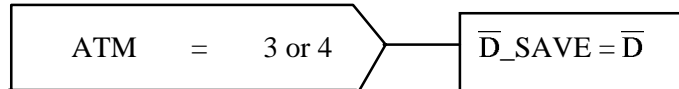
F3 This equation shall be protected against division by zero (reference 3.5)

- (4) If the drag acceleration  $\bar{D}$  is being computed for the orbiter filtered state (not the backup state) during state propagation (ATM = 0 and ORB\_PROP\_SV = OFF), it shall be stored in  $\bar{D}_{SS}$  for downlist. ALT, the vehicle altitude above the Earth's reference ellipsoid, will be also saved in ALT\_SS for downlist.



- (5) If  $ATM \neq 0$  or  $ORB\_PROP\_SV = ON$ , then perform the following logic:

If the drag acceleration  $\bar{D}$  is being computed for either the orbiter or the target for a prediction task initiated by the orbit processing processor ( $ATM = 3$  or  $4$ ), then save the value of the drag for orbit targeting:



5. Finally, the acceleration values  $\bar{G}$ ,  $\bar{D}$ , and  $\bar{VENT}$  determined by the nonspherical Earth gravitational, vehicle drag, and vent and thrust models, respectively, will be combined with the value of point mass Earth gravitational acceleration ( $\bar{G\_CENTRAL}$ ) to result in the final  $\bar{ACCEL\_ONORBIT}$  function M50 output vector.

$$\bar{ACCEL\_ONORBIT} = \bar{G\_CENTRAL} + \bar{G} + \bar{D} + \bar{VENT}$$

B. Interface Requirements. The input and output data are shown in Table 4.2.4.1.1. It should be noted that  $\bar{ACCEL\_ONORBIT}$  is treated as a function subprogram; that is, the computed value of the acceleration vector will be returned and occupy the position of the function name.

C. Processing Requirements. This function subprogram shall be performed each time the function name is encountered with suitable expressions for arguments such as:

$$\bar{ACCEL\_ONORBIT} (GMD, GMO, DM, VM, ATM, \bar{R}, \bar{V}, T)$$

The  $\bar{ACCEL\_ONORBIT}$  function is used by the following:

SUPER\_G  
ONORBIT\_SV\_INTERP  
REND\_COV\_INIT  
PINES\_METHOD  
AVERAGE\_G\_INTEGRATOR

D. Constraints. The currently functioning propagator and a predictor may need different acceleration models at the same time. It is therefore necessary that execution of the acceleration calculations be protected from interruption by other users.

E. Supplementary Information. A suggested implementation of the  $\bar{ACCEL\_ONORBIT}$  in the form of detailed flow charts may be found in Section 5.2 under the names:

$\bar{ACCEL\_ONORBIT}$  FUNCTION  
ACCEL\_EARTH\_GRAV CODE  
ACCEL\_ONORBIT\_VENT\_AND\_THRUST\_CODE  
SOLAR\_EPHEM  
ONORBIT\_DENSITY CODE  
H\_ELLIPSOID FUNCTION

ACCEL\_ONORBIT\_DRAG CODE  
 $\bar{V}$ \_REL FUNCTION

and the following from Section 5.3:

EARTH\_FIXED\_TO\_M50\_COORD FUNCTION

Table 4.2.4.1.1. $\bar{A}$ CCCEL_ONORBIT Input/Output			
Inlist/outlist		Input Source	Output Destination
Internal Name	External Name		
ATM	ATM	SUPER_G	
DM	DM	SUPER_G	
GMD	GMD	SUPER_G	
GMO	GMO	SUPER_G	
VM	VM	SUPER_G	
$\bar{R}$	$\bar{R}$ _IN	SUPER_G	
T	T_IN	SUPER_G	
$\bar{V}$	$\bar{V}$ _IN	SUPER_G	
ATM	ATM	SUPER_G	
DM	DM	SUPER_G	
GMD	GMD	SUPER_G	
GMO	GMO	SUPER_G	
VM	VM	SUPER_G	
$\bar{R}$	$\bar{R}$ _FIN	SUPER_G	
T	T_FIN	SUPER_G	
$\bar{V}$	$\bar{V}$ _IN	SUPER_G	
ATM	IATM	ONORBIT_SV_INTERP	
DM	IDM	ONORBIT_SV_INTERP	
GMD	IGD	ONORBIT_SV_INTERP	
GMO	IGO	ONORBIT_SV_INTERP	
VM	IVM	ONORBIT_SV_INTERP	
$\bar{R}$	$\bar{R}$ _RESID	ONORBIT_SV_INTERP	
T	T_RESID	ONORBIT_SV_INTERP	
$\bar{V}$	$\bar{V}$ _RESID	ONORBIT_SV_INTERP	
ATM	ATFL_OV	REND_COV_INIT	
DM	IDRAG	REND_COV_INIT	
GMD	IGD	REND_COV_INIT	
GMO	IGO	REND_COV_INIT	
VM	IVENT	REND_COV_INIT	
$\bar{R}$	$\bar{R}$ _FILT	REND_COV_INIT	
T	T_LAST_FILT	REND_COV_INIT	

Table 4.2.4.1.1. $\bar{A}$ CCEL_ONORBIT Input/Output			
Inlist/outlist		Input Source	Output Destination
Internal Name	External Name		
$\bar{V}$	$\bar{V}$ _FILT	REND_COV_INIT	
ATM	ATFL_TV	REND_COV_INIT	
DM	DFL	REND_COV_INIT	
GMD	GM_DEG	REND_COV_INIT	
GMO	GM_ORD	REND_COV_INIT	
$\bar{R}$	$\bar{R}$ _TV	REND_COV_INIT	
T	T_TV	REND_COV_INIT	
VM	VFL_TV	REND_COV_INIT	
$\bar{V}$	$\bar{V}$ _TV	REND_COV_INIT	
ATM	ATM	PINES_METHOD	
DM	DM	PINES_METHOD	
GMD	GMD	PINES_METHOD	
GMO	GMO	PINES_METHOD	
T	T_ACCEL	PINES_METHOD	
VM	VM	PINES_METHOD	
$\bar{R}$	X <sub>1to3</sub>	PINES_METHOD	
$\bar{V}$	X <sub>4to6</sub>	PINES_METHOD	
ATM	ATFL_OV	AVERAGE_G_INTEGRATOR	
DM	DFL_AVG	AVERAGE_G_INTEGRATOR	
GMD	GM_DEG_LOW	AVERAGE_G_INTEGRATOR	
GMO	GM_ORD_LOW	AVERAGE_G_INTEGRATOR	
$\bar{R}$	$\bar{R}$ _AV	AVERAGE_G_INTEGRATOR	
T	T_STATE	AVERAGE_G_INTEGRATOR	
$\bar{V}$	$\bar{V}$ _AV	AVERAGE_G_INTEGRATOR	
VM	VFLTV_PRED	AVERAGE_G_INTEGRATOR	
ATM	ATFL_OV	AVERAGE_G_INTEGRATOR	
DM	DFL_AVG	AVERAGE_G_INTEGRATOR	
GMD	GM_DEG_LOW	AVERAGE_G_INTEGRATOR	
GMO	GM_ORD_LOW	AVERAGE_G_INTEGRATOR	
$\bar{R}$	$\bar{R}$ _AV	AVERAGE_G_INTEGRATOR	
T	T_IMU	AVERAGE_G_INTEGRATOR	
$\bar{V}$	$\bar{V}$ _AV	AVERAGE_G_INTEGRATOR	
VM	VFLTV_PRED	AVERAGE_G_INTEGRATOR	

Table 4.2.4.1.1.(1) ACCEL\_ONORBIT Input/Output

Variable Name	Input Source	Output Destination
ABM	**	
ALT_L	**	
BM	**	
C	**	
CBD1	**	
CBD2	**	
CMD2	**	
CDA	**	
CDEC1	SOLAR_EPHEM	
C_DENSEA	**	
CDF	**	
CDN	**	
CDS	**	
COS_LAG	**	
COS_SOL_RA	SOLAR_EPHEM	
†	EARTH_FIXED_TO_M50_COORD	
EARTH_MU	**	
EARTH_RADIUS_GRAV	**	
EXP_SHAPE_FACTOR	**	
GDIE	**	
KFACTOR	**, *	
M_BODYM50	NAV_ONORBIT_RENDEZVOUS	
NAV_CURR_ORB_MASS	ONORBIT_REND_NAV_ SEQUENCER, NAV_ONORBIT_RENDEZVOUS	
ORB_PROP_SV	ONORBIT_REND_R_V_STATE_ PROP, **	
PRED_ORB_AREA	***, ONORBIT_REND_AUTO_ INFLIGHT_UPDATE	
PRED_ORB_CD	***, ONORBIT_REND_AUTO_ INFLIGHT_UPDATE	
PRED_ORB_MASS	***, ONORBIT_REND_AUTO_ INFLIGHT_UPDATE	
REF_ORB_AREA	**	
RREF	**	
S	**	
SDEC	SOLAR_EPHEM	
SHUTTLE_FILTER_FLAG	*	
SIN_LAG	**	
SIN_SOL_RA	SOLAR_EPHEM	

Table 4.2.4.1.1.(1) $\bar{A}$ CCEL_ONORBIT Input/Output		
Variable Name	Input Source	Output Destination
TARGET_AREA	**	
TARGET_CD	**	
TARGET_KFACTOR	**, *	
TARGET_MASS	**	
TFOFF	**, *	
TFON	**, *	
$\bar{U}$ NMOD_ACC_BIAS	OPS_2_OR_8_INITIALIZE, REND_NAV_EXIT, U_A_BIAS_AND_COVINIT, REND_BIAS_AND_COV_PROP, REND_NAV_FILTER, *	
$\bar{V}$ FORCE	**, *	
ZONAL	**	AVERAGE_G_INTEGRATOR, ONORBIT_SV_INTERP, PINES_METHOD, REND_COV_INIT, SUPER_G
ALT_SS		*
$\bar{D}$ _SAVE		***
$\bar{D}$ _SS		*
$\bar{G}$ _CENTRAL		PINES_METHOD, AVERAGE_G_INTEGRATOR
$\bar{V}$ ENT_SS		*
$\bar{R}$		H_ELLIPSOID, V_REL
$\bar{V}$		$\bar{V}$ _REL
T		EARTH_FIXED_TO_M50_COORD, SOLAR_EPHEM
†	$\bar{V}$ _REL	
†	H_ELLIPSOID	
† Only the value of the function is passed. * Onorbit/Rendezvous principal function, see Tables 4.2.11–1 and 4.2.11–2. ** Initialization parameters, see section 4.7. *** Onorbit Precision State Prediction principal function, see Tables 4.3.3–1 and 4.3.3–2.		



#### 4.2.4.1.1.1 Altitude Above the Reference Ellipsoid (H\_ELLIPSOID)

Altitude above the Earth's reference ellipsoid in M50 coordinates will be determined using the H\_ELLIPSOID function.

A. Detailed Requirements. Altitude above the Earth's reference ellipsoid will be calculated each time the statement H\_ELLIPSOID ( $\bar{R}$ ) is encountered. Here  $\bar{R}$  is the vehicle M50 position vector. The value of altitude above the Earth's reference ellipsoid will be determined using the following:

$$H\_ELLIPSOID(\bar{R}) =$$

$$|\bar{R}| - \frac{(1\_ELLIPT) \text{ EARTH\_RADIUS\_EQUATOR}}{\sqrt{1 + [(1 - ELLIPT)^2 - 1] [1 - [\bar{UNIT}(\bar{R}) \bullet \bar{EARTH\_POLE}]^2]}} \quad \begin{array}{l} \text{F3} \\ \text{F4} \end{array}$$

- F3 This equation shall be protected against division by zero (reference 3.5).  
 F4 This equation shall be protected against square roots of a negative number (reference 3.5).

where ELLIPT and EARTH\_RADIUS\_EQUATOR are constants defined in Section 4.7 (initialization parameters).  $\bar{UNIT}(\bar{R})$  is the unit vector constructed from the vector  $\bar{R}$ .  $\bar{EARTH\_POLE}$  is a functional parameter defined in Table 4.1.3-1.

B. Interface Requirements. The input and output data are shown in Table 4.2.4.1.1.1. It should be noted that only the value of H\_ELLIPSOID is passed.

C. Processing Requirements. The H\_ELLIPSOID function will be processed each time the function name is encountered with a suitable expression for the argument such as: H\_ELLIPSOID ( $\bar{R}$ ). The H\_ELLIPSOID function is used by the following:

$$\bar{ACCEL\_ONORBIT}$$

D. Constraints. None

E. Supplementary Information. A suggested implementation of the H\_ELLIPSOID function in the form of a detailed flow chart may be found in Section 5.2 under the name:

H\_ELLIPSOID FUNCTION

Table 4.2.4.1.1.1. H_ELLIPSOID Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
$\bar{R}$	$\bar{R}$	$\bar{ACCEL\_ONORBIT}$ (ONORBIT_DENSITY CODE)	
Variable Name		Input Source	Output Destination
$\bar{EARTH\_POLE}$		*	$\bar{ACCEL\_ONORBIT}$
EARTH_RADIUS_EQUATOR		**	
ELLIPT		**	
†			
† The value of H_ELLIPSOID only is passed to output destination. * See On-orbit/Rendezvous Navigation Sequencer principal function input parameter table. ** Initialization parameters, see Section 4.7.			

#### 4.2.4.1.1.2 Earth-Relative Velocity Computation ( $\bar{V}_{REL}$ )

The velocity vector relative to the Earth but expressed in M50 coordinates will be determined using the  $\bar{V}_{REL}$  function.

A. Detailed Requirements. The function is activated whenever the statement  $\bar{V}_{REL}(\bar{V},\bar{R})$  is encountered. The function arguments are the M50 velocity vector ( $\bar{V}$ ) and M50 position vector ( $\bar{R}$ ). The vector  $\bar{V}_{REL}$  is determined by the following:

$$\bar{V}_{REL}(\bar{V},\bar{R}) = \bar{V} = EARTH\_RATE (\bar{EARTH\_POLE} \times \bar{R})$$

where EARTH\_RATE is a constant defined in Section 4.7 (initialization parameters).  $\bar{EARTH\_POLE}$  is a functional parameter defined in Table 4.1.3-1.

B. Interface Requirements. The input and output data are shown in Table 4.2.4.1.1.2. It should be noted that only the value of  $\bar{V}_{REL}$  is passed.

C. Processing Requirements. The  $\bar{V}_{REL}$  function will be processed each time the function name is encountered with a suitable expression for the arguments such as  $\bar{V}_{REL}(\bar{V},\bar{R})$ . The  $\bar{V}_{REL}$  function is used by ACCEL\_ONORBIT.

D. Constraints. None

E. Supplementary Information. A suggested implementation of the  $\bar{V}_{REL}$  function in the form of a detailed flowchart may be found in Section 5.2 under the name:

#### $\bar{V}_{REL}$ FUNCTION

Table 4.2.4.1.1.2. $\bar{V}_{REL}$ Input/Output			
Inlist/outlist		Input Source	Output Destination
Internal Name	External Name		
$\bar{R}$	$\bar{R}$	$\bar{ACCEL\_ONORBIT}$ (ACCEL_ONORBIT_DRAG CODE)	
$\bar{V}$	$\bar{V}$	$\bar{ACCEL\_ONORBIT}$ (ACCEL_ONORBIT_DRAG CODE)	
Variable Name		Input Source	Output Destination
$\bar{EARTH\_POLE}$		***	
EARTH_RATE		**	
*			$\bar{ACCEL\_ONORBIT}$ (ACCEL_ONORBIT_DRAG CODE)
<p>* <math>\bar{V}_{REL}</math> value only is passed to output destinations.</p> <p>** Initialization parameters, see Section 4.7. <math>\bar{V}_{REL}</math> value only is passed to output destinations.</p> <p>*** See On-orbit/Rendezvous Navigation Sequencer principal function input parameter table.</p>			

#### 4.2.4.1.1.3 Solar Ephemeris Model (SOLAR\_EPHEM)

Output from the solar ephemeris model will provide sine and cosine functions of the solar right ascension and declination. These outputs are to be used in the acceleration models ( $\overline{\text{ACCEL\_ONORBIT}}$ ) for determination of atmospheric density and in position and velocity state propagation ( $\text{ONORBIT\_REND\_R\_V\_STATE\_PROP}$ ) for computation of a unit vector from earth center to the center of the sun in M50 coordinates to be available for the universal pointing processing principal function.

A. Detailed Requirements. The solar ephemeris subfunction shall be invoked whenever the following statement is encountered:

```
CALL:      SOLAR_EPHEM
IN LIST:   T
OUT LIST:  SDEC,CDEC1,COS_SOL_RA,SIN_SOL_RA
```

where:

CDEC1 = cosine of the solar declination  
COS\_SOL\_RA = cosine of the solar right ascension  
SDEC = sine of the solar declination  
SIN\_SOL\_RA = sine of the solar right ascension  
T = time of desired computation

The SOLAR\_EPHEM subfunction will initiate the following calculations in the indicated order:

1. The longitude of the sun in M50 coordinates, LOS, will be determined as

$$\text{LOS} = \text{LOS\_ZERO} + T \text{LOS\_R} - \text{LOC} \text{SIN}(T \text{OMEG\_C} + \text{PHASE\_C}). \quad \text{F9}$$

Here, LOS\_R and OMEG\_C are K-Loads, and LOS\_ZERO, LOC, and PHASE\_C are mission-dependent parameters (see Section 4.7).

2. The sine and cosine of the solar declination SDEC and CDEC1 are calculated by

$$\begin{aligned} \text{SDEC} &= \text{LOSK3} \text{SIN}(\text{LOS}) & \text{F9} \\ \text{CDEC1} &= \text{SQRT}(1. - \text{SDEC}^2) & \text{F4} \end{aligned}$$

3. The cosine and sine of the solar right ascension are determined by

$$\begin{aligned} \text{COS\_SOL\_RA} &= \text{COS}(\text{LOS})/\text{CDEC1} & \text{F9,F3} \\ \text{SIN\_SOL\_RA} &= \text{LOSK1} \text{SIN}(\text{LOS})/\text{CDEC1} & \text{F9,F3} \end{aligned}$$

LOSK1 and LOSK3 are mission-dependent parameters (see Section 4.7).

F3 This equation shall be protected against division by zero (reference 3.5).

F4 This equation shall be protected against square roots of a negative number (reference 3.5).

F9 This equation shall be protected against return value of sine or cosine with a magnitude greater than unity (reference 3.5).

B. Interface Requirements. The input and output required of the SOLAR\_EPHEM subfunction are listed in Table 4.2.4.1.1.3.

C. Processing Requirements. The SOLAR\_EPHEM subfunction shall be called by the acceleration subfunction program ACCEL\_ONORBIT and the ONORBIT\_REND\_R\_V\_STATE\_PROP.

D. Constraints. None

E. Supplementary Information. A suggested implementation of the SOLAR\_EPHEM function in the form of a detailed flowchart may be found in Section 5.2. under the name:

SOLAR\_EPHEM

Table 4.2.4.1.1.3. SOLAR_EPHEM Input/Output			
Inlist/outlist		Input Source	Output Destination
Internal Name	External Name		
T	T	ACCEL_ONORBIT	
T	T_CURRENT_FILT	ONORBIT_REND_R_V_STATE_PROP	
CDEC1	CDEC1		ACCEL_ONORBIT
COS_SOL_RA	COS_SOL_RA		ACCEL_ONORBIT
SDEC	SDEC		ACCEL_ONORBIT
SIN_SOL_RA	SIN_SOL_RA		ACCEL_ONORBIT
CDEC1	CDEC1		ONORBIT_REND_R_V_STATE_PROP
COS_SOL_RA	COS_SOL_RA		ONORBIT_REND_R_V_STATE_PROP
SDEC	SDEC		ONORBIT_REND_R_V_STATE_PROP
SIN_SOL_RA	SIN_SOL_RA		ONORBIT_REND_R_V_STATE_PROP
Variable Name		Input Source	Output Destination
LOC		**	
LOSK1		**	
LOSK3		**	
LOS_R		**	
LOS_ZERO		**	
OMEG_C		**	
PHASE_C		**	
** Initialization parameters, see Section 4.7.			

#### 4.2.5 Unmodeled Acceleration State and Covariance Matrix Propagation (REND\_BIAS\_AND\_COV\_PROP)

The Unmodeled Acceleration State and Covariance Matrix Propagation subfunction will be executed only during the rendezvous navigation phase and will be scheduled by the Onorbit/Rendezvous Control subfunction, ONORBIT\_RENDEZVOUS\_NAV, at an N\_CYCLE multiple of the state propagation rate. The rate at which this subfunction is executed will be called the filter subcycle rate. The following tasks will be performed during each execution.

- If IMU-sensed accelerations were used at any time during the previous covariance propagation interval but are not used at all during the current propagation interval, or if IMU-sensed accelerations were not used at all during the previous covariance propagation interval but are used at some time during the current propagation interval, then the unmodeled acceleration bias vector as well as the unmodeled acceleration portions of the covariance matrix are reinitialized.
- The unmodeled acceleration bias vector will be propagated to current time as an exponentially correlated random variable (ECRV).
- A 13-by-13 covariance matrix, E, shall be propagated to current time by using a state transition matrix.
- Additive process noise will be incorporated into the covariance matrix to account for unmodeled state and dynamic errors.
- Finally, a flag (NAV\_MEAS) is set to ON, to allow measurement incorporation, only if the magnitude of the IMU-sensed acceleration vector is below a design-dependent threshold.

The 13-by-13 state transition matrix  $\phi$  is mathematically defined as the partial of the current state with respect to the previous state. For propagation of the filter vehicle covariance matrix,  $\phi$  will be formulated as shown below.

$\phi =$	PHI <sub>6x9</sub>		0 <sub>3x4</sub>
			0 <sub>3x4</sub>
	0 <sub>3x6</sub>	PHI_UNMOD_ACC	0 <sub>3x4</sub>
	0 <sub>4x6</sub>	0 <sub>4x3</sub>	PHI_BIAS

State Transition Matrix Composition

The submatrices  $\phi_{1 \text{ to } 9, 10 \text{ to } 13}$ ,  $\phi_{7 \text{ to } 9, 1 \text{ to } 6}$ , and  $\phi_{10 \text{ to } 13, 1 \text{ to } 9}$  are null matrices.

The state noise matrix, NOISE, shall be formulated as shown below. The matrix is to be used to account for unmodeled state errors, unmodeled acceleration errors, and sensor bias errors.

NOISE =	$S_{6 \times 6}$	$0_{6 \times 3}$	$0_{6 \times 4}$
	$0_{3 \times 6}$	S_UNMOD_ACC	$0_{3 \times 4}$
	$0_{4 \times 6}$	$0_{4 \times 3}$	$\bar{S}_{BIAS}$

### State Noise Matrix Composition

The submatrices NOISE<sub>1 to 6, 7 to 13</sub>, NOISE<sub>7 to 9, 10 to 13</sub>, NOISE<sub>7 to 9, 1 to 6</sub>, and NOISE<sub>10 to 13, 1 to 9</sub> are null matrices.

The above formulations for both the state transition and the state noise transition matrices were made for clarity and code efficiency.

The unmodeled acceleration state and covariance matrix propagation subfunction will also propagate the unmodeled acceleration bias states as ECRV's.

A. Detailed Requirements. The following steps shall be performed:

1. If there has been a change in the value of the COV\_PWRD\_FLT flag (COV\_PWRD\_FLT = ON indicates that the sensed delta velocity has exceeded a threshold value since the previous covariance propagation cycle) since the last filter cycle, then reinitialize the unmodeled acceleration states.

If COV\_PWRD\_FLT  $\neq$  COV\_PWRD\_FLT\_LAST, then

EXECUTE: UNMOD\_ACC\_REINIT CODE

- (1) Zero the unmodeled acceleration state portions of the covariance matrix
 
$$E_{7 \text{ to } 9, 1 \text{ to } 13} = 0.0$$

$$E_{1 \text{ to } 13, 7 \text{ to } 9} = 0.0$$
- (2) Set up the time constants and variances as a function of the COV\_PWRD\_FLT flag.

– If the sensed delta velocity is above the threshold (COV\_PWRD\_FLT = ON), then

$$\begin{aligned} \tau_{UNMOD\_ACC\_COV} &= \tau_{U\_A\_PWRD\_FLT} \\ \bar{VAR}_{UNMOD\_ACC} &= \bar{VAR}_{U\_A\_PWRD\_FLT} \\ \bar{COV}_{ACCEL\_UVW\_INIT} &= \bar{COV}_{U\_A\_PWRD\_FLT} \end{aligned}$$

– If the sensed delta velocity is less than or equal to the threshold (COV\_PWRD\_FLT = OFF), then

$$\begin{aligned} \tau_{UNMOD\_ACC\_COV} &= \tau_{U\_A\_COAST} \\ \bar{VAR}_{UNMOD\_ACC} &= \bar{VAR}_{U\_A\_COAST} \\ \bar{COV}_{ACCEL\_UVW\_INIT} &= \bar{COV}_{U\_A\_COAST} \end{aligned}$$

- (3) Reinitialize the unmodeled acceleration biases and the unmodeled acceleration slots of the covariance matrix.

– If the Shuttle is the filter vehicle (SHUTTLE\_FILTER\_FLAG = ON), then

CALL: U\_A\_BIAS\_AND\_COVINIT  
IN LIST:  $\bar{R}_{FILT}$ ,  $\bar{V}_{FILT}$

(Refer to Section 4.2.5.1 for detailed requirements.)

- If the target is the filter vehicle (SHUTTLE\_FILTER\_FLAG = OFF), then

CALL: U\_A\_BIAS\_AND\_COVINIT  
IN LIST:  $\bar{R}_{TV}$ ,  $\bar{V}_{TV}$

(Refer to Section 4.2.5.1 for detailed requirements.)

- (4) Save the last value of COV\_PWRD\_FLT.  
COV\_PWRD\_FLT\_LAST = COV\_PWRD\_FLT

- 2. Compute the change in time since the last covariance propagation subcycle

$$DT\_COV = T\_CURRENT\_FILT - T\_COV\_LAST$$

where T\_COV\_LAST is the time of the last covariance matrix propagation subcycle. Also  $\bar{TOT\_ACC}$ , the total acceleration vector for the Shuttle, shall be calculated for use in the state vector interpolation routine

$$\bar{TOT\_ACC} = \bar{G\_NEW} + \bar{DV\_COV}/DT\_COV \quad F3$$

F3 This equation shall be protected against division by zero (reference 3.5).

where  $\bar{DV\_COV}$  is the total accumulated sensed delta velocity since the time of the last covariance matrix propagation subcycle and  $\bar{G\_NEW}$  is the Shuttle acceleration vector.

- 3. The SHUTTLE\_FILTER\_FLAG is tested to determine which vehicle is used to calculate the 6-by-6 submatrix,  $\bar{PHI}_{1\ to\ 6,\ 1\ to\ 6}$  ( $\phi_{1\ to\ 6,\ 1\ to\ 6}$ ), composed of the filter vehicle position and velocity portion of the total state transition matrix. This submatrix is calculated by calling the mean conic partials subfunction (described in Section 4.2.5.2).

- a. If the Shuttle is the filter vehicle

(SHUTTLE\_FILTER\_FLAG = ON)

- (1) CALL: MEAN\_CONIC\_PARTIAL\_TRANSITION\_MATRIX\_6x6

IN LIST:  $\bar{R}_{LAST}$ ,  $\bar{V}_{LAST}$ ,  $\bar{TOT\_ACC\_LAST}$ ,  $\bar{R}_{FILT}$ ,  $\bar{V}_{FILT}$ ,  
 $\bar{TOT\_ACC}$ , DT\_COV

OUT LIST:  $\bar{PHI}_{1\ to\ 6,\ 1\ to\ 6}$

- (2) Compute a UVW to mean of 1950 transformation matrix for the Shuttle for use in the state noise formulation.

$$MAT = UVW\_TO\_M50(\bar{R}_{FILT}, \bar{V}_{FILT})$$

(Refer to Section 4.10.10 for a detailed description.)



The current inertial orbiter vehicle acceleration shall be saved for the next filter subcycle

$$\overline{\text{TOT\_ACC\_LAST}} = \overline{\text{TOT\_ACC}}$$

- b. If the target is the filter vehicle

(SHUTTLE\_FILTER\_FLAG = OFF)

- (1) CALL: MEAN\_CONIC\_PARTIAL\_TRANSITION\_MATRIX\_6x6

IN LIST:  $\overline{\text{R\_TV\_LAST}}, \overline{\text{V\_TV\_LAST}}, \overline{\text{G\_TV\_LAST}},$   
 $\overline{\text{R\_TV}}, \overline{\text{V\_TV}}, \overline{\text{G\_TV}}, \text{DT\_COV}$

OUT LIST:  $\text{PHI}_{1 \text{ to } 6, 1 \text{ to } 6}$

- (2) Compute a UVW to mean of 1950 transformation matrix for the target vehicle for use in the state noise formulation.

$$\text{MAT} = \text{UVW\_TO\_M50}(\overline{\text{R\_TV}}, \overline{\text{V\_TV}})$$

(Refer to Section 4.10.10 for a detailed description.)

The current inertial target vehicle acceleration vector shall be saved for the next filter subcycle.

$$\overline{\text{G\_TV\_LAST}} = \overline{\text{G\_TV}}$$

4. Calculate a scalar, PHI\_UNMOD\_ACC, which will be stored into the diagonal elements of the unmodeled acceleration bias portion of the state transition matrix ( $\phi_{7 \text{ to } 9, 7 \text{ to } 9}$ )

$$\text{PHI\_UNMOD\_ACC} = \exp(-\text{DT\_COV}/\text{TAU\_UNMOD\_ACC\_COV}) \quad \text{F2}$$

F2 This equation shall be protected against floating point underflow (reference 3.5).

A value used to compute the remainder of the PHI matrix is also calculated.

$$\text{DIAG} = \text{TAU\_UNMOD\_ACC\_COV} (1. - \text{PHI\_UNMOD\_ACC})$$

where DIAG is in mean of 1950 coordinates.

5. The unmodeled acceleration bias states shall be propagated as ECRV's as follows:

$$\frac{\overline{\text{UNMOD\_ACC\_BIAS}}}{\overline{\text{UNMOD\_ACC\_BIAS}}} = \exp(-\text{DT\_COV}/\text{TAU\_UNMOD\_ACC\_STATE}) \quad \text{F2}$$

F2 This equation shall be protected against floating point underflow (reference 3.5).

6. Calculate a 3-by-3 diagonal matrix S\_UNMOD\_ACC ( $\text{NOISE}_{7 \text{ to } 9, 7 \text{ to } 9}$ ) composed of the unmodeled acceleration errors where

$$S\_UNMOD\_ACC_{I,I} = VAR\_UNMOD\_ACC_I(1. - PHI\_UNMOD\_ACC^2) \text{ (for } I = 1 \text{ to } 3)$$

$$S\_UNMOD\_ACC = MAT \ S\_UNMOD\_ACC \ MAT^T$$

and MAT is the UVW to mean of 1950 coordinate transformation matrix for the filter vehicle.

7. Calculate a 6-by-3 submatrix,  $PHI_{1 \text{ to } 6, 7 \text{ to } 9}$  ( $\phi_{1 \text{ to } 6, 7 \text{ to } 9}$ ), composed of two 3-by-3 diagonal submatrices that correlate the position and velocity with the estimated unmodeled accelerations where

$$PHI_{I+3,I+6} = DIAG$$

$$PHI_{I,I+6} = TAU\_UNMOD\_ACC\_COV \ (DT\_COV-DIAG)$$

(for  $I = 1$  to  $3$ )

8. Calculate a vector, PHI\_BIAS, which will be stored into the diagonal elements of the sensor bias portion of the total state transition matrix ( $\phi_{10 \text{ to } 13, 10 \text{ to } 13}$ ).

$$PHI\_BIAS_I = \exp(-DT\_COV/TAU\_SENS_I) \tag{F2}$$

(for  $I = 1$  to  $4$ )

F2 This equation shall be protected against floating point underflow (reference 3.5).

9. Calculate a vector, S\_BIAS, which will be stored into the diagonal elements of the sensor bias portion of the total state noise matrix ( $NOISE_{10 \text{ to } 13, 10 \text{ to } 13}$ )

$$S\_BIAS_I = VAR\_SENS_I \ (1. - PHI\_BIAS_I^2) \text{ (for } I = 1 \text{ to } 4)$$

10. Propagate the covariance matrix

EXECUTE: PHI\_E\_PHI\_TRANSPOSE CODE

$$a. \ E \ \phi^T \quad \left\{ \begin{array}{l} TEMP_{1 \text{ to } 13, 1 \text{ to } 6} = E_{1 \text{ to } 13, 1 \text{ to } 9} \ PHI^T \\ TEMP_{J, I+6} = E_{J, I+6} \ PHI\_UNMOD\_ACC \text{ (for } I=1 \text{ to } 3, J=1 \text{ to } 13) \\ TEMP_{J, K+9} = E_{J, K+9} \ PHI\_BIAS_K \text{ (for } J=1 \text{ to } 13, K=1 \text{ to } 4) \end{array} \right.$$

$$b. \ \phi \ E \ \phi^T \quad \left\{ \begin{array}{l} E_{1 \text{ to } 6, 1 \text{ to } 13} = PHI \ TEMP_{1 \text{ to } 9, 1 \text{ to } 13} \\ E_{I+6, J} = PHI\_UNMOD\_ACC \ TEMP_{I+6, J} \text{ (for } I=1 \text{ to } 3, J=1 \text{ to } 13) \\ E_{K+9, J} = PHI\_BIAS_K \ TEMP_{K+9, J} \text{ (for } J=1 \text{ to } 13, K=1 \text{ to } 4) \end{array} \right.$$

$$c. \ \phi \ E \ \phi^T \quad \left\{ \begin{array}{l} E_{7 \text{ to } 9, 7 \text{ to } 9} = E_{7 \text{ to } 9, 7 \text{ to } 9} + S\_UNMOD\_ACC \\ E_{K+9, K+9} = E_{K+9, K+9} + S\_BIAS_K \text{ (for } K=1 \text{ to } 4) \end{array} \right. \\ + \ NOISE$$

- d. If IMU-sensed acceleration data have been used (COV\_PWRD\_FLT=ON) since the last covariance matrix propagation subcycle, then

- (1) Reset the COV\_PWRD\_FLT flag

COV\_PWRD\_FLT = OFF and

EXECUTE: PWRD\_FLT\_NOISE CODE

- Calculate a 6-by-6 matrix S (NOISE<sub>1 to 6,1 to 6</sub>) composed of misalignment errors:

$$S_{4,4} = DV\_COV_3^2 + DV\_COV_2^2$$

$$S_{5,5} = DV\_COV_1^2 + DV\_COV_3^2$$

$$S_{6,6} = DV\_COV_1^2 + DV\_COV_2^2$$

$$S_{4,5} = -DV\_COV_1 DV\_COV_2$$

$$S_{4,6} = -DV\_COV_1 DV\_COV_3$$

$$S_{5,6} = -DV\_COV_2 DV\_COV_3$$

$$S_{6,5} = S_{5,6}$$

$$S_{6,4} = S_{4,6}$$

$$S_{5,4} = S_{4,5}$$

$$S_{4\ to\ 6,4\ to\ 6} = (VAR\_IMU\_ALIGN) S_{4\ to\ 6,4\ to\ 6}$$

$$S_{1\ to\ 3,4\ to\ 6} = 0.5 (DT\_COV) S_{4\ to\ 6,4\ to\ 6}$$

$$S_{1\ to\ 3,1\ to\ 3} = 0.5 (DT\_COV) S_{1\ to\ 3,4\ to\ 6}$$

- (2) Add the powered flight noise to the covariance matrix

$$E_{1\ to\ 6,1\ to\ 6} = E_{1\ to\ 6,1\ to\ 6} + S$$

- e. Test the flag NOISY\_NAV\_MEAS to see if the sensed contact acceleration has exceeded the measurement threshold

- (1) If NOISY\_NAV\_MEAS = ON

– Reset NOISY\_NAV\_MEAS to OFF for the next covariance matrix propagation subcycle.

– Reset the measurement ACCEPT/REJECT counters. (See Section 4.1.2.2.1.2)

CALL: DISPLAY\_COUNT\_INIT

- (2) If NOISY\_NAV\_MEAS = OFF

– Set the flag NAV\_MEAS to ON so that the sensor measurements may be incorporated on the current filter subcycle.

11. As a final step in the covariance propagation, the entire 13-by-13 covariance matrix shall be made symmetric:

$$E_{J,I} = E_{I,J} \text{ (for } I = 1 \text{ to } 12, J = I+1 \text{ to } 13)$$

12. The measurement correction vectors for position and velocity must be initialized.

$$\begin{aligned}\bar{R}_{\text{MEAS}} &= \bar{0}. \\ \bar{V}_{\text{MEAS}} &= \bar{0}.\end{aligned}$$

B. Interface Requirements. The input and output data are shown in Table 4.2.5.

C. Processing Requirements. The subfunction is called by NAV\_ONORBIT\_RENDEZVOUS (Section 4.2.1).

D. Constraints. Either uplinked or mission dependent data are to be used for initialization. The propagated matrix must remain symmetric.

E. Supplementary Information. A suggested implementation in the form of detailed flow charts can be found in Section 5.2 under the following names:

PHI\_E\_PHI\_TRANSPOSE CODE  
PWRD\_FLT\_NOISE CODE  
REND\_BIAS\_AND\_COV\_PROP  
UNMOD\_ACC\_REINIT CODE

A detailed flow chart for UVW\_TO\_M50 function can be found in Section 5.3.

Table 4.2.5. REND\_BIAS\_AND\_COV\_PROP Input/Output

Variable Name	Input Source	Output Destination
$\overline{\text{COV\_ACCEL\_UVW\_INIT}}$		U_A_BIAS_AND_COVINIT
COV_PWRD_FLT	NAV_ONORBIT_ RENDEZVOUS,*	
COV_PWRD_FLT_LAST	*	
$\overline{\text{COV\_U\_A\_COAST}}$	**	
$\overline{\text{COV\_U\_A\_PWRD\_FLT}}$	**	
$\overline{\text{DV\_COV}}$	NAV_ONORBIT_ RENDEZVOUS, COV_LAST_RESET,*	
E	COVINIT_UVW, SETUP, REND_NAV_FILTER, REND_COV_INIT, U_A_BIAS_AND_COVINIT,*	COV_LAST_RESET, REND_NAV_FILTER,*
$\overline{\text{G\_NEW}}$	ONORBIT_REND_R_V_STATE _PROP, SUPER_G	
$\overline{\text{G\_TV}}$	ONORBIT_REND_R_V_STATE _PROP	MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6x6
$\overline{\text{G\_TV\_LAST}}$	REND_COV_INIT,*	MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6x6
NOISY_NAV_MEAS	NAV_ONORBIT_ RENDEZVOUS,*,**	
$\text{PHI}_{1\text{to}6,1\text{to}6}$	MEAN_CONIC_PARTIAL TRANSITION_MATRIX_6x6	
$\overline{\text{R\_FILT}}$	ONORBIT_REND_R_V_STATE _PROP	MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6x6, UVW_TO_M50, U_A_BIAS_AND_COVINIT
$\overline{\text{R\_LAST}}$	COV_LAST_RESET,*	MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6x6
$\overline{\text{R\_MEAS}}$		REND_NAV_FILTER, MEAS_ PROCESSING_STATISTICS_REND
$\overline{\text{R\_TV}}$	ONORBIT_REND_R_V_ STATE_PROP	MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6x6, UVM_TO_M50, U_A_BIAS_AND_COVINIT
$\overline{\text{R\_TV\_LAST}}$	COV_LAST_RESET,*	MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6x6
SHUTTLE_FILTER_FLAG	*	
TAU_SENS	SETUP,**	
TAU_U_A_COAST	**	
TAU_U_A_PWRD_FLT	**	
TAU_UNMOD_ACC_COV	*	
TAU_UNMOD_ACC_ STATE	**	

Table 4.2.5. REND\_BIAS\_AND\_COV\_PROP Input/Output

Variable Name	Input Source	Output Destination
T_COV_LAST	COV_LAST_RESET,*	
T_CURRENT_FILT	NAV_ONORBIT_ RENDEZVOUS	
TOT_ACC_LAST	REND_COV_INIT,*	MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6x6
UNMOD_ACC_BIAS	U_A_BIAS_AND_COVINIT, REND_NAV_FILTER,*	REND_NAV_FILTER, ACCEL_ONORBIT, NAV_ONORBIT_RENDEZVOUS
VAR_IMU_ALIGN	**	
VAR_SENS	SETUP	
VAR_U_A_COAST	**	
VAR_U_A_PWRD_FLT	**	
VAR_UNMOD_ACC	*	
V_FILT	ONORBIT_REND_R_V_STATE _PROP	MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6x6, UVW_TO_M50, U_A_BIAS_AND_COVINIT
V_LAST	COV_LAST_RESET,*	MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6x6
V_TV	ONORBIT_REND_R_V_STATE _PROP	MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6x6, UVW_TO_M50, U_A_BIAS_AND_COVINIT
V_TV_LAST	COV_LAST_RESET,*	MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6x6
†	UVW_TO_M50	
DT_COV		MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6x6, ONORBIT_SV_INTERP,*
V_MEAS		REND_NAV_FILTER, MEAS_ PROCESSING_STATISTICS_REND
NAV_MEAS		NAV_ONORBIT_RENDEZVOUS
TOT_ACC		MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6x6, REND_NAV_INTERP,*

\* Onorbit/Rendezvous principal function, see Table 4.2.11-1.

\*\* Initialization parameters, see Section 4.7.

† Value returned from the function.

#### 4.2.5.1 Unmodeled Acceleration Bias and Covariance Initialization (U\_A\_BIAS\_AND\_COVINIT)

The initialization subfunction initializes the unmodeled acceleration bias states and the corresponding elements of the covariance matrix whenever the covariance matrix is reinitialized or whenever the unmodeled acceleration bias and covariance propagation subfunction has detected a change in the value of the flag COV\_PWRD\_FLT, which indicates whether the magnitude of the IMU-sensed acceleration has exceeded the threshold value DA\_THRESHOLD on the current covariance propagation subcycle.

A. Detailed Requirements. This subfunction is called with the following internal variables in the IN LIST:

IN LIST:  $\bar{R}, \bar{V}$

where  $\bar{R}$  and  $\bar{V}$  are the input position and velocity vectors of the filter vehicle in mean of 1950 coordinates.

The following steps shall be performed (in the order indicated):

1. Zero the unmodeled acceleration bias states

$$\bar{U}NMOD\_ACC\_BIAS = \bar{0}.$$

2. Compute the UVW-to-mean of 1950 coordinate transformation matrix

$$M\_UVW\_M50 = UVW\_TO\_M50(\bar{R}, \bar{V})$$

(refer to Section 4.10.10 for a detailed description).

3. Initialize the unmodeled acceleration bias slots of the covariance matrix to initial UVW values and transform to mean of 1950 coordinates,

$$E_{1+6,1+6} = COV\_ACCEL\_UVW\_INIT_I \text{ (for } I = 1 \text{ to } 3)$$

$$E_{7to9,7to9} = M\_UVW\_M50 E_{7to9,7to9} M\_UVW\_M50^T$$

B. Interface Requirements. The input and output data are shown in Table 4.2.5.1.

C. Processing Requirements. This subfunction is called by

REND_BIAS_AND_COV_PROP	(Section 4.2.5) and by
COVINIT_UVW	(Section 4.1.2.2.1.1)

D. Constraints. Mission-dependent (I-load) data are used for initialization.

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart may be found in Section 5.2 under the name U\_A\_BIAS\_AND\_COVINIT. A detailed flow chart for UVW\_TO\_M50 function may be found in Section 5.3.

Table 4.2.5.1. U_A_BIAS_AND_COVINIT Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
$\bar{R}$	$\bar{R}$	COVINIT_UVW	
$\bar{V}$	$\bar{V}$	COVINIT_UVW	
$\bar{R}$	$\bar{R}_{FILT}$	REND_BIAS_AND_COV_PROP	
$\bar{V}$	$\bar{V}_{FILT}$	REND_BIAS_AND_COV_PROP	
$\bar{R}$	$\bar{R}_{TV}$	REND_BIAS_AND_COV_PROP	
$\bar{V}$	$\bar{V}_{TV}$	REND_BIAS_AND_COV_PROP	
Variable Name		Input Source	Output Destination
$\bar{COV\_ACCEL\_UVW\_INIT}$		REND_NAV_INIT, REND_BIAS_AND_COV_PROP, *	
†		UVW_TO_M50	
$E_{7to9,7to9}$			COV_LAST_RESET, REND_BIAS_AND_COV_PROP, REND_NAV_FILTER, *, ***
M_UVW_M50			COVINIT_UVW
$\bar{R}$			UVW_TO_M50
$\bar{UNMOD\_ACC\_BIAS}$			REND_BIAS_AND_COV_PROP, ACCEL_ONORBIT, REND_NAV_FILTER, ***, NAV_ONORBIT_RENDEZVOUS
$\bar{V}$			UVW_TO_M50
† Value returned from the function. * Onorbit/Rendezvous principal function, see Table 4.2.11-1. *** Onorbit/Rendezvous Nav Sequencer principal function, see Table 4.1.3-1.			



**4.2.5.2 Position-Velocity Submatrix of the State Transition Matrix  
(MEAN\_CONIC\_PARTIAL\_TRANSITION\_MATRIX\_6X6)**

This subfunction computes a 6-by-6 submatrix (PHI\_MC) of a larger state transition matrix for use in propagating the covariance matrix. This subfunction is also invoked by the Rendezvous Navigation Interpolation subfunction for use in calculating the partial derivative vector.

A. Detailed Requirements. This subfunction is called with the following internal variables in the INLIST and OUTLIST:

INLIST:  $\bar{R}_ONE$ ,  $\bar{V}_ONE$ ,  $\bar{G}_ONE$ ,  $\bar{R}_TWO$ ,  $\bar{V}_TWO$ ,  $\bar{G}_TWO$ , DELTIM

OUTLIST: PHI\_MC

where

$\bar{R}_ONE$	initial position vector
$\bar{V}_ONE$	initial velocity vector
$\bar{G}_ONE$	initial total acceleration vector
$\bar{R}_TWO$	final position vector
$\bar{V}_TWO$	final velocity vector
$\bar{G}_TWO$	final total acceleration vector
DELTIM	time step

The following steps shall be performed (in the order indicated):

1. A formulation is used that assumes that a mean conic section may be used to describe the path taken between the initial position and velocity ( $\bar{R}_ONE$  and  $\bar{V}_ONE$ ) at initial total acceleration ( $\bar{G}_ONE$ ) and the final position and velocity ( $\bar{R}_TWO$  and  $\bar{V}_TWO$ ) at final total acceleration ( $\bar{G}_TWO$ ) over a time step DELTIM.

The following local variables are computed:

R_ONE_INV	=	$1./ \bar{R}_ONE $	F3
R_TWO_INV	=	$1./ \bar{R}_TWO $	F3
D_ONE	=	$\bar{R}_ONE \cdot \bar{V}_ONE$	
D_TWO	=	$\bar{R}_TWO \cdot \bar{V}_TWO$	

F3 This equation shall be protected against division by zero (reference 3.5)

2. The ergodic semimajor axis SMA, is computed by using the average of the reciprocal of the semimajor axis derived from combination of the respective vis-viva computations at the initial and final orbital states, and is given by:

$$SMA = 1./((R\_ONE\_INV + R\_TWO\_INV - (\bar{V}_ONE \cdot \bar{V}_ONE + \bar{V}_TWO \cdot \bar{V}_TWO)/(2. EARTH\_MU))) \quad F3$$

F3 This equation shall be protected against division by zero (reference 3.5)

where EARTH\_MU is the Earth's gravitational constant. The Stumpff constant, C1, predicated on the mean conic semimajor axis, is computed by:

$$C1 = \text{SQRT}(\text{SMA})/\text{SQR\_EMU} \quad \text{F3,F4}$$

- F3 This equation shall be protected against division by zero (reference 3.5).  
F4 This equation shall be protected against square roots of a negative number (reference 3.5).

3. The F\_AND\_G subfunction is then invoked to compute the F and G functions, the derivatives of F and G, as well as the auxiliary variables S0, S1, S2, and S3. These quantities are fundamental to the computation of the mean conic transition matrix.

CALL: F\_AND\_G

IN LIST: SMA, DELTIM, C1,  $\bar{R\_ONE}$ , R\_ONE\_INV, R\_TWO\_INV,  $\bar{V\_ONE}$ , D\_ONE, D\_TWO

OUT LIST: F, G, FDOT, GDOT, S0, S1, S2, S3,  $\bar{R\_TWO}$ , R\_TWO\_INV, THETA

For this case,  $\bar{R\_TWO}$  and R\_TWO\_INV are not updated since R\_TWO\_INV is supplied as a nonzero quantity. However, THETA, the eccentric anomaly angle, is generated as an output in any case.

4. Compute auxiliary constants:

$$FM1 = F-1$$

$$GDM1 = GDOT-1$$

$$S1 = C1 S1$$

$$C2 = C1^2$$

$$\text{CONST} = C2 (\text{EARTH\_MU} C2 (3. S3 C1-S1 S2) + G S2)$$

$$S2 = C2 S2$$

which represent common functionals and Stumpff series summations for circular or elliptical orbits.

5. The partial derivatives are now calculated. The equation for the partial derivatives are written algebraically for clarity, with  $R_o$

representing  $\bar{R\_ONE}$ ,  $\dot{R}$  representing  $\bar{R\_TWO}$ ,  $\dot{R}_o$  representing  $\bar{V\_ONE}$ ,  $\ddot{R}$  representing  $\bar{V\_TWO}$ ,  $\ddot{R}_o$  representing  $\bar{G\_ONE}$ ,  $\ddot{R}$  representing  $\bar{G\_TWO}$ ,  $\dot{f}$  representing F,  $\dot{g}$  representing G,  $\dot{f}$  representing FDOT,  $\dot{g}$  representing GDOT, U representing CONST, and I representing ID\_MATRIX\_3X3, as well as having lower case letters representing the scalar magnitude of the respective upper case letter vectors.

$$\begin{aligned}
 \text{PHI\_MC}_{1 \text{ to } 3, 1 \text{ to } 3} &= \frac{\partial \mathbf{R}}{\partial \mathbf{R}_0} = - \left[ \frac{\dot{\mathbf{f}} \mathbf{S}_1 + (\mathbf{f} - 1)/r_0}{r_0} \right] \mathbf{R} \mathbf{R}_0^T & \text{F3} \\
 &\quad - \dot{\mathbf{f}} \mathbf{S}_2 \mathbf{R} \dot{\mathbf{R}}_0^T \\
 &\quad + \frac{(\mathbf{f} - 1) \mathbf{S}_1}{r_0} \dot{\mathbf{R}} \mathbf{R}_0^T + (\mathbf{f} - 1) \mathbf{S}_2 \dot{\mathbf{R}} \dot{\mathbf{R}}_0^T \\
 &\quad + \mathbf{U} \dot{\mathbf{R}} \ddot{\mathbf{R}}_0^T + \mathbf{f} \mathbf{I}
 \end{aligned}$$

$$\begin{aligned}
 \text{PHI\_MC}_{1 \text{ to } 3, 4 \text{ to } 6} &= \frac{\partial \mathbf{R}}{\partial \dot{\mathbf{R}}_0} = - \dot{\mathbf{f}} \mathbf{S}_2 \mathbf{R} \mathbf{R}_0^T - (\dot{\mathbf{g}} - 1) \mathbf{S}_2 \mathbf{R} \dot{\mathbf{R}}_0^T \\
 &\quad + (\mathbf{f} - 1) \mathbf{S}_2 \dot{\mathbf{R}} \mathbf{R}_0^T + \mathbf{g} \mathbf{S}_2 \dot{\mathbf{R}} \dot{\mathbf{R}}_0^T \\
 &\quad + \mathbf{g} \mathbf{I} - \mathbf{U} \dot{\mathbf{R}} \dot{\mathbf{R}}_0^T
 \end{aligned}$$

F3

$$\begin{aligned}
 \text{PHI\_MC}_{4 \text{ to } 6, 1 \text{ to } 3} &= \frac{\partial \dot{\mathbf{R}}}{\partial \mathbf{R}_0} = - \dot{\mathbf{f}} \left( \frac{\mathbf{S}_0}{r r_0} + \frac{1}{r^2} + \frac{1}{r_0^2} \right) \mathbf{R} \mathbf{R}_0^T \\
 &\quad - \left[ \frac{\dot{\mathbf{f}} \mathbf{S}_1 + (\dot{\mathbf{g}} - 1)/r}{r} \right] \mathbf{R} \dot{\mathbf{R}}_0^T \\
 &\quad + \left[ \frac{\dot{\mathbf{f}} \mathbf{S}_1 + (\mathbf{f} - 1)/r_0}{r_0} \right] \dot{\mathbf{R}} \mathbf{R}_0^T + \dot{\mathbf{f}} \mathbf{S}_2 \dot{\mathbf{R}} \dot{\mathbf{R}}_0^T \\
 &\quad + \dot{\mathbf{f}} \mathbf{I} + \mathbf{U} \ddot{\mathbf{R}} \ddot{\mathbf{R}}_0^T
 \end{aligned}$$

F3

$$\begin{aligned}
 \text{PHI\_MC}_{4 \text{ to } 6, 4 \text{ to } 6} &= \frac{\partial \dot{\mathbf{R}}}{\partial \mathbf{R}_0} = - \left[ \frac{\dot{\mathbf{f}} \mathbf{S}_1 + (\dot{\mathbf{g}} - 1)/r}{r} \right] \mathbf{R} \mathbf{R}_0^T \\
 &\quad - \left[ \frac{(\dot{\mathbf{g}} - 1) \mathbf{S}_1}{r} \right] \mathbf{R} \dot{\mathbf{R}}_0^T + \dot{\mathbf{f}} \mathbf{S}_2 \dot{\mathbf{R}} \mathbf{R}_0^T \\
 &\quad + (\dot{\mathbf{g}} - 1) \mathbf{S}_2 \dot{\mathbf{R}} \dot{\mathbf{R}}_0^T + \dot{\mathbf{g}} \mathbf{I} - \mathbf{U} \ddot{\mathbf{R}} \dot{\mathbf{R}}_0^T
 \end{aligned}$$

F3 This equation shall be protected against division by zero (reference 3.5)

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Certain recurring groups of symbols may be collected to facilitate ease of coding and minimization of error. Each 3-by-3 submatrix of the 6-by-6 matrix PHI\_MC results from the summation of 3-by-3 matrices generated by the dyadic product of groups of vectors of length three.

B. Interface Requirements. The input and output data are shown in table 4.2.5.2.

C. Processing Requirements. This subfunction is called by the following subfunctions:

REND\_BIAS\_AND\_COV\_PROP (section 4.2.5)

REND\_NAV\_INTERP (section 4.2.8.1.1)

D. Constraints. None

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart may be found in Section 5.2 under the name of MEAN\_CONIC\_PARTIAL\_TRANSITION\_MATRIX\_6X6.

Table 4.2.5.2. MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6 Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
DELTIM	DT_COV	REND_BIAS_AND_COV_PROP	
$\bar{G}_{ONE}$	$\bar{TOT\_ACC\_LAST}$	REND_BIAS_AND_COV_PROP	
$\bar{G}_{TWO}$	$\bar{TOT\_ACC}$	REND_BIAS_AND_COV_PROP	
$\bar{R}_{ONE}$	$\bar{R\_LAST}$	REND_BIAS_AND_COV_PROP	
$\bar{R}_{TWO}$	$\bar{R\_FILT}$	REND_BIAS_AND_COV_PROP	
$\bar{V}_{ONE}$	$\bar{V\_LAST}$	REND_BIAS_AND_COV_PROP	
$\bar{V}_{TWO}$	$\bar{V\_FILT}$	REND_BIAS_AND_COV_PROP	
DELTIM	DT_COV	REND_BIAS_AND_COV_PROP	
$\bar{G}_{ONE}$	$\bar{G\_TV\_LAST}$	REND_BIAS_AND_COV_PROP	
$\bar{G}_{TWO}$	$\bar{G\_TV}$	REND_BIAS_AND_COV_PROP	
$\bar{R}_{ONE}$	$\bar{R\_TV\_LAST}$	REND_BIAS_AND_COV_PROP	
$\bar{R}_{TWO}$	$\bar{R\_TV}$	REND_BIAS_AND_COV_PROP	
$\bar{V}_{ONE}$	$\bar{V\_TV\_LAST}$	REND_BIAS_AND_COV_PROP	
$\bar{V}_{TWO}$	$\bar{V\_TV}$	REND_BIAS_AND_COV_PROP	
DELTIM	DELTAT_GO	REND_NAV_INTERP	
$\bar{G}_{ONE}$	$\bar{TOT\_ACC}$	REND_NAV_INTERP	
$\bar{G}_{TWO}$	$\bar{A\_RESID}$	REND_NAV_INTERP	
$\bar{R}_{ONE}$	$\bar{R\_FILT}$	REND_NAV_INTERP	
$\bar{R}_{TWO}$	$\bar{R\_RESID}$	REND_NAV_INTERP	
$\bar{V}_{ONE}$	$\bar{V\_FILT}$	REND_NAV_INTERP	
$\bar{V}_{TWO}$	$\bar{V\_RESID}$	REND_NAV_INTERP	
DELTIM	DELTAT_GO	REND_NAV_INTERP	
$\bar{G}_{ONE}$	$\bar{G\_TV}$	REND_NAV_INTERP	
$\bar{G}_{TWO}$	$\bar{A\_TV\_RESID}$	REND_NAV_INTERP	
$\bar{R}_{ONE}$	$\bar{R\_TV}$	REND_NAV_INTERP	
$\bar{R}_{TWO}$	$\bar{R\_TV\_RESID}$	REND_NAV_INTERP	
$\bar{V}_{ONE}$	$\bar{V\_TV}$	REND_NAV_INTERP	
$\bar{V}_{TWO}$	$\bar{V\_TV\_RESID}$	REND_NAV_INTERP	
PHI_MC	PHI <sub>1to6, 1to6</sub>		REND_BIAS_AND_COV_PROP
PHI_MC	PHI <sub>1to6, 1to6</sub>		REND_BIAS_AND_COV_PROP
PHI_MC	PHI_PATCH		REND_NAV_INTERP
PHI_MC	PHI_PATCH		REND_NAV_INTERP

Table 4.2.5.2.(1) MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6 Input/Output		
Variable Name	Input Source	Output Destination
EARTH_MU	**	
F	F_AND_G	
FDOT	F_AND_G	
G	F_AND_G	
GDOT	F_AND_G	
ID_MATRIX_3X3	**	
$\bar{R}_T$	F_AND_G	
R_TWO_INV	F_AND_G	F_AND_G
SQR_EMU	*	
S0	F_AND_G	
S1	F_AND_G	
S2	F_AND_G	
S3	F_AND_G	
THETA	F_AND_G	
C1		F_AND_G
DELTIM		F_AND_G
D_ONE		F_AND_G
D_TWO		F_AND_G
$\bar{R}_O$		F_AND_G
R_ONE_INV		F_AND_G
SMA		F_AND_G
$\bar{V}_O$		F_AND_G

\* Onorbit/Rendezvous principal function, see Table 4.2.11-1.  
 \*\* Initialization parameters, see Section 4.7.

#### 4.2.5.2.1 Conic Solution (F\_AND\_G)

The Conic Solution subfunction utilized by the State Vector Interpolation, Position–Velocity Submatrix of the State Transition Matrix, and Precision Integration subfunctions shall provide the capability to trace the progress of a point along its orbit, assuming pure Keplerian motion, by means of the F and G algorithm in terms of the eccentric anomaly.

The variables F and G and  $\dot{F}$  and  $\dot{G}$  shall be calculated as functions of the difference in eccentric anomaly between an initial time at which a position and a velocity vector are known and a final time at which they are required.

If the final position and velocity are known, the difference in eccentric anomaly can be easily calculated and the F, G,  $\dot{F}$  and  $\dot{G}$  expressions can be obtained with the use of certain auxiliary variables called here S0, S1, S2, and S3.

If the final position and velocity are not known but only the transfer time, it is necessary to solve a form of Kepler's equation to obtain the difference in eccentric anomaly.

A. Detailed Requirements. The Conic Solution (F\_AND\_G) subfunction will be initiated by the call statement of the following form:

```
CALL:          F_AND_G
IN LIST:       SMA,DELTAT,C1, $\bar{R}_{IN}$ ,R_IN_INV,R_FIN_INV, $\bar{V}_{IN}$ ,D_IN, D_FIN
OUT LIST:      F,G,FDOT,GDOT,S0,S1,S2,S3, $\bar{R}_{FIN}$ ,R_FIN_INV,THETA
```

where:

SMA	= semimajor axis of the conic
DELTAT	= transfer time
C1	= an auxiliary constant, equal to the square root of SMA divided by the square root of Earth's gravitational constant
$\bar{R}_{IN}$	= the initial position vector (M50)
R_IN_INV	= the reciprocal of the magnitude of $\bar{R}_{IN}$
R_FIN_INV	= the reciprocal of the magnitude of $\bar{R}_{FIN}$ (if unknown, a zero shall be input)
$\bar{V}_{IN}$	= the initial velocity vector (M50)
D_IN	= the dot product of the initial position and velocity vectors
D_FIN	= the dot product of the final position and velocity vectors (if unknown, a zero shall be input)

The Conic Solution subfunction shall perform the following in the order indicated:

1. Check the value of R\_FIN\_INV to see if Kepler's equation is to be solved.



- a. If R\_FIN\_INV ≠ 0., which indicates that the final position vector is already known, the difference in eccentric anomaly shall be obtained from the expression

$$\text{THETA} = (\text{C1}(\text{D\_FIN} - \text{D\_IN}) + \text{DELTAT}/\text{C1})/\text{SMA} \quad \text{F3}$$

F3 This equation shall be protected against division by zero (reference 3.5).

- b. If R\_FIN\_INV = 0., the final position vector is to be calculated. This requires solving a modified form of Kepler's equation, which shall be accomplished by an iterative process that consists of the following steps:

- (1) Two auxiliary quantities shall be obtained from the input data:

$$\text{ONEMRIN} = (\text{SMA} - 1./\text{R\_IN\_INV})/\text{SMA} \quad \text{F3}$$

$$\text{D\_MN\_AN} = \text{DELTAT}/(\text{C1 SMA}) \quad \text{F3}$$

F3 This equation shall be protected against division by zero (reference 3.5).

D\_MN\_AN is the difference in mean anomaly, which shall be taken as a first approximation to the difference in eccentric anomaly, THETA. An iteration counter shall also be started.

$$\text{THETA} = \text{D\_MN\_AN}$$

$$\text{I} = 1$$

- (2) Then THETA and THETA\_COR shall be recalculated until the number of iterations attains a predetermined maximum.

DO UNTIL

$$\text{I} = \text{NUM\_KEP\_ITER}$$

by repeatedly evaluating the equations

$$\text{S0} = \text{COS}(\text{THETA}) \quad \text{F9}$$

$$\text{S1} = \text{SIN}(\text{THETA}) \quad \text{F9}$$

$$\text{S2} = 1. - \text{S0}$$

F3 This equation shall be protected against division by zero (reference 3.5).

F9 This equation shall be protected against return nvalue of sine or cosine with magnitude greater than unity (reference 3.5).



$$\text{ERR} = \text{D\_MN\_AN} - \text{THETA} - \text{D\_IN C1 S2/SMA} + \text{ONEMRIN S1} \quad \text{F3}$$

$$\text{THETA\_COR} = \text{ERR}/(1. + \text{D\_IN C1 S1/SMA} - \text{ONEMRIN S0}) \quad \text{F3}$$

$$\text{THETA} = \text{THETA} + \text{THETA\_COR}$$

$$\text{I} = \text{I} + 1$$

F3 This equation shall be protected against division by zero (reference 3.5).

- When the difference in eccentric anomaly is determined, certain auxiliary variables shall be calculated.

$$\text{S0} = \text{COS}(\text{THETA}) \quad \text{F9}$$

$$\text{S1} = \text{SIN}(\text{THETA}) \quad \text{F9}$$

$$\text{S2} = 1. - \text{S0}$$

$$\text{S3} = \text{THETA} - \text{S1}$$

- The values of F and G shall then be determined:

$$\text{F} = 1. - \text{SMA S2 R\_IN\_INV}$$

$$\text{G} = \text{DELTAT} - \text{C1 SMA S3}$$

- If the final position vector and the reciprocal of its magnitude were not known, they shall be calculated:

IF R\_FIN\_INV = 0., then set

$$\bar{\text{R}}_{\text{FIN}} = \text{F} \bar{\text{R}}_{\text{IN}} + \text{G} \bar{\text{V}}_{\text{IN}}$$

$$\bar{\text{R}}_{\text{FIN\_INV}} = 1./ |\bar{\text{R}}_{\text{FIN}}| \quad \text{F3}$$

F3 This equation shall be protected against division by zero (reference 3.5).

F9 This equation shall be protected against return nvalue of sine or cosine with magnitude greater than unity (reference 3.5).

- The functions  $\dot{\text{F}}$  and  $\dot{\text{G}}$ , required for the calculation of the final velocity vector, shall be evaluated:

$$\text{FDOT} = - \text{EARTH\_MU C1 S1 R\_IN\_INV R\_FIN\_INV}$$

$$\text{GDOT} = 1. - \text{SMA S2 R\_FIN\_INV}$$

Finally, the out list of the Conic Solution subfunction shall contain the following quantities (different users require different sets of these):

$$\text{F, G, FDOT, GDOT, S0, S1, S2, S3, } \bar{\text{R}}_{\text{FIN}}, \text{R\_FIN\_INV, THETA}$$

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B. Interface Requirements. Input and output parameters for the conic solution (F\_AND\_G) are given in Table 4.2.5.2.1.

C. Processing Requirements. The following are the code names of those subfunctions which call the F\_AND\_G conic solution subfunction:

PINES\_METHOD

MEAN\_CONIC\_PARTIAL\_TRANSITION\_MATRIX\_6X6

ONORBIT\_SV\_INTERP

D. Constraints. None

E. Supplementary Information. A suggested implementation of this subfunction in the form of a detailed flow diagram may be found in Section 5.2 under the following: F\_AND\_G

Table 4.2.5.2.1. F_AND_G Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
C1	C1	PINES_METHOD	
DELTAT	DELTAT	PINES_METHOD	
D_FIN	D_FIN_TEMP	PINES_METHOD	
D_IN	D_IN	PINES_METHOD	
R_FIN_INV	R_FIN_TEMP_INV	PINES_METHOD	
$\bar{R}_IN$	XN <sub>1 to 3</sub>	PINES_METHOD	
R_IN_INV	R_IN_INV	PINES_METHOD	
SMA	SMA	PINES_METHOD	
$\bar{V}_IN$	XN <sub>4 to 6</sub>	PINES_METHOD	
C1	C1	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6	
DELTAT	DELTIM	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6	
D_FIN	D_TWO	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6	
D_IN	D_ONE	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6	
R_FIN_INV	R_TWO_INV	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6	
$\bar{R}_IN$	$\bar{R}_ONE$	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6	
R_IN_INV	R_ONE_INV	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6	
SMA	SMA	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6	
$\bar{V}_IN$	$\bar{V}_ONE$	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6	
C1	C1	ONORBIT_SV_INTERP	
DELTAT	-DELTAT_GO	ONORBIT_SV_INTERP	
D_FIN	D_FIN_TEMP	ONORBIT_SV_INTERP	
D_IN	D_TWO	ONORBIT_SV_INTERP	
R_FIN_INV	R_FIN_TEMP_INV	ONORBIT_SV_INTERP	

Table 4.2.5.2.1. F_AND_G Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
$\bar{R}_{IN}$	$\bar{R}_{TWO}$	ONORBIT_SV_INTERP	
R_IN_INV	R_TWO_INV	ONORBIT_SV_INTERP	
SMA	SMA	ONORBIT_SV_INTERP	
$\bar{V}_{IN}$	$\bar{V}_{TWO}$	ONORBIT_SV_INTERP	
F	F		PINES_METHOD
FDOT	FDOT		PINES_METHOD
G	G		PINES_METHOD
GDOT	GDOT		PINES_METHOD
$\bar{R}_{FIN}$	$X_{1 \text{ to } 3}$		PINES_METHOD
R_FIN_INV	R_FIN_INV		PINES_METHOD
S0	S0		PINES_METHOD
S1	S1		PINES_METHOD
S2	S2		PINES_METHOD
S3	S3		PINES_METHOD
THETA	THETA		PINES_METHOD
F	F		MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
FDOT	FDOT		MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
G	G		MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
GDOT	GDOT		MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
$\bar{R}_{FIN}$	$\bar{R}_{TWO}$		MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
R_FIN_INV	R_TWO_INV		MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
S0	S0		MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
S1	S1		MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
S2	S2		MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6

Table 4.2.5.2.1. F\_AND\_G Input/Output

Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
S3	S3		MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
THETA	THETA		MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
F	F		ONORBIT_SV_INTERP
FDOT	FDOT		ONORBIT_SV_INTERP
G	G		ONORBIT_SV_INTERP
GDOT	GDOT		ONORBIT_SV_INTERP
$\bar{R}_{FIN}$	$\bar{R}_{RESID}$		ONORBIT_SV_INTERP
R_FIN_INV	R_FIN_INV		ONORBIT_SV_INTERP
S0	S0		ONORBIT_SV_INTERP
S1	S1		ONORBIT_SV_INTERP
S2	S2		ONORBIT_SV_INTERP
S3	S3		ONORBIT_SV_INTERP
THETA	THETA		ONORBIT_SV_INTERP
Variable Name		Input Source	Output Destination
EARTH_MU		**	
NUM_KEP_ITER		**	
** Initialization parameters, see Section 4.7.			

#### 4.2.6 Rendezvous Sensor Measurement Selection (REND\_SENSOR\_SELECT)

The Rendezvous Sensor Measurement Selection subfunction shall perform the following tasks when in the rendezvous navigation phase, when the magnitude of the IMU-sensed accelerations are below a predetermined threshold, and when on a covariance propagation cycle.

- Supply certain positive feedback flags to the REL\_NAV display
- Select the proper rendezvous sensor navigation measurement incorporation subfunctions (Section 4.2.8) to process the sensor angle data
- Select the type of data processing by the rendezvous navigation Kalman filter, REND\_NAV\_FILTER (Section 4.2.8.1.2). Data are used to compute statistical parameters for display only, or data are used to update the state and covariance matrix as well as for the statistical computations
- Select the proper type of edit criteria to be used by the rendezvous navigation filter, REND\_NAV\_FILTER (Section 4.2.8.1.2), in the bilevel edit test which determines if data are to be edited
- Reset the AUTO/INHIBIT/FORCE (AIF) flags so that a FORCE will be in effect for only one navigation filter cycle without being reset by the crew

##### A. Detailed Requirements.

1. The Rendezvous Sensor Measurement Selection subfunction initially sets certain positive feedback display parameters and then sets other appropriate flags to OFF so that the selection tasks are correctly accomplished. The following flags are required to be initialized upon each execution of the Rendezvous Sensor Measurement Selection subfunction.

- a. Certain positive feedback flags are defined for the REL\_NAV display.

RDOT\_AIF\_DISPLAY = NAV\_RDOT\_AIF  
RANGE\_AIF\_DISPLAY = NAV\_RANGE\_AIF  
ANGLES\_AIF\_DISPLAY = NAV\_ANGLES\_AIF  
DOING\_MEAS\_ENABLE = NAV\_MEAS\_ENABLE

- b. In order for this subfunction to properly select the appropriate rendezvous sensor navigation measurement incorporation subfunction for the proper angle set, the following flags (DO NAV flags) are initially set to OFF.

DO\_RR\_ANGLES\_NAV = OFF  
DO\_ST\_ANGLES\_NAV = OFF  
DO\_COAS\_ANGLES\_NAV = OFF

- c. In order to properly process and record the type of processing of the data, the following flags are initially set to OFF.

(1) Statistical processing flags

RDOT\_STAT = OFF  
ST\_ANGLES\_STAT = OFF  
COAS\_ANGLES\_STAT = OFF  
RANGE\_STAT = OFF  
RR\_ANGLES\_STAT = OFF

(2) EDIT OVERRIDE flags for the bilevel edit test

RANGE\_EDIT\_OVERRIDE = OFF  
RDOT\_EDIT\_OVERRIDE = OFF  
RR\_ANGLES\_EDIT\_OVERRIDE = OFF  
ST\_ANGLES\_EDIT\_OVERRIDE = OFF  
COAS\_ANGLES\_EDIT\_OVERRIDE = OFF

(3) A 4-dimensional array to record the type of processing of the data by the Rendezvous Sensor Navigation Measurement Incorporation subfunction

SENSOR\_EDIT = OFF

2. Next, a local flag (MEAS\_STAT) is set to control measurement processing for statistical display purposes when in Major Mode 202.
  - a. MEAS\_STAT = ON when NAV\_MEAS\_ENABLE = OFF and NAV\_MM\_CODE = 202. This will result in measurement processing proceeding as if all the measurement AIF flags are set to INHIBIT, i.e., measurements are only used to compute statistical parameters for display purposes.
  - b. MEAS\_STAT = OFF when NAV\_MEAS\_ENABLE = ON or NAV\_MM\_CODE ≠ 202. This will result in the measurement data being processed in the nominal manner.
3. The NAV\_RANGE\_AIF switch and the MEAS\_STAT flag are tested to appropriately set the RANGE\_STAT flag and the RANGE\_EDIT\_OVERRIDE flag.
  - a. If either NAV\_RANGE\_AIF = INHIBIT or MEAS\_STAT = ON, then

RANGE\_STAT = ON

resulting in the range measurement being processed for statistical display only.
  - b. If NAV\_RANGE\_AIF is not set to INHIBIT and MEAS\_STAT = OFF, then the NAV\_RANGE\_AIF flag is tested for a FORCE value.
    - (1) If NAV\_RANGE\_AIF = FORCE, then

RANGE\_EDIT\_OVERRIDE = ON

so that the edit criteria will be relaxed for the bilevel residual edit test.

4. Next, the NAV\_RDOT\_AIF switch and the MEAS\_STAT flag are tested to appropriately set the RDOT\_STAT flag and the RDOT\_EDIT\_OVERRIDE flag.

- a. If either NAV\_RDOT\_AIF = INHIBIT or MEAS\_STAT = ON, then

RDOT\_STAT = ON,

resulting in the range rate measurement being processed for statistical display only.

- b. If NAV\_RDOT\_AIF is not set to INHIBIT and MEAS\_STAT = OFF, then the NAV\_RDOT\_AIF flag is tested for a FORCE value.

- (1) If NAV\_RDOT\_AIF = FORCE, then

RDOT\_EDIT\_OVERRIDE = ON

so that the edit criteria will be relaxed for the bilevel residual edit test.

5. The NAV\_ST\_RR\_COAS switch is tested to see if the rendezvous radar angle set has been selected by the crew.

- a. If NAV\_ST\_RR\_COAS = 2, then set

DO\_RR\_ANGLES\_NAV = ON

so that the proper initialization procedure will take place for the angle data, and the Rendezvous Radar Angles Measurement Incorporation subfunction will be executed.

- (1) Next, the NAV\_ANGLES\_AIF switch and the MEAS\_STAT flags are tested to set the RR\_ANGLES\_STAT flag and the RR\_ANGLES\_EDIT\_OVERRIDE flag.

If either NAV\_ANGLES\_AIF = INHIBIT or MEAS\_STAT = ON, then

RR\_ANGLES\_STAT = ON,

resulting in the rendezvous radar angle measurements being processed for statistical display only.

If NAV\_ANGLES\_AIF is not set to INHIBIT and MEAS\_STAT = OFF, the NAV\_ANGLES\_AIF flag is tested for a FORCE value.

If NAV\_ANGLES\_AIF = FORCE, then

RR\_ANGLES\_EDIT\_OVERRIDE = ON

so that the edit criteria will be relaxed for the bilevel residual edit test.

- b. If NAV\_ST\_RR\_COAS ≠ 2, then the NAV\_ST\_RR\_COAS switch is tested to see if the star tracker angles set has been selected by the crew.

- (1) If NAV\_ST\_RR\_COAS = 1, then set

DO\_ST\_ANGLES\_NAV = ON



so that the proper initialization procedure will take place for the angle data and the Star Tracker Measurement Incorporation subfunction will be executed.

Next, the NAV\_ANGLES\_AIF switch and the MEAS\_STAT flags are tested to set the ST\_ANGLES\_STAT flag and the ST\_ANGLES\_EDIT\_OVERRIDE flag.

If either NAV\_ANGLES\_AIF = INHIBIT or MEAS\_STAT = ON, then

ST\_ANGLES\_STAT = ON,

resulting in the star tracker angle measurements being processed for statistical display only.

If NAV\_ANGLES\_AIF is not set to INHIBIT and MEAS\_STAT = OFF, the NAV\_ANGLES\_AIF flag is tested for a FORCE value.

If NAV\_ANGLES\_AIF = FORCE, then

ST\_ANGLES\_EDIT\_OVERRIDE = ON

so that the edit criteria will be relaxed for the bilevel residual edit test.

- c. If NAV\_ST\_RR\_COAS  $\neq$  1 and NAV\_ST\_RR\_COAS  $\neq$  2, then the COAS angle data set is assumed to be enable, thus

DO\_COAS\_ANGLES\_NAV = ON

so that the proper initialization procedure will take place for the angle data and the COAS Measurement Incorporation subfunction will be executed.

- (1) Next, the NAV\_ANGLES\_AIF switch and the MEAS\_STAT flags are tested to set the COAS\_ANGLES\_STAT flag and the COAS\_ANGLES\_EDIT\_OVERRIDE flag.

If either NAV\_ANGLES\_AIF = INHIBIT or MEAS\_STAT = ON, then

COAS\_ANGLES\_STAT = ON,

resulting in the COAS angle measurements being processed for statistical display only.

If NAV\_ANGLES\_AIF is not set to INHIBIT and MEAS\_STAT = OFF, the NAV\_ANGLES\_AIF flag is tested for a FORCE value.

If NAV\_ANGLES\_AIF = FORCE, then

COAS\_ANGLES\_EDIT\_OVERRIDE = ON

so that the edit criteria will be relaxed for the bilevel residual edit test.

6. The NAV\_RANGE\_AIF flag is tested so that a FORCE value will be acknowledged for one navigation cycle without being reset by the crew.

- a. If NAV\_RANGE\_AIF = FORCE, then

RANGE\_AIF = RANGE\_AIF\_LAST.

where the RANGE\_AIF\_LAST flag is a local flag which records the last nonforce value of the RANGE\_AIF flag.

- b. If NAV\_RANGE\_AIF is not equal to FORCE, then

RANGE\_AIF\_LAST = RANGE\_AIF.

7. Next, the NAV\_RDOT\_AIF flag is tested for the same reasons as given in 6.

- a. If NAV\_RDOT\_AIF is equal to FORCE, then

RDOT\_AIF = RDOT\_AIF\_LAST.

- b. If NAV\_RDOT\_AIF is not equal to FORCE, then

RDOT\_AIF\_LAST = RDOT\_AIF.

8. Finally, the NAV\_ANGLES\_AIF flag is tested similarly to 6 and 7.

- a. If NAV\_ANGLES\_AIF = FORCE, then

ANGLES\_AIF = ANGLES\_AIF\_LAST.

- b. If NAV\_ANGLES\_AIF is not equal to FORCE, then

ANGLES\_AIF\_LAST = ANGLES\_AIF.

B. Interface Requirements. The input and output parameters for this subfunction are indicated in Table 4.2.6.

C. Processing Requirements. The sensor measurement selection subfunction shall be performed only when on a covariance propagation cycle and when the IMU-sensed accelerations are below a design-dependent threshold (MEAS\_THRESHOLD), i.e., NAV\_MEAS = ON. This subfunction is called by the onorbit/rendezvous trunk logic, ONORBIT\_RENDEZVOUS\_NAV, and shall be executed before the Sensor Measurement Initialization subfunction, REND\_NAV\_SENSOR\_INIT.

D. Constraints. The RANGE\_AIF\_LAST, RDOT\_AIF\_LAST, and ANGLES\_AIF\_LAST flags need to be initialized to INHIBIT.

E. Supplementary Information. A suggested implementation of this subfunction may be found in the Section 5.2 under the name:

REND\_SENSOR\_SELECT

Table 4.2.6. REND\_SENSOR\_SELECT Input/Output

Variable Name	Input Source	Output Destination
NAV_ANGLES_AIF	NAV_ONORBIT_RENDEZVOUS	
ANGLES_AIF_LAST	**	
NAV_MEAS_ENABLE	NAV_ONORBIT_RENDEZVOUS	
NAV_MM_CODE	NAV_ONORBIT_RENDEZVOUS	
NAV_RANGE_AIF	NAV_ONORBIT_RENDEZVOUS	
RANGE_AIF_LAST	**	
NAV_RDOT_AIF	NAV_ONORBIT_RENDEZVOUS	
RDOT_AIF_LAST	**	
ANGLES_AIF_DISPLAY		*
COAS_ANGLES_EDIT_OVERRIDE		COAS_NAV
COAS_ANGLES_STAT		COAS_NAV
DO_COAS_ANGLES_NAV		REND_NAV_SENSOR_INIT,*
DOING_MEAS_ENABLE		*
NAV_ST_RR_COAS	NAV_ONORBIT_RENDEZVOUS	*
DO_RR_ANGLES_NAV		REND_NAV_SENSOR_INIT,* NAV_ONORBIT_RENDEZVOUS
DO_ST_ANGLES_NAV		REND_NAV_SENSOR_INIT,* NAV_ONORBIT_RENDEZVOUS
RANGE_AIF_DISPLAY		*
RANGE_EDIT_OVERRIDE		RRDOT_NAV
RANGE_STAT		RRDOT_NAV
RDOT_AIF_DISPLAY		*
RDOT_EDIT_OVERRIDE		RRDOT_NAV
RDOT_STAT		RRDOT_NAV
RR_ANGLES_EDIT_OVERRIDE		RR_ANGLE_NAV
RR_ANGLES_STAT		RR_ANGLE_NAV
SENSOR_EDIT		MEAS_PROCESSING_ STATISTICS_REND,*
ST_ANGLES_EDIT_OVERRIDE		STAR_TRACKER_NAV
ST_ANGLES_STAT		STAR_TRACKER_NAV

\* Onorbit/Rendezvous principal function, see Table 4.2.11-2.  
\*\* Initialization parameters, see Section 4.7.

#### 4.2.7 Sensor Measurement Initialization (REND\_NAV\_SENSOR\_INIT)

This Sensor Measurement Initialization subfunction shall be invoked on each covariance propagation subcycle when the IMU-sensed accelerations fall below a design-dependent threshold (MEAS\_THRESHOLD). The reinitialization of the sensor bias portion of the state vector and covariance matrix shall be performed upon entering rendezvous navigation, whenever the measurement type configuration has changed to include new measurements, or when an automatic inflight update or a REL\_NAV display update occurs while the Onorbit/Rendezvous Navigation principal function is active. The Sensor Covariance and Bias Setup subfunction (Section 4.2.7.1) shall be invoked to account for the change in the measurement status.

A. Detailed Requirements. The following steps shall be performed (in the order indicated):

1. If the rendezvous radar range and range rate data set was off (DO\_RRDOT\_NAV\_LAST = OFF) on the previous covariance propagation subcycle:

Call the Sensor Covariance and Bias Setup subfunction to reconfigure the bias portions of the state vector and the covariance matrix for this data set (see Section 4.2.7.1)

CALL: SETUP

IN LIST: 2, TAU\_RRDOT, BIAS\_VAR\_RRDOT, VAR\_RRDOT,  
RRDOT\_BIAS\_INIT

2. Test to determine if a new angle sensor has been selected by the crew.

- a. If the rendezvous radar angle data set has been made available since the previous covariance propagation subcycle (DO\_RR\_ANGLES\_NAV = ON and DO\_RR\_ANGLES\_NAV\_LAST = OFF):

Call the Sensor Covariance and Bias Setup subfunction to reconfigure the bias portions of the state vector and the covariance matrix for this data set (see Section 4.2.7.1).

CALL: SETUP

IN LIST: 0, TAU\_RR\_ANGLES, BIAS\_VAR\_RR\_ANGLES,  
VAR\_RR\_ANGLES, RR\_ANGLES\_BIAS\_INIT

Also set the positive feedback flag to the display for rendezvous radar angles:

ANGLES\_ENABLE\_DISPLAY = 2

- b. If the star tracker angle data set has been made available since the previous covariance propagation subcycle (DO\_ST\_ANGLES\_NAV = ON and DO\_ST\_ANGLES\_NAV\_LAST = OFF):

Call the Sensor Covariance and Bias Setup subfunction to reconfigure the bias portions of the state vector and the covariance matrix for this data set (see Section 4.2.7.1).

CALL: SETUP

IN LIST: 0, TAU\_ST\_ANGLES, BIAS\_VAR\_ST\_ANGLES,  
VAR\_ST\_ANGLES, ST\_ANGLES\_BIAS\_INIT

Also set the positive feedback flag to the display for star tracker angles and initialize the star tracker data edit count indicator:

ANGLES\_ENABLE\_DISPLAY = 0

N\_EDIT = 0

- c. If the COAS angle data set has been made available since the previous covariance propagation subcycle (DO\_COAS\_ANGLES\_NAV = ON and DO\_COAS\_ANGLES\_NAV\_LAST = OFF):

Call the Sensor Covariance and Bias Setup subfunction to reconfigure the bias portions of the state vector and the covariance matrix for this data set (see Section 4.2.7.1).

CALL: SETUP

IN LIST: 0, TAU\_COAS\_ANGLES, BIAS\_VAR\_COAS\_ANGLES,  
VAR\_COAS\_ANGLES, COAS\_ANGLES\_BIAS\_INIT

Also set the positive feedback flag to the display for COAS angles:

ANGLES\_ENABLE\_DISPLAY = 1

3. Save the current values of the “DO\_NAV” flags for the next execution of this subfunction.

DO\_RRDOT\_NAV\_LAST = ON

DO\_RR\_ANGLES\_NAV\_LAST = DO\_RR\_ANGLES\_NAV

DO\_ST\_ANGLES\_NAV\_LAST = DO\_ST\_ANGLES\_NAV

DO\_COAS\_ANGLES\_NAV\_LAST = DO\_COAS\_ANGLES\_NAV

B. Interface Requirements. The input and output variables for this subfunction are described in Table 4.2.7.

C. Processing Requirements. This subfunction is called by

NAV\_ONORBIT\_RENDEZVOUS (Section 4.2.1)

D. Constraints. None

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart can be found in Section 5.2 under the name:

REND\_NAV\_SENSOR\_INIT

Table 4.2.7. REND_NAV_SENSOR_INIT Input/Output		
Variable Name	Input Source	Output Destination
BIAS_VAR_COAS_ANGLES	**	SETUP
BIAS_VAR_RR_ANGLES	**	SETUP
BIAS_VAR_RRDOT	**	SETUP
BIAS_VAR_ST_ANGLES	**	SETUP
COAS_ANGLES_BIAS_INIT	**	SETUP
DO_COAS_ANGLES_NAV	REND_SENSOR_SELECT	
DO_COAS_ANGLES_NAV_LAST	REND_COV_INIT,*	
DO_RR_ANGLES_NAV	REND_SENSOR_SELECT	
DO_RR_ANGLES_NAV_LAST	REND_COV_INIT,*	
DO_RRDOT_NAV_LAST	REND_COV_INIT,*	
DO_ST_ANGLES_NAV	REND_SENSOR_SELECT	
DO_ST_ANGLES_NAV_LAST	REND_COV_INIT,*	
RR_ANGLES_BIAS_INIT	**	SETUP
RRDOT_BIAS_INIT	**	SETUP
ST_ANGLES_BIAS_INIT	**	SETUP
TAU_COAS_ANGLES	**	SETUP
TAU_RR_ANGLES	**	SETUP
TAU_RRDOT	**	SETUP
TAU_ST_ANGLES	**	SETUP
VAR_COAS_ANGLES	**	SETUP
N_EDIT		STAR_TRACKER_NAV
VAR_RR_ANGLES	**	SETUP
VAR_RRDOT	**	SETUP
VAR_ST_ANGLES	**	SETUP
ANGLES_ENABLE_DISPLAY		*

\* Onorbit/Rendezvous principal function, see Tables 4.2.11-1 and 4.2.11-2.  
\*\* Initialization parameters, see Section 4.7.

#### 4.2.7.1 Sensor Covariance and Bias Setup (SETUP)

The Sensor Measurement Initialization subfunction (Section 4.2.7) shall invoke the Sensor Covariance and Bias Setup subfunction to reconfigure the bias portions of the state vector and the covariance matrix whenever the Covariance Matrix Initialization subfunction (REND\_COV\_INIT) has been exercised since the last covariance propagation subcycle, or when a new measurement set has been selected since the previous covariance propagation subcycle. New exponentially correlated time constants and process noise variances are also selected from premission values for use in the computation of the state transition matrix and in the addition of process noise.

A. Detailed Requirements. This subfunction is called with the following internal variables in the IN LIST:

IN LIST: I, TAU, BIAS\_VAR, BIAS\_COV\_VAR, BIAS\_INIT

where

I is a pointer for the desired measurement set

= 0 for all angle data

= 2 for rendezvous range and range rate data

TAU sensor time constants

BIAS\_VAR sensor bias variances

BIAS\_COV\_VAR sensor bias variance terms for the covariance matrix

BIAS\_INIT initial sensor bias

The following steps shall be performed for J = 1 to 2:

1.  $K = I + J$
2. The state vector is to be reconfigured by setting its bias slots associated with the new measurement types to premission values. Bias values of measurement types no longer needed do not have to be zeroed.

$$TAU\_SENS_K = TAU_J$$

$$SENSOR\_BIAS_K = BIAS\_INIT_J$$

$$VAR\_SENS_K = BIAS\_VAR_J$$

3. The covariance matrix is to be reconfigured by zeroing the off-diagonal terms associated with the new measurement type. The diagonal terms are then set equal to premission variance values of the new measurement type. The rows and columns associated with the discontinued measurement types do not have to be zeroed unless they are used by a new measurement type.

$$E_{9+K,1to13} = 0.0$$

$$E_{1to13,9+K} = 0.0$$

$$E_{9+K,9+K} = \text{BIAS\_COV\_VAR}_J$$

4. The accept/reject counters and the edit ratio of the residual edit test for each measurement group must be reset to zero for use by the Measurement Processing Statistics subfunction (Section 4.2.9).

$$N\_ACCEPT_K = 0$$

$$N\_REJECT_K = 0$$

$$SEQ\_ACCEPT_K = 0$$

$$SEQ\_REJECT_K = 0$$

$$NAV\_SIG_K = 0.0$$

B. Interface Requirements. The input and output variables for this subfunction are defined in Table 4.2.7.1.

C. Processing Requirements. This subfunction is called by

REND\_NAV\_SENSOR\_INIT (Section 4.2.7)

D. Constraints. None

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart can be found in Section 5.2 under the following name:

SETUP



Table 4.2.7.1. SETUP Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
BIAS_COV_VAR	$\bar{V}AR\_RRDOT$	REND_NAV_SENSOR_INIT	
BIAS_INIT	$\bar{R}RDOT\_BIAS\_INIT$	REND_NAV_SENSOR_INIT	
BIAS_VAR	$\bar{B}IAS\_VAR\_RRDOT$	REND_NAV_SENSOR_INIT	
I	2	REND_NAV_SENSOR_INIT	
TAU	$\bar{T}AU\_RRDOT$	REND_NAV_SENSOR_INIT	
BIAS_COV_VAR	$\bar{V}AR\_RR\_ANGLES$	REND_NAV_SENSOR_INIT	
BIAS_INIT	$\bar{R}R\_ANGLES\_BIAS\_INIT$	REND_NAV_SENSOR_INIT	
BIAS_VAR	$\bar{B}IAS\_VAR\_RR\_ANGLES$	REND_NAV_SENSOR_INIT	
I	0	REND_NAV_SENSOR_INIT	
TAU	$\bar{T}AU\_RR\_ANGLES$	REND_NAV_SENSOR_INIT	
BIAS_COV_VAR	$\bar{V}AR\_ST\_ANGLES$	REND_NAV_SENSOR_INIT	
BIAS_INIT	$\bar{S}T\_ANGLES\_BIAS\_INIT$	REND_NAV_SENSOR_INIT	
BIAS_VAR	$\bar{B}IAS\_VAR\_ST\_ANGLES$	REND_NAV_SENSOR_INIT	
TAU	$\bar{T}AU\_ST\_ANGLES$	REND_NAV_SENSOR_INIT	
BIAS_COV_VAR	$\bar{V}AR\_COAS\_ANGLES$	REND_NAV_SENSOR_INIT	
BIAS_INIT	$\bar{C}OAS\_ANGLES\_BIAS\_INIT$	REND_NAV_SENSOR_INIT	
BIAS_VAR	$\bar{B}IAS\_VAR\_COAS\_ANGLES$	REND_NAV_SENSOR_INIT	
TAU	$\bar{T}AU\_COAS\_ANGLES$	REND_NAV_SENSOR_INIT	

Table 4.2.7.1.(1) SETUP Input/Output		
Variable Name	Input Source	Output Destination
E		COV_LAST_RESET, REND_NAV_FILTER, REND_BIAS_AND_COV_PROP,*
N_ACCEPT		MEAS_PROCESSING_STATISTICS_REND,*
NAV_SIG		RRDOT_NAV, RR_ANGLE_NAV, ANGLE_NAV, MEAS_PROCESSING_STATISTICS_REND
N_REJECT		MEAS_PROCESSING_STATISTICS_REND,*
SENSOR_BIAS		REND_NAV_FILTER, RRDOT_NAV, RR_ANGLE_NAV, ANGLE_NAV, NAV_ONORBIT_RENDEZVOUS
SEQ_ACCEPT		MEAS_PROCESSING_STATISTICS_REND,*
SEQ_REJECT		MEAS_PROCESSING_STATISTICS_REND,*
TAU_SENS		REND_BIAS_AND_COV_PROP
VAR_SENS		REND_BIAS_AND_COV_PROP
* Onorbit/Rendezvous principal function, see Table 4.2.11-2.		

#### 4.2.8 State and Covariance Measurement Incorporation

This section documents the requirements for the following four rendezvous sensor navigation measurement incorporation subfunctions:

- Rendezvous radar range and range rate measurements
- Rendezvous radar shaft and trunnion angle measurements
- Star tracker horizontal and vertical angle measurements
- COAS horizontal and vertical angle measurements

Each measurement incorporation subfunction updates the state vector and covariance matrix with the corresponding rendezvous sensor data using a 13– state process noise Kalman filter.

##### 4.2.8.1 Rendezvous Radar Range and Range Rate Measurements (RRDOT\_NAV)

This subfunction is responsible for the proper processing of the rendezvous radar range and range rate measurements. This subfunction shall perform the following tasks only when the rendezvous radar is not in the self–test mode and the measurement data is labeled valid.

- Calculate the partial derivative of the measurement with respect to the estimated state at measurement time
- Compute the estimated measurement and the measurement residual
- Select the proper variances to model the uncorrelated measurement errors
- Store the old residual ratio, the EDIT OVERRIDE flag, and the STAT flags into temporary locations used by the Kalman Filter Updates subfunction (Section 4.2.8.1.2)
- Schedule the Kalman Filter Updates subfunction to process the data
- Store the current residual ratio, the EDIT flag, and the measurement residual for display purposes

A. Detailed Requirements. The following steps shall be performed (in the order indicated):

1. If the rendezvous radar is not in the self–test mode (`SELF_TEST_FLAG = OFF`), then continue with the measurement processing; otherwise exit this subfunction.
  - a. Set an offset calculation flag which will be used by `REND_NAV_INTERP` to compute variables that take into account the radar antenna offset with respect to the Shuttle navigation reference point (i.e., center of gravity).

`R_OFFSET_CALC = ON`

- b. The time interval between the current filter time and the time of the radar measurement shall be computed:

`DELTAT_GO = T_CURRENT_FILT – T_REND_RADAR`

- c. Test the range data good flag. If the data is good, perform the following steps:
- (1) Call the Measurement Interpolation subfunction to interpolate the orbiter state vector and the target state vector to the time of the range measurement (see Section 4.2.8.1.1):

CALL: REND\_NAV\_INTERP

REND\_NAV\_INTERP subfunction shall also compute an orbiter or target patch transition matrix PHI\_PATCH, and the relative position vector  $\bar{R}_{RHO}$ , its magnitude, and corresponding unit vector to be used in this subfunction.

- (2) The rendezvous radar range measurement partial vector is computed with the following equations:

$$\begin{aligned} B_{1\text{ to }6} &= -(\text{PHI\_PATCH}_{1\text{ to }3, 1\text{ to }6})^T \bar{I}_{RHO} \\ B_{12} &= 1.0 \end{aligned}$$

- (3) The estimated range measurement and the range measurement residual are then calculated:

$$\begin{aligned} \text{RNG} &= R_{RHO\_MAG} + \text{SENSOR\_BIAS}_3 \\ \text{DELQ} &= Q_{RR\_RNG} - \text{RNG} \end{aligned}$$

- (4) The variance of the uncorrelated range measurement noise is computed:

$$\begin{aligned} \text{VAR} &= (\text{SIG}_{RR\_RNG} + \text{SLOPE\_SIG}_{RR\_RNG} R_{RHO\_MAG})^2 \\ \text{VAR} &= \text{MAXIMUM} [\text{VAR}, \text{VAR}_{RR\_RNG\_MIN}] \end{aligned}$$

- (5) The residual test ratio from the previous filter cycle and the measurement processing control flags shall be set as follows:

$$\begin{aligned} \text{RESID\_RATIO\_OLD} &= \text{NAV\_SIG}_3 \\ \text{MANUAL\_EDIT\_OVERRIDE} &= \text{RANGE\_EDIT\_OVERRIDE} \\ \text{STAT\_FLAG} &= \text{RANGE\_STAT} \end{aligned}$$

where RANGE\_EDIT\_OVERRIDE and RANGE\_STAT come from the Sensor Measurement Selection subfunction (Section 4.2.6) and the NAV\_SIG<sub>3</sub> comes from the previous navigation cycle's execution of this subfunction as given in the forthcoming step (9).

- (6) The Kalman Filter Update subfunction (Section 4.2.8.1.2) shall then be called to update the state and the covariance matrix:

CALL: REND\_NAV\_FILTER

- (7) The measurement edit flag, the residual test ratio, and the range measurement residual shall then be stored for subsequent computation of measurement processing statistics, as described in Section 4.2.9:

$$\begin{aligned} \text{SENSOR\_EDIT}_3 &= \text{EDIT\_FLAG} \\ \text{NAV\_SIG}_3 &= \text{RESID\_TEST\_RATIO} \\ \text{SENSOR\_DELQ}_3 &= \text{DELQ} \end{aligned}$$

- d. Test the range rate data good flag. If the data is good, perform the following steps:

- (1) Call the Measurement Interpolation subfunction (Section 4.2.8.1.1) to interpolate the orbiter state vector and the target state vector to the time of the range rate measurement:

CALL: `REND_NAV_INTERP`.

`REND_NAV_INTERP` subfunction shall also compute an orbiter or target patch transition matrix  $\overline{\text{PHI\_PATCH}}$  and the relative position vector  $\overline{\text{R\_RHO}}$ , its magnitude, and corresponding unit vector to be used in this subfunction.

- (2) The rendezvous radar range rate measurement partial vector is computed with the following equations:

$$\overline{\text{U\_RDOT}} = \overline{\text{V\_RHO}} / \text{R\_RHO\_MAG} \quad \text{F3}$$

F3 This equation shall be protected against division by zero (reference 3.5).

$$\text{B}_{1\text{ to }3} = \overline{\text{I\_RHO}} \times (\overline{\text{I\_RHO}} \times \overline{\text{U\_RDOT}})$$

$$\text{B}_{4\text{ to }6} = -\overline{\text{I\_RHO}}$$

$$\text{B}_{1\text{ to }6} = (\text{PHI\_PATCH})^T \text{B}_{1\text{ to }6}$$

$$\text{B}_{13} = 1.0$$

- (3) The estimated range rate measurement and the measurement residual are then calculated:

$$\text{RNG\_DOT} = \overline{\text{R\_RHO}} \cdot \overline{\text{U\_RDOT}} + \text{SENSOR\_BIAS}_4$$

$$\text{DELQ} = \text{Q\_RR\_RNG\_DOT} - \text{RNG\_DOT}$$

where  $\overline{\text{R\_RHO}}$  is the antenna to target vector.

- (4) The variance of the uncorrelated range rate measurement error is defined:

$$\text{VAR} = \text{VAR\_RANGE\_DOT}$$

- (5) The residual test ratio from the previous filter cycle and the filter processing control flags shall be set as follows:

RESID\_RATIO\_OLD = NAV\_SIG<sub>4</sub>

MANUAL\_EDIT\_OVERRIDE = RDOT\_EDIT\_OVERRIDE

STAT\_FLAG = RDOT\_STAT

where RDOT\_EDIT\_OVERRIDE and RDOT\_STAT come from the Sensor Measurement Selection subfunction (Section 4.2.6) and the NAV\_SIG<sub>4</sub> comes from the previous navigation cycle's execution of this subfunction as given in the forthcoming step (9).

- (6) The Kalman Filter subfunction (Section 4.2.8.1.2) shall then be called to update the state and the covariance matrix:

CALL: REND\_NAV\_FILTER

- (7) The measurement edit flag, the residual test ratio, and the range rate measurement residual shall then be stored for subsequent computation of measurement processing statistics, as described in Section 4.2.9:

SENSOR\_EDIT<sub>4</sub> = EDIT\_FLAG

NAV\_SIG<sub>4</sub> = RESID\_TEST\_RATIO

SENSOR\_DELQ<sub>4</sub> = DELQ

- e. Reset the offset calculation flag.

R\_OFFSET\_CALC = OFF

B. Interface Requirements. The input and output variables for the Rendezvous Radar Range and Range Rate Measurement subfunction are given in Table 4.2.8.1.

C. Processing Requirements. This subfunction is called by

NAV\_ONORBIT\_RENDEZVOUS (Section 4.2.1)

D. Constraints. None

E. Supplementary Information. A suggested implementation in the form of a detailed flowchart can be found in Section 5.2 under the name:

RRDOT\_NAV

Table 4.2.8.1. RRDOT\_NAV Input/Output

Variable Name	Input Source	Output Destination
B		REND_NAV_FILTER
DELQ		REND_NAV_FILTER
DELTAT_GO		REND_NAV_INTERP, ONORBIT_SV_INTERP
EDIT_FLAG	REND_NAV_FILTER	
$\bar{I}$ _RHO	REND_NAV_INTERP	
MANUAL_EDIT_OVERRIDE		REND_NAV_FILTER
NAV_SIG	SETUP	MEAS_PROCESSING_STATISTICS_ REND
PHI_PATCH	REND_NAV_INTERP	
Q_RR_RNG	NAV_ONORBIT_RENDEZVOUS	
Q_RR_RNG_DOT	NAV_ONORBIT_RENDEZVOUS	
†	QUAT_TO_MAT	
RANGE_EDIT_OVERRIDE	REND_SENSOR_SELECT	
RANGE_STAT	REND_SENSOR_SELECT	
RDOT_DATA_GOOD	NAV_ONORBIT_RENDEZVOUS	
RDOT_EDIT_OVERRIDE	REND_SENSOR_SELECT	
RDOT_STAT	REND_SENSOR_SELECT	
RESID_RATIO_OLD		REND_NAV_FILTER
RESID_TEST_RATIO	REND_NAV_FILTER	
RNG_DATA_GOOD	NAV_ONORBIT_RENDEZVOUS	
R_OFFSET_CALC		REND_NAV_INTERP
$\bar{R}$ _RHO	REND_NAV_INTERP	
R_RHO_MAG	REND_NAV_INTERP	
SELF_TEST_FLAG	NAV_ONORBIT_RENDEZVOUS	
SENSOR_BIAS	SETUP, REND_NAV_FILTER	
SENSOR_DELQ		MEAS_PROCESSING_STATISTICS_ REND
SENSOR_EDIT		MEAS_PROCESSING_STATISTICS_ REND,*
SIG_RR_RNG	**	
SLOPE_SIG_RR_RNG	**	
STAT_FLAG		REND_NAV_FILTER
T_CURRENT_FILT	NAV_ONORBIT_RENDEZVOUS	
T_REND_RADAR	NAV_ONORBIT_RENDEZVOUS	
VAR		REND_NAV_FILTER
VAR_RANGE_DOT	**	

Table 4.2.8.1. RRDOT\_NAV Input/Output

Variable Name	Input Source	Output Destination
VAR_RR_RNG_MIN $\bar{V}$ _RHO	** REND_NAV_INTERP	
* Onorbit/Rendezvous principal function, see Table 4.2.11-2. ** Initialization parameters, see Section 4.7. † Value returned from the function.		



#### 4.2.8.1.1 Measurement Interpolation (REND\_NAV\_INTERP)

The Rendezvous Navigation Interpolation subfunction is invoked by the rendezvous sensor measurement incorporation subfunctions and is responsible for providing parameters that have been interpolated from current filter time back to the appropriate sensor measurement time. Specifically, this subfunction is charged with the following tasks.

- Invoke the Onorbit State Vector Interpolation subfunction to interpolate both the Shuttle and target position and velocity vectors from current filter time to the time of the measurement
- Invoke the Mean Conic Partial Transition Matrix subfunction to calculate a patch transition matrix from current filter time to the measurement time for either the Shuttle or target vehicle, depending on which vehicle state is to be updated by the Kalman filter
- Calculate the relative velocity, relative position vector, range, and the line of sight vector between the Shuttle and target. Each of these parameters is computed using the interpolated positions and velocities

A. Detailed Requirements. The following steps shall be performed (in the order indicated):

1. The orbiter state vector shall be interpolated to the time of the measurement with the use of the State Vector Interpolation subfunction as described in Section 4.2.8.1.1.1.

CALL: ONORBIT\_SV\_INTERP

IN LIST:  $\bar{R}_{LAST}$ ,  $\bar{V}_{LAST}$ ,  $\bar{R}_{FILT}$ ,  $\bar{V}_{FILT}$ ,  $\bar{D}V_{COV}$ , IGD, IGO, IDRAG, IVENT, ATFL\_OV

OUT LIST:  $\bar{R}_{RESID}$ ,  $\bar{V}_{RESID}$ ,  $\bar{A}_{RESID}$

2. The target state vector shall be interpolated to the time of the measurement with the use of the State Vector Interpolation subfunction as described in Section 4.2.8.1.1.1.

CALL: ONORBIT\_SV\_INTERP

IN LIST:  $\bar{R}_{TV\_LAST}$ ,  $\bar{V}_{TV\_LAST}$ ,  $\bar{R}_{TV}$ ,  $\bar{V}_{TV}$ ,  $\bar{0}$ , GM\_DEG, GM\_ORD, DFL, VFL\_TV, ATFL\_TV

OUT LIST:  $\bar{R}_{TV\_RESID}$ ,  $\bar{V}_{TV\_RESID}$ ,  $\bar{A}_{TV\_RESID}$

3. Next, the SHUTTLE\_FILTER\_FLAG is tested to see if the Shuttle state or the target state is to be included in the Kalman filter.

- a. If the Shuttle vehicle is the filter vehicle, then the Position Velocity State Transition Submatrix subfunction is used to construct an orbiter patch transition matrix as described in Section 4.2.5.2 for use in the measurement partial calculations.

CALL: MEAN\_CONIC\_PARTIAL\_TRANSITION\_MATRIX\_6X6

IN LIST:  $\bar{R}_{FILT}$ ,  $\bar{V}_{FILT}$ ,  $\bar{TOT\_ACC}$ ,  $\bar{R}_{RESID}$ ,  $\bar{V}_{RESID}$ ,  $\bar{A}_{RESID}$ ,  
-DELTAT\_GO

OUT LIST: PHI\_PATCH

- b. If the target vehicle is the filter vehicle, then the PositionVelocity State Transition Submatrix subfunction is used to construct a target patch transition matrix as described in Section 4.2.5.2 for use in the measurement partials calculation.

CALL: MEAN\_CONIC\_PARTIAL\_TRANSITION\_MATRIX\_6X6

IN LIST:  $\bar{R}_{TV}$ ,  $\bar{V}_{TV}$ ,  $\bar{G}_{TV}$ ,  $\bar{R}_{TV\_RESID}$ ,  $\bar{V}_{TV\_RESID}$ ,  
 $\bar{A}_{TV\_RESID}$ , -DELTAT\_GO

OUT LIST: PHI\_PATCH

4. The following auxiliary parameters will be calculated for use by the measurement subfunctions.

$$\bar{V}_{RHO} = \bar{V}_{TV\_RESID} - \bar{V}_{RESID}$$

$$\bar{R}_{RHO} = \bar{R}_{TV\_RESID} - \bar{R}_{RESID}$$

5. If this subfunction has been called by RRDOT\_NAV or RR\_ANGLE\_NAV (i.e., if R\_OFFSET\_CALC = ON), then perform the following computations:

- a. Transform the offset vector, Shuttle navigation reference point to the antenna, given in body coordinates into the M50 coordinate system.

$$\bar{R}_{OFFSET\_M50} = (\text{QUAT\_TO\_MAT}(\text{Q\_M50BODY\_RR}))^T \bar{R}_{OFFSET\_BODY}$$

- b. Translate the relative Shuttle-to-target M50 vector into the relative antenna-to-target M50 vector.

$$\bar{R}_{RHO} = \bar{R}_{RHO} - \bar{R}_{OFFSET\_M50}$$

6. Compute the magnitude of the relative position vector, R\_RHO, as calculated in 4 or 5.

$$R\_RHO\_MAG = |\bar{R}_{RHO}|$$

7. If R\_RHO\_MAG is less than a premission-determined constant, SENSOR\_EPS, then

$$I\_RHO_I = \text{SENSOR\_DELTA FOR } I = 1 \text{ to } 3$$

$$R\_RHO\_MAG = \text{SENSOR\_EPS}$$

Otherwise

$$\bar{I}_{RHO} = \bar{R}_{RHO}/R\_RHO\_MAG$$

F3

F3 This equation shall be protected against division by zero (reference 3.5).

B. Interface Requirements. The input and output data are shown in Table 4.2.8.1.1.

C. Processing Requirements. This subfunction is called by the following subfunctions:

ANGLE\_NAV (Section 4.2.8.3.1)

RR\_ANGLE\_NAV (Section 4.2.8.2)

RRDOT\_NAV (Section 4.2.8.1)

D. Constraints. None

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart may be found in Section 5.2 under the name REND\_NAV\_INTERP.

Table 4.2.8.1.1. REND\_NAV\_INTERP Input/Output

Variable Name	Input Source	Output Destination
$\bar{A}$ _RESID	ONORBIT_SV_INTERP	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
ATFL_OV	**	ONORBIT_SV_INTERP
ATFL_TV	**	ONORBIT_SV_INTERP
$\bar{A}$ _TV_RESID	ONORBIT_SV_INTERP	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
DELTAT_GO	COAS_NAV, RR_ANGLE_NAV, RRDOT_NAV, STAR_TRACKER_NAV	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
DFL	**	ONORBIT_SV_INTERP
$\bar{D}$ V_COV	NAV_ONORBIT_RENDEZVOUS,*, COV_LAST_RESET	ONORBIT_SV_INTERP
GM_DEG	**	ONORBIT_SV_INTERP
GM_ORD	**	ONORBIT_SV_INTERP
$\bar{G}$ _TV	ONORBIT_REND_R_V_STATE_PROP	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
IDRAG	ONORBIT_REND_R_V_STATE_PROP	ONORBIT_SV_INTERP
IGD	ONORBIT_REND_R_V_STATE_PROP	ONORBIT_SV_INTERP
IGO	ONORBIT_REND_R_V_STATE_PROP	ONORBIT_SV_INTERP
IVENT	ONORBIT_REND_R_V_STATE_PROP	ONORBIT_SV_INTERP
PHI_PATCH	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6	REND_ANGLE_PARTIALS, RRDOT_NAV
Q_M50BODY_RR	NAV_ONORBIT_RENDEZVOUS	QUAT_TO_MAT
$\bar{R}$ _FILT	ONORBIT_REND_R_V_STATE_PROP	ONORBIT_SV_INTERP, MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
$\bar{R}$ _LAST	COV_LAST_RESET,*	ONORBIT_SV_INTERP
$\bar{R}$ _OFFSET_BODY	**	
$\bar{R}$ _OFFSET_CALC	RRDOT_NAV, RR_ANGLE_NAV	
$\bar{R}$ _RESID	ONORBIT_SV_INTERP	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
$\bar{R}$ _TV	ONORBIT_REND_R_V_STATE_PROP	ONORBIT_SV_INTERP, MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
$\bar{R}$ _TV_LAST	COV_LAST_RESET,*	ONORBIT_SV_INTERP
$\bar{R}$ _TV_RESID	ONORBIT_SV_INTERP	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6
SHUTTLE_FILTER_FLAG	**	
$\bar{T}$ OT_ACC	REND_BIAS_AND_COV_PROP	MEAN_CONIC_PARTIAL_TRANSITION_MATRIX_6X6

Table 4.2.8.1.1. REND\_NAV\_INTERP Input/Output

Variable Name	Input Source	Output Destination
$\bar{V}$ _FILT	ONORBIT_REND_R_V_STATE_PROP	ONORBIT_SV_INTERP, MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6X6
VFL_TV	**	ONORBIT_SV_INTERP
$\bar{V}$ _LAST	COV_LAST_RESET,*	ONORBIT_SV_INTERP
$\bar{V}$ _RESID	ONORBIT_SV_INTERP	MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6X6
$\bar{V}$ _TV	ONORBIT_REND_R_V_STATE_PROP	ONORBIT_SV_INTERP, MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6X6
$\bar{V}$ _TV_LAST	COV_LAST_RESET,*	ONORBIT_SV_INTERP
$\bar{V}$ _TV_RESID	ONORBIT_SV_INTERP	MEAN_CONIC_PARTIAL_ TRANSITION_MATRIX_6X6
$\bar{I}$ _RHO		REND_ANGLE_PARTIALS, RRDOT_NAV, RR_ANGLE_NAV
$\bar{R}$ _RHO		REND_ANGLE_PARTIALS, RRDOT_NAV, RR_ANGLE_NAV
R_RHO_MAG		REND_NAV_FILTER, RRDOT_NAV
$\bar{V}$ _RHO		RRDOT_NAV
SENSOR_EPS	**	
SENSOR_DELTA	**	

\* Onorbit/Rendezvous principal function, see Table 4.2.11-1.  
\*\* Initialization parameters, see Section 4.7.

#### 4.2.8.1.1.1 State Vector Interpolation and Extrapolation (ONORBIT\_SV\_INTERP)

The State Vector Interpolation subfunction shall provide the approximate position, velocity, and acceleration of either the orbiter or target at a specified time by making use of the position, velocity, and acceleration vectors that are known at both ends of the interval defined by the time of the last covariance propagation cycle, T\_LAST (orbiter) or T\_TV\_LAST (target) and the time of the current covariance propagation cycle, T\_CURRENT\_FILT.

The time at which vectors are desired is the time of external sensor measurement, and the purpose of the interpolation/extrapolation is to enable the navigation filter to calculate measurement residuals at that time.

The method utilized for interpolation/extrapolation shall consist of defining a mean conic on the basis of positions and velocities of the vehicle in question at both ends of the propagation interval, and obtaining the desired vectors as if the vehicle moved along this mean conic. That is, a calculation shall be made to determine the point on the mean conic corresponding to the time of the measurement, and the velocity and position of such a point shall be taken as the state of the vehicle.

A. Detailed Requirements. This subfunction is called with the following internal variables in the IN LIST and the OUT LIST:

IN LIST:  $\bar{R}_{ONE}$ ,  $\bar{V}_{ONE}$ ,  $\bar{R}_{TWO}$ ,  $\bar{V}_{TWO}$ ,  $\bar{V}_{IMU\_DIF}$ , IGD, IGO, IDM, IVM, IATM

OUT LIST:  $\bar{R}_{RESID}$ ,  $\bar{V}_{RESID}$ ,  $\bar{A}_{RESID}$

where

$\bar{R}_{ONE}$  } position and velocity of the vehicle at the previous  
 $\bar{V}_{ONE}$  } propagation step;

$\bar{R}_{TWO}$  } current position and velocity  
 $\bar{V}_{TWO}$  }

V\_IMU\_DIF difference between IMU accumulated sensed velocities at the current time and the previous time

IGD }  
IGO } flags for the call to the acceleration function  
IDM } ACCEL\_ONORBIT (refer to Section 4.2.4.1.1 for  
IDM } details of these flags)  
IVM }  
IATM }

The following steps shall be performed (in the order indicated):

1. A check of the absolute value of DELTAT\_GO (where DELTAT\_GO is the current filter time minus the time of the sensor measurement) against a permission-specified tolerance level will be performed:

$$|\text{DELTAT\_GO}| \leq \text{EPS\_TIME}$$

- a. If it is found that DELTAT\_GO in absolute value is less than or equal to the tolerance, the values of the position and velocity of the vehicle at the current time shall be used as the state at the measurement time; the time tag at the measurement instant shall also be set equal to the current time:

$$\bar{R}_{RESID} = \bar{R}_{TWO}$$

$$\bar{V}_{RESID} = \bar{V}_{TWO}$$

$$T_{RESID} = T_{CURRENT\_FILT}$$

- b. If, on the other hand, the difference between the time of the measurement and the current time exceeds the tolerance, perform the following:

- (1) Certain parameters associated with the mean conic shall be obtained

$$R\_TWO\_INV = 1./|\bar{R}_{TWO}| \quad F3$$

$$SMA = 1./(1./|\bar{R}_{ONE}| + R\_TWO\_INV - (\bar{V}_{ONE} \cdot \bar{V}_{ONE} + \bar{V}_{TWO} \cdot \bar{V}_{TWO})/(2. \text{EARTH\_MU})) \quad F3$$

$$C1 = \text{SQRT}(SMA)/\text{SQR\_EMU} \quad F3,F4$$

$$D\_TWO = R\_TWO \cdot V\_TWO$$

and the time tag of the state vector at measurement time shall be set:

$$T_{RESID} = T_{CURRENT\_FILT} - \text{DELTAT\_GO}$$

Additionally, set  $R\_FIN\_TEMP\_INV = 0$ .

F3 This equation shall be protected against division by zero (reference 3.5).

F4 This equation shall be protected against square roots of a negative number (reference 3.5).

- (2) The F and G series subfunction shall then be called (refer to Section 4.2.5.2.1 for the description of this subfunction)

CALL: F\_AND\_G

IN LIST: SMA, -DELTAT\_GO, C1,  $\bar{R}_{TWO}$ , R\_TWO\_INV, R\_FIN\_TEMP\_INV,  $\bar{V}_{TWO}$ , D\_TWO, D\_FIN\_TEMP

OUT LIST: F, G, FDOT, GDOT, S0, S1, S2, S3,  $\bar{R}_{RESID}$ , R\_FIN\_INV, THETA

The position vector ( $\bar{R}_{RESID}$ ) comes out of this call; the velocity vector ( $\bar{V}_{RESID}$ ) does not, but it can be calculated on the basis of FDOT and GDOT, which are also obtained from the F and G series call:

$$\bar{V}_{RESID} = FDOT \bar{R}_{TWO} + GDOT \bar{V}_{TWO}$$

2. Finally, the modeled acceleration shall be obtained by invoking the acceleration function with the position, velocity, and time (determined by the above process) in the calling arguments and adding the central force term. The sensed acceleration shall be found by dividing the difference in accumulated sensed velocities at both ends of the propagation interval by the duration of the interval. Total acceleration will be the sum of these two.

$$\begin{aligned} \bar{A}_{RESID} = & \bar{ACCEL\_ONORBIT} (IGD, IGO, IDM, IVM, IATM, \\ & \bar{R}_{RESID}, \bar{V}_{RESID}, T_{RESID}) \\ & + \bar{V}_{IMU\_DIF/DT\_COV} \end{aligned} \quad F3$$

(refer to Section 4.2.4.1.1 for the description of this subfunction)

B. Interface Requirements. The input and output data are shown in Table 4.2.8.1.1.1.

C. Processing Requirements. This subfunction is called by

REND\_NAV\_INTERP (Section 4.2.8.1.1)

D. Constraints. None

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart may be found in Section 5.2 under the name of ONORBIT\_SV\_INTERP.



Table 4.2.8.1.1.1. ONORBIT_SV_INTERP Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
IATM	ATFL_OV	REND_NAV_INTERP	
IDM	IDRAG	REND_NAV_INTERP	
IGD	IGD	REND_NAV_INTERP	
IGO	IGO	REND_NAV_INTERP	
IVM	IVENT	REND_NAV_INTERP	
$\bar{R}$ _ONE	$\bar{R}$ _LAST	REND_NAV_INTERP	
$\bar{R}$ _TWO	$\bar{R}$ _FILT	REND_NAV_INTERP	
$\bar{V}$ _IMU_DIF	$\bar{D}$ V_COV	REND_NAV_INTERP	
$\bar{V}$ _ONE	$\bar{V}$ _LAST	REND_NAV_INTERP	
$\bar{V}$ _TWO	$\bar{V}$ _FILT	REND_NAV_INTERP	
IATM	ATFL_TV	REND_NAV_INTERP	
IDM	DFL	REND_NAV_INTERP	
IGD	GM_DEG	REND_NAV_INTERP	
IGO	GM_ORD	REND_NAV_INTERP	
IVM	VFL_TV	REND_NAV_INTERP	
$\bar{R}$ _ONE	$\bar{R}$ _TV_LAST	REND_NAV_INTERP	
$\bar{R}$ _TWO	$\bar{R}$ _TV	REND_NAV_INTERP	
$\bar{V}$ _IMU_DIF	O	REND_NAV_INTERP	
$\bar{V}$ _ONE	$\bar{V}$ _TV_LAST	REND_NAV_INTERP	
$\bar{V}$ _TWO	$\bar{V}$ _TV	REND_NAV_INTERP	
$\bar{A}$ _RESID	$\bar{A}$ _RESID		REND_NAV_INTERP
$\bar{R}$ _RESID	$\bar{R}$ _RESID		REND_NAV_INTERP
$\bar{V}$ _RESID	$\bar{V}$ _RESID		REND_NAV_INTERP
$\bar{A}$ _RESID	$\bar{A}$ _TV_RESID		REND_NAV_INTERP
$\bar{R}$ _RESID	$\bar{R}$ _TV_RESID		REND_NAV_INTERP
$\bar{V}$ _RESID	$\bar{V}$ _TV_RESID		REND_NAV_INTERP

Table 4.2.8.1.1.1.(1) ONORBIT_SV_INTERP Input/Output		
Variable Name	Input Source	Output Destination
DELTAT_GO	COAS_NAV, RR_ANGLE_NAV, RRDOT_NAV, STAR_TRACKER_NAV	F_AND_G
DT_COV	REND_BIAS_AND_COV_PROP	
EARTH_MU	**	
EPS_TIME	**	
F	F_AND_G	
FDOT	F_AND_G	
G	F_AND_G	
GDOT	F_AND_G	
R_FIN_INV	F_AND_G	
$\bar{R}$ _RESID	F_AND_G	$\bar{A}$ CCEL_ONORBIT
SQR_EMU	*	
S0	F_AND_G	
S1	F_AND_G	
S2	F_AND_G	
S3	F_AND_G	
T_CURRENT_FILT	NAV_ONORBIT_RENDEZVOUS	
THETA	F_AND_G	
†	$\bar{A}$ CCEL_ONORBIT	
C1		F_AND_G
D_FIN_TEMP	**	F_AND_G
D_TWO		F_AND_G
IATM		$\bar{A}$ CCEL_ONORBIT
IDM		$\bar{A}$ CCEL_ONORBIT
IGD		$\bar{A}$ CCEL_ONORBIT
IGO		$\bar{A}$ CCEL_ONORBIT
IVM		$\bar{A}$ CCEL_ONORBIT
R_FIN_TEMP_INV		F_AND_G
$\bar{R}$ _TWO		F_AND_G
R_TWO_INV		F_AND_G
SMA		F_AND_G
T_RESID		$\bar{A}$ CCEL_ONORBIT
$\bar{V}$ _RESID		$\bar{A}$ CCEL_ONORBIT
$\bar{V}$ _TWO		F_AND_G
<p>* Onorbit/Rendezvous principal function, see Table 4.2.11-1.  ** Initialization parameters, see Section 4.7.  † Value returned from the function.</p>		

#### 4.2.8.1.2 Kalman Filter Updates (REND\_NAV\_FILTER)

The Kalman Filter Updates subfunction shall be responsible for the processing of the rendezvous sensor measurement data. If the estimated range between the orbiter and target vehicles is greater than or equal to a design dependent minimum range threshold, then the Kalman Filter Updates subfunction will perform the following major tasks.

- A bilevel residual edit test will be performed to determine whether the Kalman filter scheme will be used to update the state vector. This subfunction shall be able to respond to crew requests to relax the edit criteria thereby increasing the likelihood of incorporating the measurement data into the state vector.
- This subfunction shall be able to update the covariance matrix as well as the state vector by means of the Kalman update equations. The Kalman filter scheme shall be modified to allow for underweighting of the estimated sensor variance and the selective updating of the unmodeled acceleration bias states.
- Finally, the Kalman Filter Updates subfunction shall record the type of data processing that has occurred for crew display.

A. Detailed Requirements. For the measurement type to be processed on this cycle, test the magnitude of the relative position vector (R\_RHO\_MAG) against the minimum separation distance (RNG\_MIN) to determine whether or not to exercise the Kalman filter update equations.

If  $R\_RHO\_MAG < RNG\_MIN$ , the EDIT\_FLAG is to be set to OFF in order to blank the display. (Note: The measurement subfunction generates the partial vector, the residual, the magnitude of the relative position vector, and the a priori variance.) The logic then exits REND\_NAV\_FILTER without exercising the Kalman filter equations.

If  $R\_RHO\_MAG \geq RNG\_MIN$ , exercise the Kalman filter update equations, as follows:

1. Test the SHUTTLE\_FILTER\_FLAG. If the target is the filter vehicle (SHUTTLE\_FILTER\_FLAG = OFF), the sign is changed on the measurement partials vector.

$$B_{1\text{ to }6} = -B_{1\text{ to }6}$$

2. The scalar quantity BT\_E\_B is to be calculated from the covariance matrix E and vector measurement partials  $\bar{B}$ ,

$$\begin{aligned} EB\_COPY &= E B \\ BT\_E\_B &= B \cdot EB\_COPY, \end{aligned}$$

where the second equation requires a dot product. The partials vector B shall then be set equal to zero so that subsequent measurement subroutines will only be required to calculate nonzero elements.

$$B = 0.$$

The quantity MS\_DELQ, which represents the expected variance in the residual, is then to be computed by

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

3. If the trace of the filter vehicle position portion of the covariance matrix ( $E_{1,1} + E_{2,2} + E_{3,3}$ ) is greater than a threshold, MS\_POS\_UND\_WGT, then the denominator of the Kalman gains is underweighted in order to improve the transient response of the filter.

$$MS\_DELQ = MS\_DELQ + K\_UND\_WGT(BT\_E\_B)$$

4. The residual test quantity (RESID\_TEST) shall be computed for the residual edit test and for display purposes,

$$RESID\_TEST = (K\_RES\_EDIT) MS\_DELQ$$

where K\_RES\_EDIT is a premission constant.

5. The residual edit test ratio (RESID\_TEST\_RATIO) is to be computed.

$$RESID\_TEST\_RATIO = ABS(DELQ) / \sqrt{RESID\_TEST} \quad \begin{array}{l} F3 \\ F4 \end{array}$$

F3 This equation shall be protected against division by zero (reference 3.5).

F4 This equation shall be protected against square roots of a negative number (reference 3.5).

6. Test STAT\_FLAG to determine if the residual and residual ratio have been computed on this cycle for display purposes only. If STAT\_FLAG = ON, set

$$EDIT\_FLAG = STAT$$

for display (Section 4.2.9) and exit REND\_NAV\_FILTER. If STAT\_FLAG is OFF, proceed to the next step in the logic.

7. Preparations for a residual edit test shall be performed. If the manual edit override is inactive, the test quantity (TEST\_VALUE) shall be set equal to 1.0. If, however, a manual edit override is active, the test quantity will be altered according to the following equation:

$$TEST\_VALUE = MAXIMUM (RESID\_RATIO\_OLD + DELTA\_RESID\_RATIO, 1.0)$$

where DELTA\_RESID\_RATIO is a design-dependent constant and RESID\_RATIO\_OLD is the value of the residual ratio for the sensor type being processed as calculated by the State and Covariance Measurement Incorporation subfunction during the previous navigation cycle.

8. The edit test ( $RESID\_TEST\_RATIO \leq TEST\_VALUE$ ) is performed.

- a. If the test fails, the edit flag is set to ON for crew information.

$$EDIT\_FLAG = ON$$

- b. If the measurements are to be incorporated, then update the state and the covariance matrix.

EXECUTE: REND\_STATE\_AND\_COV\_UPDATE CODE

- (1) Compute the Kalman filter gain and update and symmetrize the covariance matrix.

$$\left. \begin{aligned} \text{OMEGA} &= \text{EB\_COPY}/\text{MS\_DELQ} \\ E_{i,i} &= E_{i,i} - \text{OMEGA}_i \text{EB\_COPY}_i \\ E_{i,j} &= E_{i,j} - \text{OMEGA}_i \text{EB\_COPY}_j \\ E_{j,i} &= E_{i,j} \end{aligned} \right\} \begin{array}{l} \text{for } I = 1,12 \\ \text{and } J = I + 1,13 \end{array} \quad \text{F3}$$

F3 This equation shall be protected against division by zero (reference 3.5).

Finally,  $E_{13,13} = E_{13,13} - \text{OMEGA}_{13} \text{EB\_COPY}_{13}$ .

- (2) Compute the correction to the position and velocity, and add these to  $\bar{R}_{\text{MEAS}}$  and  $\bar{V}_{\text{MEAS}}$  for later use in computation of a downlist and display parameter.

$$\begin{aligned} \bar{R}_{\text{CORR}} &= \text{OMEGA}_{1 \text{ to } 3} \text{DELQ} \\ \bar{V}_{\text{CORR}} &= \text{OMEGA}_{4 \text{ to } 6} \text{DELQ} \\ \bar{R}_{\text{MEAS}} &= \bar{R}_{\text{MEAS}} + \bar{R}_{\text{CORR}} \\ \bar{V}_{\text{MEAS}} &= \bar{V}_{\text{MEAS}} + \bar{V}_{\text{CORR}} \end{aligned}$$

- (3) Test the SHUTTLE\_FILTER\_FLAG.

If the Shuttle vehicle is the filter vehicle (SHUTTLE\_FILTER\_FLAG = ON), then this subfunction shall update the Shuttle state vector by application of the following equations:

$$\begin{aligned} \bar{R}_{\text{FILT}} &= \bar{R}_{\text{FILT}} + \bar{R}_{\text{CORR}} \\ \bar{V}_{\text{FILT}} &= \bar{V}_{\text{FILT}} + \bar{V}_{\text{CORR}} \end{aligned}$$

If the target vehicle is the filter vehicle (SHUTTLE\_FILTER\_FLAG = OFF), then this subfunction shall update the target state vector by application of the following equations:

$$\begin{aligned} \bar{R}_{\text{TV}} &= \bar{R}_{\text{TV}} + \bar{R}_{\text{CORR}} \\ \bar{V}_{\text{TV}} &= \bar{V}_{\text{TV}} + \bar{V}_{\text{CORR}} \end{aligned}$$

- (4) If the unmodeled acceleration bias states are to be updated (UNMOD\_ACC\_UPDATE\_FLAG = ON), then this subfunction shall update the unmodeled acceleration bias states by application of the following equation:

$$\bar{\text{UNMOD\_ACC\_BIAS}} = \bar{\text{UNMOD\_ACC\_BIAS}} + \text{OMEGA}_{7 \text{ to } 9} \text{DELQ}$$

- (5) The sensor bias states shall be updated by application of the following equation:

$$\text{SENSOR\_BIAS} = \text{SENSOR\_BIAS} + \text{OMEGA}_{10 \text{ to } 13} \text{DELQ}$$

where DELQ corresponds to the appropriate measurement residual.

After executing `REND_STATE_AND_COV_UPDATE` code, if the manual edit override is active (`MANUAL_EDIT_OVERRIDE = ON`), the edit flag is set to `FORCED`.

`EDIT_FLAG = FORCED`

Otherwise, set the edit flag to `PROCESSED`.

`EDIT_FLAG = PROCESSED`

Both the `FORCED` and the `PROCESSED` conditions result from measurement incorporation.

It is required that the residual, the residual test quantity (`RESID_TEST_RATIO`), and the residual edit flag corresponding to each measurement subfunction be saved for display purposes.

B. Interface Requirements. The inputs and outputs for this subfunction are given in Table 4.2.8.1.2.

C. Processing Requirements. This subfunction is called by the following subfunctions:

<code>ANGLE_NAV</code>	(Section 4.2.8.3.1)
<code>RR_ANGLE_NAV</code>	(Section 4.2.8.2)
<code>RRDOT_NAV</code>	(Section 4.2.8.1)

D. Constraints. None

E. Supplementary Information. A suggested implementation in the form of detailed flow charts can be found in Section 5.2 under the following names:

`REND_NAV_FILTER`

`REND_STATE_AND_COV_UPDATE CODE`

Table 4.2.8.1.2. REND\_NAV\_FILTER Input/Output

Variable Name	Input Source	Output Destination
B	RRDOT_NAV, RR_ANGLE_NAV, REND_ANGLE_PARTIALS, ANGLE_NAV	
DELTA_RESID_RATIO	**	
DELQ	RRDOT_NAV, RR_ANGLE_NAV, ANGLE_NAV	
E	REND_BIAS_AND_COV_PROP, REND_COV_INIT, COVINIT_UVW, U_A_BIAS_AND_COVINIT, SETUP	COV_LAST_RESET, REND_BIAS_AND_COV_PROP,*
EDIT_FLAG		RRDOT_NAV, RR_ANGLE_NAV, ANGLE_NAV
K_RESID_EDIT	**	
K_UND_WGT	**	
MANUAL_EDIT_OVERRIDE	RRDOT_NAV, RR_ANGLE_NAV, ANGLE_NAV	
MS_POS_UND_WGT	**	
RESID_RATIO_OLD	RRDOT_NAV, RR_ANGLE_NAV, ANGLE_NAV	
RESID_TEST_RATIO		RRDOT_NAV, RR_ANGLE_NAV, ANGLE_NAV
$\bar{R}$ _FILT	ONORBIT_REND_R_V_STATE_PROP	COV_LAST_RESET, SHUTTLE_RESET, ONORBIT_REND_R_V_STATE_PROP,* REL_NAV_DISPLAY_UPDATES, REND_COV_INIT, NAV_ONORBIT_RENDEZVOUS
$\bar{R}$ _MEAS	REND_BIAS_AND_COV_PROP	MEAS_PROCESSING_STATISTICS_REND
RNG_MIN	**	
R_RHO_MAG	REND_NAV_INTERP	
$\bar{R}$ _TV	ONORBIT_REND_R_V_STATE_PROP	COV_LAST_RESET, TARGET_RESET, ONORBIT_REND_R_V_STATE_PROP,* REL_NAV_DISPLAY_UPDATES, REND_COV_INIT, NAV_ONORBIT_RENDEZVOUS
SENSOR_BIAS	SETUP	RR_ANGLE_NAV, RRDOT_NAV, ANGLE_NAV, NAV_ONORBIT_RENDEZVOUS
SHUTTLE_FILTER_FLAG	*	
STAT_FLAG	RRDOT_NAV, RR_ANGLE_NAV, ANGLE_NAV	

Table 4.2.8.1.2. REND\_NAV\_FILTER Input/Output

Variable Name	Input Source	Output Destination
$\bar{U}$ NMOD_ACC_BIAS	REND_BIAS_AND_COV_PROP, U_A_BIAS_AND_COVINIT	$\bar{A}$ CCEL_ONORBIT, REND_BIAS_AND_COV_PROP, NAV_ONORBIT_RENDEZVOUS
UNMOD_ACC_UPDATE_FLAG	**	
VAR	RRDOT_NAV, RR_ANGLE_NAV, ANGLE_NAV	
$\bar{V}$ _FILT	ONORBIT_REND_R_V_STATE_PROP	COV_LAST_RESET, SHUTTLE_RESET, ONORBIT_REND_R_V_STATE_PROP,*, REL_NAV_DISPLAY_UPDATES, REND_COV_INIT, NAV_ONORBIT_RENDEZVOUS
$\bar{V}$ _MEAS	REND_BIAS_AND_COV_PROP	MEAS_PROCESSING_STATISTICS_REND
$\bar{V}$ _TV	ONORBIT_REND_R_V_STATE_PROP	COV_LAST_RESET, TARGET_RESET, ONORBIT_REND_R_V_STATE_PROP,*, REL_NAV_DISPLAY_UPDATES, REND_COV_INIT, NAV_ONORBIT_RENDEZVOUS

\* Onorbit/Rendezvous principal function, see Tables 4.2.11-1. and 4.2.11-2.

\*\* Initialization parameters, see Section 4.7.



#### 4.2.8.2 Rendezvous Radar Shaft and Trunnion Angle Measurements (RR\_ANGLE\_NAV)

This subfunction is responsible for the proper processing of the rendezvous radar shaft and trunnion angle measurements. This subfunction shall perform the following tasks only when the rendezvous radar is not in the self-test mode and the measurement data is labeled valid.

- Calculate the partial derivative of the measurement with respect to the estimated state at measurement time.
- Compute the estimated measurement and the measurement residual.
- Select the proper variances to model the uncorrelated measurement errors.
- Store the old residual ratio, the EDIT OVERRIDE flag, and the STAT flags into temporary locations used by the Kalman Filter Updates subfunction (Section 4.2.8.1.2).
- Schedule the Kalman Filter Updates subfunction to process the data.
- Store the current residual ratio, the EDIT flag, and the measurement residual for display purposes.

A. Detailed Requirements. Process the rendezvous radar angle data only if the data are valid and the rendezvous radar is not in the self-test mode (SELF\_TEST\_FLAG = OFF). The following steps shall be performed in the order indicated.

1. Set an offset calculation flag which will be used by REND\_NAV\_INTERP to compute variables that will take into account the radar antenna offset with respect to the Shuttle navigation reference point (i.e., center of gravity).

R\_OFFSET\_CALC = ON

2. Compute the mean of 1950 to sensor coordinate transformation matrix.

M\_M50\_TO\_SENSOR = M\_BODY\_TO\_RR QUAT\_TO\_MAT (Q\_M50BODY\_RR)

3. Compute the time difference between current filter time and the time of the rendezvous radar angle data measurements.

DELTAT\_GO = T\_CURRENT\_FILT - T\_REND\_RADAR

4. Call the Measurement Interpolation subfunction and interpolate the orbiter and target state vectors to the time of the shaft angle measurement (see Section 4.2.8.1.1).

CALL: REND\_NAV\_INTERP

5. Call the Angle Partial subfunction to compute the partial vector (see Section 4.2.8.2.1)

CALL: REND\_ANGLE\_PARTIALS

IN LIST: M\_M50\_TO\_SENSOR<sub>1, 1 to 3</sub>

6. Transform the measurements Q\_RR\_ROLL and Q\_RR\_PITCH, which represent roll and pitch angles, respectively, into shaft and trunnion angles with respect to the antenna system.

$$\text{ROLL} = \text{Q\_RR\_ROLL RAD\_PER\_DEG}$$

$$\text{PITCH} = \text{Q\_RR\_PITCH RAD\_PER\_DEG}$$

$$\text{TRUNNION} = -\text{COS}(\text{K\_ANG})\text{SIN}(\text{PITCH}) + \text{SIN}(\text{K\_ANG})\text{SIN}(\text{ROLL})\text{COS}(\text{PITCH})$$

$$\text{TRUNNION} = \text{ARCSIN}(\text{TRUNNION}) \quad \text{F5}$$

$$\text{SHFT} = -\text{SIN}(\text{K\_ANG})\text{SIN}(\text{PITCH}) - \text{COS}(\text{K\_ANG})\text{SIN}(\text{ROLL})\text{COS}(\text{PITCH})$$

$$\text{SHFT} = \text{ARCTAN2}(\text{SHFT}, \text{COS}(\text{ROLL})\text{COS}(\text{PITCH})) \quad \text{F7}$$

7. Calculation of the partial vector is completed by setting the appropriate value in the bias slot of that vector.

$$B_{10} = 1.0$$

8. Compute the estimated shaft angle measurement and the shaft angle measurement residual.

$$\text{SHAFT} = \text{ARCTAN2} (+U\_M_2, -U\_M_3) + \text{SENSOR\_BIAS}_1 \quad \text{F7}$$

$$\text{DELQ} = \text{SHFT} - \text{SHAFT}$$

9. If measurement residual (DELQ) falls outside the range  $-\pi$  to  $\pi$ , adjust DELQ such that it falls inside the range.

$$\text{If } \text{DELQ} > 0. \text{ DELQ} = \text{DELQ} - 2 \pi$$

$$\text{DELQ} \leq 0. \text{ DELQ} = \text{DELQ} + 2 \pi$$

10. Assign the appropriate variance for the rendezvous radar shaft angle.

$$\text{VAR} = \text{VAR\_SHAFT}$$

11. The residual test ratio from the previous filter cycle and the measurement processing control flags shall be set as follows:

$$\text{RESID\_RATIO\_OLD} = \text{MAX} (\text{NAV\_SIG}_1, \text{NAV\_SIG}_2)$$

$$\text{MANUAL\_EDIT\_OVERRIDE} = \text{RR\_ANGLES\_EDIT\_OVERRIDE}$$

$$\text{STAT\_FLAG} = \text{RR\_ANGLES\_STAT}$$

(where RR\_ANGLES\_EDIT\_OVERRIDE and RR\_ANGLES\_STAT come from the Sensor Measurement Selection subfunction (Section 4.2.6) and NAV\_SIG comes from the previous execution of this subfunction as given in Step 13).

F5 This equation shall be protected against arc sine of arguments with magnitudes greater than unity (reference 3.5).

F7 This equation shall be protected against arc tangents with both arguments equal to zero (reference 3.5).

12. Call the Kalman Filter subfunction to process the rendezvous radar shaft angle measurement (see Section 4.2.8.1.2)

CALL: REND\_NAV\_FILTER

13. Store the output data from the Kalman Filter subfunction in the appropriate variables for use by the Measurement Processing Statistics subfunction.

SENSOR\_EDIT<sub>1</sub> = EDIT\_FLAG  
NAV\_SIG<sub>1</sub> = RESID\_TEST\_RATIO  
SENSOR\_DELQ<sub>1</sub> = DELQ

14. Call the Measurement Interpolation subfunction to interpolate the orbiter and target state vectors to the time of the trunnion angle measurement (see Section 4.2.8.1.1)

CALL: REND\_NAV\_INTERP

15. Call the Angle Partial subfunction to compute the partial vector (see Section 4.2.8.2.1)

CALL: REND\_ANGLE\_PARTIALS

IN LIST: -UNIT ( $\bar{I}$ \_RHO x M\_M50\_TO\_SENSOR<sub>1,1 to 3</sub>)

16. Calculation of the partial vector is completed by setting the appropriate value in the bias slot of that vector.

B<sub>11</sub> = 1.0

17. Compute the estimated trunnion angle measurement and the trunnion angle measurement residual.

TRUN = ARCSIN(-U\_M<sub>1</sub>) + SENSOR\_BIAS<sub>2</sub> F5  
DELQ = TRUNNION - TRUN

F5 This equation shall be protected against arc sine of arguments with magnitudes greater than unity (reference 3.5).

18. Assign the appropriate variance for the rendezvous radar trunnion angle

VAR = VAR\_TRUN

19. Call the Kalman filter to process the rendezvous radar trunnion angle measurement (see Section 4.2.8.1.2)

CALL: REND\_NAV\_FILTER

20. Store the output data from the Kalman Filter subfunction in the appropriate variables for use by the Measurement Processing Statistics subfunction

SENSOR\_EDIT<sub>2</sub> = EDIT\_FLAG  
NAV\_SIG<sub>2</sub> = RESID\_TEST\_RATIO

$$\text{SENSOR\_DELQ}_2 = \text{DELQ}$$

21. Reset the OFFSET calculation flag.

$$\text{R\_OFFSET\_CALC} = \text{OFF}$$

B. Interface Requirements. The input and output variables for this subfunction are defined in Table 4.2.8.2.

C. Processing Requirements. This subfunction is called by NAV\_ONORBIT\_RENDEZVOUS (Section 4.2.1).

D. Constraints. None

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart can be found in Section 5.2 under the name RR\_ANGLE\_NAV.

Table 4.2.8.2. RR_ANGLE_NAV Input/Output		
Variable Name	Input Source	Output Destination
EDIT_FLAG	REND_NAV_FILTER	
I_RHO	REND_NAV_INTERP	
K_ANG	**	
M_BODY_TO_RR	**	
NAV_SIG	SETUP	MEAS_PROCESSING_STATISTICS_REND
PI	**	
Q_M50BODY_RR	NAV_ONORBIT_RENDEZVOUS	QUAT_TO_MAT
Q_RR_ROLL	NAV_ONORBIT_RENDEZVOUS	
Q_RR_PITCH	NAV_ONORBIT_RENDEZVOUS	
R_OFFSET_CALC		REND_NAV_INTERP
RAD_PER_DEG	**	
RESID_TEST_RATIO	REND_NAV_FILTER	
RR_ANGLE_DATA_GOOD	NAV_ONORBIT_RENDEZVOUS	
RR_ANGLES_EDIT_OVERRIDE	REND_SENSOR_SELECT	
RR_ANGLES_STAT	REND_SENSOR_SELECT	
SELF_TEST_FLAG	NAV_ONORBIT_RENDEZVOUS	
SENSOR_BIAS	SETUP, REND_NAV_FILTER	
T_CURRENT_FILT	NAV_ONORBIT_RENDEZVOUS	
T_REND_RADAR	NAV_ONORBIT_RENDEZVOUS	
U_M	REND_ANGLE_PARTIALS	
VAR_SHAFT	**	
VAR_TRUN	**	
B		REND_NAV_FILTER

Table 4.2.8.2. RR_ANGLE_NAV Input/Output		
Variable Name	Input Source	Output Destination
DELQ		REND_NAV_FILTER
DELTAT_GO		REND_NAV_INTERP, ONORBIT_SV_INTERP
MANUAL_EDIT_OVERRIDE		REND_NAV_FILTER
M_M50_TO_SENSOR		REND_ANGLE_PARTIALS
RESID_RATIO_OLD		REND_NAV_FILTER
SENSOR_DELQ		MEAS_PROCESSING_STATISTICS_REND
SENSOR_EDIT		MEAS_PROCESSING_STATISTICS_REND,*
STAT_FLAG		REND_NAV_FILTER
VAR		REND_NAV_FILTER
†	QUAT_TO_MAT	
UNIT ( $\bar{I}_{RHO} \times M_{M50\_TO\_SENSOR_{1,1to3}}$ )		REND_ANGLE_PARTIALS
* Onorbit/Rendezvous principal function, see Table 4.2.11-2.		
** Initialization parameters, see Section 4.7.		
† Value returned from the function.		

#### 4.2.8.2.1 Angle Partial (REND\_ANGLE\_PARTIALS)

The Angle Partial subfunction (REND\_ANGLE\_PARTIALS) is a utility subfunction whose purpose is to compute the angle measurement partial derivatives, with respect to the orbiter position and velocity, for all sensor angle measurements. The partials vector is used by the Kalman Filter Updates subfunction, REND\_NAV\_FILTER (Section 4.2.8.1.2).

##### A. Detailed Requirements.

1. First, we compute  $\bar{RHO\_PLANE}$ , which is the projection of the Shuttle/ target relative position vector,  $\bar{R\_RHO}$ , into the orthogonal complement plane of the axis of rotation of the angle measurement,

$$\bar{RHO\_PLANE} = \bar{R\_RHO} - (\bar{R\_RHO} \cdot \bar{I\_N})\bar{I\_N},$$

where  $\bar{I\_N}$  is a unit vector along the axis of rotation.

2. Next, the partial derivative of the angle measurement with respect to the Shuttle position and velocity is computed.

$$B_{1\ to\ 6} = (PHI\_PATCH_{1\ to\ 3,\ 1\ to\ 6})^T (UNIT(\bar{RHO\_PLANE} \times \bar{I\_N})/|\bar{RHO\_PLANE}|) \quad F3$$

PHI\_PATCH is the position-velocity part of the state transition matrix calculated in the Measurement Interpolation subfunction, REND\_NAV\_INTERP (Section 4.2.8.1.1).

F3 This equation shall be protected against division by zero (reference 3.5).

3. Finally, the unit vector in the line of sight direction,  $\bar{I}_{RHO}$ , is rotated into sensor coordinates

$$\bar{U}_M = M_{M50\_TO\_SENSOR} \bar{I}_{RHO}$$

B. Interface Requirements. Input and output parameters are listed in Table 4.2.8.2.1.

C. Processing Requirements. This subfunction is called by the following subfunctions:

ANGLE\_NAV (Section 4.2.8.3.1)  
RR\_ANGLE\_NAV (Section 4.2.8.2)

D. Constraints. None

E. Supplemental Information. A suggested implementation of the Angle Partial subfunction may be found in Section 5.2 flow chart REND\_ANGLE\_PARTIALS.

Table 4.2.8.2.1. REND_ANGLE_PARTIALS Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
$\bar{I}_N$	M_M50_TO_SENSOR <sub>1,1to3</sub>	RR_ANGLE_NAV	
$\bar{I}_N$	-UNIT (I_RHO x M_M50_TO_SENSOR <sub>1,1to3</sub> )	RR_ANGLE_NAV	
$\bar{I}_N$	-M_M50_TO_SENSOR <sub>2,1to3</sub>	ANGLE_NAV	
$\bar{I}_N$	-M_M50_TO_SENSOR <sub>1,1to3</sub>	ANGLE_NAV	
Variable Name		Input Source	Output Destination
$\bar{R}_{RHO}$		REND_NAV_INTERP	RR_ANGLE_NAV, ANGLE_NAV REND_NAV_FILTER
PHI_PATCH		REND_NAV_INTERP	
M_M50_TO_SENSOR		RR_ANGLE_NAV, STAR_TRACKER_NAV, COAS_NAV	
$\bar{U}_M$			
B			
$\bar{I}_{RHO}$		REND_NAV_INTERP	

#### 4.2.8.3 Star Tracker Horizontal and Vertical Measurements (STAR\_TRACKER\_NAV)

This subfunction is responsible for the proper processing of the star tracker vertical and horizontal measurement data. This subfunction shall perform the following tasks provided the star tracker is in the target track mode and the angle data are valid.

- Store the mean of 1950 to star tracker transformation matrix for use in the Angle Measurements subfunction.
- Compute the time difference between current filter time and measurement time.
- Invoke the Angle Measurements subfunction for the processing of the angle data with the proper IN LIST arguments.

If the star tracker time tag is too close in value to the star tracker time tag on the last filter cycle, the Angle Measurements subfunction is not invoked in order to avoid the processing of the same measurement twice.

A. Detailed Requirements. If the star tracker data is good (ST\_DATA\_GOOD = ON) and the star tracker is in the target track mode (TRG\_TRK\_MODE = ON), then the following steps shall be performed in the order indicated.

1. Store the mean of 1950 to star tracker transformation matrix into the mean of 1950 to sensor transformation matrix for use in the Angle Measurements subfunction (Section 4.2.8.3.1)

$$M\_M50\_TO\_SENSOR = M\_M50\_TO\_ST$$

2. Compute both the time difference between the current time and the star tracker measurement time and the time difference between the current star tracker measurement time and the time of the last processed measurement.

$$\begin{aligned} \text{DELTAT\_GO} &= T\_CURRENT\_FILT - T\_STAR\_TRACKER \\ \text{DELTAT\_ST} &= T\_STAR\_TRACKER - T\_ST\_LAST \end{aligned}$$

3. Test the time difference between the current star tracker measurement time and the time of the last processed measurement to avoid the redundant processing of the star tracker data.

If DELTAT\_ST is larger than a premission time difference, DELTAT\_ST\_MIN, then

- a. Invoke the Angle Measurements subfunction to incorporate the star tracker angle data into the filter vehicle state.

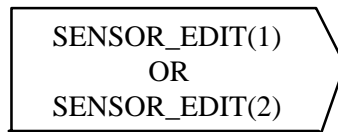
CALL: ANGLE\_NAV

IN LIST: VAR\_ST\_HORIZ, Q\_ST\_HORIZ, VAR\_ST\_VERT, Q\_ST\_VERT,  
ST\_ANGLES\_EDIT\_OVERRIDE, ST\_ANGLES\_STAT

- b. Set the time of the last star tracker measurement.

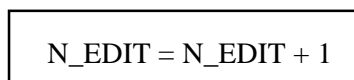
$$T\_ST\_LAST = T\_STAR\_TRACKER$$

- c. Next, a test shall be made on the sensor edit flags (SENSOR\_EDIT(1) and SENSOR\_EDIT(2)) to detect a star tracker measurement editing condition (i.e., RESID\_TEST\_RATIO > TEST\_VALUE). Both flags shall be checked as follows:

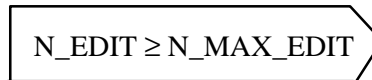


- (1) If either of these two flags is ON, an excessively large measurement residual has been computed. The following steps are then performed:

The edit counter is incremented:



If the number of sequentially edited measurements exceeds a premission– determined maximum (N\_MAX\_EDIT), it will be assumed that the star tracker is no longer tracking the current rendezvous target and a false target flag will be set (= 1) to indicate to the star tracker that it should attempt a reacquisition. The edit counter will also be reinitialized.



If  $N\_EDIT \geq N\_MAX\_EDIT$ , then FALSE\_TARG = 1 and N\_EDIT = 0.

- (2) If neither SENSOR\_EDIT(1) nor SENSOR\_EDIT(2) is ON, the edit counter (N\_EDIT) will be zeroed:

$$N\_EDIT = 0$$

- d. Next, a flag NAV\_FALSE\_TARG is set each cycle through STAR\_TRACKER\_NAV to send to telemetry and the ST SOP in order to drive the ST/COAS CNTL and REL NAV displays. This flag is required because the FALSE\_TARG flag is updated at a rate inconsistent with usage for driving displays and for telemetry.



B. Interface Requirements. The input and output variables for this subfunction are defined in Table 4.2.8.3.

C. Processing Requirements. This subfunction is called by NAV\_ONORBIT\_RENDEZVOUS (Section 4.2.1).

D. Constraints. None

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart can be found in Section 5.2 under the name STAR\_TRACKER\_NAV.



Table 4.2.8.3. STAR\_TRACKER\_NAV Input/Output

Variable Name	Input Source	Output Destination
M_M50_TO_ST	NAV_ONORBIT_RENDEZVOUS	
Q_ST_HORIZ	NAV_ONORBIT_RENDEZVOUS	ANGLE_NAV
Q_ST_VERT	NAV_ONORBIT_RENDEZVOUS	ANGLE_NAV
ST_ANGLES_EDIT_OVERRIDE	REND_SENSOR_SELECT	ANGLE_NAV
ST_ANGLES_STAT	REND_SENSOR_SELECT	ANGLE_NAV
ST_DATA_GOOD	NAV_ONORBIT_RENDEZVOUS	
T_CURRENT_FILT	NAV_ONORBIT_RENDEZVOUS	
TRG_TRK_MODE	NAV_ONORBIT_RENDEZVOUS	
T_STAR_TRACKER	NAV_ONORBIT_RENDEZVOUS	
VAR_ST_HORIZ	**	ANGLE_NAV
VAR_ST_VERT	**	ANGLE_NAV
DELTAT_GO		REND_NAV_INTERP, ONORBIT_SV_INTERP
M_M50_TO_SENSOR		ANGLE_NAV, REND_ANGLE_PARTIALS
DELTAT_ST_MIN	**	
N_MAX_EDIT	**	
FALSE_TARG	**,*	*
SENSOR_EDIT	ANGLE_NAV	
N_EDIT	REND_NAV_SENSOR_INIT	
NAV_FALSE_TARG		*

\* Onorbit/Rendezvous principal function, see Tables 4.2.11-1. and 4.2.11-2.  
\*\* Initialization of parameters, see Section 4.7.

#### 4.2.8.3.1 Angle Measurements (ANGLE\_NAV)

This utility subfunction is responsible for the proper processing of vertical and horizontal angle measurements taken by either the COAS or star tracker. This subfunction shall perform the following tasks when called by either the COAS or Star Tracker Vertical and Horizontal Measurements subfunction (see Sections 4.2.8.4 and 4.2.8.3, respectively):

- Calculate the partial derivative of the measurement with respect to the estimated state at measurement time.
- Compute the estimated measurement and the measurement residual.
- Select the proper variances to model the uncorrelated measurement errors.
- Store the old residual ratio, the EDIT OVERRIDE flag, and the STAT flags into temporary locations used by the Kalman Filter Updates subfunction (Section 4.2.8.1.2).
- Schedule the Kalman Filter Updates subfunction to process the data.
- Store the current residual ratio, the EDIT flag, and the measurement residual for display purposes.

A. Detailed Requirements. This subfunction is called with the following internal variables in the IN LIST:

IN LIST:        VAR\_HORIZ, Q\_HORIZ, VAR\_VERT, Q\_VERT,  
                  ANGLES\_MANUAL\_EDIT\_OVERRIDE, ANGLES\_STAT\_FLAG

where

VAR_HORIZ	variance of the horizontal measurement
Q_HORIZ	horizontal angle measurement
VAR_VERT	variance of the vertical measurement
Q_VERT	vertical angle measurement
ANGLES_MANUAL_EDIT_OVERRIDE	manual edit override flag
ANGLES_STAT_FLAG	stat flag

The following steps shall be performed (in the order indicated):

1. Call the Measurement Interpolation subfunction to interpolate the orbiter and target state vectors to the time of the vertical angle measurement (see Section 4.2.8.1.1).

CALL:            REND\_NAV\_INTERP

2. Call the Angle Partial subfunction to compute the partial vector (see Section 4.2.8.2.1)

CALL:            REND\_ANGLE\_PARTIALS

IN LIST:        -M\_M50\_TO\_SENSOR<sub>2, 1 to 3</sub>

3. Calculation of the partial vector is completed by setting the appropriate value in the bias slot of that vector:

$$B_{11} = 1.0$$

4. Compute the estimated vertical angle measurement and the vertical angle measurement residual.

$$\text{VERT} = \text{ARCTAN2}(-U_{M_1}, U_{M_3}) + \text{SENSOR\_BIAS}_2 \quad \text{F7}$$

$$\text{DELQ} = Q_{\text{VERT}} - \text{VERT}$$

F7 This equation shall be protected against arc tangents with both arguments equal to zero (reference 3.5).

5. Assign the appropriate variance for the vertical angle

$$\text{VAR} = \text{VAR\_VERT}$$

6. Set up the required inputs to the Kalman Filter subfunction:

$$\text{RESID\_RATIO\_OLD} = \text{MAX}(\text{NAV\_SIG}_1, \text{NAV\_SIG}_2)$$

$$\text{MANUAL\_EDIT\_OVERRIDE} = \text{ANGLES\_MANUAL\_EDIT\_OVERRIDE}$$

$$\text{STAT\_FLAG} = \text{ANGLES\_STAT\_FLAG}$$

7. Call the Kalman Filter subfunction to process the vertical angle measurement (see Section 4.2.8.1.2).

CALL: `REND_NAV_FILTER`

8. Store the output data from the Kalman Filter subfunction in the appropriate variables for use by the Measurement Processing Statistics and Star Tracker Horizontal and Vertical Measurements subfunction.

$$\text{SENSOR\_DELQ}_2 = \text{DELQ}$$

$$\text{NAV\_SIG}_2 = \text{RESID\_TEST\_RATIO}$$

$$\text{SENSOR\_EDIT}_2 = \text{EDIT\_FLAG}$$

9. Call the Measurement Interpolation subfunction to interpolate the orbiter and target state vectors to the time of the horizontal angle measurement (see Section 4.2.8.1.1).

CALL: `REND_NAV_INTERP`

10. Call the Angle Partial subfunction to compute the partial vector (see Section 4.2.8.2.1).

CALL: `REND_ANGLE_PARTIALS`

IN LIST: `-M_M50_TO_SENSOR`<sub>1,1 to 3</sub>

11. Calculation of the partial vector is completed by setting the appropriate value in the bias slot of that vector:

$$B_{10} = 1.0$$

12. Compute the estimated horizontal angle measurement and the horizontal angle measurement residual.

$$\text{HORIZ} = \text{ARCTAN2} (U\_M_2, U\_M_3) + \text{SENSOR\_BIAS}_1 \quad \text{F7}$$

$$\text{DELQ} = \text{Q\_HORIZ} - \text{HORIZ}$$

F7 This equation shall be protected against arc tangents with both arguments equal to zero (reference 3.5).

13. Assign the appropriate variance for the horizontal angle

$$\text{VAR} = \text{VAR\_HORIZ}$$

14. Call the Kalman Filter subfunction to process the horizontal angle measurement (see Section 4.2.8.1.2).

CALL: `REND_NAV_FILTER`

15. Store the output data from the Kalman Filter subfunction and star tracker horizontal and vertical measurements in the appropriate variables for use by the Measurement Processing Statistics subfunction.

$$\text{SENSOR\_DELQ}_1 = \text{DELQ}$$

$$\text{NAV\_SIG}_1 = \text{RESID\_TEST\_RATIO}$$

$$\text{SENSOR\_EDIT}_1 = \text{EDIT\_FLAG}$$

B. Interface Requirements. The input and output variables for this subfunction are defined in Table 4.2.8.3.1.

C. Processing Requirements. This subfunction is called by the following subfunctions:

`COAS_NAV` (Section 4.2.8.4)

`STAR_TRACKER_NAV` (Section 4.2.8.3)

D. Constraints. None

E. Supplementary Information. A suggested implementation of this subfunction in the form of a detailed flow chart can be found in Section 5.2 under the name

`ANGLE_NAV.`

Table 4.2.8.3.1. ANGLE_NAV Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	Internal Name		
ANGLES_MANUAL_EDIT_OVERRIDE	COAS_ANGLES_EDIT_OVERRIDE	COAS_NAV	
ANGLES_STAT_FLAG	COAS_ANGLES_STAT	COAS_NAV	
Q_HORIZ	Q_COAS_HORIZ	COAS_NAV	
Q_VERT	Q_COAS_VERT	COAS_NAV	
VAR_HORIZ	VAR_COAS_HORIZ	COAS_NAV	
VAR_VERT	VAR_COAS_VERT	COAS_NAV	
ANGLES_MANUAL_EDIT_OVERRIDE	ST_ANGLES_EDIT_OVERRIDE	STAR_TRACKER_NAV	
ANGLES_STAT_FLAG	ST_ANGLES_STAT	STAR_TRACKER_NAV	
Q_HORIZ	Q_ST_HORIZ	STAR_TRACKER_NAV	
Q_VERT	Q_ST_VERT	STAR_TRACKER_NAV	
VAR_HORIZ	VAR_ST_HORIZ	STAR_TRACKER_NAV	
VAR_VERT	VAR_ST_VERT	STAR_TRACKER_NAV	
Variable Name		Input Source	Output Destination
EDIT_FLAG		REND_NAV_FILTER	
M_M50_TO_SENSOR		COAS_NAV, STAR_TRACKER_NAV	REND_ANGLE_PARTIALS
NAV_SIG		SETUP	MEAS_PROCESSING_STATISTICS_REND
RESID_TEST_RATIO		REND_NAV_FILTER	
SENSOR_BIAS		SETUP, REND_NAV_FILTER	
$\bar{U}_M$		REND_ANGLE_PARTIALS	
B			REND_NAV_FILTER
DELQ			REND_NAV_FILTER
MANUAL_EDIT_OVERRIDE			REND_NAV_FILTER
RESID_RATIO_OLD			REND_NAV_FILTER
SENSOR_DELQ			MEAS_PROCESSING_STATISTICS_REND
SENSOR_EDIT			MEAS_PROCESSING_STATISTICS_REND*, STAR_TRACKER_NAV
STAT_FLAG			REND_NAV_FILTER
VAR			REND_NAV_FILTER
* Onorbit/Rendezvous principal function, see Table 4.2.11-2.			

#### 4.2.8.4 COAS Horizontal and Vertical Angle Measurements (COAS\_NAV)

This subfunction is responsible for the proper processing of the COAS horizontal and vertical angle measurements. This subfunction shall perform the following task if the COAS data are labeled valid.

- Compute the time difference between current filter time and measurement time (DELTAT\_GO). Also we will compute the time difference (DELTAT\_COAS) between the current COAS measurement and the measurement last used by this subfunction.
- If the COAS data satisfies the criteria for staleness and have not been processed before, the Angle Measurement subfunction shall be invoked to process the vertical and horizontal angle data.
- If the COAS Horizontal and Vertical Angle Measurements subfunction is not to process the angle data for statistical display purposes only, then the time of the last COAS measurement is reset.

A. Detailed Requirements. If the COAS data is good (COAS\_DATA\_GOOD = ON), then the following steps shall be performed (in the order indicated):

1. Determine the delta time between the current time and the time of the COAS measurements and also determine the delta time since the last processing of COAS data.

$$\begin{aligned} \text{DELTAT\_GO} &= \text{T\_CURRENT\_FILT} - \text{T\_COAS} \\ \text{DELTAT\_COAS} &= \text{T\_COAS} - \text{T\_COAS\_LAST} \end{aligned}$$

2. This subfunction will only process COAS data if the COAS data have not been previously processed and the time elapsed since the COAS data snap is smaller than a design-dependent time delta.

i.e., if  $\text{DELTAT\_COAS} > \text{DELTAT\_COAS\_MIN}$   
AND  
 $\text{DELTAT\_GO} < \text{DELTAT\_COAS\_MAX}$

- a. Compute the mean of 1950 to sensor coordinate transformation matrix.

$$\text{M\_M50\_TO\_SENSOR} = \text{M\_BODY\_TO\_COAS}_{\text{COAS\_ID}} \text{M\_M50\_TO\_BODY\_COAS}$$

- b. Call the Angle Measurements subfunction to incorporate the COAS angle data (see Section 4.2.8.3.1).

CALL: ANGLE\_NAV  
IN LIST: VAR\_COAS\_HORIZ, Q\_COAS\_HORIZ,  
VAR\_COAS\_VERT, Q\_COAS\_VERT,  
COAS\_ANGLES\_EDIT\_OVERRIDE,  
COAS\_ANGLES\_STAT

- c. If the COAS data were processed (COAS\_ANGLES\_STAT = OFF), save the time of the COAS data for use on the next filter subcycle.

$$\text{T\_COAS\_LAST} = \text{T\_COAS}$$

B. Interface Requirements. The input and output variables for this subfunction are defined in Table 4.2.8.4.

C. Processing Requirements. This subfunction is called by NAV\_ONORBIT\_RENDEZVOUS (Section 4.2.1).

D. Constraints. None.

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart can be found in Section 5.2 under the name COAS\_NAV.

Table 4.2.8.4. COAS_NAV Input/Output		
Variable Name	Input Source	Output Destination
COAS_ANGLES_EDIT_OVERRIDE	REND_SENSOR_SELECT	ANGLE_NAV
COAS_ANGLES_STAT	REND_SENSOR_SELECT	ANGLE_NAV
COAS_DATA_GOOD	NAV_ONORBIT_RENDEZVOUS	
COAS_ID	NAV_ONORBIT_RENDEZVOUS	
DELTAT_COAS_MAX	**	
DELTAT_COAS_MIN	**	
M_BODY_TO_COAS	**	
M_M50_TO_BODY_COAS	NAV_ONORBIT_RENDEZVOUS	
Q_COAS_HORIZ	NAV_ONORBIT_RENDEZVOUS	ANGLE_NAV
Q_COAS_VERT	NAV_ONORBIT_RENDEZVOUS	ANGLE_NAV
T_COAS	NAV_ONORBIT_RENDEZVOUS	
T_COAS_LAST	**	
T_CURRENT_FILT	NAV_ONORBIT_RENDEZVOUS	
VAR_COAS_HORIZ	**	ANGLE_NAV
VAR_COAS_VERT	**	ANGLE_NAV
DELTAT_GO		REND_NAV_INTERP, ONORBIT_SV_INTERP
M_M50_TO_SENSOR		ANGLE_NAV, REND_ANGLE_PARTIALS
** Initialization parameters, see Section 4.7.		

#### 4.2.9 Measurement Processing Statistics (MEAS\_PROCESSING\_STATISTICS\_REND)

During rendezvous navigation phases that utilize external measurements, the Measurement Processing Statistics subfunction will compute for display certain parameters that are indicative of the condition of the navigation filter and the external sensor measurements that it utilizes. These display parameters serve as the basis for the crew decision as to how external measurement data are to be processed by the nav filter.

The Measurement Processing Statistics subfunction will be performed after the State and Covariance Measurement Incorporation subfunctions have been performed. Filter edit indicators, which will have been initialized to a default value during the Sensor Measurement Selection subfunction, will be redefined during performance of the State and Covariance Measurement Incorporation subfunctions. This will indicate to the Measurement Processing Statistics subfunction, for each measurement type being utilized, which of the following five cases has occurred:

- Edit indicator = OFF – The filter was not configured for the measurement type or the data were bad and the filter did not attempt to process data of that type.
- Edit indicator = ON – The filter did attempt to process the measurement type but automatically edited the data.
- Edit indicator = PROCESSED – The filter processed the measurement type as a result of the data satisfying the edit criterion.
- Edit indicator = STAT – The filter was used solely for producing the residual and ratio parameters for display.
- Edit indicator = FORCED – The filter processed the data as a result of a crew edit override.

Moreover, the State and Covariance Measurement Incorporation subfunction will provide the Measurement Processing Statistics subfunction with the value of each measurement residual and the corresponding residual edit ratio value. The data supplied to the Measurement Processing Statistics subfunction are used to compute statistics for the sensor measurement type selected.

For each measurement type, the following parameters are to be computed for display to show how well the navigation filter is processing external measurements of that particular type:

$DISP\_DELQ_I$  – The actual measurement residual computed by the nav filter for the Ith measurement type.

$DISP\_SIG_I$  – The residual edit ratio for the Ith measurement type. The ratio is the absolute value of the measurement residual divided by the square root of the scaled value of the residual variance for the measurement type. (See Section 4.2.8.1.2 for the definition of RESID\_TEST\_RATIO.)

$N\_ACCEPT_I$  – The number of data marks for the Ith measurement type which have been used to update the nav state vector.

$N\_REJECT_I$  – The number of data marks for the Ith measurement type which have been automatically rejected as a result of failing the nav filter edit criterion.



DISP\_EDIT<sub>I</sub> – The status indicator which shall be displayed as a BLANK unless the nav filter has edited a predetermined number of sequential data marks for the I<sup>th</sup> type. In this case, the status indicator shall be displayed as the symbol, ↓. Once set, the down arrow symbol shall continue to be displayed until a predetermined number of sequential data marks have been processed by the nav filter, or until a data mark has been processed by the nav filter as a result of the crew setting the appropriate AUTO/INHIBIT/FORCE flag to FORCE.

In addition, the magnitude of the total correction to the filtered position and velocity is computed for downlist. If valid data were not presented to the filter or if the estimated distance between vehicles is less than a specified value (RANGE\_MIN), then all these parameters will maintain the values defined during the previous filter subcycle.

The ACCEPT/REJECT counters are initialized to zero whenever the covariance matrix is reinitialized, when leaving rendezvous navigation, when the corresponding sensor type is changed, or when the IMU-sensed accelerations exceed a premission-specified amount (MEAS\_THRESHOLD).

Sensor data will consist of two types: angular data and range data. The angular data will consist of a pair of angles from one of three mutually exclusive sources – COAS, star tracker (ST), or rendezvous radar (RR). The range data will consist of range and range rate from the rendezvous radar. Angular data, from whichever source has been chosen, can be utilized in conjunction with range data.

A. Detailed Requirements. The correspondence between the measurement type and the subscript, I, shall be as follows:

I = 1 – COAS horizontal angle, ST horizontal angle, or RR shaft angle

I = 2 – COAS vertical angle, ST vertical angle, or RR trunnion angle

I = 3 – RR range

I = 4 – RR range rate

For each value of the integer I in the interval (1,4), the following steps shall be performed (in the order indicated) when SENSOR\_EDIT<sub>I</sub> ≠ OFF:

1. DISP\_DELQ<sub>I</sub> and DISP\_SIG<sub>I</sub> are given the values:

$$\text{DISP\_DELQ}_I = \text{SENSOR\_DELQ}_I$$

$$\text{DISP\_SIG}_I = \text{NAV\_SIG}_I$$

where SENSOR\_DELQ<sub>I</sub> and NAV\_SIG<sub>I</sub> were computed in the State and Covariance Measurement Incorporation subfunctions (sections 4.2.8.1 through 4.2.8.4).

2. For the range measurement,

$$I = 3,$$

the residual is converted to kilofeet:

$$\text{DISP\_DELQ}_I = \text{DISP\_DELQ}_I / 1000.0$$

3. For the angle measurements,

$$I = 1 \text{ or } 2,$$

the residuals are converted to degrees:

$$\text{DISP\_DELQ}_I = \text{DISP\_DELQ}_I \text{ DEG\_PER\_RAD}$$

4. Test the SENSOR\_EDIT value for the Ith measurement type

- a. If  $\text{SENSOR\_EDIT}_I = \text{STAT}$ ,  $\text{DISP\_EDIT}_I$  shall be given the value BLANK:

$$\text{DISP\_EDIT}_I = \text{BLANK}$$

The logic then exits from MEAS\_PROCESSING\_STATISTICS\_REND.

- b. If  $\text{SENSOR\_EDIT}_I \neq \text{STAT}$ , then test  $\text{SENSOR\_EDIT}_I$  again.

- (1) If  $\text{SENSOR\_EDIT}_I = \text{ON}$ , the sequential accept counter shall be set to zero:

$$\text{SEQ\_ACCEPT}_I = 0_I,$$

the counter for the number of marks rejected by the nav filter shall be incremented by one:

$$\text{N\_REJECT}_I = \text{N\_REJECT}_I + 1,$$

and the sequential reject counter shall be incremented by one:

$$\text{SEQ\_REJECT}_I = \text{SEQ\_REJECT}_I + 1$$

If  $\text{SEQ\_REJECT}_I$  is found to exceed a predetermined number, REJ\_MAX,  $\text{DISP\_EDIT}_I$  shall be set to  $\Downarrow$  to indicate that a number of sequential data marks have been edited.

$$\text{DISP\_EDIT}_I = \Downarrow$$

- (2) If  $\text{SENSOR\_EDIT}_I \neq \text{ON}$ , then the sequential reject counter shall be set to zero:

$$\text{SEQ\_REJECT}_I = 0,$$

the counter for the number of marks processed by the nav filter shall be incremented:

$$\text{N\_ACCEPT}_I = \text{N\_ACCEPT}_I + 1,$$

and the sequential accept counter shall be also incremented:

$$\text{SEQ\_ACCEPT}_I = \text{SEQ\_ACCEPT}_I + 1$$

If  $\text{SEQ\_ACCEPT}_I$  exceeds a predetermined number ACC\_MIN, or  $\text{SENSOR\_EDIT}_I$  has a value of FORCED,  $\text{DISP\_EDIT}_I$  is given the value BLANK:

$$\text{DISP\_EDIT}_I = \text{BLANK}$$

If the indicator SENSOR\_EDIT<sub>1</sub> is found to have the value OFF on the initial check, both DISP\_DELQ<sub>1</sub> and DISP\_SIG<sub>1</sub> shall maintain the previous values from the prior filter subcycle.

After the above logic has been performed for each measurement, equations are exercised to compute the magnitude of the total correction to the position and velocity vectors for the whole filter cycle.

$$R\_MEAS\_RSS = |\bar{R}\_MEAS|/1000.$$

$$V\_MEAS\_RSS = |\bar{V}\_MEAS|$$

- B. Interface Requirements. Input and output parameters are listed in Table 4.2.9.
- C. Processing Requirements. The subfunction is called by NAV\_ONORBIT\_RENDEZVOUS (Section 4.2.1).
- D. Constraints. None
- E. Supplementary Information. A suggested implementation for this subfunction may be found in the detailed flow chart of Section 5.2 entitled MEAS\_PROCESSING\_STATISTICS\_REND.

Table 4.2.9. MEAS_PROCESSING_STATISTICS_REND Input/Output		
Variable Name	Input Source	Output Destination
ACC_MIN	**	
DEG_PER_RAD	**	
DISP_DELQ		*
DISP_EDIT	**	*
DISP_SIG		*
N_ACCEPT	*, SETUP, DISPLAY_COUNT_INIT	*
NAV_SIG	RRDOT_NAV, RR_ANGLE_NAV, ANGLE_NAV, SETUP	
N_REJECT	*, SETUP, DISPLAY_COUNT_INIT	*
REJ_MAX	**	
$\bar{R}$ _MEAS	REND_BIAS_AND_COV_PROP, REND_NAV_FILTER	
R_MEAS_RSS		*
SENSOR_DELQ	RRDOT_NAV, RR_ANGLE_NAV, ANGLE_NAV	
SENSOR_EDIT	REND_SENSOR_SELECT, RRDOT_NAV, RR_ANGLE_NAV, ANGLE_NAV	
SEQ_ACCEPT	SETUP,*,DISPLAY_COUNT_INIT	*
SEQ_REJECT	SETUP,*,DISPLAY_COUNT_INIT	*
$\bar{V}$ _MEAS	REND_BIAS_AND_COV_PROP, REND_NAV_FILTER	
V_MEAS_RSS		*

\* Onorbit/Rendezvous principal function, see Tables 4.2.11-1 and 4.2.11-2.  
\*\* Initialization parameters, see Section 4.7.

#### 4.2.10 GPS Specific Subfunctions

The requirements for the OPS 2 and OPS 8 GPS Update subfunction and the GPS Resynch subfunction are presented in this section. The GPS Update subfunction is executed to reset the navigation state to the selected filter state when certain criteria are met. The GPS Resynch subfunction is used to adjust the target state during a relative sensor rendezvous, when a resetting of the Shuttle inertial state with a selected GPS state occurs. This maintain the relative inertial state estimate the same both before and after the Shuttle navigation state reset so that relative sensor processing is not affected.

##### 4.2.10.1 GPS UPDATE Subfunction

The purpose of the GPS update subfunction is to reset the GPC navigation filter state to the selected GPS receiver state. If a selected GPS state is available from the GPS receiver state processing principal function execution on the previous onorbit/rendezvous navigation cycle, and if the requisite criteria are satisfied, the navigation filter state will be reset to the selected GPS state. Note that the filter state and associated time tag are at the time of the previous navigation cycle. The IMU velocity counts are not changed with a GPS filter state update since the IMU counts associated with the selected GPS state are those from the previous nav cycle and have been correctly stored to compute the velocity change for integrating the reset navigation state over the current integration time step.

A. Detailed Requirements. The GPS update subfunction shall function as follows:

- 1.0 If the copy of the GPS to navigation force flag (GPS\_TO\_NAV\_FORCE\_RCVD) set by the crew is ON, then the GPS to navigation force command flag (GPS\_TO\_NAV\_FORCE) set by the crew is set to OFF, providing a forcing of GPS data into the navigation system on this navigation cycle only. The GPS to navigation auto/inhibit/force flag, GPS\_TO\_NAV\_AIF, which is a composite flag representing the setting of both the GPS\_TO\_NAV\_RCVD and GPS\_TO\_NAV\_FORCE\_RCVD flags, is set to FORCE for this navigation cycle. If the copy of the GPS to navigation force flag (GPS\_TO\_NAV\_FORCE\_RCVD) is not set to ON, however, then the GPS to navigation auto/inhibit/force flag is set to the GPS to navigation auto/inhibit flag setting. This is accomplished as follows:

```
IF GPS_TO_NAV_FORCE_RCVD = ON THEN
    GPS_TO_NAV_FORCE = OFF
    GPS_TO_NAV_AIF = FORCE
```

```
ELSE
```

```
    GPS_TO_NAV_AIF = INTEGER(GPS_TO_NAV_RCVD)
```

- 2.0 To determine if the baseline navigation filter state is to be reset to the selected GPS state on this navigation cycle, a check is first made to see if a selected GPS state is available. If one is available, indicated by GPS\_SV\_SEL\_AVAIL = ON, step 2.1 is performed.
- 2.1 If the snapped major mode code is equal to 202, and the GPS to navigation auto/inhibit/force command (GPS\_TO\_NAV\_AIF) is set to AUTO, the GPS to navigation auto/inhibit/force execute indicator (GPS\_NAV\_AIF\_EXEC) is set to DOWN\_ARROW (value of 1) to notify the crew that automatic resetting of the baseline navigation state to the selected GPS state will be prohibited while in this major mode. However, if the snapped major mode code is not equal

to 202 or the GPS to navigation auto/inhibit/force flag is not set to AUTO, then step 2.2 will be performed.

```
IF NAV_MM_CODE = 202 and
GPS_TO_NAV_AIF = AUTO THEN
    GPS_NAV_AIF_EXEC = DOWN_ARROW

ELSE
```

- 2.2 First, the GPS to navigation auto/inhibit/force execute indicator (GPS\_NAV\_AIF\_EXEC) is set to BLANK (value of 0) indicating that resetting of the baseline navigation state to the selected GPS state will be permitted. Next a check is made to determine if the navigation filter state is to be reset to the selected GPS state. If the GPS to navigation auto/inhibit/force flag (GPS\_TO\_NAV\_AIF) is FORCE, or, if the GPS to navigation auto/inhibit/force flag is AUTO and the time since the last navigation filter state update (reset) with the selected GPS state is greater than or equal to a pre-mission defined I-load value and the selected GPS residual ratio edit flag (GPS\_RATIO\_FLAG) is OFF, then steps 2.2.1 and 2.2.2 will be performed.

```
GPS_NAV_AIF_EXEC = BLANK
IF GPS_TO_NAV_AIF = FORCE or
   [GPS_TO_NAV_AIF = AUTO and
   (T_CURRENT_FILT - T_GPS_LAST_UPDATE) ≥ T_GPS_CYCLE and
   GPS_RATIO_FLAG = OFF]
THEN
```

- 2.2.1 If the rendezvous mode is active, indicated by the flag DOING\_REND\_NAV = ON, the GPS resynch subfunction is executed (Section 4.2.10.2).

```
IF DOING_REND_NAV = ON THEN
    EXECUTE: GPS_RESYNCH
```

- 2.2.2 The filter state is then reset to the selected GPS state, the navigation reset flag shall be set ON, and the time tag of the most recent GPS state incorporation into the navigation system shall be updated. These steps are as follows:

```
 $\bar{R}_{FILT} = \bar{R}_{GPS\_SEL}$ 
 $\bar{V}_{FILT} = \bar{V}_{GPS\_SEL}$ 
NAV_RESET = ON
T_GPS_LAST_UPDATE = T_CURRENT_FILT
```

B. Interface Requirements. The input and output parameters associated with the GPS update subfunction are listed in Table 4.2.10-1.

C. Processing Requirements. This subfunction is called by NAV\_ONORBIT\_RENDEZVOUS.

D. Constraints. None.

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart can be found in Section 5.2 under the name GPS\_UPDATE.

Table 4.2.10.1. GPS Update Input/Output

Variable Name	Input Source	Output Destination
DOING_REND_NAV	NAV_ONORBIT_ RENDEZVOUS	
GPS_RATIO_FLAG	*	
GPS_SV_SEL_AVAIL	*	
GPS_TO_NAV_AIF		*
GPS_NAV_AIF_EXEC		*
GPS_TO_NAV_FORCE		*
GPS_TO_NAV_FORCE_RCVD	NAV_ONORBIT_ RENDEZVOUS	
GPS_TO_NAV_RCVD	NAV_ONORBIT_ RENDEZVOUS	
NAV_RESET		*, SHUTTLE_RESET
NAV_MM_CODE	NAV_ONORBIT_ RENDEZVOUS	
$\bar{R}$ _FILT		COV_LAST_RESET, SHUTTLE_RESET, ONORBIT_REND_R_V_STATE_PROP, REL_NAV_DISPLAY_UPDATES, REND_COV_INIT,*
$\bar{R}$ _GPS_SEL	*	
T_CURRENT_FILT	NAV_ONORBIT_ RENDEZVOUS	
T_GPS_CYCLE	**	
T_GPS_LAST_UPDATE	*, ONORB_REND_AUTO_ INFLIGHT_UPDATE	
$\bar{V}$ _GPS_SEL	*	
$\bar{V}$ _FILT		COV_LAST_RESET, SHUTTLE_RESET, ONORBIT_REND_R_V_STATE_PROP, REL_NAV_DISPLAY_UPDATES, REND_COV_INIT,*
<p>* Onorbit/Rendezvous principal function, see Tables 4.2.11-1. and 4.2.11-2. ** Initialization parameters, see Section 4.7.</p>		

#### 4.2.10.2 GPS Resynch

The purpose of the GPS Resynch subfunction is to maintain the orbiter to target M50 inertial relative state conditions and adjust the relative navigation covariance matrix state error statistics when the orbiter navigation system inertial state estimate is reset to the selected GPS orbiter state estimate.

The rendezvous navigation filter estimates the inertial state of either the orbiter or target vehicle (determined by the setting of SHUTTLE\_FILTER\_FLAG) relative to the other (non-updated) vehicle state using relative sensors whose angle measurements are referenced to the M50 inertial frame. The rendezvous navigation Kalman filter, which reflects the statistics of the relative error in the orbit-target relative frame, is coordinatized in the M50 inertial frame and reflects the error in the inertial state estimate of the updated vehicle.

At an orbiter GPS state reset, it is therefore necessary to maintain the inertial relative state and the covariance matrix relative state error statistics in the measurement frame that existed before the state reset in the measurement frame that exists after the reset. This is accomplished by changing the onboard target state estimate by the same amount that the orbiter inertial state estimate is changed by the GPS update. The relative state position and velocity covariance matrix statistics are maintained by preserving the pre state reset covariance matrix orientation in the new relative frame that exists after the orbiter and target inertial states are reset. A small change to the position and velocity covariance statistics can be made (I-load dependent) to account for the effect of the change in inertial state of the non-updated vehicle on subsequent relative sensor measurement residuals.

The PROP state is also changed by the same amount that the orbiter inertial state estimate is changed by the GPS update so that the relative state difference between the PROP state and the updated vehicle inertial state is maintained.

A. Detailed Requirements. The GPS Resynch function shall perform as follows:

- 1.0 The current relative state between the orbiter and target vehicles is computed:

$$\begin{aligned}\bar{\mathbf{R}}_{\text{REL}} &= \bar{\mathbf{R}}_{\text{TV}} - \bar{\mathbf{R}}_{\text{FILT}} \\ \bar{\mathbf{V}}_{\text{REL}} &= \bar{\mathbf{V}}_{\text{TV}} - \bar{\mathbf{V}}_{\text{FILT}}\end{aligned}$$

- 2.0 The reset target state is generated by adding the relative state just computed to the selected GPS state which will be used to reset the orbiter state.

$$\begin{aligned}\bar{\mathbf{R}}_{\text{TV}} &= \bar{\mathbf{R}}_{\text{GPS\_SEL}} + \bar{\mathbf{R}}_{\text{REL}} \\ \bar{\mathbf{V}}_{\text{TV}} &= \bar{\mathbf{V}}_{\text{GPS\_SEL}} + \bar{\mathbf{V}}_{\text{REL}}\end{aligned}$$

- 3.0 The current relative state between the orbiter and the PROP state is computed:

$$\begin{aligned}\bar{\mathbf{R}}_{\text{REL}} &= \bar{\mathbf{R}}_{\text{PROP}} - \bar{\mathbf{R}}_{\text{FILT}} \\ \bar{\mathbf{V}}_{\text{REL}} &= \bar{\mathbf{V}}_{\text{PROP}} - \bar{\mathbf{V}}_{\text{FILT}}\end{aligned}$$

- 4.0 The reset PROP state is generated by adding the relative state just computed to the selected GPS state which will be used to reset the orbiter state.

$$\begin{aligned}\bar{\mathbf{R}}_{\text{PROP}} &= \bar{\mathbf{R}}_{\text{GPS\_SEL}} + \bar{\mathbf{R}}_{\text{REL}} \\ \bar{\mathbf{V}}_{\text{PROP}} &= \bar{\mathbf{V}}_{\text{GPS\_SEL}} + \bar{\mathbf{V}}_{\text{REL}}\end{aligned}$$



- 5.0 The rendezvous navigation Kalman filter covariance matrix is adjusted to account for the effect of the inertial state reset on the relative error statistics by adding a position and velocity I-load derived covariance matrix reflecting the quality of the GPS state update. A check is made to determine if a non-zero covariance I-load has been provided. If  $SIG\_DIAG\_GPS_1 > 0$ , steps 5.1 through 5.4 are performed.
- 5.1 Compute the UVW elements of the covariance matrix  $G\_COV$  from the UVW sigmas and correlations provided by the GPS reference state processing principal function as follows:

Initialize all covariance elements to zero.

$$G\_COV_{I,J} = 0 \text{ (I=1 TO 6, J=1 TO 6)}$$

Compute the diagonal elements of the UVW covariance matrix:

DO FOR I =1 TO 6

$$G\_COV_{I,I} = SIG\_DIAG\_GPS_I \text{ SIG\_DIAG\_GPS}_I$$

Compute the off-diagonal covariance elements as follows:

$$\begin{aligned} G\_COV_{1,2} &= CORR\_COEFF\_GPS_1 \text{ SIG\_DIAG\_GPS}_1 \text{ SIG\_DIAG\_GPS}_2 \\ G\_COV_{1,4} &= CORR\_COEFF\_GPS_2 \text{ SIG\_DIAG\_GPS}_1 \text{ SIG\_DIAG\_GPS}_4 \\ G\_COV_{1,5} &= CORR\_COEFF\_GPS_3 \text{ SIG\_DIAG\_GPS}_1 \text{ SIG\_DIAG\_GPS}_5 \\ G\_COV_{2,4} &= CORR\_COEFF\_GPS_4 \text{ SIG\_DIAG\_GPS}_2 \text{ SIG\_DIAG\_GPS}_4 \\ G\_COV_{2,5} &= CORR\_COEFF\_GPS_5 \text{ SIG\_DIAG\_GPS}_2 \text{ SIG\_DIAG\_GPS}_5 \\ G\_COV_{3,6} &= CORR\_COEFF\_GPS_6 \text{ SIG\_DIAG\_GPS}_3 \text{ SIG\_DIAG\_GPS}_6 \\ G\_COV_{4,5} &= CORR\_COEFF\_GPS_7 \text{ SIG\_DIAG\_GPS}_4 \text{ SIG\_DIAG\_GPS}_5 \\ G\_COV_{2,1} &= G\_COV_{1,2} \\ G\_COV_{5,4} &= G\_COV_{4,5} \end{aligned}$$

Complete the setting of the UVW covariance matrix as follows:

$$G\_COV_{4 \text{ TO } 6, 1 \text{ TO } 3} = TRANSPOSE(G\_COV_{1 \text{ TO } 3, 4 \text{ TO } 6})$$

This step is not necessary but is shown for completeness of the matrix definition.

- 5.2 Compute the UVW to mean of 1950 coordinate transformation matrix using the states of the vehicle being updated with the relative sensor navigation. This is accomplished as follows:

```
IF SHUTTLE_FILTER_FLAG = ON THEN
    M_ROT = UVW_TO_M50 (R_FILT, V_FILT)
ELSE
    M_ROT = UVW_TO_M50 (R_TV, V_TV)
```

Rotate the  $G\_COV$  matrix to M50 coordinates:

$$\begin{aligned}G\_COV\_M50_{1\ TO\ 3,\ 1\ TO\ 3} &= M\_ROT\ G\_COV_{1\ TO\ 3,\ 1\ TO\ 3}\ M\_ROT^T \\G\_COV\_M50_{4\ TO\ 6,\ 4\ TO\ 6} &= M\_ROT\ G\_COV_{4\ TO\ 6,\ 4\ TO\ 6}\ M\_ROT^T \\G\_COV\_M50_{1\ TO\ 3,\ 4\ TO\ 6} &= M\_ROT\ G\_COV_{1\ TO\ 3,\ 4\ TO\ 6}\ M\_ROT^T \\G\_COV\_M50_{4\ TO\ 6,\ 1\ TO\ 3} &= TRANSPOSE(G\_COV\_M50_{1\ TO\ 3,\ 4\ TO\ 6})\end{aligned}$$

The setting of  $G\_COV\_M50_{4\ TO\ 6,\ 1\ TO\ 3}$  is not necessary but is shown for completeness of the matrix definition.

5.3 Add the rotated covariance to the rendezvous navigation filter covariance:

$$\begin{aligned}E_{1\ TO\ 3,\ 1\ TO\ 3} &= E_{1\ TO\ 3,\ 1\ TO\ 3} + G\_COV\_M50_{1\ TO\ 3,\ 1\ TO\ 3} \\E_{4\ TO\ 6,\ 4\ TO\ 6} &= E_{4\ TO\ 6,\ 4\ TO\ 6} + G\_COV\_M50_{4\ TO\ 6,\ 4\ TO\ 6} \\E_{1\ TO\ 3,\ 4\ TO\ 6} &= E_{1\ TO\ 3,\ 4\ TO\ 6} + G\_COV\_M50_{1\ TO\ 3,\ 4\ TO\ 6}\end{aligned}$$

5.4 Symmetrize the upper six by six covariance matrix as follows:

DO FOR I = 1 TO 5

DO FOR K = (I + 1) TO 6

$$E_{K,I} = E_{I,K}$$

Note that step 5.4 eliminates the need to set the lower left off-diagonal submatrix to the transpose of the upper right off-diagonal submatrix.

- B. Interface Requirements. The input and output data are shown Table 4.2.10.2.
- C. Processing Requirements. This subfunction is called by GPS\_UPDATE (Section 4.2.10.1).
- D. Constraints. None
- E. Supplementary Information. A suggested implementation in the form of a detailed flow chart (GPS\_RESYNCH) may be found in Section 5.2.

Table 4.2.10.2. GPS Resynch Input/Output

Variable Name	Input Source	Output Destination
CORR_COEFF_GPS	*	
E	REND_BIAS_AND_COV_PROP, REND_COV_INIT, COVINIT_UVW, U_A_BIAS_AND_COVINIT, SETUP	COV_LAST_RESET, REND_BIAS_COV_PROP, REND_NAV_FILTER,*
$\bar{R}$ _FILT	ONORBIT_REND_R_V_ STATE_PROP, ONORBIT_REND_AUTO_ INFLIGHT_UPDATE, REND_NAV_FILTER,*	UVW_TO_M50
$\bar{R}$ _GPS_SEL	*	
R_PROP	ONORBIT_REND_R_V_ STATE_PROP	NAV_ONORBIT_RENDEZVOUS
$\bar{R}$ _TV	ONORBIT_REND_R_V_ STATE_PROP, ONORBIT_REND_AUTO_ INFLIGHT_UPDATE, REND_NAV_FILTER,*	COV_LAST_RESET, UVW_TO_M50, TARGET RESET, ONORBIT_REND_R_V_STATE_PROP, REL_NAV_DISPLAY_UPDATES, REND_COV_INIT, *
SHUTTLE_FILTER_FLAG	*	
SIG_DIAG_GPS	*	
$\bar{V}$ _FILT	ONORBIT_REND_R_V_ STATE_PROP, ONORBIT_REND_AUTO_ INFLIGHT_UPDATE, REND_NAV_FILTER,*	UVW_TO_M50
$\bar{V}$ _GPS_SEL	*	
V_PROP	ONORBIT_REND_R_V_ STATE_PROP	NAV_ONORBIT_RENDEZVOUS
$\bar{V}$ _TV	ONORBIT_REND_R_V_ STATE_PROP, ONORBIT_REND_AUTO_ INFLIGHT_UPDATE, REND_NAV_FILTER,*	COV_LAST_RESET, UVW_TO_M50, TARGET_RESET, ONORBIT_REND_R_V_STATE_PROP, REL_NAV_DISPLAY_UPDATES, REND_COV_INIT, *
* Onorbit/Rendezvous principal function, see Tables 4.2.11-1 and 4.2.11-2.		

**4.2.11 Onorbit Rendezvous Navigation Tables (4.126)**

The IDD inputs and outputs are listed in Table 4.2.11-1 and 4.2.11-2 respectively. 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 4.2.11-3, K-loads are listed in Table 4.2.11-4. Constants are listed in Table 4.2.11-5, and a principal function cross-reference listing below.

Onorbit/Rendezvous Navigation Principal Function (4.126) Cross-Reference Listing	
Local Name	Source Name
COAS_DATA_GOOD	NAV_SIGHT
COAS_ID	AXN
CURR_ORB_MASS	M
DAP_JET	JETS_ON
FALSE_TARG	FALSE_FLAG
FOM	FOM_SOP
GPS_DG	GPS_DG_SOP
GPS_FAIL_FOM	GPS_FAIL_FOM_SOP
IMU_NAV_ACCEL_THRESH	IMU_NAV_ACC_THRESH
M_M50_TO_BODY_COAS	T_M50_BODY
M_M50_TO_ST	T_M50_ST
Q_COAS_HORIZ	COAS_HORIZ(+X) COAS_HORIZ(-Z)
Q_COAS_VERT	COAS_VERT(+X) COAS_VERT(-Z)
Q_M50BODY_IMU	Q_BOD_M50
Q_RR_PITCH	RR_PITCHO
Q_RR_RNG	RR_RANGEO
Q_RR_RNG_DOT	RR_RNGRO
Q_RR_ROLL	RR_ROLLO
Q_ST_HORIZ	H_NAV
Q_ST_VERT	V_NAV
R_GPS_ECEF	R_GPS_ECEF_SOP(1,1) R_GPS_ECEF_SOP(1,2) R_GPS_ECEF_SOP(1,3) R_GPS_ECEF_SOP(2,1) R_GPS_ECEF_SOP(2,2) R_GPS_ECEF_SOP(2,3) R_GPS_ECEF_SOP(3,1) R_GPS_ECEF_SOP(3,2) R_GPS_ECEF_SOP(3,3)
RDOT_DATA_GOOD	RR_RNGR_DG
RNG_DATA_GOOD	RR_RNG_DG
RR_ANGLE_DATA_GOOD	RR_ANG_DG

Onorbit/Rendezvous Navigation Principal Function (4.126) Cross-Reference Listing	
Local Name	Source Name
SELF_TEST_FLAG	RR_SELF_TEST
ST_DATA_GOOD	DATA_GOOD
T_COAS	T_TARLOS
T_CURRENT_FILT	T_IMUS
T_GPS	T_GPS_SOP
T_LAST_GPS	T_IMU_SAVE_SOP
T_REND_RADAR	RR_TIM
TRG_TRK_MODE	NAV_TARGET
T_STAR_TRACKER	T_NAV
V_CURRENT_FILT	SEL_V_M50_CG(1)
	SEL_V_M50_CG(2)
	SEL_V_M50_CG(3)
V_GPS_ECEF	V_GPS_ECEF_SOP(1,1)
	V_GPS_ECEF_SOP(1,2)
	V_GPS_ECEF_SOP(1,3)
	V_GPS_ECEF_SOP(2,1)
	V_GPS_ECEF_SOP(2,2)
	V_GPS_ECEF_SOP(2,3)
	V_GPS_ECEF_SOP(3,1)
	V_GPS_ECEF_SOP(3,2)
	V_GPS_ECEF_SOP(3,3)
V_LAST_GPS	V_IMU_SAVE_SOP(1,1)
	V_IMU_SAVE_SOP(1,2)
	V_IMU_SAVE_SOP(1,3)
	V_IMU_SAVE_SOP(2,1)
	V_IMU_SAVE_SOP(2,2)
	V_IMU_SAVE_SOP(2,3)
	V_IMU_SAVE_SOP(3,1)
	V_IMU_SAVE_SOP(3,2)
	V_IMU_SAVE_SOP(3,3)

TABLE 4.2.11-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
ANGLES_AIF	V93J6237C	V/EL/Y EDIT OVRD-A/I/F	REL NAV DISP		VAR		92834C	
ANGLES_AIF	V93J6237CA	V/EL/Y EDIT OVRD-A/I/F	ORB/RND NAV SEQ		VAR		92834C	
AXN	V95X4972X	SELECTED COAS AXIS X OR -Z	STAR TRCK SOP		HXS		93017G	*
COAS_HORIZ(+X)	V95U4968C	COAS +X HORIZ CALIBRATION ANGLE	STAR TRCK SOP	RAD				
COAS_HORIZ(-Z)	V95U4969C	COAS -Z HORIZ CALIBRATION ANGLE	STAR TRCK SOP	RAD				
COAS_VERT(+X)	V95U4993C	COAS +X VERT CALIBRATION ANGLE	STAR TRCK SOP	RAD				
COAS_VERT(-Z)	V95U4992C	COAS -Z VERT CALIBRATION ANGLE	STAR TRCK SOP	RAD				
CORR_COEFF_GPS(1)	V90U3068C	GPS COV U V CORR COEFF	GPS RCVR STATE PROC		SPL		92067D	
CORR_COEFF_GPS(2)	V90U3069C	GPS COV U UDOT CORR COEFF	GPS RCVR STATE PROC		SPL		92067D	
CORR_COEFF_GPS(3)	V90U3070C	GPS COV U VDOT CORR COEFF	GPS RCVR STATE PROC		SPL		92067D	
CORR_COEFF_GPS(4)	V90U3071C	GPS COV V UDOT CORR COEFF	GPS RCVR STATE PROC		SPL		92067D	
CORR_COEFF_GPS(5)	V90U3072C	GPS COV V VDOT CORR COEFF	GPS RCVR STATE PROC		SPL		92067D	
CORR_COEFF_GPS(6)	V90U3073C	GPS COV W WDOT CORR COEFF	GPS RCVR STATE PROC		SPL		92067D	
CORR_COEFF_GPS(7)	V90U3074C	GPS COV UDOT VDOT CORR COEFF	GPS RCVR STATE PROC		SPL		92067D	
COV_ACCEL_UVW_INIT(1)	V90H4930C	U-COMP UNMOD ACC BIAS	ORB/RND NAV SEQ	FT2/S4				
COV_ACCEL_UVW_INIT(2)	V90H4931C	V-COMP UNMOD ACC BIAS	ORB/RND NAV SEQ	FT2/S4				
COV_ACCEL_UVW_INIT(3)	V90H4932C	W-COMP UNMOD ACC BIAS	ORB/RND NAV SEQ	FT2/S4				
COV_COR_UPDATE(1)	V96H1290C	UPLINKED ORB POS/VEL COR COEFF-1	UL					
COV_COR_UPDATE(2)	V96H1291C	UPLINKED ORB POS/VEL COR COEFF-2	UL					
COV_COR_UPDATE(3)	V96H1292C	UPLINKED ORB POS/VEL COR COEFF-3	UL					
COV_COR_UPDATE(4)	V96H1293C	UPLINKED ORB POS/VEL COR COEFF-4	UL					
COV_COR_UPDATE(5)	V96H1294C	UPLINKED ORB POS/VEL COR COEFF-5	UL					
COV_COR_UPDATE(6)	V96H1295C	UPLINKED ORB POS/VEL COR COEFF-6	UL					
COV_COR_UPDATE(7)	V96H1296C	UPLINKED ORB POS/VEL COR COEFF-7	UL					
COV_PWRD_FLT	V90X4936X	CURRENT COV PROP PWRD FLT	ORB/RND NAV SEQ				92297B	
COV_PWRD_FLT_LAST	V90X4845X	LAST VALUE OF PWRD FLT COV	ORB/RND NAV SEQ					
DATA_GOOD	V95X4771X	DATA GOOD FLAG	STAR TRCK SOP					
DOING_REND_NAV	V90X4765X	RENDZ NAV ACTIVE FLAG	ORB/RND NAV SEQ		BD		93017G	*
DO_COAS_ANGLES_NAV_LAST	V90X4725X	COAS ANGLES PROCESSING LAST FLAG	ORB/RND NAV SEQ					
DO_COVAR_REINIT	V93X6233X	COVARIANCE REINIT	REL NAV DISP		BD			
DO_ORB_TO_TGT	V93X6215XA	STATE VCTR X-FER ORB TO TGT FLAG	REL NAV DISP		BD		92834C	
DO_OV_UPLINK	V90X4754XB	DO ORBITER VECTOR UPLINK	UL					
DO_RRDOT_NAV_LAST	V90X4727X	RNG & RNG RATE PROCESSING LAST FLG	ORB/RND NAV SEQ					
DO_RR_ANGLES_NAV_LAST	V90X4726X	RR ANGLES PROCESSING LAST FLAG	ORB/RND NAV SEQ					
DO_ST_ANGLES_NAV_LAST	V90X4728X	ST ANGLES PROCESSING LAST FLAG	ORB/RND NAV SEQ					
DO_ST_RR_COAS	V93J6236C	ANGLE SELECTION-ST TRK/RR/COAS	REL NAV DISP	SPECIAL	HXS		79801G	
DO_TV_UPLINK	V90X4757XB	DO TARGET VECTOR UPLINK	UL					
DV_COV(1)	V90L4772CB	COV PROP DELTA V(1)	ORB/RND NAV SEQ	FT/S			93017G	*
DV_COV(2)	V90L4891CB	COV PROP DELTA V(2)	ORB/RND NAV SEQ	FT/S			93017G	*
DV_COV(3)	V90L4892CB	COV PROP DELTA V(3)	ORB/RND NAV SEQ	FT/S			93017G	*
E(1,1)	V90U4006CB	COVARIANCE MATRIX ELEMENT 1,1	ORB/RND NAV SEQ					
E(1,10)	V90U4016CB	COVARIANCE MATRIX ELEMENT 1,10	ORB/RND NAV SEQ				89648A	
E(1,11)	V90U4017CB	COVARIANCE MATRIX ELEMENT 1,11	ORB/RND NAV SEQ				89648A	
E(1,12)	V90U4018CB	COVARIANCE MATRIX ELEMENT 1,12	ORB/RND NAV SEQ				89648A	
E(1,13)	V90U4019CB	COVARIANCE MATRIX ELEMENT 1,13	ORB/RND NAV SEQ				89648A	
E(1,2)	V90U4007CB	COVARIANCE MATRIX ELEMENT 1,2	ORB/RND NAV SEQ				89648A	

TABLE 4.2.11-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
E(1,3)	V90U4008CB	COVARIANCE MATRIX ELEMENT 1,3	ORB/RND NAV SEQ				89648A	
E(1,4)	V90U4009CB	COVARIANCE MATRIX ELEMENT 1,4	ORB/RND NAV SEQ				89648A	
E(1,5)	V90U4011CB	COVARIANCE MATRIX ELEMENT 1,5	ORB/RND NAV SEQ				89648A	
E(1,6)	V90U4012CB	COVARIANCE MATRIX ELEMENT 1,6	ORB/RND NAV SEQ				89648A	
E(1,7)	V90U4013CB	COVARIANCE MATRIX ELEMENT 1,7	ORB/RND NAV SEQ				89648A	
E(1,8)	V90U4014CB	COVARIANCE MATRIX ELEMENT 1,8	ORB/RND NAV SEQ				89648A	
E(1,9)	V90U4015CB	COVARIANCE MATRIX ELEMENT 1,9	ORB/RND NAV SEQ				89648A	
E(10,1)	V90U4179C	COVARIANCE MATRIX ELEMENT 10,1	ORB/RND NAV SEQ					
E(10,10)	V90U4188CB	COVARIANCE MATRIX ELEMENT 10,10	ORB/RND NAV SEQ					
E(10,11)	V90U4189CB	COVARIANCE MATRIX ELEMENT 10,11	ORB/RND NAV SEQ				89648A	
E(10,12)	V90U4190CB	COVARIANCE MATRIX ELEMENT 10,12	ORB/RND NAV SEQ				89648A	
E(10,13)	V90U4191CB	COVARIANCE MATRIX ELEMENT 10,13	ORB/RND NAV SEQ				89648A	
E(10,2)	V90U4180C	COVARIANCE MATRIX ELEMENT 10,2	ORB/RND NAV SEQ					
E(10,3)	V90U4181C	COVARIANCE MATRIX ELEMENT 10,3	ORB/RND NAV SEQ					
E(10,4)	V90U4182C	COVARIANCE MATRIX ELEMENT 10,4	ORB/RND NAV SEQ					
E(10,5)	V90U4183C	COVARIANCE MATRIX ELEMENT 10,5	ORB/RND NAV SEQ					
E(10,6)	V90U4184C	COVARIANCE MATRIX ELEMENT 10,6	ORB/RND NAV SEQ					
E(10,7)	V90U4185C	COVARIANCE MATRIX ELEMENT 10,7	ORB/RND NAV SEQ					
E(10,8)	V90U4186C	COVARIANCE MATRIX ELEMENT 10,8	ORB/RND NAV SEQ					
E(10,9)	V90U4187C	COVARIANCE MATRIX ELEMENT 10,9	ORB/RND NAV SEQ					
E(11,1)	V90U4198C	COVARIANCE MATRIX ELEMENT 11,1	ORB/RND NAV SEQ					
E(11,10)	V90U4208C	COVARIANCE MATRIX ELEMENT 11,10	ORB/RND NAV SEQ					
E(11,11)	V90U4209CB	COVARIANCE MATRIX ELEMENT 11,11	ORB/RND NAV SEQ					
E(11,12)	V90U4210CB	COVARIANCE MATRIX ELEMENT 11,12	ORB/RND NAV SEQ				89648A	
E(11,13)	V90U4211CB	COVARIANCE MATRIX ELEMENT 11,13	ORB/RND NAV SEQ				89648A	
E(11,2)	V90U4199C	COVARIANCE MATRIX ELEMENT 11,2	ORB/RND NAV SEQ					
E(11,3)	V90U4200C	COVARIANCE MATRIX ELEMENT 11,3	ORB/RND NAV SEQ					
E(11,4)	V90U4202C	COVARIANCE MATRIX ELEMENT 11,4	ORB/RND NAV SEQ					
E(11,5)	V90U4203C	COVARIANCE MATRIX ELEMENT 11,5	ORB/RND NAV SEQ					
E(11,6)	V90U4204C	COVARIANCE MATRIX ELEMENT 11,6	ORB/RND NAV SEQ					
E(11,7)	V90U4205C	COVARIANCE MATRIX ELEMENT 11,7	ORB/RND NAV SEQ					
E(11,8)	V90U4206C	COVARIANCE MATRIX ELEMENT 11,8	ORB/RND NAV SEQ					
E(11,9)	V90U4207C	COVARIANCE MATRIX ELEMENT 11,9	ORB/RND NAV SEQ					
E(12,1)	V90U4218C	COVARIANCE MATRIX ELEMENT 12,1	ORB/RND NAV SEQ					
E(12,10)	V90U4227C	COVARIANCE MATRIX ELEMENT 12,10	ORB/RND NAV SEQ					
E(12,11)	V90U4228C	COVARIANCE MATRIX ELEMENT 12,11	ORB/RND NAV SEQ					
E(12,12)	V90U4229CB	COVARIANCE MATRIX ELEMENT 12,12	ORB/RND NAV SEQ					
E(12,13)	V90U4230CB	COVARIANCE MATRIX ELEMENT 12,13	ORB/RND NAV SEQ				89648A	
E(12,2)	V90U4219C	COVARIANCE MATRIX ELEMENT 12,2	ORB/RND NAV SEQ					
E(12,3)	V90U4220C	COVARIANCE MATRIX ELEMENT 12,3	ORB/RND NAV SEQ					
E(12,4)	V90U4221C	COVARIANCE MATRIX ELEMENT 12,4	ORB/RND NAV SEQ					
E(12,5)	V90U4222C	COVARIANCE MATRIX ELEMENT 12,5	ORB/RND NAV SEQ					
E(12,6)	V90U4223C	COVARIANCE MATRIX ELEMENT 12,6	ORB/RND NAV SEQ					
E(12,7)	V90U4224C	COVARIANCE MATRIX ELEMENT 12,7	ORB/RND NAV SEQ					
E(12,8)	V90U4225C	COVARIANCE MATRIX ELEMENT 12,8	ORB/RND NAV SEQ					
E(12,9)	V90U4226C	COVARIANCE MATRIX ELEMENT 12,9	ORB/RND NAV SEQ					

TABLE 4.2.11-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
E(13,1)	V90U4237C	COVARIANCE MATRIX ELEMENT	13,1	ORB/RND NAV SEQ				
E(13,10)	V90U4246C	COVARIANCE MATRIX ELEMENT	13,10	ORB/RND NAV SEQ				
E(13,11)	V90U4247C	COVARIANCE MATRIX ELEMENT	13,11	ORB/RND NAV SEQ				
E(13,12)	V90U4248C	COVARIANCE MATRIX ELEMENT	13,12	ORB/RND NAV SEQ				
E(13,13)	V90U4249CB	COVARIANCE MATRIX ELEMENT	13,13	ORB/RND NAV SEQ				
E(13,2)	V90U4238C	COVARIANCE MATRIX ELEMENT	13,2	ORB/RND NAV SEQ				
E(13,3)	V90U4239C	COVARIANCE MATRIX ELEMENT	13,3	ORB/RND NAV SEQ				
E(13,4)	V90U4240C	COVARIANCE MATRIX ELEMENT	13,4	ORB/RND NAV SEQ				
E(13,5)	V90U4241C	COVARIANCE MATRIX ELEMENT	13,5	ORB/RND NAV SEQ				
E(13,6)	V90U4242C	COVARIANCE MATRIX ELEMENT	13,6	ORB/RND NAV SEQ				
E(13,7)	V90U4243C	COVARIANCE MATRIX ELEMENT	13,7	ORB/RND NAV SEQ				
E(13,8)	V90U4244C	COVARIANCE MATRIX ELEMENT	13,8	ORB/RND NAV SEQ				
E(13,9)	V90U4245C	COVARIANCE MATRIX ELEMENT	13,9	ORB/RND NAV SEQ				
E(2,1)	V90U4026C	COVARIANCE MATRIX ELEMENT	2,1	ORB/RND NAV SEQ				
E(2,10)	V90U4035CB	COVARIANCE MATRIX ELEMENT	2,10	ORB/RND NAV SEQ			89648A	
E(2,11)	V90U4036CB	COVARIANCE MATRIX ELEMENT	2,11	ORB/RND NAV SEQ			89648A	
E(2,12)	V90U4037CB	COVARIANCE MATRIX ELEMENT	2,12	ORB/RND NAV SEQ			89648A	
E(2,13)	V90U4038CB	COVARIANCE MATRIX ELEMENT	2,13	ORB/RND NAV SEQ			89648A	
E(2,2)	V90U4027CB	COVARIANCE MATRIX ELEMENT	2,2	ORB/RND NAV SEQ				
E(2,3)	V90U4028CB	COVARIANCE MATRIX ELEMENT	2,3	ORB/RND NAV SEQ			89648A	
E(2,4)	V90U4029CB	COVARIANCE MATRIX ELEMENT	2,4	ORB/RND NAV SEQ			89648A	
E(2,5)	V90U4030CB	COVARIANCE MATRIX ELEMENT	2,5	ORB/RND NAV SEQ			89648A	
E(2,6)	V90U4031CB	COVARIANCE MATRIX ELEMENT	2,6	ORB/RND NAV SEQ			89648A	
E(2,7)	V90U4032CB	COVARIANCE MATRIX ELEMENT	2,7	ORB/RND NAV SEQ			89648A	
E(2,8)	V90U4033CB	COVARIANCE MATRIX ELEMENT	2,8	ORB/RND NAV SEQ			89648A	
E(2,9)	V90U4034CB	COVARIANCE MATRIX ELEMENT	2,9	ORB/RND NAV SEQ			89648A	
E(3,1)	V90U4045C	COVARIANCE MATRIX ELEMENT	3,1	ORB/RND NAV SEQ				
E(3,10)	V90U4054CB	COVARIANCE MATRIX ELEMENT	3,10	ORB/RND NAV SEQ			89648A	
E(3,11)	V90U4055CB	COVARIANCE MATRIX ELEMENT	3,11	ORB/RND NAV SEQ			89648A	
E(3,12)	V90U4056CB	COVARIANCE MATRIX ELEMENT	3,12	ORB/RND NAV SEQ			89648A	
E(3,13)	V90U4057CB	COVARIANCE MATRIX ELEMENT	3,13	ORB/RND NAV SEQ			89648A	
E(3,2)	V90U4046C	COVARIANCE MATRIX ELEMENT	3,2	ORB/RND NAV SEQ				
E(3,3)	V90U4047CB	COVARIANCE MATRIX ELEMENT	3,3	ORB/RND NAV SEQ				
E(3,4)	V90U4048CB	COVARIANCE MATRIX ELEMENT	3,4	ORB/RND NAV SEQ			89648A	
E(3,5)	V90U4049CB	COVARIANCE MATRIX ELEMENT	3,5	ORB/RND NAV SEQ			89648A	
E(3,6)	V90U4050CB	COVARIANCE MATRIX ELEMENT	3,6	ORB/RND NAV SEQ			89648A	
E(3,7)	V90U4051CB	COVARIANCE MATRIX ELEMENT	3,7	ORB/RND NAV SEQ			89648A	
E(3,8)	V90U4052CB	COVARIANCE MATRIX ELEMENT	3,8	ORB/RND NAV SEQ			89648A	
E(3,9)	V90U4053CB	COVARIANCE MATRIX ELEMENT	3,9	ORB/RND NAV SEQ			89648A	
E(4,1)	V90U4064C	COVARIANCE MATRIX ELEMENT	4,1	ORB/RND NAV SEQ				
E(4,10)	V90U4073CB	COVARIANCE MATRIX ELEMENT	4,10	ORB/RND NAV SEQ			89648A	
E(4,11)	V90U4074CB	COVARIANCE MATRIX ELEMENT	4,11	ORB/RND NAV SEQ			89648A	
E(4,12)	V90U4075CB	COVARIANCE MATRIX ELEMENT	4,12	ORB/RND NAV SEQ			89648A	
E(4,13)	V90U4076CB	COVARIANCE MATRIX ELEMENT	4,13	ORB/RND NAV SEQ			89648A	
E(4,2)	V90U4065C	COVARIANCE MATRIX ELEMENT	4,2	ORB/RND NAV SEQ				
E(4,3)	V90U4066C	COVARIANCE MATRIX ELEMENT	4,3	ORB/RND NAV SEQ				



TABLE 4.2.11-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
E(4,4)	V90U4067CB	COVARIANCE MATRIX ELEMENT 4,4	ORB/RND NAV SEQ					
E(4,5)	V90U4068CB	COVARIANCE MATRIX ELEMENT 4,5	ORB/RND NAV SEQ				89648A	
E(4,6)	V90U4069CB	COVARIANCE MATRIX ELEMENT 4,6	ORB/RND NAV SEQ				89648A	
E(4,7)	V90U4070CB	COVARIANCE MATRIX ELEMENT 4,7	ORB/RND NAV SEQ				89648A	
E(4,8)	V90U4071CB	COVARIANCE MATRIX ELEMENT 4,8	ORB/RND NAV SEQ				89648A	
E(4,9)	V90U4072CB	COVARIANCE MATRIX ELEMENT 4,9	ORB/RND NAV SEQ				89648A	
E(5,1)	V90U4083C	COVARIANCE MATRIX ELEMENT 5,1	ORB/RND NAV SEQ					
E(5,10)	V90U4092CB	COVARIANCE MATRIX ELEMENT 5,10	ORB/RND NAV SEQ				89648A	
E(5,11)	V90U4093CB	COVARIANCE MATRIX ELEMENT 5,11	ORB/RND NAV SEQ				89648A	
E(5,12)	V90U4094CB	COVARIANCE MATRIX ELEMENT 5,12	ORB/RND NAV SEQ				89648A	
E(5,13)	V90U4095CB	COVARIANCE MATRIX ELEMENT 5,13	ORB/RND NAV SEQ				89648A	
E(5,2)	V90U4084C	COVARIANCE MATRIX ELEMENT 5,2	ORB/RND NAV SEQ					
E(5,3)	V90U4085C	COVARIANCE MATRIX ELEMENT 5,3	ORB/RND NAV SEQ					
E(5,4)	V90U4086C	COVARIANCE MATRIX ELEMENT 5,4	ORB/RND NAV SEQ					
E(5,5)	V90U4087CB	COVARIANCE MATRIX ELEMENT 5,5	ORB/RND NAV SEQ					
E(5,6)	V90U4088CB	COVARIANCE MATRIX ELEMENT 5,6	ORB/RND NAV SEQ				89648A	
E(5,7)	V90U4089CB	COVARIANCE MATRIX ELEMENT 5,7	ORB/RND NAV SEQ				89648A	
E(5,8)	V90U4090CB	COVARIANCE MATRIX ELEMENT 5,8	ORB/RND NAV SEQ				89648A	
E(5,9)	V90U4091CB	COVARIANCE MATRIX ELEMENT 5,9	ORB/RND NAV SEQ				89648A	
E(6,1)	V90U4103C	COVARIANCE MATRIX ELEMENT 6,1	ORB/RND NAV SEQ					
E(6,10)	V90U4112CB	COVARIANCE MATRIX ELEMENT 6,10	ORB/RND NAV SEQ				89648A	
E(6,11)	V90U4113CB	COVARIANCE MATRIX ELEMENT 6,11	ORB/RND NAV SEQ				89648A	
E(6,12)	V90U4114CB	COVARIANCE MATRIX ELEMENT 6,12	ORB/RND NAV SEQ				89648A	
E(6,13)	V90U4115CB	COVARIANCE MATRIX ELEMENT 6,13	ORB/RND NAV SEQ				89648A	
E(6,2)	V90U4104C	COVARIANCE MATRIX ELEMENT 6,2	ORB/RND NAV SEQ					
E(6,3)	V90U4105C	COVARIANCE MATRIX ELEMENT 6,3	ORB/RND NAV SEQ					
E(6,4)	V90U4106C	COVARIANCE MATRIX ELEMENT 6,4	ORB/RND NAV SEQ					
E(6,5)	V90U4107C	COVARIANCE MATRIX ELEMENT 6,5	ORB/RND NAV SEQ					
E(6,6)	V90U4108CB	COVARIANCE MATRIX ELEMENT 6,6	ORB/RND NAV SEQ					
E(6,7)	V90U4109CB	COVARIANCE MATRIX ELEMENT 6,7	ORB/RND NAV SEQ				89648A	
E(6,8)	V90U4110CB	COVARIANCE MATRIX ELEMENT 6,8	ORB/RND NAV SEQ				89648A	
E(6,9)	V90U4111CB	COVARIANCE MATRIX ELEMENT 6,9	ORB/RND NAV SEQ				89648A	
E(7,1)	V90U4122C	COVARIANCE MATRIX ELEMENT 7,1	ORB/RND NAV SEQ					
E(7,10)	V90U4131CB	COVARIANCE MATRIX ELEMENT 7,10	ORB/RND NAV SEQ				89648A	
E(7,11)	V90U4132CB	COVARIANCE MATRIX ELEMENT 7,11	ORB/RND NAV SEQ				89648A	
E(7,12)	V90U4133CB	COVARIANCE MATRIX ELEMENT 7,12	ORB/RND NAV SEQ				89648A	
E(7,13)	V90U4134CB	COVARIANCE MATRIX ELEMENT 7,13	ORB/RND NAV SEQ				89648A	
E(7,2)	V90U4123C	COVARIANCE MATRIX ELEMENT 7,2	ORB/RND NAV SEQ					
E(7,3)	V90U4124C	COVARIANCE MATRIX ELEMENT 7,3	ORB/RND NAV SEQ					
E(7,4)	V90U4125C	COVARIANCE MATRIX ELEMENT 7,4	ORB/RND NAV SEQ					
E(7,5)	V90U4126C	COVARIANCE MATRIX ELEMENT 7,5	ORB/RND NAV SEQ					
E(7,6)	V90U4127C	COVARIANCE MATRIX ELEMENT 7,6	ORB/RND NAV SEQ					
E(7,7)	V90U4128CB	COVARIANCE MATRIX ELEMENT 7,7	ORB/RND NAV SEQ					
E(7,8)	V90U4129CB	COVARIANCE MATRIX ELEMENT 7,8	ORB/RND NAV SEQ				89648A	
E(7,9)	V90U4130CB	COVARIANCE MATRIX ELEMENT 7,9	ORB/RND NAV SEQ				89648A	
E(8,1)	V90U4141C	COVARIANCE MATRIX ELEMENT 8,1	ORB/RND NAV SEQ					

TABLE 4.2.11-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
E(8,10)	V90U4150CB	COVARIANCE MATRIX ELEMENT 8,10	ORB/RND NAV SEQ				89648A	
E(8,11)	V90U4151CB	COVARIANCE MATRIX ELEMENT 8,11	ORB/RND NAV SEQ				89648A	
E(8,12)	V90U4152CB	COVARIANCE MATRIX ELEMENT 8,12	ORB/RND NAV SEQ				89648A	
E(8,13)	V90U4153CB	COVARIANCE MATRIX ELEMENT 8,13	ORB/RND NAV SEQ				89648A	
E(8,2)	V90U4142C	COVARIANCE MATRIX ELEMENT 8,2	ORB/RND NAV SEQ					
E(8,3)	V90U4143C	COVARIANCE MATRIX ELEMENT 8,3	ORB/RND NAV SEQ					
E(8,4)	V90U4144C	COVARIANCE MATRIX ELEMENT 8,4	ORB/RND NAV SEQ					
E(8,5)	V90U4145C	COVARIANCE MATRIX ELEMENT 8,5	ORB/RND NAV SEQ					
E(8,6)	V90U4146C	COVARIANCE MATRIX ELEMENT 8,6	ORB/RND NAV SEQ					
E(8,7)	V90U4147C	COVARIANCE MATRIX ELEMENT 8,7	ORB/RND NAV SEQ					
E(8,8)	V90U4148CB	COVARIANCE MATRIX ELEMENT 8,8	ORB/RND NAV SEQ					
E(8,9)	V90U4149CB	COVARIANCE MATRIX ELEMENT 8,9	ORB/RND NAV SEQ				89648A	
E(9,1)	V90U4160C	COVARIANCE MATRIX ELEMENT 9,1	ORB/RND NAV SEQ					
E(9,10)	V90U4169CB	COVARIANCE MATRIX ELEMENT 9,10	ORB/RND NAV SEQ				89648A	
E(9,11)	V90U4170CB	COVARIANCE MATRIX ELEMENT 9,11	ORB/RND NAV SEQ				89648A	
E(9,12)	V90U4171CB	COVARIANCE MATRIX ELEMENT 9,12	ORB/RND NAV SEQ				89648A	
E(9,13)	V90U4172CB	COVARIANCE MATRIX ELEMENT 9,13	ORB/RND NAV SEQ				89648A	
E(9,2)	V90U4161C	COVARIANCE MATRIX ELEMENT 9,2	ORB/RND NAV SEQ					
E(9,3)	V90U4162C	COVARIANCE MATRIX ELEMENT 9,3	ORB/RND NAV SEQ					
E(9,4)	V90U4163C	COVARIANCE MATRIX ELEMENT 9,4	ORB/RND NAV SEQ					
E(9,5)	V90U4164C	COVARIANCE MATRIX ELEMENT 9,5	ORB/RND NAV SEQ					
E(9,6)	V90U4165C	COVARIANCE MATRIX ELEMENT 9,6	ORB/RND NAV SEQ					
E(9,7)	V90U4166C	COVARIANCE MATRIX ELEMENT 9,7	ORB/RND NAV SEQ					
E(9,8)	V90U4167C	COVARIANCE MATRIX ELEMENT 9,8	ORB/RND NAV SEQ					
E(9,9)	V90U4168CB	COVARIANCE MATRIX ELEMENT 9,9	ORB/RND NAV SEQ					
EARTH_POLE(1)	V90U0190C	X-COMP UNIT VCTR ALONG EARTH AXIS	RNP MAT COMP	ND	DPL		93090E	
EARTH_POLE(2)	V90U0191C	Y-COMP UNIT VCTR ALONG EARTH AXIS	RNP MAT COMP	ND	DPL		93090E	
EARTH_POLE(3)	V90U0192C	Z-COMP UNIT VCTR ALONG EARTH AXIS	RNP MAT COMP	ND	DPL		93090E	
FOM_SOP(1)	V90H3009C	GPS 1 FIGURE OF MERIT	GPS SOP		HXS		92067D	
FOM_SOP(2)	V90H3010C	GPS 2 FIGURE OF MERIT	GPS SOP		HXS		92067D	
FOM_SOP(3)	V90H3011C	GPS 3 FIGURE OF MERIT	GPS SOP		HXS		92067D	
GPS_DG_SOP(1)	V90X3012X	GPS 1 DATA GOOD FLAG	GPS SOP		BD		92067D	
GPS_DG_SOP(2)	V90X3013X	GPS 2 DATA GOOD FLAG	GPS SOP		BD		92067D	
GPS_DG_SOP(3)	V90X3014X	GPS 3 DATA GOOD FLAG	GPS SOP		BD		92067D	
GPS_FAIL_FOM_SOP(1)	V90X3015X	GPS 1 FOM THRESH FAIL FLAG	GPS SOP		BD		92067D	
GPS_FAIL_FOM_SOP(2)	V90X3016X	GPS 2 FOM THRESH FAIL FLAG	GPS SOP		BD		92067D	
GPS_FAIL_FOM_SOP(3)	V90X3017X	GPS 3 FOM THRESH FAIL FLAG	GPS SOP		BD		92067D	
GPS_RATIO_FLAG	V90X0440X	SEL GPS RESID RATIO EDIT FLAG	GPS RCVR STATE PROC		BD		92132C	
GPS_SV_SEL_AVAIL	V90X3081XB	GPS SEL STATE VCTR AVAIL FLAG	ORB/RND NAV SEQ		BD		91051K	
GPS_SV_SEL_AVAIL	V90X3081XC	GPS SEL STATE VCTR AVAIL FLAG	GPS RCVR STATE PROC		BD		92132C	
GPS_TO_GC_AIF	V93J1200CB	GPS TO G&C A/I/F CMD	GPS STATUS DISP		HXS		92067D	
GPS_TO_NAV_AI	V93X1202XB	GPS TO NAV AUTO/INHIBIT CMD	GPS STATUS DISP		BD		92067D	
GPS_TO_NAV_AI	V93X1202XC	GPS TO NAV AUTO/INHIBIT CMD	REL NAV DISP		BD		92144C	
GPS_TO_NAV_FORCE	V93X1201XB	GPS TO NAV FORCE CMD	GPS STATUS DISP		BD		92067D	
GPS_TO_NAV_FORCE	V93X1201XC	GPS TO NAV FORCE CMD	REL NAV DISP		BD		92144C	
G_TV_LAST(1)	V90A4796C	TARGET TOTAL X-COMP ACCEL VEC-M50	ORB/RND NAV SEQ	FT/S2				

TABLE 4.2.11-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
G_TV_LAST(2)	V90A4797C	TARGET TOTAL Y-COMP ACCEL VEC-M50	ORB/RND NAV SEQ	FT/S2				
G_TV_LAST(3)	V90A4788C	TARGET TOTAL Z-COMP ACCEL VEC-M50	ORB/RND NAV SEQ	FT/S2				
H_NAV	V95H4753C	SEL ST AVERAGE HORIZONTAL ANGLE	STAR TRCK SOP	RAD				
IMU_NAV_ACC_THRESH	V93A6710C	IMU NAV ACCEL THRESHOLD	IMU ALIGN DISP	MICROG	VAR		89813B	
I_CYCLE	V90J4889CB	COVARIANCE PROP COUNTER	ORB/RND NAV SEQ				93017G	*
JETS_ON	V90X2349X	RCS JET FIRING INDICATION FLAG	ORB DAP					
KFACTOR	V96U8173C	UPLINKED ORB DRAG SCALE FACTOR	UL	ND	SPL		92545B	
M	V90U1961CD	CURRENT VEHICLE MASS	ORB GUID	SLUGS			89648A	
M/CURR_ORB_MASS/WEIGHT	V90U1961CK	CURRENT VEHICLE MASS	ORB/RND NAV SEQ	SLUGS				
MEAS_ENABLE	V93X6232XA	NAV MEASUREMENT ENA CMD	REL NAV DISP					
MEAS_ENABLE	V93X6232XB	NAV MEASUREMENT ENA CMD	ORB/RND NAV SEQ					
MM_CODE	V90Q8001C	MAJOR MODE CODE	UI		HXS		93017G	*
M_M50TOEF_AT_EPOCH(1,1)	V97U5738C	M50 TO EF TRANS MATRIX ELEM 1,1	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(1,2)	V97U5739C	M50 TO EF TRANS MATRIX ELEM 1,2	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(1,3)	V97U5740C	M50 TO EF TRANS MATRIX ELEM 1,3	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(2,1)	V97U5741C	M50 TO EF TRANS MATRIX ELEM 2,1	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(2,2)	V97U5742C	M50 TO EF TRANS MATRIX ELEM 2,2	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(2,3)	V97U5743C	M50 TO EF TRANS MATRIX ELEM 2,3	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(3,1)	V97U5744C	M50 TO EF TRANS MATRIX ELEM 3,1	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(3,2)	V97U5745C	M50 TO EF TRANS MATRIX ELEM 3,2	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(3,3)	V97U5746C	M50 TO EF TRANS MATRIX ELEM 3,3	RNP MAT COMP	ND	DPL		93090E	
NAV_SIGHT	V95X4779X	NAVIGATION SIGHTING FLAG COAS	STAR TRCK SOP					
NAV_TARGET	V95X4778X	NAV TARGET TRACK MODE FLAG	STAR TRCK SOP					
NOISY_NAV_MEAS	V90X4937X	NAV MEAS PROC FLAG	ORB/RND NAV SEQ				92297B	
N_ACCEPT(1)	V90J1402CB	H/X/AZ ANGULAR MARKS ACCEPTED	ORB/RND NAV SEQ				93017G	*
N_ACCEPT(2)	V90J1403CB	V/Y/EL ANGULAR MARKS ACCEPTED	ORB/RND NAV SEQ				93017G	*
N_ACCEPT(3)	V90J1400CB	RR RNG MARKS ACCEPTED	ORB/RND NAV SEQ				93017G	*
N_ACCEPT(4)	V90J1401CB	RR R DOT MARKS ACCEPTED	ORB/RND NAV SEQ				93017G	*
N_REJECT(1)	V90J1407CB	H/X/AZ ANGULAR MARKS REJECTED	ORB/RND NAV SEQ				93017G	*
N_REJECT(2)	V90J1408CB	V/Y/EL ANGULAR MARKS REJECTED	ORB/RND NAV SEQ				93017G	*
N_REJECT(3)	V90J1405CB	RR RNG MARKS REJECTED	ORB/RND NAV SEQ				93017G	*
N_REJECT(4)	V90J1406CB	RR RDOT MARKS REJECTED	ORB/RND NAV SEQ				93017G	*
PRED_ENA_FLAG	V90X4266X	PREDICTOR ENABLE FLAG	ORB/RND NAV SEQ					
PRED_USE	V90J4768CB	PREDICTOR STATE INDICATOR	ORB/RND NAV SEQ				93017G	*
PWRD_FLT_NAV	V93X5408XA	PWR FLT NAV AVG G ON/OFF CMD	ORB/RND NAV SEQ					
PWRD_FLT_NAV	V93X5408XB	PWR FLT NAV AVG G ON/OFF CMD	FCS/DED DISP					
PWRD_FLT_NAV	V93X5408XC	PWR FLT NAV AVG G ON/OFF CMD	REL NAV DISP					
Q_BOD_M50(1)/Q_B_M50(1)	V90U2240CB	M50 TO BODY QUAT MEASURED ELEM 1	ORB ATT PROC		SPL		93017G	*
Q_BOD_M50(2)/Q_B_M50(2)	V90U2241CB	M50 TO BODY QUAT MEASURED ELEM 2	ORB ATT PROC		SPL		93017G	*
Q_BOD_M50(3)/Q_B_M50(3)	V90U2242CB	M50 TO BODY QUAT MEASURED ELEM 3	ORB ATT PROC		SPL		93017G	*
Q_BOD_M50(4)/Q_B_M50(4)	V90U2243CB	M50 TO BODY QUAT MEASURED ELEM 4	ORB ATT PROC		SPL		93017G	*
Q_M50BODY_RR(1)	V95U4312C	M50 TO BODY R RADAR ELEM 1	RR SOP					
Q_M50BODY_RR(2)	V95U4313C	M50 TO BODY R RADAR ELEM 2	RR SOP					
Q_M50BODY_RR(3)	V95U4314C	M50 TO BODY R RADAR ELEM 3	RR SOP					
Q_M50BODY_RR(4)	V95U4315C	M50 TO BODY R RADAR ELEM 4	RR SOP					
RANGE_AIF	V93J6241C	RANGE EDIT OVRD-A/I/F	REL NAV DISP		VAR			

TABLE 4.2.11-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
RANGE_AIF	V93J6241CA	RANGE EDIT OVRD-A/I/F	ORB/RND NAV SEQ		VAR		92834C	
RDOT_AIF	V93J6247C	RR RANGE RATE EDIT OVRD-A/I/F	REL NAV DISP		VAR			
RDOT_AIF	V93J6247CA	RR RANGE RATE EDIT OVRD-A/I/F	ORB/RND NAV SEQ		VAR		92834C	
RNP_TIME_UL	V90X0441X	RNP TIME PARAMETERS UPLINK CMD RCV	UL		BD		92392C	
RR_ANG_DG	V95X4295X	R RADAR ANGLE DATA GOOD	RR SOP					
RR_PITCHO	V95H4281C	R RADAR PITCH ANGLE	RR SOP	DEG	VAR		92297B	
RR_RANGEO	V95H4287C	R RADAR RANGE	RR SOP	FT	VAR		92297B	
RR_RNGRO	V95R4288C	R RADAR RANGE RATE	RR SOP	FT/S	VAR		92297B	
RR_RNGR_DG	V95X4294X	R RADAR RANGE RATE DATA GOOD	RR SOP					
RR_RNG_DG	V95X4293X	R RADAR RANGE DATA GOOD	RR SOP					
RR_ROLLO	V95H4284C	R RADAR ROLL ANGLE	RR SOP	DEG	VAR		92297B	
RR_SELF_TEST	V95X4309X	R RADAR SELF TEST ON FLAG	RR SOP				92297B	
RR_TIM	V95W4292C	R RADAR TIME	RR SOP	S			92297B	
R_FILT(1)	V90H0584CD	X-COMP OF FLTR'S CURR POS VECTOR	ORB/RND NAV SEQ	FT				
R_FILT(2)	V90H0585CD	Y-COMP OF FLTR'S CURR POS VECTOR	ORB/RND NAV SEQ	FT				
R_FILT(3)	V90H0586CD	Z-COMP OF FLTR'S CURR POS VECTOR	ORB/RND NAV SEQ	FT				
R_GND(1)	V96H3500CA	UPLINKED ORBITER POS VECTOR X	UL	FT			92237	
R_GND(2)	V96H3501CA	UPLINKED ORBITER POS VECTOR Y	UL	FT			92237	
R_GND(3)	V96H3502CA	UPLINKED ORBITER POS VECTOR Z	UL	FT			92237	
R_GPS_ECEF_SOP(1,1)	V90H3036C	GPS 1 WGS84 POS VECTOR X-COMP	GPS SOP	FT	DPL		92067D	
R_GPS_ECEF_SOP(1,2)	V90H3037C	GPS 1 WGS84 POS VECTOR Y-COMP	GPS SOP	FT	DPL		92067D	
R_GPS_ECEF_SOP(1,3)	V90H3038C	GPS 1 WGS84 POS VECTOR Z-COMP	GPS SOP	FT	DPL		92067D	
R_GPS_ECEF_SOP(2,1)	V90H3039C	GPS 2 WGS84 POS VECTOR X-COMP	GPS SOP	FT	DPL		92067D	
R_GPS_ECEF_SOP(2,2)	V90H3040C	GPS 2 WGS84 POS VECTOR Y-COMP	GPS SOP	FT	DPL		92067D	
R_GPS_ECEF_SOP(2,3)	V90H3041C	GPS 2 WGS84 POS VECTOR Z-COMP	GPS SOP	FT	DPL		92067D	
R_GPS_ECEF_SOP(3,1)	V90H3042C	GPS 3 WGS84 POS VECTOR X-COMP	GPS SOP	FT	DPL		92067D	
R_GPS_ECEF_SOP(3,2)	V90H3043C	GPS 3 WGS84 POS VECTOR Y-COMP	GPS SOP	FT	DPL		92067D	
R_GPS_ECEF_SOP(3,3)	V90H3044C	GPS 3 WGS84 POS VECTOR Z-COMP	GPS SOP	FT	DPL		92067D	
R_GPS_SEL(1)	V90H3082C	X-COMP OF SEL GPS POS VECTOR	GPS RCVR STATE PROC	FT	DPL		92067D	
R_GPS_SEL(2)	V90H3083C	Y-COMP OF SEL GPS POS VECTOR	GPS RCVR STATE PROC	FT	DPL		92067D	
R_GPS_SEL(3)	V90H3084C	Z-COMP OF SEL GPS POS VECTOR	GPS RCVR STATE PROC	FT	DPL		92067D	
R_LAST(1)	V90H4782C	CURR ORB X-POS FOR COV PROP	ORB/RND NAV SEQ	FT				
R_LAST(2)	V90H4783C	CURR ORB Y-POS FOR COV PROP	ORB/RND NAV SEQ	FT				
R_LAST(3)	V90H4784C	CURR ORB Z-POS FOR COV PROP	ORB/RND NAV SEQ	FT				
R_PRED_FINAL(1)	V95H0811C	X-COMP PRED SHUTTLE POS VECTOR	ORB PRED	FT	DPL		93017G	*
R_PRED_FINAL(2)	V95H0812C	Y-COMP PRED SHUTTLE POS VECTOR	ORB PRED	FT	DPL		93017G	*
R_PRED_FINAL(3)	V95H0813C	Z-COMP PRED SHUTTLE POS VECTOR	ORB PRED	FT	DPL		93017G	*
R_PROP(1)	V90H4991C	X-COMP OF BU POS VECTOR	ORB/RND NAV SEQ	FT				
R_PROP(2)	V90H4992C	Y-COMP OF BU POS VECTOR	ORB/RND NAV SEQ	FT				
R_PROP(3)	V90H4993C	Z-COMP OF BU POS VECTOR	ORB/RND NAV SEQ	FT				
R_TV(1)	V90H0307CB	X-COMP TARGET VEH POS VCTR-M50	ORB/RND NAV SEQ	FT				
R_TV(2)	V90H0308CB	Y-COMP TARGET VEH POS VCTR-M50	ORB/RND NAV SEQ	FT				
R_TV(3)	V90H0309CB	Z-COMP TARGET VEH POS VCTR-M50	ORB/RND NAV SEQ	FT				
R_TV_GND(1)	V96H1277C	UPLINKED TARGET POS VECTOR-1	UL	FT				
R_TV_GND(2)	V96H1278C	UPLINKED TARGET POS VECTOR-2	UL	FT				
R_TV_GND(3)	V96H1279C	UPLINKED TARGET POS VECTOR-3	UL	FT				

TABLE 4.2.11-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
R_TV_LAST(1)	V90H4789C	TARGET X-POS FOR COV PROP	ORB/RND NAV SEQ	FT				
R_TV_LAST(2)	V90H4790C	TARGET Y-POS FOR COV PROP	ORB/RND NAV SEQ	FT				
R_TV_LAST(3)	V90H4791C	TARGET Z-POS FOR COV PROP	ORB/RND NAV SEQ	FT				
SEL_V_M50_CG(1)	V90L2607C	SEL TOTAL X VEL M50 AT CG	IMU RM	FT/S				
SEL_V_M50_CG(2)	V90L2608C	SEL TOTAL Y VEL M50 AT CG	IMU RM	FT/S				
SEL_V_M50_CG(3)	V90L2609C	SEL TOTAL Z VEL M50 AT CG	IMU RM	FT/S				
SEQ_ACCEPT(1)	V90J4732CB	NUM SEQ MARKS ACCEPT-H/X/AZ	ORB/RND NAV SEQ				93017G	*
SEQ_ACCEPT(2)	V90J4733CB	NUM SEQ MARKS ACCEPT-V/Y/EL	ORB/RND NAV SEQ				93017G	*
SEQ_ACCEPT(3)	V90J4730CB	NUM SEQ MARKS ACCEPT-RNG	ORB/RND NAV SEQ				93017G	*
SEQ_ACCEPT(4)	V90J4731CB	NUM SEQ MARKS ACCEPT-RDOT	ORB/RND NAV SEQ				93017G	*
SEQ_REJECT(1)	V90J4737CB	NUM SEQ MARKS REJECT-H/X/AZ	ORB/RND NAV SEQ				93017G	*
SEQ_REJECT(2)	V90J4738CB	NUM SEQ MARKS REJECT-V/Y/EL	ORB/RND NAV SEQ				93017G	*
SEQ_REJECT(3)	V90J4735CB	NUM SEQ MARKS REJECT-RNG	ORB/RND NAV SEQ				93017G	*
SEQ_REJECT(4)	V90J4736CB	NUM SEQ MARKS REJECT-RDOT	ORB/RND NAV SEQ				93017G	*
SHUTTLE_FILTER_FLAG	V90X4952X	VEHICLE STATE TO BE FILTERED	REL NAV DISP		BD		92067D	
SIG_DIAG_GPS(1)	V90H3094C	GPS NAV RESET COV DIAG ELEM 1	GPS RCVR STATE PROC	FT	SPL		92067D	
SIG_DIAG_GPS(2)	V90H3095C	GPS NAV RESET COV DIAG ELEM 2	GPS RCVR STATE PROC	FT	SPL		92067D	
SIG_DIAG_GPS(3)	V90H3096C	GPS NAV RESET COV DIAG ELEM 3	GPS RCVR STATE PROC	FT	SPL		92067D	
SIG_DIAG_GPS(4)	V90L3097C	GPS NAV RESET COV DIAG ELEM 4	GPS RCVR STATE PROC	FT/S	SPL		92067D	
SIG_DIAG_GPS(5)	V90L3098C	GPS NAV RESET COV DIAG ELEM 5	GPS RCVR STATE PROC	FT/S	SPL		92067D	
SIG_DIAG_GPS(6)	V90L3099C	GPS NAV RESET COV DIAG ELEM 6	GPS RCVR STATE PROC	FT/S	SPL		92067D	
SIG_UPDATE(1)	V96H1284C	UPLINKED ORB POS/VEL UVW STD DEV-1	UL	FT				
SIG_UPDATE(2)	V96H1285C	UPLINKED ORB POS/VEL UVW STD DEV-2	UL	FT				
SIG_UPDATE(3)	V96H1286C	UPLINKED ORB POS/VEL UVW STD DEV-3	UL	FT				
SIG_UPDATE(4)	V96H1287C	UPLINKED ORB POS/VEL UVW STD DEV-4	UL	FT/S				
SIG_UPDATE(5)	V96H1288C	UPLINKED ORB POS/VEL UVW STD DEV-5	UL	FT/S				
SIG_UPDATE(6)	V96H1289C	UPLINKED ORB POS/VEL UVW STD DEV-6	UL	FT/S				
SQR_EMU	V90U1241C	SQUARE ROOT OF EARTH MU	ORB/RND NAV SEQ	FT3/S2			89648A	
SV_SOURCE_FOR_UPP	V90X4989XA	USER STATE SELECTION FLAG	ORB/RND NAV SEQ					
SV_SOURCE_FOR_UPP	V90X4989XB	USER STATE SELECTION FLAG	REL NAV DISP				92157	
TARGET_KFACTOR	V90U4004C	UPLINKED TGT DRAG SCALE FACTOR	UL	ND	SPL		92545B	
TAU_UNMOD_ACC_COV	V90W4929C	CORR TIME CONST UNMOD ACC COV PROP	ORB/RND NAV SEQ	S			89648A	
TFOFF	V96W8178C	UPLINKED VENT OFF TIME	UL	S				
TFON	V96W8177C	UPLINKED VENT ON TIME	UL	S				
TOT_ACC_LAST(1)	V90A1262C	LAST X-COMP OF TOTAL ORB ACCEL-M50	ORB/RND NAV SEQ	FT/S2				
TOT_ACC_LAST(2)	V90A1263C	LAST Y-COMP OF TOTAL ORB ACCEL-M50	ORB/RND NAV SEQ	FT/S2				
TOT_ACC_LAST(3)	V90A1264C	LAST Z-COMP OF TOTAL ORB ACCEL-M50	ORB/RND NAV SEQ	FT/S2				
T_COV_LAST	V90W4771C	TIME OF COV MATRIX	ORB/RND NAV SEQ	S				
T_EPOCH	V97W5528C	TIME TAG FOR M_M50TOEF_AT_EPOCH	RNP MAT COMP	S	DPL		93090E	
T_GND	V96W3520CA	UPLINKED ORB STATE VEC TIME TAG	UL	S			92237	
T_GPS_LAST_UPDATE	V90W3556CA	TIME OF NAV RESET WITH SEL GPS	D/L NAV SEQ	S	DPL		92369B	
T_GPS_LAST_UPDATE	V90W3556CB	TIME OF NAV RESET WITH SEL GPS	ENT NAV	S	DPL		92369B	
T_GPS_LAST_UPDATE	V90W3556CD	TIME OF NAV RESET WITH SEL GPS	ORB/RND NAV SEQ	S	DPL		92369B	
T_GPS_LAST_UPDATE	V90W3556CF	TIME OF NAV RESET WITH SEL GPS	ASC NAV SEQ	S	DPL		92369B	
T_GPS_SEL	V90W3561C	GPS SEL SV TIME TAG	GPS RCVR STATE PROC	S	DPL		92067D	
T_GPS_SOP(1)	V90W3045C	GPS 1 STATE TIME TAG(GMT)	GPS SOP	S	DPL		92067D	

TABLE 4.2.11-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
T_GPS_SOP(2)	V90W3046C	GPS 2 STATE TIME TAG(GMT)	GPS SOP	S	DPL		92067D	
T_GPS_SOP(3)	V90W3047C	GPS 3 STATE TIME TAG(GMT)	GPS SOP	S	DPL		92067D	
T_IMUS	V95W0002C	IMU INPUT TRANS TIME TAG	IMU INT PROC	S	DPL		93017G	*
T_IMU_SAVE_SOP(1)	V90W3048C	IMU TIME TAG FOR CURNT GPS 1 STATE	GPS SOP	S	DPL		92067D	
T_IMU_SAVE_SOP(2)	V90W3049C	IMU TIME TAG FOR CURNT GPS 2 STATE	GPS SOP	S	DPL		92067D	
T_IMU_SAVE_SOP(3)	V90W3050C	IMU TIME TAG FOR CURNT GPS 3 STATE	GPS SOP	S	DPL		92067D	
T_LAST_FILT	V90W1252CB	TIME OF FILTER STATE VECTOR	ORB/RND NAV SEQ	S				
T_M50_BODY(1,1)	V95U4809C	M50 TO BODY/COMPONENT 1,1	STAR TRCK SOP					
T_M50_BODY(1,2)	V95U4810C	M50 TO BODY/COMPONENT 1,2	STAR TRCK SOP					
T_M50_BODY(1,3)	V95U4811C	M50 TO BODY/COMPONENT 1,3	STAR TRCK SOP					
T_M50_BODY(2,1)	V95U4812C	M50 TO BODY/COMPONENT 2,1	STAR TRCK SOP					
T_M50_BODY(2,2)	V95U4813C	M50 TO BODY/COMPONENT 2,2	STAR TRCK SOP					
T_M50_BODY(2,3)	V95U4814C	M50 TO BODY/COMPONENT 2,3	STAR TRCK SOP					
T_M50_BODY(3,1)	V95U4815C	M50 TO BODY/COMPONENT 3,1	STAR TRCK SOP					
T_M50_BODY(3,2)	V95U4816C	M50 TO BODY/COMPONENT 3,2	STAR TRCK SOP					
T_M50_BODY(3,3)	V95U4817C	M50 TO BODY/COMPONENT 3,3	STAR TRCK SOP					
T_M50_ST(1,1)	V95U4800C	M50 TO SEL ST/COMPONENT 1,1	STAR TRCK SOP					
T_M50_ST(1,2)	V95U4801C	M50 TO SEL ST/COMPONENT 1,2	STAR TRCK SOP					
T_M50_ST(1,3)	V95U4802C	M50 TO SEL ST/COMPONENT 1,3	STAR TRCK SOP					
T_M50_ST(2,1)	V95U4803C	M50 TO SEL ST/COMPONENT 2,1	STAR TRCK SOP					
T_M50_ST(2,2)	V95U4804C	M50 TO SEL ST/COMPONENT 2,2	STAR TRCK SOP					
T_M50_ST(2,3)	V95U4805C	M50 TO SEL ST/COMPONENT 2,3	STAR TRCK SOP					
T_M50_ST(3,1)	V95U4806C	M50 TO SEL ST/COMPONENT 3,1	STAR TRCK SOP					
T_M50_ST(3,2)	V95U4807C	M50 TO SEL ST/COMPONENT 3,2	STAR TRCK SOP					
T_M50_ST(3,3)	V95U4808C	M50 TO SEL ST/COMPONENT 3,3	STAR TRCK SOP					
T_NAV	V95W4760C	TIME TAG FOR TARGET SIGHTING DATA	STAR TRCK SOP	S			89673B	
T_RESET	V90W0534CH	TIME OF FILTER STATE VCTR	ORB/RND NAV SEQ	S			92834C	
T_TARLOS	V95W4985C	TIME OF TARGET SIGHTING(COAS)	STAR TRCK SOP	S			89673B	
T_TV	V90W0315CB	TIME TAG OF TARGET VEH STATE VCTR	ORB/RND NAV SEQ	S			93017G	*
T_TV_GND	V96W1283C	UPLINKED TGT STATE VECTOR TIME TAG	UL	S				
UNMOD_ACC_BIAS(1)	V90U1265C	X-COMP OF UNMODELED ACCEL BIAS ERR	ORB/RND NAV SEQ	FT/S2				
UNMOD_ACC_BIAS(2)	V90U1266C	Y-COMP OF UNMODELED ACCEL BIAS ERR	ORB/RND NAV SEQ	FT/S2				
UNMOD_ACC_BIAS(3)	V90U1267C	Z-COMP OF UNMODELED ACCEL BIAS ERR	ORB/RND NAV SEQ	FT/S2				
VAR_UNMOD_ACC(1)	V90A4933C	VARIANCE OF UNMOD ACC-1	ORB/RND NAV SEQ	FT2/S4				
VAR_UNMOD_ACC(2)	V90A4934C	VARIANCE OF UNMOD ACC-2	ORB/RND NAV SEQ	FT2/S4				
VAR_UNMOD_ACC(3)	V90A4935C	VARIANCE OF UNMOD ACC-3	ORB/RND NAV SEQ	FT2/S4				
VFORCE(X)	V96U8174C	UPLINKED VENT FORCE X BODY COMP	UL	LBS				
VFORCE(Y)	V96U8175C	UPLINKED VENT FORCE Y BODY COMP	UL	LBS				
VFORCE(Z)	V96U8176C	UPLINKED VENT FORCE Z BODY COMP	UL	LBS				
V_FILT(1)	V90L0624CD	X-COMP OF FLTR'S CURR VEL VECTOR	ORB/RND NAV SEQ	FT/S	SPL			
V_FILT(2)	V90L0625CD	Y-COMP OF FLTR'S CURR VEL VECTOR	ORB/RND NAV SEQ	FT/S	SPL			
V_FILT(3)	V90L0626CD	Z-COMP OF FLTR'S CURR VEL VECTOR	ORB/RND NAV SEQ	FT/S	SPL			
V_GND(1)	V96L3510CA	UPLINKED ORBITER VEL VECTOR X	UL	FT/S			92237	
V_GND(2)	V96L3511CA	UPLINKED ORBITER VEL VECTOR Y	UL	FT/S			92237	
V_GND(3)	V96L3512CA	UPLINKED ORBITER VEL VECTOR Z	UL	FT/S			92237	
V_GPS_ECEF_SOP(1,1)	V90L3051C	GPS 1 WGS84 VEL VECTOR X-COMP	GPS SOP	FT/S	SPL		92067D	

TABLE 4.2.11-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
V_GPS_ECEF_SOP(1,2)	V90L3052C	GPS 1 WGS84 VEL VECTOR Y-COMP	GPS SOP	FT/S	SPL		92067D	
V_GPS_ECEF_SOP(1,3)	V90L3053C	GPS 1 WGS84 VEL VECTOR Z-COMP	GPS SOP	FT/S	SPL		92067D	
V_GPS_ECEF_SOP(2,1)	V90L3054C	GPS 2 WGS84 VEL VECTOR X-COMP	GPS SOP	FT/S	SPL		92067D	
V_GPS_ECEF_SOP(2,2)	V90L3055C	GPS 2 WGS84 VEL VECTOR Y-COMP	GPS SOP	FT/S	SPL		92067D	
V_GPS_ECEF_SOP(2,3)	V90L3056C	GPS 2 WGS84 VEL VECTOR Z-COMP	GPS SOP	FT/S	SPL		92067D	
V_GPS_ECEF_SOP(3,1)	V90L3057C	GPS 3 WGS84 VEL VECTOR X-COMP	GPS SOP	FT/S	SPL		92067D	
V_GPS_ECEF_SOP(3,2)	V90L3058C	GPS 3 WGS84 VEL VECTOR Y-COMP	GPS SOP	FT/S	SPL		92067D	
V_GPS_ECEF_SOP(3,3)	V90L3059C	GPS 3 WGS84 VEL VECTOR Z-COMP	GPS SOP	FT/S	SPL		92067D	
V_GPS_SEL(1)	V90L3108C	X-COMP OF SEL GPS VEL VECTOR	GPS RCVR STATE PROC	FT/S	DPL		92244A	
V_GPS_SEL(2)	V90L3109C	Y-COMP OF SEL GPS VEL VECTOR	GPS RCVR STATE PROC	FT/S	DPL		92244A	
V_GPS_SEL(3)	V90L3110C	Z-COMP OF SEL GPS VEL VECTOR	GPS RCVR STATE PROC	FT/S	DPL		92244A	
V_IMU_SAVE_SOP(1,1)	V95L0133C	IMU ACCUM X VEL FOR CURRENT GPS 1	GPS SOP	FT/S	DPL		92067D	
V_IMU_SAVE_SOP(1,2)	V95L0134C	IMU ACCUM Y VEL FOR CURRENT GPS 1	GPS SOP	FT/S	DPL		92067D	
V_IMU_SAVE_SOP(1,3)	V95L0135C	IMU ACCUM Z VEL FOR CURRENT GPS 1	GPS SOP	FT/S	DPL		92067D	
V_IMU_SAVE_SOP(2,1)	V95L0136C	IMU ACCUM X VEL FOR CURRENT GPS 2	GPS SOP	FT/S	DPL		92067D	
V_IMU_SAVE_SOP(2,2)	V95L0137C	IMU ACCUM Y VEL FOR CURRENT GPS 2	GPS SOP	FT/S	DPL		92067D	
V_IMU_SAVE_SOP(2,3)	V95L0138C	IMU ACCUM Z VEL FOR CURRENT GPS 2	GPS SOP	FT/S	DPL		92067D	
V_IMU_SAVE_SOP(3,1)	V95L0139C	IMU ACCUM X VEL FOR CURRENT GPS 3	GPS SOP	FT/S	DPL		92067D	
V_IMU_SAVE_SOP(3,2)	V95L0140C	IMU ACCUM Y VEL FOR CURRENT GPS 3	GPS SOP	FT/S	DPL		92067D	
V_IMU_SAVE_SOP(3,3)	V95L0141C	IMU ACCUM Z VEL FOR CURRENT GPS 3	GPS SOP	FT/S	DPL		92067D	
V_LAST(1)	V90L4785C	CURR ORB X-VEL FOR COV PROP	ORB/RND NAV SEQ	FT/S				
V_LAST(2)	V90L4786C	CURR ORB Y-VEL FOR COV PROP	ORB/RND NAV SEQ	FT/S				
V_LAST(3)	V90L4787C	CURR ORB Z-VEL FOR COV PROP	ORB/RND NAV SEQ	FT/S				
V_LAST_FILT(1)	V90L0621CD	X-COMP VEL W COV MTRX & FLTR UPDTE	ORB/RND NAV SEQ	FT/S				
V_LAST_FILT(2)	V90L0622CD	Y-COMP VEL W COV MTRX & FLTR UPDTE	ORB/RND NAV SEQ	FT/S				
V_LAST_FILT(3)	V90L0623CD	Z-COMP VEL W COV MTRX & FLTR UPDTE	ORB/RND NAV SEQ	FT/S				
V_NAV	V95H4754C	SEL ST AVERAGE VERTICAL ANGLE	STAR TRCK SOP	RAD				
V_PRED_FINAL(1)	V95L0814C	X-COMP PRED SHUTTLE VEL VECTOR	ORB PRED	FT/S	DPL		93017G	*
V_PRED_FINAL(2)	V95L0815C	Y-COMP PRED SHUTTLE VEL VECTOR	ORB PRED	FT/S	DPL		93017G	*
V_PRED_FINAL(3)	V95L0816C	Z-COMP PRED SHUTTLE VEL VECTOR	ORB PRED	FT/S	DPL		93017G	*
V_PROP(1)	V90L4994C	X-COMP OF BU VEL VECTOR	ORB/RND NAV SEQ	FT/S				
V_PROP(2)	V90L4995C	Y-COMP OF BU VEL VECTOR	ORB/RND NAV SEQ	FT/S				
V_PROP(3)	V90L4996C	Z-COMP OF BU VEL VECTOR	ORB/RND NAV SEQ	FT/S			89493B	
V_TV(1)	V90L0310CB	X-COMP TARGET VEH VEL VCTR-M50	ORB/RND NAV SEQ	FT/S				
V_TV(2)	V90L0311CB	Y-COMP TARGET VEH VEL VCTR-M50	ORB/RND NAV SEQ	FT/S				
V_TV(3)	V90L0312CB	Z-COMP TARGET VEH VEL VCTR-M50	ORB/RND NAV SEQ	FT/S				
V_TV_GND(1)	V96L1280C	UPLINKED TARGET VEL VECTOR-1	UL	FT/S				
V_TV_GND(2)	V96L1281C	UPLINKED TARGET VEL VECTOR-2	UL	FT/S				
V_TV_GND(3)	V96L1282C	UPLINKED TARGET VEL VECTOR-3	UL	FT/S				
V_TV_LAST(1)	V90L4792C	TARGET X-VEL FOR COV PROP	ORB/RND NAV SEQ	FT/S				
V_TV_LAST(2)	V90L4793C	TARGET Y-VEL FOR COV PROP	ORB/RND NAV SEQ	FT/S				
V_TV_LAST(3)	V90L4794C	TARGET Z-VEL FOR COV PROP	ORB/RND NAV SEQ	FT/S				
	V90X8646X	MM 202 FROM MM 201 FLAG	MSC				92355B	

TABLE 4.2.11-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
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**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**



TABLE 4.2.11-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
ALT_SS	V90H4945C	ALTITUDE OF THE SHUTTLE	DL FMT 22/1 DL FMT 32/1	FT	SPL		93017G	*
ANGLES_AIF_DISPLAY	V90J1361C	RNDZ NAV ANGLE AUT/INH/FOR FLAG	DL FMT 22/A REL NAV DISP		HXS		93017G	*
ANGLES_ENABLE_DISPLAY	V90J1416C	ST/RR/COAS DATA SEL IND	DL FMT 22/A REL NAV DISP		HXS		93017G	*
ATMP	V94J3999CC	ATTITUDE MODE FLAG	DL FMT 22/1 DL FMT 32/1 ORB PRED				93017G	*
COAS_DATA_GOOD	V90X4849X	SNAP COAS ANGLE MEAS DATA GOOD	DL FMT 22/A		BD		93017G	*
COAS_ID	V90J4854C	SNAP COAS IDENTIFICATION	DL FMT 22/1		HXS		93017G	*
COAS_MARK_NUM	V90J4827C	NO OF COAS MEAS PROCESSED	DL FMT 22/1		HXS		93017G	*
CONT_ACC	V90A4944C	BODY CONTACT ACCELERATION	DL FMT 22/1 DL FMT 32/A	FT/S2	SPL		93017G	*
COV_POS_SIG	V90H0438CC	RSS OF COVARIANCE POS ELEMENTS	DL FMT 22/1	FT	SPL		93017G	*
COV_VEL_SIG	V90L0439CC	RSS OF COVARIANCE VEL ELEMENTS	DL FMT 22/1	FT/S	SPL		93017G	*
DA_THRESHOLD	V90A4747C	IMU ACCEL THRESH FOR NAV	DL FMT 22/1 DL FMT 32/1	FT/S2	SPL	S	93017G	*
DID_COVAR_REINIT	V90X1415X	COVAR MATRIX REINIT IN PROG FLAG	DL FMT 22/A REL NAV DISP		BD		93017G	*
DID_FILT_TO_PROP	V90X4984X	POS FDBK FLTRD TO PROP FLAG	DL FMT 22/A REL NAV DISP		BD		93017G	*
DID_ORB_TO_TGT	V90X1413X	ORBITER TO TARGET SV IND	DL FMT 22/A DL FMT 32/A REL NAV DISP		BD		93017G	*
DID_PROP_TO_FILTER	V90X4985X	POS FDBK PROP TO FLTRD FLAG	DL FMT 22/A REL NAV DISP		BD		93017G	*
DID_SV_SRC_FOR_UPP	V90X4986X	POS FDBK UPP SOURCE FLAG	DL FMT 22/A REL NAV DISP		BD		93017G	*
DID_TGT_TO_ORB	V90X1414X	TARGET TO ORBITER SV IND	DL FMT 22/A DL FMT 32/A REL NAV DISP		BD		93017G	*
DISP_DELQ(1)	V90H0212CD	TAC AZ/OPTICS H/X/AZ MEAS RESIDUAL	DL FMT 22/A REL NAV DISP	DEG			93017G	*
DISP_DELQ(2)	V90H0214CD	TAC R/OPTICS V/Y/EL MEAS RESIDUAL	DL FMT 22/A REL NAV DISP	DEG			93017G	*
DISP_DELQ(3)	V90H0221CD	BARO ALT/RR RNG MEAS RESIDUAL	DL FMT 22/A REL NAV DISP	KFT			93017G	*
DISP_DELQ(4)	V90A0711CC	DRAG ALT/RR R DOT MEAS RESIDUAL	DL FMT 22/A REL NAV DISP	FT/S			93017G	*
DISP_EDIT(1)	V90X0213XD	TAC AZ/OPTICS H/X/AZ EDIT HIST IND	DL FMT 22/A GAX REL NAV DISP				93017G	*
DISP_EDIT(2)	V90X0215XD	TAC R/OPTICS V/Y/EL EDIT HIST IND	DL FMT 22/A GAX REL NAV DISP				93017G	*

TABLE 4.2.11-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
DISP_EDIT(3)	V90X0223XD	BARO ALT/RR RNG EDIT HIST IND	DL FMT 22/A GAX				93017G	*
DISP_EDIT(4)	V90X0712XD	DRAG ALT/RR R DOT EDIT HIST IND	REL NAV DISP DL FMT 22/A GAX				93017G	*
DISP_SIG(1)	V90U0216CD	TAC AZ/OPTICS H/X/AZ RESID RATIO	REL NAV DISP DL FMT 22/A				93017G	*
DISP_SIG(2)	V90U0217CD	TAC R/OPTICS V/Y/EL RESID RATIO	REL NAV DISP DL FMT 22/A				93017G	*
DISP_SIG(3)	V90U0222CD	BARO ALT/RR RNG RESID RATIO	REL NAV DISP DL FMT 22/A				93017G	*
DISP_SIG(4)	V90U0713CC	DRAG ALT/RR R DOT RESID RATIO	REL NAV DISP DL FMT 22/A				93017G	*
DMP	V94X3969XC	PROPER DRAG MODEL FLAG	ORB PRED					
DOING_MEAS_ENABLE	V90X1417XB	NAV MEASUREMENT ENABLE IND	DL FMT 22/A DL FMT 32/A REL NAV DISP				93017G	*
DOING_ST_RR_COAS	V90J4872C	ANGLES SELECTED-ST TRK/RR/COAS	DL FMT 22/1 ORB ATT PROC	SPECIAL	HXS		93017G	*
DO_COAS_ANGLES_NAV	V90X4880X	IND COAS TO BE PROC BY FILTER	DL FMT 22/1		BD		93017G	*
DO_FILTERED_TO_PROP	V90X4987X	FLTRD TO PROP STATE X-FER FLAG	REL NAV DISP		BD		39766G	
DO_ORB_TO_TGT	V93X6215X	STATE VCTR X-FER ORB TO TGT FLAG	REL NAV DISP		BD		39766G	
DO_OV_UPLINK	V90X4754XA	DO ORBITER VECTOR UPLINK	UL					
DO_PROP_TO_FILTERED	V90X4988X	PROP TO FLTRD STATE X-FER FLAG	REL NAV DISP		BD		39766G	
DO_RR_ANGLES_NAV	V90X4866X	IND RR TO BE PROC BY FILTER	DL FMT 22/1		BD		93017G	*
DO_ST_ANGLES_NAV	V90X4868X	IND ST TO BE PROC BY FILTER	DL FMT 22/1		BD		93017G	*
DO_TGT_TO_ORB	V93X6216X	STATE VCTR X-FER TGT TO ORB FLAG	REL NAV DISP		BD		39766G	
DO_TV_UPLINK	V90X4757XA	DO TARGET VECTOR UPLINK	UL					
DT_COV	V90W1366C	DELTA TIME FOR COV PROP	DL FMT 22/1	S	DPL		93017G	*
DT_FILT	V90W4946C	DELTA TIME FOR NAV INTERVAL	ORB/RND NAV SEQ	S				
DV_COUNT	V90J5184C	NO. OF ACCUM DELTA VELOCITIES	DL FMT 22/A DL FMT 32/A		FXS		93017G	*
DV_COV(1)	V90L4772CA	COV PROP DELTA V(1)	DL FMT 22/1	FT/S			93017G	*
DV_COV(2)	V90L4891CA	COV PROP DELTA V(2)	DL FMT 22/1	FT/S			93017G	*
DV_COV(3)	V90L4892CA	COV PROP DELTA V(3)	DL FMT 22/1	FT/S			93017G	*
DV_DISP(1)	V90L5181C	X-COMP ACCUM DELTA VELOCITY	DL FMT 22/A DL FMT 32/A		SPL		93017G	*
DV_DISP(2)	V90L5182C	Y-COMP ACCUM DELTA VELOCITY	DL FMT 22/A DL FMT 32/A	FT/S	SPL		93017G	*
DV_DISP(3)	V90L5183C	Z-COMP ACCUM DELTA VELOCITY	DL FMT 22/A DL FMT 32/A	FT/S	SPL		93017G	*
DV_FILT(1)	V90L4953C	ACCUM VELOCITY - X	ORB/RND NAV SEQ	FT/S			89648A	
DV_FILT(2)	V90L4954C	ACCUM VELOCITY - Y	ORB/RND NAV SEQ	FT/S			89648A	
DV_FILT(3)	V90L4955C	ACCUM VELOCITY - Z	ORB/RND NAV SEQ	FT/S			89648A	

TABLE 4.2.11-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
D_SS(1)	V90U4842C	SHUTTLE DRAG VECTOR-X	DL FMT 22/1	FT/S	SPL		93017G	*
			DL FMT 32/1					
D_SS(2)	V90U4843C	SHUTTLE DRAG VECTOR-Y	DL FMT 22/1	FT/S	SPL		93017G	*
			DL FMT 32/1					
D_SS(3)	V90U4844C	SHUTTLE DRAG VECTOR-Z	DL FMT 22/1	FT/S	SPL		93017G	*
			DL FMT 32/1					
E(1,1)	V90U4006CA	COVARIANCE MATRIX ELEMENT 1,1	TLM					
E(10,10)	V90U4188CA	COVARIANCE MATRIX ELEMENT 10,10	TLM					
E(11,11)	V90U4209CA	COVARIANCE MATRIX ELEMENT 11,11	TLM					
E(12,12)	V90U4229CA	COVARIANCE MATRIX ELEMENT 12,12	TLM					
E(13,13)	V90U4249CA	COVARIANCE MATRIX ELEMENT 13,13	TLM					
E(2,2)	V90U4027CA	COVARIANCE MATRIX ELEMENT 2,2	TLM					
E(3,3)	V90U4047CA	COVARIANCE MATRIX ELEMENT 3,3	TLM					
E(4,4)	V90U4067CA	COVARIANCE MATRIX ELEMENT 4,4	TLM					
E(5,5)	V90U4087CA	COVARIANCE MATRIX ELEMENT 5,5	TLM					
E(6,6)	V90U4108CA	COVARIANCE MATRIX ELEMENT 6,6	TLM					
E(7,7)	V90U4128CA	COVARIANCE MATRIX ELEMENT 7,7	TLM					
E(8,8)	V90U4148CA	COVARIANCE MATRIX ELEMENT 8,8	TLM					
E(9,9)	V90U4168CA	COVARIANCE MATRIX ELEMENT 9,9	TLM					
FALSE_FLAG	V90X1422X	FALSE TRACKING FLAG	STAR TRCK SOP				89493B	
FILT_UPDATE	V90X0224XF	FLAG IND NAV FILTER PROC COMPLETE	ORB UPP					
FOM(1)	V94H0982CC	GPS 1 FOM SNAPPED	GPS RCVR STATE PROC		HXS		91051K	
FOM(2)	V94H0983CC	GPS 2 FOM SNAPPED	GPS RCVR STATE PROC		HXS		91051K	
FOM(3)	V94H0984CC	GPS 3 FOM SNAPPED	GPS RCVR STATE PROC		HXS		91051K	
GMDP	V94J3975CC	GRAVITY MODEL DEGREE FLAG	ORB PRED					
GMOP	V94J3963CC	GRAVITY MODEL ORDER FLAG	ORB PRED					
GPS_AIF_EXEC	V94X1041XC	GPS TO G&C EXEC STATUS	GPS STATUS DISP		BD		91051K	
GPS_AIF_RCVD	V94J1042CC	GPS TO G&C AUT/INH/FOR FLAG FDBK	GPS RCVR STATE PROC		HXS		91051K	
			GPS STATUS DISP					
GPS_DG(1)	V90X3450XC	GPS 1 DG SNAPPED	GPS RCVR STATE PROC		BD		91051K	
GPS_DG(2)	V90X3451XC	GPS 2 DG SNAPPED	GPS RCVR STATE PROC		BD		91051K	
GPS_DG(3)	V90X3452XC	GPS 3 DG SNAPPED	GPS RCVR STATE PROC		BD		91051K	
GPS_FAIL_FOM(1)	V90X3453XC	GPS 1 FAIL FOM SNAPPED	GPS RCVR STATE PROC		BD		91051K	
GPS_FAIL_FOM(2)	V90X3454XC	GPS 2 FAIL FOM SNAPPED	GPS RCVR STATE PROC		BD		91051K	
GPS_FAIL_FOM(3)	V90X3455XC	GPS 3 FAIL FOM SNAPPED	GPS RCVR STATE PROC		BD		91051K	
GPS_NAV_AIF_EXEC	V94X6082X	GPS TO NAV EXEC STATUS	GPS STATUS DISP		BD		92067D	
			REL NAV DISP					
GPS_REF_INIT_VALID	V90X3642XC	GPS INIT REF STATE VALID FLAG	GPS REF STATE PROC		BD		92067D	
GPS_TO_NAV_AIF	V90J3463CC	GPS TO NAV AUTO/INHIBIT/FORCE FDBK	GPS RCVR STATE PROC		HXS		92132C	
			GPS STATUS DISP					
			REL NAV DISP					
GPS_TO_NAV_FORCE_RCVD	V90X3461XC	GPS TO NAV FORCE FLAG FDBK	GPS RCVR STATE PROC		BD		91051K	
GPS_TO_NAV_RCVD	V90X3462XC	GPS TO NAV AUT/INH FLAG FDBK	GPS RCVR STATE PROC		BD		91051K	
G_GPS_INIT(1)	V90A2619CE	X GRAV ACC FOR GPS REF STATE INIT	GPS REF STATE PROC	FT/S2	SPL		92214A	
G_GPS_INIT(2)	V90A2620CE	Y GRAV ACC FOR GPS REF STATE INIT	GPS REF STATE PROC	FT/S2	SPL		92214A	
G_GPS_INIT(3)	V90A2621CE	Z GRAV ACC FOR GPS REF STATE INIT	GPS REF STATE PROC	FT/S2	SPL		92214A	

TABLE 4.2.11-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
G_NEW(1)	V90U4940C	SHUTTLE GRAVITY VCTR M50-X	DL FMT 22/1 DL FMT 32/1	FT/S2	DPL		93017G	*
G_NEW(2)	V90U4941C	SHUTTLE GRAVITY VCTR M50-Y	DL FMT 22/1 DL FMT 32/1	FT/S2	DPL		93017G	*
G_NEW(3)	V90U4942C	SHUTTLE GRAVITY VCTR M50-Z	DL FMT 22/1 DL FMT 32/1	FT/S2	DPL		93017G	*
G_TV(1)	V90L4961C	TARGET ACCELERATION - X	DL FMT 22/1	FT/S2	DPL		93017G	*
G_TV(2)	V90L4962C	TARGET ACCELERATION - Y	DL FMT 22/1	FT/S2	DPL		93017G	*
G_TV(3)	V90L4963C	TARGET ACCELERATION - Z	DL FMT 22/1	FT/S2	DPL		93017G	*
IDRAG	V90X4950X	DRAG FLAG FOR ACCEL MODEL	ORB/RND NAV SEQ					
IGD	V90J4947C	DEGREE OF ACCEL MODEL	ORB/RND NAV SEQ					
IGO	V90J4948C	ORDER OF ACCEL MODEL	ORB/RND NAV SEQ					
IVENT	V90X4951X	VENT FLAG FOR ACCEL MODEL	ORB/RND NAV SEQ					
I_CYCLE	V90J4889CA	COVARIANCE PROP COUNTER	DL FMT 22/1				93017G	*
M_M50_TO_BODY_COAS(1)	V90U4857C	SNAP TRANS MTRX M50 TO BODY COAS-1	DL FMT 22/1		SPL		93017G	*
M_M50_TO_BODY_COAS(2)	V90U4858C	SNAP TRANS MTRX M50 TO BODY COAS-2	DL FMT 22/1		SPL		93017G	*
M_M50_TO_BODY_COAS(3)	V90U4859C	SNAP TRANS MTRX M50 TO BODY COAS-3	DL FMT 22/1		SPL		93017G	*
M_M50_TO_BODY_COAS(4)	V90U4860C	SNAP TRANS MTRX M50 TO BODY COAS-4	DL FMT 22/1		SPL		93017G	*
M_M50_TO_BODY_COAS(5)	V90U4861C	SNAP TRANS MTRX M50 TO BODY COAS-5	DL FMT 22/1		SPL		93017G	*
M_M50_TO_BODY_COAS(6)	V90U4862C	SNAP TRANS MTRX M50 TO BODY COAS-6	DL FMT 22/1		SPL		93017G	*
M_M50_TO_BODY_COAS(7)	V90U4863C	SNAP TRANS MTRX M50 TO BODY COAS-7	DL FMT 22/1		SPL		93017G	*
M_M50_TO_BODY_COAS(8)	V90U4864C	SNAP TRANS MTRX M50 TO BODY COAS-8	DL FMT 22/1		SPL		93017G	*
M_M50_TO_BODY_COAS(9)	V90U4865C	SNAP TRANS MTRX M50 TO BODY COAS-9	DL FMT 22/1		SPL		93017G	*
M_M50_TO_ST(1)	V90U4920C	SNAP TRANS MTRX M50 TO ST COORD-1	DL FMT 22/1		SPL		93017G	*
M_M50_TO_ST(2)	V90U4921C	SNAP TRANS MTRX M50 TO ST COORD-2	DL FMT 22/1		SPL		93017G	*
M_M50_TO_ST(3)	V90U4922C	SNAP TRANS MTRX M50 TO ST COORD-3	DL FMT 22/1		SPL		93017G	*
M_M50_TO_ST(4)	V90U4923C	SNAP TRANS MTRX M50 TO ST COORD-4	DL FMT 22/1		SPL		93017G	*
M_M50_TO_ST(5)	V90U4924C	SNAP TRANS MTRX M50 TO ST COORD-5	DL FMT 22/1		SPL		93017G	*
M_M50_TO_ST(6)	V90U4925C	SNAP TRANS MTRX M50 TO ST COORD-6	DL FMT 22/1		SPL		93017G	*
M_M50_TO_ST(7)	V90U4926C	SNAP TRANS MTRX M50 TO ST COORD-7	DL FMT 22/1		SPL		93017G	*
M_M50_TO_ST(8)	V90U4927C	SNAP TRANS MTRX M50 TO ST COORD-8	DL FMT 22/1		SPL		93017G	*
M_M50_TO_ST(9)	V90U4928C	SNAP TRANS MTRX M50 TO ST COORD-9	DL FMT 22/1		SPL		93017G	*
NAV_ANGLES_AIF	V90J4253C	NAV ANGLES AIF INPUT	DL FMT 22/1		HXS		93017G	*
NAV_CURR_ORB_MASS	V90U4254CA	NAV CURRENT ORB MASS	DL FMT 22/1 DL FMT 32/1	SLUGS			93017G	*
NAV_DAP_JET	V90X5185X	NAV RCS JET ON/OFF FLAG	DL FMT 22/A DL FMT 32/A		BD		93017G	*
NAV_DO_COVAR_REINIT	V90X4256X	NAV DO COVAR REINIT	DL FMT 22/1		BD		93017G	*
NAV_DO_FILT_TO_PROP	V90X4975X	NAV FLTRD TO PROP X-FER FLAG	DL FMT 22/1		BD		93017G	*
NAV_DO_ORB_TO_TGT	V90X4258X	NAV DO ORB TO TGT	DL FMT 22/1		BD		93017G	*
NAV_DO_OV_UPLINK	V90X4260X	NAV ORB SV UPLINK FLAG	DL FMT 22/1 DL FMT 32/1		BD		93017G	*
NAV_DO_PROP_TO_FILT	V90X4976X	NAV PROP TO FLTRD	DL FMT 22/1		BD		93017G	*
NAV_DO_TGT_TO_ORB	V90X4259X	NAV DO TGT TO ORB	DL FMT 22/1		BD		93017G	*
NAV_DO_TV_UPLINK	V90X4261X	NAV DO TV UPLINK	DL FMT 22/1		BD		93017G	*

TABLE 4.2.11-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
NAV_FALSE_TGT	V90X4300X	FALSE TARGET FLAG FOR DISP	DL FMT 22/1 STAR TRCK SOP		BD		93017G	*
NAV_MEAS	V90X4967X	NAV MEASUREMENT PROCESSING FLAG	DL FMT 22/1		BD		93017G	*
NAV_MEAS_ENABLE	V90X4262X	NAV MEAS ENABLE	DL FMT 22/1		BD		93017G	*
NAV_MM_CODE	V90J4263C	NAV MM CODE	DL FMT 22/1 GPS RCVR STATE PROC		HXS		93017G	*
NAV_PWRD_FLT_NAV	V90X4264X	NAV POWERED FLIGHT FLAG	DL FMT 22/1 DL FMT 32/1		BD		93017G	*
NAV_RANGE_AIF	V90J4268C	NAV RANGE AIF INPUT	DL FMT 22/1		HXS		93017G	*
NAV_RDOT_AIF	V90J4269C	NAV RDOT AIF INPUT	DL FMT 22/1		HXS		93017G	*
NAV_RR_ANGLES_ENABLE	V90X4273X	NAV RR ANGLES ENABLE	DL FMT 22/1		BD		93017G	*
NAV_ST_ENABLE	V90X4274X	NAV ST ENABLE	DL FMT 22/1		BD		93017G	*
NAV_SV_SRC_FOR_UPP	V90X4977X	NAV USER STATE SEL FLAG	DL FMT 22/1		BD		93017G	*
N_ACCEPT(1)	V90J1402CA	H/X/AZ ANGULAR MARKS ACCEPTED	DL FMT 22/A REL NAV DISP				93017G	*
N_ACCEPT(2)	V90J1403CA	V/Y/EL ANGULAR MARKS ACCEPTED	DL FMT 22/A REL NAV DISP				93017G	*
N_ACCEPT(3)	V90J1400CA	RR RNG MARKS ACCEPTED	DL FMT 22/A REL NAV DISP				93017G	*
N_ACCEPT(4)	V90J1401CA	RR R DOT MARKS ACCEPTED	DL FMT 22/A REL NAV DISP				93017G	*
N_REJECT(1)	V90J1407CA	H/X/AZ ANGULAR MARKS REJECTED	DL FMT 22/A REL NAV DISP				93017G	*
N_REJECT(2)	V90J1408CA	V/Y/EL ANGULAR MARKS REJECTED	DL FMT 22/A REL NAV DISP				93017G	*
N_REJECT(3)	V90J1405CA	RR RNG MARKS REJECTED	DL FMT 22/A REL NAV DISP				93017G	*
N_REJECT(4)	V90J1406CA	RR RDOT MARKS REJECTED	DL FMT 22/A REL NAV DISP				93017G	*
OV_PREDICT_FAIL	V90X4770X	ORBITER PREDICTION FAILURE IND	DL FMT 22/1 DL FMT 32/1		BD		93017G	*
PRED_ORB_AREA	V93U6955CA	ORBITER REF AREA USED IN PRED	DL FMT 22/1 DL FMT 32/1 ORB PRED	FT2			93017G	*
PRED_ORB_CD	V93U6954CA	ORBITER DRAG COEFF USED IN PRED	DL FMT 22/1 DL FMT 32/1 ORB PRED				93017G	*
PRED_ORB_MASS	V93U6953CA	ORBITER MASS USED IN PREDICTION	DL FMT 22/1 DL FMT 32/1 ORB PRED	SLUGS			93017G	*
PRED_STEP	V90W3964CC	INTEGRATION STEP SIZE	DL FMT 22/1 DL FMT 32/1 ORB PRED	S			93017G	*
PRED_USE	V90J4768CA	PREDICTOR STATE INDICATOR	DL FMT 22/1 DL FMT 32/1 ORB/RND NAV SEQ				93017G	*

TABLE 4.2.11-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
Q_COAS_HORIZ	V90U4847C	SNAP COAS HORIZ ANGLE MEAS	DL FMT 22/1	RAD	SPL		93017G	*
Q_COAS_VERT	V90U4848C	SNAP COAS VERT ANGLE MEAS	DL FMT 22/1	RAD	SPL		93017G	*
Q_M50BODY_IMU(1)	V95U0873CB	SNAP M50 TO BODY QUAT MEAS ELEM 1	DL FMT 22/1 DL FMT 32/1				93017G	*
Q_M50BODY_IMU(2)	V95U0874CB	SNAP M50 TO BODY QUAT MEAS ELEM 2	DL FMT 22/1 DL FMT 32/1				93017G	*
Q_M50BODY_IMU(3)	V95U0875CB	SNAP M50 TO BODY QUAT MEAS ELEM 3	DL FMT 22/1 DL FMT 32/1				93017G	*
Q_M50BODY_IMU(4)	V95U0876CB	SNAP M50 TO BODY QUAT MEAS ELEM 4	DL FMT 22/1 DL FMT 32/1				93017G	*
Q_M50BODY_RR(1)	V90U4829C	SNAP M50 TO BODY QUAT-RR-ELEM-1	DL FMT 22/A		SPL		93017G	*
Q_M50BODY_RR(2)	V90U4830C	SNAP M50 TO BODY QUAT-RR-ELEM-2	DL FMT 22/A		SPL		93017G	*
Q_M50BODY_RR(3)	V90U4831C	SNAP M50 TO BODY QUAT-RR-ELEM-3	DL FMT 22/A		SPL		93017G	*
Q_M50BODY_RR(4)	V90U4832C	SNAP M50 TO BODY QUAT-RR-ELEM-4	DL FMT 22/A		SPL		93017G	*
Q_RR_PITCH	V90U4894C	SNAP RR PITCH ANGLE MEAS	DL FMT 22/A	DEG	SPL		93017G	*
Q_RR_RNG	V90U4895C	SNAP RR RANGE MEAS	DL FMT 22/A	FT	SPL		93017G	*
Q_RR_RNG_DOT	V90U4896C	SNAP RR RANGE RATE MEAS	DL FMT 22/A	FT/S	SPL		93017G	*
Q_RR_ROLL	V90U4893C	SNAP RR ROLL ANGLE MEAS	DL FMT 22/A	DEG	SPL		93017G	*
Q_ST_HORIZ	V90U4833C	SNAP ST HORIZ ANGLE MEAS	DL FMT 22/A	RAD	SPL		93017G	*
Q_ST_VERT	V90U4834C	SNAP ST VERT ANGLE MEAS	DL FMT 22/A	RAD	SPL		93017G	*
RANGE_AIF_DISPLAY	V90J1362C	RNDZ NAV RR RNGE AUTO/INH/FOR FLAG	DL FMT 22/A		HXS		93017G	*
			REL NAV DISP					
RDOT_AIF_DISPLAY	V90J1368C	RNDZ NAV RANGE RATE A/I/F FLAG	DL FMT 22/A		HXS		93017G	*
			REL NAV DISP					
RDOT_DATA_GOOD	V90X4900X	SNAP RR RNG RATE DATA GOOD	DL FMT 22/A		BD		93017G	*
RNG_DATA_GOOD	V90X4899X	SNAP RR RANGE DATA GOOD	DL FMT 22/A		BD		93017G	*
RR_ANGLE_DATA_GOOD	V90X4901X	SNAP RR ANGLES DATA GOOD	DL FMT 22/A		BD		93017G	*
RR_ANGLE_MARK_NUM	V90J4824C	NO OF RR ANGLE MEAS PROCESSED	DL FMT 22/1		HXS		93017G	*
RR_DOT_MARK_NUM	V90J4825C	NO OF RR RNG RDOT MEAS PROCESSED	DL FMT 22/1		HXS		93017G	*
R_FILT(1)	V90H0584CC	X-COMP OF FLTR'S CURR POS VECTOR	GPS RCVR STATE PROC ORB/RND NAV SEQ	FT			91051K	
R_FILT(2)	V90H0585CC	Y-COMP OF FLTR'S CURR POS VECTOR	GPS RCVR STATE PROC ORB/RND NAV SEQ	FT			91051K	
R_FILT(3)	V90H0586CC	Z-COMP OF FLTR'S CURR POS VECTOR	GPS RCVR STATE PROC ORB/RND NAV SEQ	FT			91051K	
R_FILT_DISP(1)	V90H5040C	X-COMP OF FLTRS CURR POS VCTR-DISP	ORB TGTING DISP	KFT			89387D	
R_FILT_DISP(2)	V90H5041C	Y-COMP OF FLTRS CURR POS VCTR-DISP	ORB TGTING DISP	KFT			89387D	
R_FILT_DISP(3)	V90H5042C	Z-COMP OF FLTRS CURR POS VCTR-DISP	ORB TGTING DISP	KFT			89387D	
R_FILT_TLM(1)	V90H4277C	X-COMP OF FLTRS CURR POS VCTR-TLM	DL FMT 22/A DL FMT 32/A	FT	DPL		93017G	*
R_FILT_TLM(2)	V90H4278C	Y-COMP OF FLTRS CURR POS VCTR-TLM	DL FMT 22/A DL FMT 32/A	FT	DPL		93017G	*
R_FILT_TLM(3)	V90H4279C	Z-COMP OF FLTRS CURR POS VCTR-TLM	DL FMT 22/A DL FMT 32/A	FT	DPL		93017G	*
R_FMP_DISP	V90H4997C	RSS FLTR MINUS PROP POS	DL FMT 22/A REL NAV DISP	KFT	SPL		93017G	*

TABLE 4.2.11-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
R_GPS_ECEF(1,1)	V90H3467CC	GPS 1 WGS84 POS X-COMP	GPS RCVR STATE PROC	FT	DPL		91051K	
R_GPS_ECEF(1,2)	V90H3468CC	GPS 1 WGS84 POS Y-COMP	GPS RCVR STATE PROC	FT	DPL		91051K	
R_GPS_ECEF(1,3)	V90H3469CC	GPS 1 WGS84 POS Z-COMP	GPS RCVR STATE PROC	FT	DPL		91051K	
R_GPS_ECEF(2,1)	V90H3470CC	GPS 2 WGS84 POS X-COMP	GPS RCVR STATE PROC	FT	DPL		91051K	
R_GPS_ECEF(2,2)	V90H3471CC	GPS 2 WGS84 POS Y-COMP	GPS RCVR STATE PROC	FT	DPL		91051K	
R_GPS_ECEF(2,3)	V90H3472CC	GPS 3 WGS84 POS Z-COMP	GPS RCVR STATE PROC	FT	DPL		91051K	
R_GPS_ECEF(3,1)	V90H3473CC	GPS 3 WGS84 POS X-COMP	GPS RCVR STATE PROC	FT	DPL		91051K	
R_GPS_ECEF(3,2)	V90H3474CC	GPS 3 WGS84 POS Y-COMP	GPS RCVR STATE PROC	FT	DPL		91051K	
R_GPS_ECEF(3,3)	V90H3475CC	GPS 3 WGS84 POS Z-COMP	GPS RCVR STATE PROC	FT	DPL		91051K	
R_GPS_INIT(1)	V90H3476CC	GPS INIT POS VECTOR X-COMP	GPS REF STATE PROC	FT	DPL		91051K	
R_GPS_INIT(2)	V90H3477CC	GPS INIT POS VECTOR Y-COMP	GPS REF STATE PROC	FT	DPL		91051K	
R_GPS_INIT(3)	V90H3478CC	GPS INIT POS VECTOR Z-COMP	GPS REF STATE PROC	FT	DPL		91051K	
R_MEAS_RSS	V90H4999C	RSS FLTR CORRECTION POS	DL FMT 22/A	KFT	SPL		93017G	*
			REL NAV DISP					
R_PRED_INIT(1)	V94H4002CC	X-COMP POS VEC AT INITIAL TIME	DL FMT 22/1	FT			93017G	*
			DL FMT 32/1					
			ORB PRED					
R_PRED_INIT(2)	V94H4003CC	Y-COMP POS VEC AT INITIAL TIME	DL FMT 22/1	FT			93017G	*
			DL FMT 32/1					
			ORB PRED					
R_PRED_INIT(3)	V94H4004CC	Z-COMP POS VEC AT INITIAL TIME	DL FMT 22/1	FT			93017G	*
			DL FMT 32/1					
			ORB PRED					
R_PROP_TLM(1)	V90H4978C	X-COMP BU POS VECTOR-TLM	DL FMT 22/A	FT	DPL		93017G	*
R_PROP_TLM(2)	V90H4979C	Y-COMP BU POS VECTOR-TLM	DL FMT 22/A	FT	DPL		93017G	*
R_PROP_TLM(3)	V90H4980C	Z-COMP BU POS VECTOR-TLM	DL FMT 22/A	FT	DPL		93017G	*
R_RESET(1)	V90H0235CG	SEL X-COMP OF UPDATED POS VCTR RST	ORB UPP	FT	DPL			
R_RESET(2)	V90H0236CG	SEL Y-COMP OF UPDATED POS VCTR RST	ORB UPP	FT	DPL			
R_RESET(3)	V90H0237CG	SEL Z-COMP OF UPDATED POS VCTR RST	ORB UPP	FT	DPL			
R_TV(1)	V90H0307CA	X-COMP TARGET VEH POS VCTR-M50	ORB/RND NAV SEQ	FT			89648A	
R_TV(2)	V90H0308CA	Y-COMP TARGET VEH POS VCTR-M50	ORB/RND NAV SEQ	FT			89648A	
R_TV(3)	V90H0309CA	Z-COMP TARGET VEH POS VCTR-M50	ORB/RND NAV SEQ	FT			89648A	
R_TV_RESET(1)	V90H1383CA	X-COMP OF CURR TARGET POS VCT RST	ORB UPP	FT	DPL			
R_TV_RESET(2)	V90H1384CA	Y-COMP OF CURR TARGET POS VCT RST	ORB UPP	FT	DPL			
R_TV_RESET(3)	V90H1385CA	Z-COMP OF CURR TARGET POS VCT RST	ORB UPP	FT	DPL			
R_TV_TLM(1)	V90H4287C	X-COMP TARGET VEH POS VCTR-M50-TLM	DL FMT 22/A	FT	DPL		93017G	*
R_TV_TLM(2)	V90H4288C	Y-COMP TARGET VEH POS VCTR-M50-TLM	DL FMT 22/A	FT	DPL		93017G	*
R_TV_TLM(3)	V90H4289C	Z-COMP TARGET VEH POS VCTR-M50-TLM	DL FMT 22/A	FT	DPL		93017G	*
SELF_TEST_FLAG	V90X4888X	RR SELF TEST INDICATOR(SNAPPED)	DL FMT 22/A		BD		93017G	*
SENSOR_BIAS_TLM(1)	V90U4295C	SENSOR BIAS TLM 1	DL FMT 22/A	RAD	SPL		93017G	*
SENSOR_BIAS_TLM(2)	V90U4296C	SENSOR BIAS TLM 2	DL FMT 22/A	RAD	SPL		93017G	*
SENSOR_BIAS_TLM(3)	V90U4297C	SENSOR BIAS TLM 3	DL FMT 22/A	FT	SPL		93017G	*
SENSOR_BIAS_TLM(4)	V90U4298C	SENSOR BIAS TLM 4	DL FMT 22/A	FT/S	SPL		93017G	*
SENSOR_EDIT(1)	V90U8841CD	TAC AZ/OPTICS H/X/AZ FILTER FLAG	DL FMT 22/A				93017G	*
SENSOR_EDIT(2)	V90J8880CD	TAC R/OPTICS V/Y/EL FILTER FLAG	DL FMT 22/A				93017G	*
SENSOR_EDIT(3)	V90J8881CD	BARO ALT/RR RNG FILTER FLAG	DL FMT 22/A				93017G	*

TABLE 4.2.11-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
SENSOR_EDIT(4)	V90J8882CA	DRAG ALT/RR R DOT FILTER FLAG	DL FMT 22/A				93017G	*
SEQ_ACCEPT(1)	V90J4732CA	NUM SEQ MARKS ACCEPT-H/X/AZ	DL FMT 22/1				93017G	*
SEQ_ACCEPT(2)	V90J4733CA	NUM SEQ MARKS ACCEPT-V/Y/EL	DL FMT 22/1				93017G	*
SEQ_ACCEPT(3)	V90J4730CA	NUM SEQ MARKS ACCEPT-RNG	DL FMT 22/1				93017G	*
SEQ_ACCEPT(4)	V90J4731CA	NUM SEQ MARKS ACCEPT-RDOT	DL FMT 22/1				93017G	*
SEQ_REJECT(1)	V90J4737CA	NUM SEQ MARKS REJECT-H/X/AZ	DL FMT 22/1				93017G	*
SEQ_REJECT(2)	V90J4738CA	NUM SEQ MARKS REJECT-V/Y/EL	DL FMT 22/1				93017G	*
SEQ_REJECT(3)	V90J4735CA	NUM SEQ MARKS REJECT-RNG	DL FMT 22/1				93017G	*
SEQ_REJECT(4)	V90J4736CA	NUM SEQ MARKS REJECT-RDOT	DL FMT 22/1				93017G	*
ST_DATA_GOOD	V90X4835X	SNAP STAR TRACKER DATA GOOD	DL FMT 22/A		BD		93017G	*
ST_MARK_NUM	V90J4826C	NO OF STAR TRACKER MEAS PROCESSED	DL FMT 22/1		HXS		93017G	*
TFOFF	V90W4960C	OFF TIME FOR VENT SNAP	DL FMT 22/1	S	DPL		93017G	*
			DL FMT 32/1					
TFON	V90W4959C	ON TIME FOR VENT SNAP	DL FMT 22/1	S	DPL		93017G	*
			DL FMT 32/1					
TOT_ACC(1)	V90A4874C	X-COMP OF TOTAL ORBITER ACCEL-M50	DL FMT 22/1	FT/S2	DPL		93017G	*
TOT_ACC(2)	V90A4875C	Y-COMP OF TOTAL ORBITER ACCEL-M50	DL FMT 22/1	FT/S2	DPL		93017G	*
TOT_ACC(3)	V90A4876C	Z-COMP OF TOTAL ORBITER ACCEL-M50	DL FMT 22/1	FT/S2	DPL		93017G	*
TRG_TRK_MODE	V90U4836C	SNAP STAR TRACKER MODE IND	DL FMT 22/A		BD		93017G	*
TV_PREDICT_FAIL	V90X4769XA	TARGET PREDICTION FAILURE IND	DL FMT 22/1				93017G	*
T_COAS	V90W4853C	SNAP COAS ANGLE MEAS TIME	DL FMT 22/1	S	DPL		93017G	*
T_CURRENT_FILT	V90W4749CB	SNAP TIME TAG CURR IMU/ATT DATA	DL FMT 22/1	S	DPL		93017G	*
			DL FMT 32/1					
			GPS RCVR STATE PROC					
T_FILT_DAYS	V90W5043C	GMT DAYS OF FLTR STATE VCTR-DISP	ORB TGTING DISP	DAYS			89387D	
T_FILT_HRS	V90W5044C	GMT HRS OF FLTR STATE VCTR-DISP	ORB TGTING DISP	HRS			89387D	
T_FILT_MIN	V90W5045C	GMT MIN OF FLTR STATE VCTR-DISP	ORB TGTING DISP	MIN			89387D	
T_FILT_SECS	V90W5046C	GMT SECS OF FLTR STATE VCTR-DISP	ORB TGTING DISP	S			89387D	
T_GPS(1)	V90W3479CC	GPS 1 STATE TIME	GPS RCVR STATE PROC	S	DPL		91051K	
T_GPS(2)	V90W3480CC	GPS 2 STATE TIME	GPS RCVR STATE PROC	S	DPL		91051K	
T_GPS(3)	V90W3481CC	GPS 3 STATE TIME	GPS RCVR STATE PROC	S	DPL		91051K	
T_GPS_INIT	V90W3482CC	GPS INIT STATE TIME TAG	GPS REF STATE PROC	S	DPL		91051K	
T_GPS_LAST_UPDATE	V90W3556CE	TIME OF NAV RESET WITH SEL GPS	ENT NAV	S	DPL		92369B	
			GPS RCVR STATE PROC					
			PRELAND NAV					
T_LAST_FILT	V90W1252CA	TIME OF FILTER STATE VECTOR	ORB/RND NAV SEQ	S				
T_LAST_FILT_TLM	V90W4285C	TIME OF FILTER STATE VECTOR-TLM	DL FMT 22/A	S	DPL		93017G	*
			DL FMT 32/A					
T_LAST_GPS(1)	V90W3483CC	CURRENT GPS 1 STATE IMU TIME TAG	GPS RCVR STATE PROC	S	DPL		91051K	
T_LAST_GPS(2)	V90W3484CC	CURRENT GPS 2 STATE IMU TIME TAG	GPS RCVR STATE PROC	S	DPL		91051K	
T_LAST_GPS(3)	V90W3485CC	CURRENT GPS 3 STATE IMU TIME TAG	GPS RCVR STATE PROC	S	DPL		91051K	
T_ORB_STATE_UPDATE	V94W3727CA	LAST SV UPDATE TIME	DL FMT 22/1	S			93017G	*
			DL FMT 32/1					
T_PRED_FINAL	V94W3979CC	TIME AT WHICH STATE IS DESIRED	DL FMT 22/1	S			93017G	*
			DL FMT 32/1					
			ORB PRED					



TABLE 4.2.11-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
T_PRED_INIT	V94W3970CC	TIME AT BEGINNING OF PRED	DL FMT 22/1 DL FMT 32/1 ORB PRED	S			93017G	*
T_REND_RADAR	V90W4841C	SNAP R RADAR TIME	DL FMT 22/A	S	DPL		93017G	*
T_RESET	V90W0534CG	TIME OF FILTER STATE VCTR	GPS RCVR STATE PROC ORB UPP ORB/RND NAV SEQ REL NAV DISP	S			92834C	
T_STAR_TRACKER	V90W4837C	SNAP ST ANGLE MEAS TIME	DL FMT 22/A	S	DPL		93017G	*
T_TV	V90W0315CA	TIME TAG OF TARGET VEH STATE VCTR	DL FMT 22/1 ORB/RND NAV SEQ REL NAV DISP	S			93017G	*
T_TV_STATE_UPDATE	V90W4939C	TIME OF TARG STATE UPDATE	DL FMT 22/1	S	DPL		93017G	*
UNMOD_ACC_BIAS_TLM(1)	V90U4301C	UNMOD ACC BIAS TLM 1	DL FMT 22/1	FT/S2	SPL		93017G	*
UNMOD_ACC_BIAS_TLM(2)	V90U4302C	UNMOD ACC BIAS TLM 2	DL FMT 22/1	FT/S2	SPL		93017G	*
UNMOD_ACC_BIAS_TLM(3)	V90U4303C	UNMOD ACC BIAS TLM 3	DL FMT 22/1	FT/S2	SPL		93017G	*
UR_SUN(1)	V90U4972C	X-COMP SUN UNIT VECTOR-M50	UNIV POINT PROC					
UR_SUN(2)	V90U4973C	Y-COMP SUN UNIT VECTOR-M50	UNIV POINT PROC					
UR_SUN(3)	V90U4974C	Z-COMP SUN UNIT VECTOR-M50	UNIV POINT PROC					
USE_IMU_DATA	V90X0538XG	FLAG TO USE IMU ACCUM VEL OR NOT	DL FMT 22/A DL FMT 32/A				93017G	*
VENT_SS(1)	V90U4964C	SHUTTLE VENT VECTOR - X	DL FMT 22/1 DL FMT 32/1	FT/S2	SPL		93017G	*
VENT_SS(2)	V90U4965C	SHUTTLE VENT VECTOR - Y	DL FMT 22/1 DL FMT 32/1	FT/S2	SPL		93017G	*
VENT_SS(3)	V90U4966C	SHUTTLE VENT VECTOR - Z	DL FMT 22/1 DL FMT 32/1	FT/S2	SPL		93017G	*
VFORCE(1)	V90U4956C	UPLINK VENT VECTOR X SNAP	DL FMT 22/1 DL FMT 32/1	LBS	SPL		93017G	*
VFORCE(2)	V90U4957C	UPLINK VENT VECTOR Y SNAP	DL FMT 22/1 DL FMT 32/1	LBS	SPL		93017G	*
VFORCE(3)	V90U4958C	UPLINK VENT VECTOR Z SNAP	DL FMT 22/1 DL FMT 32/1	LBS	SPL		93017G	*
VMP	V94X3971XC	PROPER VENT MODEL FLAG	ORB PRED					
V_CURRENT_FILT(1)	V90L8927CD	SNAPPED SEL TOTAL X VEL M50	DL FMT 22/1 DL FMT 32/1 GPS RCVR STATE PROC	FT/S	DPL		93017G	*
V_CURRENT_FILT(2)	V90L8928CD	SNAPPED SEL TOTAL Y VEL M50	DL FMT 22/1 DL FMT 32/1 GPS RCVR STATE PROC	FT/S	DPL		93017G	*
V_CURRENT_FILT(3)	V90L8929CD	SNAPPED SEL TOTAL Z VEL M50	DL FMT 22/1 DL FMT 32/1 GPS RCVR STATE PROC	FT/S	DPL		93017G	*
V_FILT(1)	V90L0624CC	X-COMP OF FLTR'S CURR VEL VECTOR	GPS RCVR STATE PROC GPS RCVR STATE PROC ORB/RND NAV SEQ	FT/S	SPL		91051K	

TABLE 4.2.11-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
V_FILT(2)	V90L0625CC	Y-COMP OF FLTR'S CURR VEL VECTOR	GPS RCVR STATE PROC ORB/RND NAV SEQ	FT/S	SPL		91051K	
V_FILT(3)	V90L0626CC	Z-COMP OF FLTR'S CURR VEL VECTOR	GPS RCVR STATE PROC ORB/RND NAV SEQ	FT/S	SPL		91051K	
V_FILT_DISP(1)	V90L5047C	X-COMP OF FLTRS CORR VEL VCTR-DISP	ORB TGTING DISP	KFT/S			89387D	
V_FILT_DISP(2)	V90L5048C	Y-COMP OF FLTRS CORR VEL VCTR-DISP	ORB TGTING DISP	KFT/S			89387D	
V_FILT_DISP(3)	V90L5049C	Z-COMP OF FLTRS CORR VEL VCTR-DISP	ORB TGTING DISP	KFT/S			89387D	
V_FILT_TLM(1)	V90L4281C	X-COMP OF FLTRS CURR VEL VCTR-TLM	DL FMT 22/A DL FMT 32/A	FT/S	DPL		93017G	*
V_FILT_TLM(2)	V90L4282C	Y-COMP OF FLTRS CURR VEL VCTR-TLM	DL FMT 22/A DL FMT 32/A	FT/S	DPL		93017G	*
V_FILT_TLM(3)	V90L4283C	Z-COMP OF FLTRS CURR VEL VCTR-TLM	DL FMT 22/A DL FMT 32/A	FT/S	DPL		93017G	*
V_FMP_DISP	V90L4998C	RSS FLTR MINUS PROP VEL	DL FMT 22/A REL NAV DISP	FT/S	SPL		93017G	*
V_GPS_ECEF(1,1)	V90L3486CC	GPS 1 WGS84 VEL X-COMP	GPS RCVR STATE PROC	FT/S	SPL		91051K	
V_GPS_ECEF(1,2)	V90L3487CC	GPS 1 WGS84 VEL Y-COMP	GPS RCVR STATE PROC	FT/S	SPL		91051K	
V_GPS_ECEF(1,3)	V90L3488CC	GPS 1 WGS84 VEL Z-COMP	GPS RCVR STATE PROC	FT/S	SPL		91051K	
V_GPS_ECEF(2,1)	V90L3489CC	GPS 2 WGS84 VEL X-COMP	GPS RCVR STATE PROC	FT/S	SPL		91051K	
V_GPS_ECEF(2,2)	V90L3490CC	GPS 2 WGS84 VEL Y-COMP	GPS RCVR STATE PROC	FT/S	SPL		91051K	
V_GPS_ECEF(2,3)	V90L3491CC	GPS 2 WGS84 VEL Z-COMP	GPS RCVR STATE PROC	FT/S	SPL		91051K	
V_GPS_ECEF(3,1)	V90L3492CC	GPS 3 WGS84 VEL X-COMP	GPS RCVR STATE PROC	FT/S	SPL		91051K	
V_GPS_ECEF(3,2)	V90L3493CC	GPS 3 WGS84 VEL Y-COMP	GPS RCVR STATE PROC	FT/S	SPL		91051K	
V_GPS_ECEF(3,3)	V90L3494CC	GPS 3 WGS84 VEL Z-COMP	GPS RCVR STATE PROC	FT/S	SPL		91051K	
V_GPS_INIT(1)	V90L3495CC	GPS INIT VEL VECTOR X-COMP	GPS REF STATE PROC	FT/S	SPL		91051K	
V_GPS_INIT(2)	V90L3496CC	GPS INIT VEL VECTOR Y-COMP	GPS REF STATE PROC	FT/S	SPL		91051K	
V_GPS_INIT(3)	V90L3497CC	GPS INIT VEL VECTOR Z-COMP	GPS REF STATE PROC	FT/S	SPL		91051K	
V_IMU_GPS_INIT(1)	V90L3506CC	IMU ACCUM X VEL FOR GPS INIT	GPS REF STATE PROC	FT/S	SPL		92369B	
V_IMU_GPS_INIT(2)	V90L3507CC	IMU ACCUM Y VEL FOR GPS INIT	GPS REF STATE PROC	FT/S	SPL		92369B	
V_IMU_GPS_INIT(3)	V90L3508CC	IMU ACCUM Z VEL FOR GPS INIT	GPS REF STATE PROC	FT/S	DPL		92369B	
V_IMU_RESET(1)	V90L0247CG	SEL X-COMP OF ACCUM SENSED VEL RST	DL FMT 22/1 DL FMT 32/1 ORB UPP	FT/S			93017G	*
V_IMU_RESET(2)	V90L0248CG	SEL Y-COMP OF ACCUM SENSED VEL RST	DL FMT 22/1 DL FMT 32/1 ORB UPP	FT/S			93017G	*
V_IMU_RESET(3)	V90L0249CG	SEL Z-COMP OF ACCUM SENSED VEL RST	DL FMT 22/1 DL FMT 32/1 ORB UPP	FT/S			93017G	*
V_LAST_GPS(1,1)	V90L3515CC	IMU ACCUM X VEL FOR GPS 1	GPS RCVR STATE PROC	FT/S	DPL		91051K	
V_LAST_GPS(1,2)	V90L3516CC	IMU ACCUM Y VEL FOR GPS 1	GPS RCVR STATE PROC	FT/S	DPL		91051K	
V_LAST_GPS(1,3)	V90L3517CC	IMU ACCUM Z VEL FOR GPS 1	GPS RCVR STATE PROC	FT/S	DPL		91051K	
V_LAST_GPS(2,1)	V90L3518CC	IMU ACCUM X VEL FOR GPS 2	GPS RCVR STATE PROC	FT/S	DPL		91051K	
V_LAST_GPS(2,2)	V90L3519CC	IMU ACCUM Y VEL FOR GPS 2	GPS RCVR STATE PROC	FT/S	DPL		91051K	
V_LAST_GPS(2,3)	V90L3520CC	IMU ACCUM Z VEL FOR GPS 2	GPS RCVR STATE PROC	FT/S	DPL		91051K	
V_LAST_GPS(3,1)	V90L3521CC	IMU ACCUM X VEL FOR GPS 3	GPS RCVR STATE PROC	FT/S	DPL		91051K	

TABLE 4.2.11-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
V_LAST_GPS(3,2)	V90L3522CC	IMU ACCUM Y VEL FOR GPS 3	GPS RCVR STATE PROC	FT/S	DPL		91051K	
V_LAST_GPS(3,3)	V90L3523CC	IMU ACCUM Z VEL FOR GPS 3	GPS RCVR STATE PROC	FT/S	DPL		91051K	
V_MEAS_RSS	V90L5000C	RSS FLTR CORRECTION VEL	DL FMT 22/A REL NAV DISP	FT/S	SPL		93017G	*
V_PRED_INIT(1)	V94L4006CC	X-COMP VEL VEC AT INITIAL TIME	DL FMT 22/1 DL FMT 32/1 ORB PRED	FT/S			93017G	*
V_PRED_INIT(2)	V94L4007CC	Y-COMP VEL VEC AT INITIAL TIME	DL FMT 22/1 DL FMT 32/1 ORB PRED	FT/S			93017G	*
V_PRED_INIT(3)	V94L4008CC	Z-COMP VEL VEC AT INITIAL TIME	DL FMT 22/1 DL FMT 32/1 ORB PRED	FT/S			93017G	*
V_PROP_TLM(1)	V90L4981C	X-COMP BU VEL VECTOR-TLM	DL FMT 22/A	FT/S	DPL		93017G	*
V_PROP_TLM(2)	V90L4982C	Y-COMP BU VEL VECTOR-TLM	DL FMT 22/A	FT/S	DPL		93017G	*
V_PROP_TLM(3)	V90L4983C	Z-COMP BU VEL VECTOR-TLM	DL FMT 22/A	FT/S	DPL		93017G	*
V_RESET(1)	V90L0239CG	SEL X-COMP OF UPDATED VEL VCTR RST	ORB UPP	FT/S				
V_RESET(2)	V90L0240CG	SEL Y-COMP OF UPDATED VEL VCTR RST	ORB UPP	FT/S				
V_RESET(3)	V90L0241CG	SEL Z-COMP OF UPDATED VEL VCTR RST	ORB UPP	FT/S				
V_TV(1)	V90L0310CA	X-COMP TARGET VEH VEL VCTR-M50	ORB/RND NAV SEQ	FT/S				
V_TV(2)	V90L0311CA	Y-COMP TARGET VEH VEL VCTR-M50	ORB/RND NAV SEQ	FT/S				
V_TV(3)	V90L0312CA	Z-COMP TARGET VEH VEL VCTR-M50	ORB/RND NAV SEQ	FT/S				
V_TV_RESET(1)	V90L1380CA	X-COMP OF CURR TARGET VEL VCT RST	ORB UPP	FT/S				
V_TV_RESET(2)	V90L1381CA	Y-COMP OF CURR TARGET VEL VCT RST	ORB UPP	FT/S				
V_TV_RESET(3)	V90L1382CA	Z-COMP OF CURR TARGET VEL VCT RST	ORB UPP	FT/S				
V_TV_TLM(1)	V90L4291C	X-COMP TARGET VEH VEL VCTR-M50-TLM	DL FMT 22/A	FT/S	DPL		93017G	*
V_TV_TLM(2)	V90L4292C	Y-COMP TARGET VEH VEL VCTR-M50-TLM	DL FMT 22/A	FT/S	DPL		93017G	*
V_TV_TLM(3)	V90L4293C	Z-COMP TARGET VEH VEL VCTR-M50-TLM	DL FMT 22/A	FT/S	DPL		93017G	*
	V90M2852PG	CGEB_FLT_LG3_FLAG2_LFE	DL FMT 22/A DL FMT 32/A				93017G	*
	V90M2933PD	CGNB_DISP_EDIT	DL FMT 22/A				93017G	*
	V90M3135P	CGNB_ORBNAV_UPLINK_FLG_LFE	DL FMT 22/1 DL FMT 32/1				93017G	*
	V90M3136P	CGNB_ORB_NAV_FLAG_WD1	DL FMT 22/1 DL FMT 32/1				93017G	*
	V90M3137PA	CGNB_ORB_NAV_FLAG_WD2	DL FMT 22/1 DL FMT 32/1				93017G	*
	V90M3138PB	CGNB_POS_FEEDBACK_IND_MFE	DL FMT 22/A DL FMT 32/A				93017G	*
	V90M3143P	CGEB_IPE_LG4_FLAG_WD2_LFE	DL FMT 22/A				93017G	*
	V90M3144P	CGYB_ST_TARG_FLAGS_LFE	DL FMT 22/A				93017G	*
	V90M3145P	CGEB_IPE_HFE_LFE_FLAG_WD1_LFE	DL FMT 22/A DL FMT 32/A				93017G	*
	V90M3146P	CGNB_REND_NAV	DL FMT 22/1				93017G	*
	V90M3147P	CGNB_ORB_REND_NAV_FLAGS	DL FMT 22/1				93017G	*
	V90M3155P	CGYB_FALSE_TARG_LFE	DL FMT 22/1				93017G	*

TABLE 4.2.11-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT/RENDEZVOUS NAVIGATION (G4.126)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
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**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**

**Rate Codes: (HDR Only) 1 = 1 sample/sec 2 = 5 samples/sec 3 = 12.5 samples/sec 4 = 25 samples/sec 5 = 100 samples/sec  
(HDR and LDR) A = 1 sample/sec B = 5 samples/sec C = 12.5 samples/sec D = 25 samples/sec E = 100 samples/sec**

TABLE 4.2.11-3 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
ABM(1,1)	V96U9061C	ND	F	S	M	P	G4.126	00	POA	DC0599	
ABM(1,2)	V96U9062C	ND	F	S	M	P	G4.126	00	POA	DC0599	
ABM(2,1)	V96U9063C	FT**-1	F	S	M	P	G4.126	00	POA	DC0599	
ABM(2,2)	V96U9064C	FT**-1	F	S	M	P	G4.126	00	POA	DC0599	
ABM(3,1)	V96U9065C	FT	F	S	M	P	G4.126	00	POA	DC0599	
ABM(3,2)	V96U9066C	FT	F	S	M	P	G4.126	00	POA	DC0599	
ACC_MIN	V96U9067C	ND	I	S	D	P	G4.126	00	ZFB	89622A	
ALT_L	V96U9068C	FT	F	S	M	P	G4.126	00	POA	DC0599	
BIAS_VAR_COAS_ANGLES(1)	V96U9069C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
BIAS_VAR_COAS_ANGLES(2)	V96U9070C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
BIAS_VAR_RRDOT(1)	V96U9073C	FT**2	F	S	D	P	G4.126	00	ZPA	DC0617	
BIAS_VAR_RRDOT(2)	V96U9074C	FT**2/SEC**2	F	S	D	P	G4.126	00	ZPA	DC0617	
BIAS_VAR_RR_ANGLES(1)	V96U9071C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
BIAS_VAR_RR_ANGLES(2)	V96U9072C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
BIAS_VAR_ST_ANGLES(1)	V96U9075C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
BIAS_VAR_ST_ANGLES(2)	V96U9076C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
BM(1)	V96U9077C	ND	F	S	M	P	G4.126	00	POA	DC0599	
BM(2)	V96U9078C	FT**-1	F	S	M	P	G4.126	00	POA	DC0599	
BM(3)	V96U9079C	FT	F	S	M	P	G4.126	00	POA	DC0599	
CBM2	V96U9089C	ND	F	S	M	P	G4.126	00	POA	DC0599	
CDA	V97U5281C	ND	F	D	D	X	G4.126	01	ZFJ	DC0617	
							G4.223	02	ZFJ		
							G4.224	03	ZFJ		
							G4.236	08	ZFJ		
CDF	V97U6002C	ND	F	D	D	X	G4.126	01	ZFJ	DC0617	
							G4.223	02	ZFJ		
							G4.224	03	ZFJ		
							G4.236	08	ZFJ		
CDN	V97U5282C	ND	F	D	D	X	G4.126	01	ZFJ	DC0617	
							G4.223	02	ZFJ		
							G4.224	03	ZFJ		
							G4.236	08	ZFJ		
CDS	V97U6010C	ND	F	D	D	X	G4.126	01	ZFJ	DC0617	
							G4.223	02	ZFJ		
							G4.224	03	ZFJ		
							G4.236	08	ZFJ		
COAS_ANGLES_BIAS_INIT(1)	V96U9084C	RAD	F	S	M	P	G4.126	00	RDZ	DC0617	
COAS_ANGLES_BIAS_INIT(2)	V96U9085C	RAD	F	S	M	P	G4.126	00	RDZ	DC0617	
COS_LAG	V96U9086C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
COV_COR_UPDATE(1)	V96H1290C	ND	F	S	M	P	G4.126	00	ZPB	DC1981	
							G4.148				
COV_COR_UPDATE(2)	V96H1291C	ND	F	S	M	P	G4.126	00	ZPB	DC1981	
							G4.148				
COV_COR_UPDATE(3)	V96H1292C	ND	F	S	M	P	G4.126	00	ZPB	DC1981	
							G4.148				
COV_COR_UPDATE(4)	V96H1293C	ND	F	S	M	P	G4.126	00	ZPB	DC1981	
							G4.148				

TABLE 4.2.11-3 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
COV_COR_UPDATE (5)	V96H1294C	ND	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
COV_COR_UPDATE (6)	V96H1295C	ND	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
COV_COR_UPDATE (7)	V96H1296C	ND	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
COV_U_A_COAST (1)	V96U9095C	FT**2/SEC**4	F	S	D	P	G4.126 G4.148	00	ZPA	DC0617	
COV_U_A_COAST (2)	V96U9096C	FT**2/SEC**4	F	S	D	P	G4.126 G4.148	00	ZPA	DC0617	
COV_U_A_COAST (3)	V96U9097C	FT**2/SEC**4	F	S	D	P	G4.126 G4.148	00	ZPA	DC0617	
COV_U_A_PWRD_FLT (1)	V96U9098C	FT**2/SEC**4	F	S	D	P	G4.126	00	ZPA	DC0617	
COV_U_A_PWRD_FLT (2)	V96U9099C	FT**2/SEC**4	F	S	D	P	G4.126	00	ZPA	DC0617	
COV_U_A_PWRD_FLT (3)	V96U9100C	FT**2/SEC**4	F	S	D	P	G4.126	00	ZPA	DC0617	
C_DENSEA	V96U9094C	FT	F	S	D	P	G4.126	00	ZFB	89622A	
DELTAT_COAS_MAX	V96U9108C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
DELTAT_COAS_MIN	V96U9109C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
DELTAT_ST_MIN	V96U9110C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
DELTA_RESID_RATIO	V96U9107C	ND	F	S	D	P	G4.126	00	ZPA	DC0617	
EPS_TIME	V96U9115C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
EXP_SHAPE_FACTOR	V97U5334C	ND	F	D	D	X	G4.126 G4.223 G4.224 G4.236	01 02 03 08	ZFJ ZFJ ZFJ ZFJ	DC0617	
GDIE	V96U9116C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
IMU_NAV_ACCEL_THRESH	V93A6710C	UG	I	D	D	P	G4.126 G4.22	00	ZPA	DC0617	
KFACTOR	V96U8173C	ND	F	S	M	P	G4.126	00	POA	DC0599	
K_ANG	V99U7430C	RAD	F	S	D	P	G4.126	00	ZFB	89622A	
K_RESID_EDIT	V96U9121C	ND	F	S	D	P	G4.126	00	ZPA	DC0617	
K_UND_WGT	V97U5350C	ND	F	S	M	X	G4.126 G4.127 G4.144 G4.15 G4.205	01 02 03	ZFT ZPA ZFT	DC0617	
LOC	V96U9122C	RAD	F	D	M	P	G4.126	00	EPH	DC0599	
LOSK1	V96U9123C	ND	F	D	M	P	G4.126 G4.66	00	EPH	92537A	
LOSK3	V96U9124C	ND	F	D	M	P	G4.126 G4.66	00	EPH	92537A	
LOS_ZERO	V96U9126C	RAD	F	D	M	P	G4.126 G4.66	00	EPH	92537A	
MEAS_THRESHOLD	V96U9154C	FT/SEC**2	F	S	D	P	G4.126	00	ZFB	89622A	

TABLE 4.2.11-3 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
MS_POS_UND_WGT	V97U5411C	FT**2	F	S	D	X	G4.126	01	ZFT	DC0617	
							G4.127	02	ZPA		
							G4.144	03	ZFT		
							G4.15				
							G4.205				
M_BODY_TO_COAS(1,1,1)	V96U9127C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(1,1,2)	V96U9136C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(1,2,1)	V96U9128C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(1,2,2)	V96U9137C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(1,3,1)	V96U9129C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(1,3,2)	V96U9138C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(2,1,1)	V96U9130C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(2,1,2)	V96U9139C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(2,2,1)	V96U9131C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(2,2,2)	V96U9140C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(2,3,1)	V96U9132C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(2,3,2)	V96U9141C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(3,1,1)	V96U9133C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(3,1,2)	V96U9142C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(3,2,1)	V96U9134C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(3,2,2)	V96U9143C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(3,3,1)	V96U9135C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_COAS(3,3,2)	V96U9144C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_RR(1,1)	V96U9145C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_RR(1,2)	V96U9146C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_RR(1,3)	V96U9147C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_RR(2,1)	V96U9148C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_RR(2,2)	V96U9149C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_RR(2,3)	V96U9150C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_RR(3,1)	V96U9151C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_RR(3,2)	V96U9152C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
M_BODY_TO_RR(3,3)	V96U9153C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
N_CYCLE_SUB	V96U8681C	ND	I	S	D	P	G4.126	00	ZPA	92067D	
N_MAX_EDIT	V96U9537C	ND	I	S	D	P	G4.126	00	ZPA	DC0617	
PHASE_C	V96U9158C	RAD	F	D	M	P	G4.126	00	EPH	DC0599	
REF_ORB_AREA	V96U9160C	FT**2	F	S	D	P	G4.126	00	ZFB	89622A	
							G4.148				
							G4.158				
REJ_MAX	V96U9162C	ND	I	S	D	P	G4.126	00	ZPA	DC0617	
RNG_MIN	V96U9163C	FT	F	S	D	P	G4.126	00	ZFB	89622A	
RRDOT_BIAS_INIT(1)	V96U9166C	FT	F	S	M	P	G4.126	00	RDZ	DC0617	
RRDOT_BIAS_INIT(2)	V96U9167C	FT/SEC	F	S	M	P	G4.126	00	RDZ	DC0617	
RR_ANGLES_BIAS_INIT(1)	V96U9164C	RAD	F	S	M	P	G4.126	00	RDZ	DC0617	
RR_ANGLES_BIAS_INIT(2)	V96U9165C	RAD	F	S	M	P	G4.126	00	RDZ	DC0617	
R_OFFSET_BODY(1)	V99U7431C	FT	F	S	D	P	G4.126	00	ZFB	89622A	
R_OFFSET_BODY(2)	V99U7432C	FT	F	S	D	P	G4.126	00	ZFB	89622A	
R_OFFSET_BODY(3)	V99U7433C	FT	F	S	D	P	G4.126	00	ZFB	89622A	

TABLE 4.2.11-3 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
SIG_RR_RNG	V96U9775C	FT	F	S	D	P	G4.126	00	ZFB	89622A	
SIG_UPDATE(1)	V96H1284C	FT	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
SIG_UPDATE(2)	V96H1285C	FT	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
SIG_UPDATE(3)	V96H1286C	FT	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
SIG_UPDATE(4)	V96H1287C	FT/SEC	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
SIG_UPDATE(5)	V96H1288C	FT/SEC	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
SIG_UPDATE(6)	V96H1289C	FT/SEC	F	S	M	P	G4.126 G4.148	00	ZPB	DC1981	
SIN_LAG	V96U9169C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
SLOPE_SIG_RR_RNG	V96U9170C	ND	F	S	D	P	G4.126	00	ZFB	89622A	
ST_ANGLES_BIAS_INIT(1)	V96U9171C	RAD	F	S	M	P	G4.126	00	RDZ	DC0617	
ST_ANGLES_BIAS_INIT(2)	V96U9172C	RAD	F	S	M	P	G4.126	00	RDZ	DC0617	
TAU_COAS_ANGLES(1)	V96U9176C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
TAU_COAS_ANGLES(2)	V96U9177C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
TAU_RRDOT(1)	V96U9180C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
TAU_RRDOT(2)	V96U9181C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
TAU_RR_ANGLES(1)	V96U9178C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
TAU_RR_ANGLES(2)	V96U9179C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
TAU_ST_ANGLES(1)	V96U9182C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
TAU_ST_ANGLES(2)	V96U9183C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
TAU_UNMOD_ACC_COV	V90W4929C	SEC	F	S	D	P	G4.126	00	ZPA	DC0617	
TAU_UNMOD_ACC_STATE	V96U9186C	SEC	F	S	D	P	G4.126	00	ZPA	DC0617	
TAU_U_A_COAST	V96U9184C	SEC	F	S	D	P	G4.126 G4.148	00	ZPA	DC0617	
TAU_U_A_PWRD_FLT	V96U9185C	SEC	F	S	D	P	G4.126	00	ZPA	DC0617	
TFOFF	V96W8178C	SEC	F	D	M	P	G4.126 G4.148	00	ZFB	89622A	
TFON	V96W8177C	SEC	F	D	M	P	G4.126 G4.148	00	ZFB	89622A	
T_BIAS_COAS	V96U9187C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
T_BIAS_REND_RADAR	V96U9188C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
T_BIAS_ST	V96U9189C	SEC	F	S	D	P	G4.126	00	ZFB	89622A	
T_GPS_CYCLE	V97U2926C	SEC	F	S	D	P	G4.126 G4.127 G4.144 G4.205	03 08 02 01	GP3 GP2 GP2 GP3	92178C	
T_ORB_STATE_UPDATE	V94W3727C	SEC	F	D	M	P	G4.126	00	YD1	90243C	
T_TV_STATE_UPDATE	V90W4939C	SEC	F	D	M	P	G4.126	00	YD1	90243C	
UNMOD_ACC_UPDATE_FLAG	V96U9190C	NONE	D		M	P	G4.126	00	ZPB	DC1981	
VAR_COAS_ANGLES(1)	V96U9191C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_COAS_ANGLES(2)	V96U9192C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_COAS_HORIZ	V96U9193C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	



TABLE 4.2.11-3 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
VAR_COAS_VERT	V96U9194C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_IMU_ALIGN	V96U9195C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_RANGE_DOT	V96U9196C	FT**2/SEC**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_RRDOT(1)	V96U9199C	FT**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_RRDOT(2)	V96U9200C	FT**2/SEC**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_RR_ANGLES(1)	V96U9197C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_RR_ANGLES(2)	V96U9198C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_RR_RNG_MIN	V96U9201C	FT**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_SHAFT	V96U9202C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_ST_ANGLES(1)	V96U9203C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_ST_ANGLES(2)	V96U9204C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_ST_HORIZ	V96U9205C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_ST_VERT	V96U9206C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_TRUN	V96U9207C	RAD**2	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_U_A_COAST(1)	V96U9208C	FT**2/SEC**4	F	S	D	P	G4.126 G4.148	00	ZPA	DC0617	
VAR_U_A_COAST(2)	V96U9209C	FT**2/SEC**4	F	S	D	P	G4.126 G4.148	00	ZPA	DC0617	
VAR_U_A_COAST(3)	V96U9210C	FT**2/SEC**4	F	S	D	P	G4.126 G4.148	00	ZPA	DC0617	
VAR_U_A_PWRD_FLT(1)	V96U9211C	FT**2/SEC**4	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_U_A_PWRD_FLT(2)	V96U9212C	FT**2/SEC**4	F	S	D	P	G4.126	00	ZPA	DC0617	
VAR_U_A_PWRD_FLT(3)	V96U9213C	FT**2/SEC**4	F	S	D	P	G4.126	00	ZPA	DC0617	
VEL_THRESH	V99U7496C	FT/SEC	F	S	D	P	G4.126	00	ZPA	DC0617	
VFORCE(1)	V96U8174C	LBS	F	S	M	P	G4.126 G4.148	00	ZFB	89622A	
VFORCE(2)	V96U8175C	LBS	F	S	M	P	G4.126 G4.148	00	ZFB	89622A	
VFORCE(3)	V96U8176C	LBS	F	S	M	P	G4.126 G4.148	00	ZFB	89622A	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

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TABLE 4.2.11-4 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) K-LOADS

FSSR NAME DESCRIPTION	MSID	MC	KLOAD VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
CBD1	V96U9087C	00	+1.4036	E-05 FT**-1	F		S P	G4.126	59953	
CBD2	V96U9088C	00	-1.3716	E-05 FT**-1	F		S P	G4.126	59953	
GM_DEG	V96U9117C	00	+4	ND	I		S P	G4.126 G4.148	59953	
GM_DEG_LOW	V96U9118C	00	+2	ND	I		S P	G4.126 G4.22	59953	
GM_ORD	V96U9119C	00	+4	ND	I		S P	G4.126 G4.148	59953	
GM_ORD_LOW	V96U9120C	00	+0	ND	I		S P	G4.126 G4.22	59953	
LOS_R	V96U9125C	00	+1.990986594	E-07 RAD/SEC	F		D P	G4.126 G4.66	92537A	
MEAN MOTION OF EARTH										
MAX_TIME_TOL	V96U8685C	00	+5.4	E+04 SEC	F		S P	G4.126 G4.127 G4.148 G4.15 G6.11	92834C	
MAX ALLOWABLE TOTAL PREDICTION INTERVAL										
OMEG_C	V96U9157C	00	+1.990968715	E-07 RAD/SEC	F		D P	G4.126	59953	
PREC_STEP_PRED	V98U8726C	00	+3.00	E+02 SEC	F		D P	G4.126 G4.148	89648A	
REF_ORB_CD	V96U9161C	00	+2.0	E+00 ND	F		S P	G4.126 G4.148 G4.158	89542A	
RREF	V96U9168C	00	+2.3769016	E-03 SLUGS/FT**3	F		D P	G4.126	59953	
SENSOR_DELTA	V96U9766C	00	+5.773503	E-01 ND	F		S P	G4.126	29772A	
SENSOR_EPS	V96U9765C	00	+1.0	E+00 FT	F		S P	G4.126	29772A	
TARGET_AREA	V96U9173C	00	+1.0	E+00 FT**2	F		S P	G4.126 G4.148	92545B	
TARGET AREA FOR DRAG ACCELERATION										
TARGET_CD	V96U9174C	00	+2.0	E+00 ND	F		S P	G4.126 G4.148	92545B	
TARGET CD FOR DRAG ACCELERATION										
TARGET_MASS	V96U9175C	00	+1.0	E+00 SLUGS	F		S P	G4.126 G4.148	92545B	
TARGET MASS FOR DRAG ACCELERATION										

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.2.11-5 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
ATFL_OV CONTROLS USE OF CURRENT ORB ATTITUDE IN DRAG COMPUTE	V97U6102C	00	+0		ND		I	S C G4.126 G4.148 G4.18 G4.21 G4.22	91051K	
ATFL_TV CONTROLS USE OF MASS, AREA & DC FOR TARGET	V97U6103C	00	+2		ND		I	S C G4.126 G4.148	90374C	
C(01) TESSERAL HARMONIC COEFFICIENT ELEM 1	V97U6104C	00	-2.7635957	E-10	ND		F	D C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
C(02) TESSERAL HARMONIC COEFFICIENT ELEM 2	V97U6105C	00	+1.5711423	E-06	ND		F	D C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
C(03) TESSERAL HARMONIC COEFFICIENT ELEM 3	V97U6106C	00	+2.1907694	E-06	ND		F	D C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
C(04) TESSERAL HARMONIC COEFFICIENT ELEM 4	V97U6107C	00	+3.0466825	E-07	ND		F	D C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	

TABLE 4.2.11-5 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
C(05) TESSERAL HARMONIC COEFFICIENT ELEM 5	V97U6108C	00	+9.7966803	E-08	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
C(06) TESSERAL HARMONIC COEFFICIENT ELEM 6	V97U6109C	00	-5.0552749	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
C(07) TESSERAL HARMONIC COEFFICIENT ELEM 7	V97U6110C	00	+7.8842515	E-08	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
C(08) TESSERAL HARMONIC COEFFICIENT ELEM 8	V97U6111C	00	+5.9073749	E-08	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
C(09) TESSERAL HARMONIC COEFFICIENT ELEM 9	V97U6112C	00	-4.1542493	E-09	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	

TABLE 4.2.11-5 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
DEG_PER_RAD RADIAN TO DEGREE CONVERSION FACTOR	V97U0112C	00	+5.72957795131E+01	DEG/RAD	F		S C	A6.9 G4.10 G4.126 G4.127 G4.128 G4.175 G4.20 G4.201 G4.204 G4.208 G4.21 G4.213 G4.220 G4.226 G4.227 G4.23 G4.234 G4.237 G4.24 G4.25 G4.35 G4.36 G4.5 G4.6 G4.66 G4.8 G4.9 G4.97 G5.26 G5.27 V4.10 V4.11 V4.11B V4.11C V4.9A	93090E	
DFL INDICATES ACTIVATION (1) OF DRAG MODEL	V97U6114C	00	ON	ND	D		C	G4.126 G4.148	90374C	
D_FIN_TEMP TEMPORARY STORAGE FOR D_FIN	V97U6113C	00	+0.0	E+00 FT**2/SEC	F		D C	G4.126 G4.224	90374C	

TABLE 4.2.11-5 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
EARTH_MU EARTH GRAVITATIONAL CONSTANT	V97U4378C	00	+1.40764487566E+16	FT**3/SEC**2	F		D C	A6.9 G4.126 G4.127 G4.13 G4.139 G4.144 G4.148 G4.15 G4.158 G4.2 G4.205 G4.209 G4.210 G4.211 G4.224 G4.236 G4.3 G4.4 G5.10 G5.24 G5.26 G5.27	93090E	
EARTH_RADIUS_EQUATOR EARTH EQUATORIAL RADIUS	V97U5324C	00	+2.09257414698E+07	FT	F		D C	A6.9 G4.126 G4.127 G4.13 G4.139 G4.144 G4.148 G4.15 G4.158 G4.19 G4.20 G4.205 G4.210 G4.211 G4.213 G4.23 G4.236 G4.238 G4.24 G4.25 G5.26 G5.27 V5.1.8	93090E	

TABLE 4.2.11-5 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
EARTH_RADIUS_GRAV EARTH RADIUS(GRAV ACCEL)	V97U5325C	00	+2.09256561680E+07	FT	F		D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
EARTH_RATE EARTH'S ROTATIONAL RATE	V97U4379C	00	+7.29211514646E-05	RAD/SEC	F		D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.17 G4.19 G4.20 G4.205 G4.21 G4.213 G4.22 G4.236 G4.237 G4.4 G5.26	93090E	
ELLIPT EARTH'S ELLIPTICITY CONSTANT	V97U5332C	00	+3.352329869 E-03	ND	F		D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.19 G4.20 G4.205 G4.213 G4.23 G4.236 G4.237 G4.238 G4.24 G4.25 G5.26 G5.27 V5.1.8	93090E	



TABLE 4.2.11-5 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
GO EARTH GRAV ACCEL CONSTANT	V90A7622C	00	+3.2174049	E+01	FT/SEC**2	F	S	P A6.9 G4.10 G4.105 G4.126 G4.204 G4.208 G4.22 G4.220 G4.227 G4.234 G4.237 G4.36 G4.8 G4.9 G5.27 V4.10 V4.11 V4.11B V4.11C V4.9A	93090E	
ID_MATRIX_3X3(01) COMPONENT OF 3X3 IDENTITY MATRIX (1,1)	V97U6196C	00	+1.0	E+00	ND	F	S	C G4.126 G4.127 G4.144 G4.15 G4.205	90374C	
ID_MATRIX_3X3(02) COMPONENT OF 3X3 IDENTITY MATRIX (1,2)	V97U6197C	00	+0.0	E+00	ND	F	S	C G4.126 G4.127 G4.144 G4.15 G4.205	90374C	
ID_MATRIX_3X3(03) COMPONENT OF 3X3 IDENTITY MATRIX (1,3)	V97U6198C	00	+0.0	E+00	ND	F	S	C G4.126 G4.127 G4.144 G4.15 G4.205	90374C	
ID_MATRIX_3X3(04) COMPONENT OF 3X3 IDENTITY MATRIX (2,1)	V97U6199C	00	+0.0	E+00	ND	F	S	C G4.126 G4.127 G4.144 G4.15 G4.205	90374C	
ID_MATRIX_3X3(05) COMPONENT OF 3X3 IDENTITY MATRIX (2,2)	V97U6200C	00	+1.0	E+00	ND	F	S	C G4.126 G4.127 G4.144 G4.15 G4.205	90374C	

TABLE 4.2.11-5 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
ID_MATRIX_3X3(06) COMPONENT OF 3X3 IDENTITY MATRIX (2,3)	V97U6201C	00	+0.0	E+00	ND	F	S	C G4.126 G4.127 G4.144 G4.15 G4.205	90374C	
ID_MATRIX_3X3(07) COMPONENT OF 3X3 IDENTITY MATRIX (3,1)	V97U6202C	00	+0.0	E+00	ND	F	S	C G4.126 G4.127 G4.144 G4.15 G4.205	90374C	
ID_MATRIX_3X3(08) COMPONENT OF 3X3 IDENTITY MATRIX (3,2)	V97U6203C	00	+0.0	E+00	ND	F	S	C G4.126 G4.127 G4.144 G4.15 G4.205	90374C	
ID_MATRIX_3X3(09) COMPONENT OF 3X3 IDENTITY MATRIX (3,3)	V97U6204C	00	+1.0	E+00	ND	F	S	C G4.126 G4.127 G4.144 G4.15 G4.205	90374C	
NUM_KEP_ITER MAXIMUM NUMBER OF ITERATIONS TO SOLVE KEPLER EQUATION	V97U6220C	00	+5.0	E+00	ND	F	S	P G4.126	90374C	

TABLE 4.2.11-5 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
PI RATIO OF CIRCUMFERENCE TO DIAMETER	V98U8725C	00	+3.14159265358E+00	ND	F	D	C	A6.9 G4.126 G4.127 G4.13 G4.144 G4.15 G4.158 G4.16 G4.19 G4.2 G4.20 G4.205 G4.209 G4.210 G4.213 G4.220 G4.236 G4.237 G4.3 G4.4 G4.5 G4.97 G5.10 G5.24 G5.26 G5.27	93090E	

TABLE 4.2.11-5 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
RAD_PER_DEG DEGREE TO RADIAN CONVERSION FACTOR	V97U0383C	00	+1.7453293	E-02	RAD/DEG	F	S	C A6.9 G4.1 G4.126 G4.127 G4.128 G4.144 G4.15 G4.158 G4.175 G4.20 G4.201 G4.204 G4.205 G4.209 G4.210 G4.211 G4.213 G4.220 G4.223 G4.226 G4.227 G4.236 G4.237 G4.3 G4.35 G4.36 G4.7 G4.72 G4.9 G4.97 G5.27	93090E	
S(01) TESSERAL HARMONIC COEFFICIENT ELEM 1	V97U5492C	00	-5.2357454	E-09	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	

TABLE 4.2.11-5 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
S(02) TESSERAL HARMONIC COEFFICIENT ELEM 2	V97U5493C	00	-9.0231337	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
S(03) TESSERAL HARMONIC COEFFICIENT ELEM 3	V97U5494C	00	+2.7267074	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
S(04) TESSERAL HARMONIC COEFFICIENT ELEM 4	V97U5495C	00	-2.1259298	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
S(05) TESSERAL HARMONIC COEFFICIENT ELEM 5	V97U5496C	00	+1.9681077	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
S(06) TESSERAL HARMONIC COEFFICIENT ELEM 6	V97U5497C	00	-4.4125015	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	

TABLE 4.2.11-5 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
S(07) TESSERAL HARMONIC COEFFICIENT ELEM 7	V97U5498C	00	+1.4818958	E-07	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
S(08) TESSERAL HARMONIC COEFFICIENT ELEM 8	V97U5499C	00	-1.2140873	E-08	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
S(09) TESSERAL HARMONIC COEFFICIENT ELEM 9	V97U5500C	00	+6.3163541	E-09	ND	F	D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
SV_TIME_TAG_DIFF TIME TOLERANCE FOR PREDICTION	V97U6132C	01 02 03 08	+1.0 +5.0 +1.0 +5.0	E+00 E-01 E+00 E-01	SEC	F	S	P G4.126 G4.127 G4.148 G4.15	90374C	
TDV_FILT(1) DUMMY VECTOR FOR TARGET ACCUMULATED VELOCITY	V97U6145C	00	+0.0	E+00	FT/SEC	F	S	P G4.126	90374C	
TDV_FILT(2) DUMMY VECTOR FOR TARGET ACCUMULATED VELOCITY	V97U6146C	00	+0.0	E+00	FT/SEC	F	S	P G4.126	90374C	
TDV_FILT(3) DUMMY VECTOR FOR TARGET ACCUMULATED VELOCITY	V97U6147C	00	+0.0	E+00	FT/SEC	F	S	P G4.126	90374C	
VFLOV ACTIVATION(1) OF VENT/RCS THRUST FOR ORB PROPAGATION	V97U6134C	00	ON		ND	D	P	G4.126	90374C	
VFL_OV_PRED DEACTIVATION(0) OF VENT FOR ORBITER PREDICTION	V97U6135C	00	OFF		ND	D	P	G4.126 G4.148	90374C	

TABLE 4.2.11-5 ONORBIT/RENDEZVOUS NAVIGATION (G4.126) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
VFL_TV SPECIFIES(1) USE OF UNMODELED ACCEL FOR TARGET PROP	V97U6136C	00	ON	ND	D		P	G4.126 G4.148	90374C	
VFL_TV_PROP SPECIFIES(1) USE OF VENT IN BACKUP PROP FOR TARGET	V97U6140C	00	OFF	ND	D		P	G4.126 G4.148	90374C	
ZONAL(01) ZONAL HARMONICS COEFFICIENT ELEM 1	V97U5582C	00	+0.0	E+00	ND	F	D C	A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
ZONAL(02) ZONAL HARMONICS COEFFICIENT ELEM 2	V97U5583C	00	+1.0826271	E-03	ND	F	D C	A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
ZONAL(03) ZONAL HARMONICS COEFFICIENT ELEM 3	V97U5584C	00	-2.5358868	E-06	ND	F	D C	A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	
ZONAL(04) ZONAL HARMONICS COEFFICIENT ELEM 4	V97U5585C	00	-1.6246180	E-06	ND	F	D C	A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.205 G4.236	90374C	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

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### 4.3 ONORBIT PRECISION STATE PREDICTION PRINCIPAL FUNCTION

A capability shall be provided for predicting the position and velocity of the orbiter or target at some final time in the future or past, when an initial state and time are given.

The Onorbit Precision State Prediction principal function shall make no use of the IMU accumulated sensed velocities and therefore is a free-flight prediction process even though it may be performed during periods of flight in which navigation is using accumulated sensed velocities.

Since this principal function shall be used for different purposes having different environmental requirements in various navigation phases, the user shall, by setting the control flags to the appropriate values and by choosing the prediction method or integration step size, have the option to trade off the accuracy of the integration and the fidelity of the mathematical models in favor of the shorter execution time. This is accomplished with parameters specified prior to the invoking of the Onorbit Precision State Prediction principal function.

Table 4.3-1 contains the parameter interface to local modules for this principal function. Table 4.3.3-1 is the principal function input and output list and shows data flow between the Onorbit Precision State Prediction principal function and other principal functions. Other available parameter tables include I-loads in Table 4.3.3-2, K-loads in Table 4.3.3-3, constants in Table 4.3.3-4, and a parameter cross-reference list, in Table 4.3.3-5.

This principal function, which provides for onorbit precision state prediction and rapid state prediction of the orbiter or target position and velocity states, shall use either a fourth-order Runge-Kutta numerical integration technique, modified with Gill's coefficients, or a single-step two-body method (rapid state prediction). The S. Pines formulation of the equations of motion shall be used with each technique. Detailed requirements for the Runge-Kutta Gill integration technique and the Pines formulation are provided in Sections 4.3.1 and 4.3.2. Noncentral body accelerations shall be generated by the user-selected acceleration models (Section 4.2.4.1.1) to account for perturbations due to drag, venting and uncoupled thrusting, and variations in the Earth's gravitational potential.

A. Detailed Requirements. The Onorbit Precision State Prediction principal function computational scheme shall be performed as follows:

1. The desired gravity (GMDP and GMOP), drag (DMP), venting and uncoupled thrusting (VMP), and vehicle-attitude (ATMP) mode flags shall be obtained from the user, together with the prediction integration step size (PRED\_STEP), initial state and time ( $\bar{R}_{\text{PRED\_INIT}}$ ,  $\bar{V}_{\text{PRED\_INIT}}$ , and  $T_{\text{PRED\_INIT}}$ ), and final time at the end of the prediction interval ( $T_{\text{PRED\_FINAL}}$ ). If prediction is being performed for the orbiter (i.e.,  $ATMP = 1$ ), the orbiter mass to be used during prediction shall be user specified (PRED\_ORB\_MASS) along with an orbiter reference area (PRED\_ORB\_AREA) and drag coefficient (PRED\_ORB\_CD).

The initial state vector shall then be renamed for use in the Pines equations-of-motion formulation and the seventh variable of integration ( $XN_7$ ) initialized to zero:

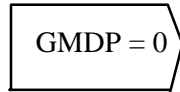
$$XN_{1 \text{ to } 3} = \bar{R}_{\text{PRED\_INIT}}$$

$$XN_{4 \text{ to } 6} = \bar{V}_{\text{PRED\_INIT}}$$

$$XN_7 = 0.$$

In the above equations, the seventh variable of integration ( $XN_7$ , required by the Pines technique) is the integrated initial time  $T\_PRED\_INIT$ .

2. A check shall now be made on the gravity mode flag (GMDP) to determine if prediction is to be accomplished through the use of a simple two-body solution of a more precise integration technique.



- a. If a two-body solution is required (i.e.,  $GMDP = 0$ ) the prediction interval is computed as

$$T\_CUR = T\_PRED\_FINAL - T\_PRED\_INIT$$

- b. If a more precise integration technique is required (i.e.,  $GMDP \neq 0$ ), several steps shall be performed to set up parameters required for the integration process.

- (1) The input prediction step ( $PRED\_STEP$ ) is checked against a hard-coded maximum stepsize ( $DT\_MAX$ ) to verify its reasonability:



If the input step is greater than the allowable maximum, then the value is reset to the maximum stepsize:

$$PRED\_STEP = DT\_MAX$$

Otherwise, the prediction stepsize input is left unchanged.

- (2) Next, the total prediction time interval is calculated from the input initial and final times, and the current integrator time is set to zero:

$$TIME\_DEL = T\_PRED\_FINAL - T\_PRED\_INIT$$

$$T\_CUR = 0.$$

- (3) If the total prediction time interval,  $TIME\_DEL$ , is less than zero, a backward prediction has been requested and the internal integration step ( $DT\_STEP$ ) is set to a negative value of the input stepsize:



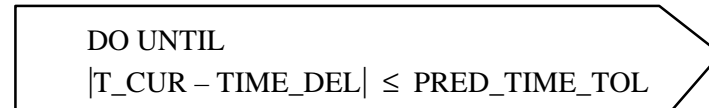
$$\text{Then: } DT\_STEP = - PRED\_STEP$$

Otherwise,  $TIME\_DEL \geq 0$ ., the internal prediction step is set to the input prediction step:

$$DT\_STEP = PRED\_STEP$$

- (4) The actual integration of the orbiter or target state equations (formulated according to the Pines technique) shall now be performed by proceeding as follows for each step in the integration interval. Note that, in the Pines equations-of-motion formulation, it is the initial conditions ( $\bar{R}_{PRED\_INIT}$ ,  $\bar{V}_{PRED\_INIT}$ , and  $T_{PRED\_INIT}$ ) that are integrated and then used in the closed-form solution of a two-body, unperturbed orbital problem using an F and G series.

The fourth-order Runge-Kutta-Gill integration technique shall be invoked in conjunction with the Pines equations-of-motion formulation for each predictor step (as discussed in Section 4.3.1) until the prediction interval has been covered as follows (i.e., until  $T_{CUR} = TIME\_DEL$ ):



- Check the PRED\_ENA\_FLAG for an OFF value to determine if an event has been initiated to leave OPS 2 or OPS 8. If PRED\_ENA\_FLAG = OFF, set

$T_{CUR} = TIME\_DEL$

to initiate termination of the current prediction task.

- Check, on each step, to determine if the absolute value of the prediction step is greater than the absolute value of the prediction interval remaining;

If,



then:  $DT\_STEP = TIME\_DEL - T_{CUR}$

- The Runge-Kutta-Gill integrator shall then be invoked, with the input or adjusted value of DT\_STEP;

CALL: RK\_GILL

IN LIST: XN, DT\_STEP, T\_CUR, GMOP, GMDP, DMP,  
VMP, ATMP, T\_PRED\_INIT

OUT LIST: XN, T\_CUR

The output vector (XN), are the adjusted initial conditions to be used in the Pines equations of motion for a precision prediction conic solution.

3. After the calculations, as dictated by the testing of step 2, have been performed, the Pines equations of motion will be invoked to solve for the position and velocity vectors corresponding to  $T_{PRED\_FINAL}$ :

CALL: PINES\_METHOD

IN LIST: XN, T\_CUR, GMOP, GMDP, DMP, VMP, ATMP, T\_PRED\_INIT

OUT LIST: DERIV, X

4. Upon being calculated (whether by a precise technique or a single step two-body solution), the final position and velocity are renamed for output:

$$\bar{R}_{\_PRED\_FINAL} = X_{1\ to\ 3}$$

$$\bar{V}_{\_PRED\_FINAL} = X_{4\ to\ 6}$$

B. Interface Requirements. Input and output requirements are contained in Table 4.3-2.

C. Processing Requirements. This principal function requires user-supplied values of gravity (GMOP and GMDP), drag (DMP), venting and uncoupled thrusting (VMP), and vehicle-attitude (ATMP) mode flags, in conjunction with the initial state and time ( $\bar{R}_{\_PRED\_INIT}$ ,  $\bar{V}_{\_PRED\_INIT}$ , T\_PRED\_INIT) and the final time (T\_PRED\_FINAL). Appropriate acceleration models may be found in Section 4.2.4.1.1. When using this function for orbiter or target vehicle state prediction, the venting and uncoupled thrusting flag (VMP) shall be set to zero. Additionally, if drag modeling is desired for orbiter or target state prediction, the drag mode flag (DMP) should be set to one and the attitude mode flag (ATMP) set equal to one for the orbiter or equal to two for the target. For prediction of the orbiter's state, an orbiter reference area (PRED\_ORB\_AREA), an orbiter drag coefficient (PRED\_ORB\_CD), and an orbiter mass (PRED\_ORB\_MASS) are also to be supplied. The Onorbit Precision State Prediction principal function is called by the following modules in the Onorbit/Rendezvous Navigation Sequencer principal function:

OPS\_2\_OR\_8\_INITIALIZE

STATE\_VECTOR\_PREDICT\_TASK

and by the following module in the Onorbit/Rendezvous Navigation principal function:

STATE\_VECTOR\_PREDICT\_TASK

In addition it may be called by other users outside of navigation.

D. Constraints. Vent thrust is not to be modeled in prediction. Hence, the vent thrust flag (VMP) is to be set to zero. Atmospheric drag is to be modeled with constant coefficients. Hence, whenever drag is to be modeled in a prediction, the vehicle attitude flag (ATMP) is not to be set to zero (see Section 4.2.4.1.1).

Since the same compool locations are used by all users of this principal function for setup and output, it is required that these parameters be protected from alteration by other users during execution of this principal function. Variables to be protected are listed as follows: GMOP, GMDP, DMP, VMP, ATMP, PRED\_STEP,  $\bar{R}_{\_PRED\_INIT}$ ,  $\bar{V}_{\_PRED\_INIT}$ , T\_PRED\_INIT,  $\bar{R}_{\_PRED\_FINAL}$ ,  $\bar{V}_{\_PRED\_FINAL}$ , T\_PRED\_FINAL, PRED\_ORB\_AREA, PRED\_ORB\_CD, PRED\_ORB\_MASS.

E. Supplementary Information. The Onorbit Precision State Prediction principal function shall be used for both precision and rapid state prediction. Rapid state prediction consists of a less accurate, single-step two-body F and G series solution involving no numerical integration. Table 4.3-3 lists several examples of input variable list combinations for the various types of prediction performed. A suggested implementation of this principal function may be found in Section 5.3 under the following:

ONORBIT\_PREDICT

Table 4.3-1. Onorbit Precision State Prediction Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
ATMP	Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, ORB MNVR DIP, ORB_TGTING	PINES_METHOD, RK_GILL	TLM	NONE
$\bar{D}$ _SAVE			ORB_TGTING	$\bar{A}$ CCEL_ ONORBIT
DMP	Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, ORB MNVR DIP, ORB_TGTING	PINES_METHOD, RK_GILL		
GMDP	Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, ORB MNVR DIP, ORB_TGTING	PINES_METHOD, RK_GILL		
GMOP	Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, ORB MNVR DIP, ORB_TGTING	PINES_METHOD, RK_GILL		
PRED_ENA_ FLAG	Onorbit/Rendezvous Nav Seq	ONORBIT PREDICT		
PRED_ORB_ AREA	Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, ORB MNVR DIP, ORB_TGTING	$\bar{A}$ CCEL_PREDICT		
PRED_ORB_CD	Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, ORB MNVR DIP, ORB_TGTING	$\bar{A}$ CCEL_ ONORBIT		
PRED_ORB_ MASS	Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, ORB MNVR DIP, ORB_TGTING	$\bar{A}$ CCEL_ ONORBIT		
PRED_STEP	Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, ORB MNVR DIP, ORB_TGTING	ONORBIT_ PREDICT	TLM	NONE
$\bar{R}$ _PRED_FINAL			Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, TLM, ORB MNVR DIP, ORB_TGTING	ONORBIT PREDICT
$\bar{R}$ _PRED_INIT	Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, ORB MNVR DIP, ORB_TGTING	ONORBIT_ PREDICT	TLM	NONE
SQR_EMU	Onorbit/Rendezvous Nav, Seq	PINES_METHOD		

Table 4.3-1. Onorbit Precision State Prediction Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
T_PRED_FINAL	Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, ORB MNVR DIP, ORB_TGTING	ONORBIT_ PREDICT	TLM	NONE
T_PRED_INIT	Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, ORB MNVR DIP, ORB_TGTING	PINES_METHOD, RK_GILL	TLM	NONE
VMP	Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, ORB MNVR DIP, ORB_TGTING	PINES_METHOD, RK_GILL		
$\bar{V}$ _PRED_FINAL			Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, TLM, ORB MNVR DIP, ORB_TGTING	ONORBIT_ PREDICT
$\bar{V}$ _PRED_INIT	Onorbit/Rendezvous Nav, Onorbit/Rendezvous Nav Seq, ORB MNVR DIP, ORB_TGTING	ONORBIT_ PREDICT	TLM	NONE

Table 4.3-2. ONORBIT\_PREDICT Input/Output

Variable Name	Input Source	Output Destination
ATMP	*	PINES_METHOD, RK_GILL
DERIV	PINES_METHOD	
DMP	*	PINES_METHOD, RK_GILL
DT_MAX	**	
DT_STEP		RK_GILL
GMDP	*	PINES_METHOD, RK_GILL
GMOP	*	PINES_METHOD, RK_GILL
PRED_ENA_FLAG	*	
PRED_STEP	*	
PRED_TIME_TOL	**	
$\bar{R}$ _PRED_FINAL		*
$\bar{R}$ _PRED_INIT	*	
T_CUR	RK_GILL	PINES_METHOD, RK_GILL
T_PRED_FINAL	*	
T_PRED_INIT	*	PINES_METHOD, RK_GILL
VMP	*	PINES_METHOD, RK_GILL
$\bar{V}$ _PRED_FINAL		*
$\bar{V}$ _PRED_INIT	*	
X	PINES_METHOD	
XN	RK_GILL	PINES_METHOD, RK_GILL
<p>* PF I/O for Onorbit Precision State Prediction principal function, see Tables 4.3.3-1. and 4.3.3-2.  ** Initialization parameters, see Section 4.7.</p>		

Table 4.3-3. Predictor Suggested Flag Settings

Vehicle	Prediction Type	GMDP*	GMOP*	DMP	VMP	ATMP	PRED_STEP	Comments
Orbiter	Precision	4	4	1	0	1	User selects	Full fourth degree potential model. Drag with constant drag coefficient, area.
Orbiter	Rapid precision	2	0	1	0	1	User selects	J <sub>2</sub> only potential model with constant drag coefficient, area.
Orbiter	Rapid two-body	0	0	0	0	0	0	Single-step two-body F and G series solution.
Target	Precision	4	4	1	0	2	User selects	Full fourth degree potential model drag with constant area, drag coefficient.
Target	Rapid precision	2	0	1	0	2	User selects	J <sub>2</sub> only potential model with constant drag coefficient, area.
Target	Rapid two-body	0	0	0	0	0	0	Single-step two-body F and G series solution.

\* When prediction is being performed for both vehicles (Orbiter and target) over a similar trajectory, the same degree and order potential model should be used for each prediction so that potential model errors will be avoided.



### 4.3.1 Integration of the Equations of Motion (RK\_GILL)

A fourth-order Runge-Kutta-Gill integration technique is used for prediction of the orbiter and target state vectors. The technique is actually a fourth-order Runge-Kutta numerical integration technique, modified with Gill's coefficients, used in conjunction with S. Pines' formulation for the equations of motion (see Section 4.3.2).

A. Detailed Requirements. The Runge-Kutta-Gill (RK\_GILL) integration subfunction will be activated each time a call statement of the following form is encountered:

CALL: RK\_GILL

IN LIST: XN,DT\_STEP, T\_CUR,GMO,GMD,DM,VM,ATM,T\_IN

OUT LIST: XN,T\_CUR

where:

XN	= an array containing the seven variables of integration (i.e., integrated initial conditions)
DT_STEP	= the integration step size
T_CUR	= the RK_GILL step size subinterval time (i.e., there are four cycles of RK_GILL per integration step size)
GMO	= the Earth gravitational potential model order
GMD	= the Earth gravitational potential model degree
DM	= the drag acceleration model flag
VM	= the vent and uncoupled thrust acceleration model flag
ATM	= the vehicle attitude mode flag
T_IN	= the initial state time

The computations initiated by call to the Runge-Kutta-Gill subfunction will be the following and in the order indicated.

1. The initial time of the current integration step, T\_CUR, shall be saved in T\_STOR.

$$T\_STOR = T\_CUR$$

2. Next a counter, J, shall be tested to ensure that four evaluations of Runge-Kutta-Gill are determined.

DO FOR  
J = 1 TO 4

- a. If the evaluation cycle is 4 or less, a new value of T\_CUR (the integration step time) shall be determined as:

$$T\_CUR = T\_STOR + AA_1 BB_J DT\_STEP$$

- b. Next the Pines method will be called to calculate derivatives (DERIV), of the initial conditions.

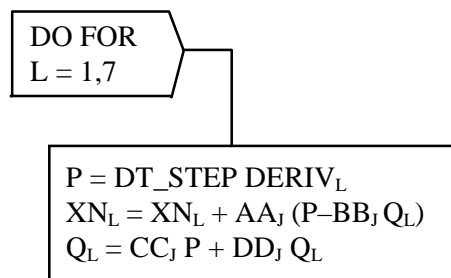
CALL: PINES\_METHOD

IN LIST: XN,T\_CUR,GMO,GMD,DM,VM,ATM,T\_IN

OUT LIST: DERIV,X

The call arguments are as previously described, and details of the Pines method are given in Section 4.3.2.

- c. The Runge–Kutta–Gill integration continues with the numerical integration of derivatives of the initial conditions (XN<sub>L</sub>) in the following manner:



where:

AA, BB, CC, DD = premission–loaded arrays (J = 1 to 4) containing coefficients required for this formulation of the Runge–Kutta–Gill integration technique

XN = an array containing the seven variables of integration (i.e., integrated initial conditions)

DERIV = an array containing the total derivatives of the initial conditions at the current time

P = integration variable used in Runge–Kutta–Gill technique

Q<sub>L</sub> = integration variable used in the Runge–Kutta–Gill technique

After the seven variables of integration have been obtained, the RK\_GILL will return to repeat step 2, and cycle through until J is greater than 4.

B. Interface Requirements. Input and output parameters for the Runge–Kutta–Gill integration subfunction are given in Table 4.3.1.

C. Processing Requirements. The Runge–Kutta–Gill subfunction is called by

Onorbit precision state prediction (ONORBIT\_PREDICT)

D. Constraints. Because the Runge–Kutta–Gill subfunction is used by precision prediction subfunctions which may be executed by multiple users at the same time, it should be protected against interruption.

E. Supplementary Information. A suggested implementation of this subfunction in the form of detailed flow diagrams may be found in Section 5.3 under the following:

RK\_GILL

Table 4.3.1. RK_GILL INPUT/OUTPUT			
Inlist/Outlist			
Internal Name	External Name	Input Source	Output Destination
ATM	ATMP	ONORBIT_PREDICT	
DM	DMP	ONORBIT_PREDICT	
DT_STEP	DT_STEP	ONORBIT_PREDICT	
GMD	GMDP	ONORBIT_PREDICT	
GMO	GMOP	ONORBIT_PREDICT	
T_CUR	T_CUR	ONORBIT_PREDICT	
T_IN	T_PRED_INIT	ONORBIT_PREDICT	
VM	VMP	ONORBIT_PREDICT	
XN	XN	ONORBIT_PREDICT	
T_CUR	T_CUR		ONORBIT_PREDICT
XN	XN		ONORBIT_PREDICT
Variable Name		Input Source	Output Destination
AA		**	
ATM			PINES_METHOD
BB		**	
CC		**	
DD		**	
DM			PINES_METHOD
DERIV		PINES_METHOD	
GMD			PINES_METHOD
GMO			PINES_METHOD
T_CUR			PINES_METHOD
T_IN			PINES_METHOD
VM			PINES_METHOD
X		PINES_METHOD	
XN			PINES_METHOD
** Initialization parameters, see Section 4.7.			

#### 4.3.2 Equations of Motion (PINES\_METHOD)

For predicting the orbiter and target state vectors, the equations of motion are to take the form of a variation-of-parameters method devised by S. Pines, where parameters to be varied are the Cartesian initial conditions of the motion. The integration scheme to be used in connection with these equations is the Gill modification of the Runge-Kutta technique (see Section 4.3.1).

A. Detailed Requirements. The Pines Equations of Motion subfunction will be invoked whenever a call statement of the following form is encountered:

```
CALL:      PINES_METHOD  
  
IN LIST:   XN, T_CUR, GMO, GMD, DM, VM, ATM, T_IN  
  
OUT LIST:  DERIV, X
```

where:

XN = the seven variables of integration  
T\_CUR = the initial integration time of the current step  
GMO = Earth's gravitational potential model order  
GMD = Earth's gravitational potential model degree  
DM = drag model acceleration computation flag  
VM = vent and thrusting acceleration model flag  
ATM = attitude mode flag  
T\_IN = initial time

and:

DERIV = the output total derivatives of integration  
X = output two body position and velocity vectors of conic

The PINES\_METHOD subfunction will cause the following calculations to be made in the order given:

1. Several terms used in the F and G series calculations for the closedform two-body equations are computed.

$$R\_IN = |XN_{1\ to\ 3}|$$

$$R\_IN\_INV = 1. / R\_IN \quad F3$$

$$SMA = 1. / [2. R\_IN\_INV - (XN_{4\ to\ 6} \bullet XN_{4\ to\ 6}) / EARTH\_MU] \quad F3$$

F3 This equation shall be protected against division by zero (reference 3.5).

$$C1 = \text{SQRT} (\text{SMA}) / \text{SQR\_EMU} \quad \text{F3,F4}$$

$$\text{DELTAT} = \text{T\_CUR} - \text{XN}_7$$

$$\text{D\_IN} = \text{XN}_{1 \text{ to } 3} \cdot \text{XN}_{4 \text{ to } 6}$$

$$\text{R\_FIN\_TEMP\_INV} = 0.$$

F3 This equation shall be protected against division by zero (reference 3.5).

F4 This equation shall be protected against square roots of a negative number (reference 3.5).

- The Conic Solution subfunction (F\_AND\_G) shall then be invoked to calculate several terms used in computation of the conic velocity vector ( $X_{4 \text{ to } 6}$ ) and initial condition derivatives and compute the two-body conic position vector ( $X_{1 \text{ to } 3}$ ) as follows (see section 4.2.5.2.1).

CALL: F\_AND\_G

IN LIST: SMA, DELTAT, C1,  $XN_{1 \text{ to } 3}$ , R\_IN\_INV, R\_FIN\_TEMP\_INV,  
 $XN_{4 \text{ to } 6}$ , D\_IN, D\_FIN\_TEMP

OUT LIST: F, G, FDOT, GDOT, S0, S1, S2, S3,  $X_{1 \text{ to } 3}$ , R\_FIN\_INV, THETA

- The two-body velocity vector shall then be computed:

$$X_{4 \text{ to } 6} = \text{FDOT } XN_{1 \text{ to } 3} + \text{GDOT } XN_{4 \text{ to } 6}$$

- Perturbation accelerations shall now be calculated and several computations shall then be performed to compute perturbation derivatives for F and G series terms used in calculating total derivatives of the seven variables of integration.

$$\text{T\_ACCEL} = \text{T\_IN} + \text{T\_CUR}$$

$$\bar{P} = \bar{\text{ACCEL\_ONORBIT}} (\text{GMD}, \text{GMO}, \text{DM}, \text{VM}, \text{ATM}, X_{1 \text{ to } 3}, X_{4 \text{ to } 6}, \text{T ACCEL})$$

$$\bar{P} = \bar{P} - \bar{G\_CENTRAL}$$

$$\text{D\_TAU} = X_{1 \text{ to } 3} \cdot \bar{P}$$

$$\text{D\_AUX} = X_{4 \text{ to } 6} \cdot \bar{P}$$

$$\text{C2} = \text{C1}^2$$

$$\text{S1} = \text{C1 S1}$$

$$\text{S2} = \text{C2 S2}$$

$$\text{C3} = 1. / \text{C2}$$

F3

F3 This equation shall be protected against division by zero (reference 3.5).

$$\text{S3} = \text{SMA S2}$$

$$S4 = 2. S3 D\_AUX$$

$$C4 = C2 D\_AUX$$

$$C5 = C4 S1$$

$$S5 = S2 D\_TAU$$

$$DD = S1 C3 R\_IN (SMA R\_IN\_INV\_1.) + S0 D\_IN$$

$$S6 = 2. S2 C4 DD + S5$$

$$R\_IN\_TAU = S4 - C2 S1 D\_AUX DD - S1 D\_TAU$$

$$R\_IN\_AUX = R\_IN\_INV R\_IN\_TAU$$

$$F\_TAU = (S3 C3 R\_IN\_AUX - S4) R\_IN\_INV$$

$$G\_TAU = C5/R\_FIN\_INV - S6$$

F3

$$FD\_TAU = FDOT (C4 - R\_IN\_AUX)$$

$$GD\_TAU = - S4 R\_FIN\_INV$$

F3 This equation shall be protected against division by zero (reference 3.5).

5. Finally, the total derivatives of the variables of integration are to be computed as follows:

$$DERIV_{1\ to\ 3} = GD\_TAU X_{1\ to\ 3} - G\_TAU X_{4\ to\ 6} - G \bar{P}$$

$$DERIV_{4\ to\ 6} = - FD\_TAU X_{1\ to\ 3} + F\_TAU X_{4\ to\ 6} + F \bar{P}$$

$$DERIV_7 = S6 - 3. C4 SMA (C1 THETA-S1) - C5/R\_FIN\_INV$$

F3

F3 This equation shall be protected against division by zero (reference 3.5).

B. Interface Requirements. Input and output for the Pines method subfunction are given in Table 4.3.2.

C. Processing Requirements. The following is a list of subfunctions and principal functions that call the Pines method.

RK\_GILL

ONORBIT\_PREDICT

D. Constraints. The  $\bar{ACCEL\_ONORBIT}$  function shall not be invoked by any other software module during the computation of the perturbation acceleration vector,  $\bar{P}$ , to maintain the correct value of the central force term,  $\bar{G\_CENTRAL}$ .

E. Supplementary Information. A suggested implementation of the Pines method of the equations of motion in the form of detailed flow charts may be found in Section 5.3 under the following:

PINES\_METHOD

Table 4.3.2. PINES_METHOD Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
ATM	ATM	RK_GILL	
DM	DM	RK_GILL	
GMD	GMD	RK_GILL	
GMO	GMO	RK_GILL	
T_CUR	T_CUR	RK_GILL	
T_IN	T_IN	RK_GILL	
VM	VM	RK_GILL	
XN	XN	RK_GILL	
ATM	ATMP	ONORBIT_PREDICT	
DM	DMP	ONORBIT_PREDICT	
GMD	GMDP	ONORBIT_PREDICT	
GMO	GMOP	ONORBIT_PREDICT	
T_CUR	T_CUR	ONORBIT_PREDICT	
T_IN	T_PRED_INIT	ONORBIT_PREDICT	
VM	VMP	ONORBIT_PREDICT	
XN	XN	ONORBIT_PREDICT	
DERIV	DERIV		RK_GILL
X	X		RK_GILL
DERIV	DERIV		ONORBIT_PREDICT
X	X		ONORBIT_PREDICT

Table 4.3.2.(1) PINES_METHOD Input/Output		
Variable Name	Input Source	Output Destination
ATM		$\overline{\text{ACCEL\_ONORBIT}}$
†	$\overline{\text{ACCEL\_ONORBIT}}$	
C1		F_AND_G
DELTAT		F_AND_G
D_FIN_TEMP	**	F_AND_G
D_IN		F_AND_G
DM		$\overline{\text{ACCEL\_ONORBIT}}$
EARTH_MU	**	
F	F_AND_G	
FDOT	F_AND_G	
G	F_AND_G	
$\overline{\text{G\_CENTRAL}}$	$\overline{\text{ACCEL\_ONORBIT}}$	
GDOT	F_AND_G	
GMD		$\overline{\text{ACCEL\_ONORBIT}}$
GMO		$\overline{\text{ACCEL\_ONORBIT}}$
R_FIN_INV	F_AND_G	
R_FIN_TEMP_INV		F_AND_G
R_IN_INV		F_AND_G
S0	F_AND_G	
S1	F_AND_G	
S2	F_AND_G	
S3	F_AND_G	
SMA		F_AND_G
SQR_EMU	*	
T_ACCEL		$\overline{\text{ACCEL\_ONORBIT}}$
THETA	F_AND_G	
VM		$\overline{\text{ACCEL\_ONORBIT}}$
X <sub>1 to 3</sub>	F_AND_G	$\overline{\text{ACCEL\_ONORBIT}}$
X <sub>4 to 6</sub>		$\overline{\text{ACCEL\_ONORBIT}}$
XN		F_AND_G
<p>* Precision State Prediction principal function, see Table 4.3.3-1  ** Initialization parameters, see Section 4.7.  † Only the value of ACCEL_ONORBIT is used.</p>		



### 4.3.3 Onorbit Precision State Prediction Tables (4.224)

The IDD inputs and outputs are listed in Table 4.3.3-1 and 4.3.3-2 respectively. 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 4.3.3-3. K-loads are listed in Table 4.3.3-4. Constants are listed in Table 4.3.3-5, and a principal function cross-reference listing is presented in table listed below.

Onorbit Precision State Prediction Principal Function (4.224) Cross-Reference Listing	
Local Name	Source Name
ATMP	ATM
GMDP	GMD_PRED
GMOP	GMO_PRED

TABLE 4.3.3-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT PREDICTOR (G4.224)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
ATM	V94J3999CA	ATTITUDE MODE FLAG	ORB MNVR DIP				93017G	*
ATM	V94J3999CB	ATTITUDE MODE FLAG	ORB TGT SPEC					
ATMP	V94J3999CC	ATTITUDE MODE FLAG	ORB/RND NAV				93017G	*
ATMP	V94J3999CD	ATTITUDE MODE FLAG	ORB/RND NAV SEQ				93017G	*
DMP	V94X3969XA	PROPER DRAG MODEL FLAG	ORB MNVR DIP					
DMP	V94X3969XB	PROPER DRAG MODEL FLAG	ORB TGT SPEC					
DMP	V94X3969XC	PROPER DRAG MODEL FLAG	ORB/RND NAV					
DMP	V94X3969XD	PROPER DRAG MODEL FLAG	ORB/RND NAV SEQ					
EARTH_POLE(1)	V90U0190C	X-COMP UNIT VCTR ALONG EARTH AXIS	RNP MAT COMP	ND	DPL		93090E	
EARTH_POLE(2)	V90U0191C	Y-COMP UNIT VCTR ALONG EARTH AXIS	RNP MAT COMP	ND	DPL		93090E	
EARTH_POLE(3)	V90U0192C	Z-COMP UNIT VCTR ALONG EARTH AXIS	RNP MAT COMP	ND	DPL		93090E	
GMDP	V94J3975CC	GRAVITY MODEL DEGREE FLAG	ORB/RND NAV					
GMDP	V94J3975CD	GRAVITY MODEL DEGREE FLAG	ORB/RND NAV SEQ					
GMD_PRED	V94J3975CA	GRAVITY MODEL DEGREE FLAG	ORB MNVR DIP					
GMD_PRED	V94J3975CB	GRAVITY MODEL DEGREE FLAG	ORB TGT SPEC					
GMOP	V94J3963CC	GRAVITY MODEL ORDER FLAG	ORB/RND NAV					
GMOP	V94J3963CD	GRAVITY MODEL ORDER FLAG	ORB/RND NAV SEQ					
GMO_PRED	V94J3963CA	GRAVITY MODEL ORDER FLAG	ORB MNVR DIP					
GMO_PRED	V94J3963CB	GRAVITY MODEL ORDER FLAG	ORB TGT SPEC					
M_M50TOEF_AT_EPOCH(1,1)	V97U5738C	M50 TO EF TRANS MATRIX ELEM 1,1	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(1,2)	V97U5739C	M50 TO EF TRANS MATRIX ELEM 1,2	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(1,3)	V97U5740C	M50 TO EF TRANS MATRIX ELEM 1,3	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(2,1)	V97U5741C	M50 TO EF TRANS MATRIX ELEM 2,1	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(2,2)	V97U5742C	M50 TO EF TRANS MATRIX ELEM 2,2	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(2,3)	V97U5743C	M50 TO EF TRANS MATRIX ELEM 2,3	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(3,1)	V97U5744C	M50 TO EF TRANS MATRIX ELEM 3,1	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(3,2)	V97U5745C	M50 TO EF TRANS MATRIX ELEM 3,2	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(3,3)	V97U5746C	M50 TO EF TRANS MATRIX ELEM 3,3	RNP MAT COMP	ND	DPL		93090E	
PRED_ENA_FLAG	V90X4266X	PREDICTOR ENABLE FLAG	ORB/RND NAV SEQ					
PRED_ORB_AREA	V93U6955CA	ORBITER REF AREA USED IN PRED	ORB/RND NAV	FT2			93017G	*
PRED_ORB_AREA	V93U6955CB	ORBITER REF AREA USED IN PRED	ORB TGT SPEC	FT2			89648A	
PRED_ORB_AREA	V93U6955CC	ORBITER REF AREA USED IN PRED	ORB MNVR DIP	FT2			93017G	*
PRED_ORB_AREA	V93U6955CD	ORBITER REF AREA USED IN PRED	ORB/RND NAV SEQ	FT2			93017G	*
PRED_ORB_CD	V93U6954CA	ORBITER DRAG COEFF USED IN PRED	ORB/RND NAV				93017G	*
PRED_ORB_CD	V93U6954CB	ORBITER DRAG COEFF USED IN PRED	ORB TGT SPEC					
PRED_ORB_CD	V93U6954CC	ORBITER DRAG COEFF USED IN PRED	ORB MNVR DIP				93017G	*
PRED_ORB_CD	V93U6954CD	ORBITER DRAG COEFF USED IN PRED	ORB/RND NAV SEQ				93017G	*
PRED_ORB_MASS	V93U6953CA	ORBITER MASS USED IN PREDICTION	ORB/RND NAV	SLUGS			93017G	*
PRED_ORB_MASS	V93U6953CB	ORBITER MASS USED IN PREDICTION	ORB TGT SPEC	SLUGS			89648A	
PRED_ORB_MASS	V93U6953CC	ORBITER MASS USED IN PREDICTION	ORB MNVR DIP	SLUGS			93017G	*
PRED_ORB_MASS	V93U6953CD	ORBITER MASS USED IN PREDICTION	ORB/RND NAV SEQ	SLUGS			93017G	*
PRED_STEP	V90W3964CA	INTEGRATION STEP SIZE	ORB MNVR DIP	S			93017G	*
PRED_STEP	V90W3964CB	INTEGRATION STEP SIZE	ORB TGT SPEC	S				
PRED_STEP	V90W3964CC	INTEGRATION STEP SIZE	ORB/RND NAV	S			93017G	*
PRED_STEP	V90W3964CD	INTEGRATION STEP SIZE	ORB/RND NAV SEQ	S			93017G	*
R_PRED_INIT(1)	V94H4002CA	X-COMP POS VEC AT INITIAL TIME	ORB MNVR DIP	FT			93017G	*

TABLE 4.3.3-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT PREDICTOR (G4.224)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
R_PRED_INIT(1)	V94H4002CB	X-COMP POS VEC AT INITIAL TIME	ORB TGT SPEC	FT			89493B	
R_PRED_INIT(1)	V94H4002CC	X-COMP POS VEC AT INITIAL TIME	ORB/RND NAV	FT			93017G	*
R_PRED_INIT(1)	V94H4002CD	X-COMP POS VEC AT INITIAL TIME	ORB/RND NAV SEQ	FT			93017G	*
R_PRED_INIT(2)	V94H4003CA	Y-COMP POS VEC AT INITIAL TIME	ORB MNVR DIP	FT			93017G	*
R_PRED_INIT(2)	V94H4003CB	Y-COMP POS VEC AT INITIAL TIME	ORB TGT SPEC	FT			89493B	
R_PRED_INIT(2)	V94H4003CC	Y-COMP POS VEC AT INITIAL TIME	ORB/RND NAV	FT			93017G	*
R_PRED_INIT(2)	V94H4003CD	Y-COMP POS VEC AT INITIAL TIME	ORB/RND NAV SEQ	FT			93017G	*
R_PRED_INIT(3)	V94H4004CA	Z-COMP POS VEC AT INITIAL TIME	ORB MNVR DIP	FT			93017G	*
R_PRED_INIT(3)	V94H4004CB	Z-COMP POS VEC AT INITIAL TIME	ORB TGT SPEC	FT			89493B	
R_PRED_INIT(3)	V94H4004CC	Z-COMP POS VEC AT INITIAL TIME	ORB/RND NAV	FT			93017G	*
R_PRED_INIT(3)	V94H4004CD	Z-COMP POS VEC AT INITIAL TIME	ORB/RND NAV SEQ	FT			93017G	*
SQR_EMU	V90U1241C	SQUARE ROOT OF EARTH MU	ORB/RND NAV SEQ	FT3/S2			89648A	
T_EPOCH	V97W5528C	TIME TAG FOR M_M50TOEF_AT_EPOCH	RNP MAT COMP	S	DPL		93090E	
T_PRED_FINAL	V94W3979CA	TIME AT WHICH STATE IS DESIRED	ORB MNVR DIP	S			93017G	*
T_PRED_FINAL	V94W3979CB	TIME AT WHICH STATE IS DESIRED	ORB TGT SPEC	S			89493B	
T_PRED_FINAL	V94W3979CC	TIME AT WHICH STATE IS DESIRED	ORB/RND NAV	S			93017G	*
T_PRED_FINAL	V94W3979CD	TIME AT WHICH STATE IS DESIRED	ORB/RND NAV SEQ	S			93017G	*
T_PRED_INIT	V94W3970CA	TIME AT BEGINNING OF PRED	ORB MNVR DIP	S			93017G	*
T_PRED_INIT	V94W3970CB	TIME AT BEGINNING OF PRED	ORB TGT SPEC	S			89493B	
T_PRED_INIT	V94W3970CC	TIME AT BEGINNING OF PRED	ORB/RND NAV	S			93017G	*
T_PRED_INIT	V94W3970CD	TIME AT BEGINNING OF PRED	ORB/RND NAV SEQ	S			93017G	*
VMP	V94X3971XA	PROPER VENT MODEL FLAG	ORB MNVR DIP					
VMP	V94X3971XB	PROPER VENT MODEL FLAG	ORB TGT SPEC					
VMP	V94X3971XC	PROPER VENT MODEL FLAG	ORB/RND NAV					
VMP	V94X3971XD	PROPER VENT MODEL FLAG	ORB/RND NAV SEQ					
V_PRED_INIT(1)	V94L4006CA	X-COMP VEL VEC AT INITIAL TIME	ORB MNVR DIP	FT/S			93017G	*
V_PRED_INIT(1)	V94L4006CB	X-COMP VEL VEC AT INITIAL TIME	ORB TGT SPEC	FT/S			89493B	
V_PRED_INIT(1)	V94L4006CC	X-COMP VEL VEC AT INITIAL TIME	ORB/RND NAV	FT/S			93017G	*
V_PRED_INIT(1)	V94L4006CD	X-COMP VEL VEC AT INITIAL TIME	ORB/RND NAV SEQ	FT/S			93017G	*
V_PRED_INIT(2)	V94L4007CA	Y-COMP VEL VEC AT INITIAL TIME	ORB MNVR DIP	FT/S			93017G	*
V_PRED_INIT(2)	V94L4007CB	Y-COMP VEL VEC AT INITIAL TIME	ORB TGT SPEC	FT/S			89493B	
V_PRED_INIT(2)	V94L4007CC	Y-COMP VEL VEC AT INITIAL TIME	ORB/RND NAV	FT/S			93017G	*
V_PRED_INIT(2)	V94L4007CD	Y-COMP VEL VEC AT INITIAL TIME	ORB/RND NAV SEQ	FT/S			93017G	*
V_PRED_INIT(3)	V94L4008CA	Z-COMP VEL VEC AT INITIAL TIME	ORB MNVR DIP	FT/S			93017G	*
V_PRED_INIT(3)	V94L4008CB	Z-COMP VEL VEC AT INITIAL TIME	ORB TGT SPEC	FT/S			89493B	
V_PRED_INIT(3)	V94L4008CC	Z-COMP VEL VEC AT INITIAL TIME	ORB/RND NAV	FT/S			93017G	*
V_PRED_INIT(3)	V94L4008CD	Z-COMP VEL VEC AT INITIAL TIME	ORB/RND NAV SEQ	FT/S			93017G	*

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.3.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT PREDICTOR (G4.224)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
D_SAVE(1)	V95A0804C	ORB OR TGT DRAG ACCEL (1)	ORB TGT SPEC	FT/S2			89648A	
D_SAVE(2)	V95A0805C	ORB OR TGT DRAG ACCEL (2)	ORB TGT SPEC	FT/S2			89648A	
D_SAVE(3)	V95A0806C	ORB OR TGT DRAG ACCEL (3)	ORB TGT SPEC	FT/S2			89648A	
R_PRED_FINAL(1)	V95H0811C	X-COMP PRED SHUTTLE POS VECTOR	DL FMT 22/1 DL FMT 32/1 ORB MNVR DIP ORB TGT SPEC ORB/RND NAV ORB/RND NAV SEQ	FT	DPL		93017G	*
R_PRED_FINAL(2)	V95H0812C	Y-COMP PRED SHUTTLE POS VECTOR	DL FMT 22/1 DL FMT 32/1 ORB MNVR DIP ORB TGT SPEC ORB/RND NAV ORB/RND NAV SEQ	FT	DPL		93017G	*
R_PRED_FINAL(3)	V95H0813C	Z-COMP PRED SHUTTLE POS VECTOR	DL FMT 22/1 DL FMT 32/1 ORB MNVR DIP ORB TGT SPEC ORB/RND NAV ORB/RND NAV SEQ	FT	DPL		93017G	*
V_PRED_FINAL(1)	V95L0814C	X-COMP PRED SHUTTLE VEL VECTOR	DL FMT 22/1 DL FMT 32/1 ORB MNVR DIP ORB TGT SPEC ORB/RND NAV ORB/RND NAV SEQ	FT/S	DPL		93017G	*
V_PRED_FINAL(2)	V95L0815C	Y-COMP PRED SHUTTLE VEL VECTOR	DL FMT 22/1 DL FMT 32/1 ORB MNVR DIP ORB TGT SPEC ORB/RND NAV ORB/RND NAV SEQ	FT/S	DPL		93017G	*
V_PRED_FINAL(3)	V95L0816C	Z-COMP PRED SHUTTLE VEL VECTOR	DL FMT 22/1 DL FMT 32/1 ORB MNVR DIP ORB TGT SPEC ORB/RND NAV ORB/RND NAV SEQ	FT/S	DPL		93017G	*

TABLE 4.3.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT PREDICTOR (G4.224)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
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**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**

**Rate Codes: (HDR Only) 1 = 1 sample/sec 2 = 5 samples/sec 3 = 12.5 samples/sec 4 = 25 samples/sec 5 = 100 samples/sec  
 (HDR and LDR) A = 1 sample/sec B = 5 samples/sec C = 12.5 samples/sec D = 25 samples/sec E = 100 samples/sec**

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TABLE 4.3.3-3. ONORBIT PREDICTOR (G4.224) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
CDA	V97U5281C	ND	F	D	D	X	G4.126	01	ZFJ	DC0617	
							G4.223	02	ZFJ		
							G4.224	03	ZFJ		
							G4.236	08	ZFJ		
CDF	V97U6002C	ND	F	D	D	X	G4.126	01	ZFJ	DC0617	
							G4.223	02	ZFJ		
							G4.224	03	ZFJ		
							G4.236	08	ZFJ		
CDN	V97U5282C	ND	F	D	D	X	G4.126	01	ZFJ	DC0617	
							G4.223	02	ZFJ		
							G4.224	03	ZFJ		
							G4.236	08	ZFJ		
CDS	V97U6010C	ND	F	D	D	X	G4.126	01	ZFJ	DC0617	
							G4.223	02	ZFJ		
							G4.224	03	ZFJ		
							G4.236	08	ZFJ		
EXP_SHAPE_FACTOR	V97U5334C	ND	F	D	D	X	G4.126	01	ZFJ	DC0617	
							G4.223	02	ZFJ		
							G4.224	03	ZFJ		
							G4.236	08	ZFJ		

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.3.3-4. ONORBIT PREDICTOR (G4.224) K-LOADS

FSSR NAME DESCRIPTION	MSID	MC	KLOAD VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
AA(1)	V96U9057C	00	+5.0	E-01	ND	F	D	P G4.224	59953	
AA(2)	V96U9058C	00	+2.92893218813E-01	ND	F	D	P G4.224	59953		
AA(3)	V96U9059C	00	+1.70710678119E+00	ND	F	D	P G4.224	59953		
AA(4)	V96U9060C	00	+1.66666666667E-01	ND	F	D	P G4.224	59953		
BB(1)	V96U9080C	00	+0.00	E+00	ND	F	D	P G4.224	59953	
BB(2)	V96U9081C	00	+1.00	E+00	ND	F	D	P G4.224	59953	
BB(3)	V96U9082C	00	+1.00	E+00	ND	F	D	P G4.224	59953	
BB(4)	V96U9083C	00	+2.00	E+00	ND	F	D	P G4.224	59953	
CC(1)	V96U9090C	00	+1.00	E+00	ND	F	D	P G4.224	59953	
CC(2)	V96U9091C	00	+5.85786437627E-01	ND	F	D	P G4.224	59953		
CC(3)	V96U9092C	00	+3.41421356237E+00	ND	F	D	P G4.224	59953		
CC(4)	V96U9093C	00	+0.00	E+00	ND	F	D	P G4.224	59953	
DD(1)	V96U9103C	00	+0.00	E+00	ND	F	D	P G4.224	59953	
DD(2)	V96U9104C	00	+1.21320343556E-01	ND	F	D	P G4.224	59953		
DD(3)	V96U9105C	00	-4.12132034356E+00	ND	F	D	P G4.224	59953		
DD(4)	V96U9106C	00	+0.00	E+00	ND	F	D	P G4.224	59953	
DT_MAX	V96U9227C	00	+1200	SEC		I	D	P G4.224	29858	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.



TABLE 4.3.3-5. ONORBIT PREDICTOR (G4.224) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
D_FIN_TEMP	V97U6113C	00	+0.0	E+00	FT**2/SEC	F	D	C G4.126	90374C	
TEMPORARY STORAGE FOR D_FIN								G4.224		
EARTH_MU	V97U4378C	00	+1.40764487566E+16	FT**3/SEC**2	F	D	C A6.9	93090E		
EARTH GRAVITATIONAL CONSTANT								G4.126		
								G4.127		
								G4.13		
								G4.139		
								G4.144		
								G4.148		
								G4.15		
								G4.158		
								G4.2		
								G4.205		
								G4.209		
								G4.210		
								G4.211		
								G4.224		
								G4.236		
								G4.3		
								G4.4		
								G5.10		
								G5.24		
								G5.26		
								G5.27		
PRED_TIME_TOL	V97U6142C	00	+1.0	E-08	SEC	F	S	P G4.224	90374C	
TIME TOLERANCE FOR THE PREDICTOR										

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

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#### **4.4 ONORBIT/RENDEZVOUS USER PARAMETER PROCESSING SEQUENCER PRINCIPAL FUNCTION (ONORBIT\_REND\_UPP\_SEQ)**

This principal function shall provide a capability for initialization and control of those principal functions and subfunctions associated with the computation of user parameters and GPS reference state vector processing during the onorbit/rendezvous operational sequence. This sequencer will provide initialization and control of the onorbit/rendezvous user parameter processing principal function and its subfunctions, and also provide initialization and control of the GPS reference state processing principal function and its subfunctions.

Events to be used as cues by the sequencer for performing the required initialization and sequencing are defined in the Level B GN&C CPDS. The particular events and a summary of the associated user parameter actions pertaining to this user parameter sequencer are given in Table 4.4–1.

Table 4.4.1–1 describes the input data flow between the Onorbit/Rendezvous User Parameter Processing Sequencer principal function and other principal functions.

A. Detailed Requirements. The onorbit/rendezvous user parameter processing sequencer will be initiated upon the occurrence of any of the following events:

- Major mode transition from 106 to 201
- Major mode transition from 301 to 201
- Transition from OPS 2 to OPS 8
- Transition from OPS 00 to Major Mode 201
- Transition from OPS 8 to Major Mode 201

This sequencer shall be terminated upon the transition from OPS 2 or OPS 8 to OPS 3 or OPS 00.

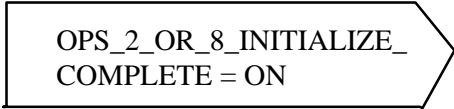
The following paragraph specifies the detailed requirements that are summarized in Table 4.4–1.

The onorbit user parameter processing sequencer shall check the following event flags to determine if any entry has been made into OPS 2 or OPS 8 from another OPS sequence:

- EVENT\_60; transition from OPS 1 to OPS 2
- EVENT\_E1; transition from OPS 3 to OPS 2
- EVENT\_84; transition from OPS 00 to OPS 2
- EVENT\_60A; transition from OPS 8 to OPS 2
- EVENT\_60B; transition from OPS 2 to OPS 8

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If any of the preceding event flags have been set to “ON” by Moding, Sequencing, and Control (MSC), or crew input and detected “ON” by this sequencer, a check shall be made on a flag set by the onorbit/rendezvous navigation sequencer:



This signal (= ON) indicates that the necessary initialization of certain state parameters has been accomplished within the onorbit/rendezvous navigation sequencer (Section 4.1) and that the Onorbit/Rendezvous User Parameter State Propagation and Onorbit User Parameter Calculations subfunctions shall commence at a repetition rate of 1.04 hertz. This signal will also initiate the cyclic execution of the GPS reference state processing principal function at a repetition rate of 6.25 Hertz.

B. Interface Requirements. Input and output requirements for this principal function are presented in Table 4.4.1-1.

C. Processing Requirements. None

D. Constraints. None

E. Supplemental Information. A suggested implementation of the onorbit/ rendezvous UPP sequencer in the form of detailed flow charts is shown in Section 5.4 under ONORBIT\_REND\_UPP\_SEQ. The 6.25 Hertz repetition rate of the GPS reference state processing principal function is maintained throughout the OPS2 and OPS8 operational sequences. The phasing requirements of this principal function relative to the GPS SOP principal function are defined in the Entry Through Landing Navigation FSSR STS 83-0004.

Event No.	Event Name/Description	Action Taken by Sequencer in Response to Event
60	Transition from OPS 1 to OPS 2	Initiate cyclic execution of onorbit user parameter state propagation and onorbit user parameter calculations at a repetition rate of 1.04 Hertz and initiate cyclic execution of the GPS reference state processing at a repetition rate of 6.25 Hertz.
E1	Transition from 301 to 201	Same as Event 60 action
84	Transition from OPS 00 to 201	Same as Event 60 action
60A	Transition from OPS 8 to 201	Same as Event 60 action
60B	Transition from 201 to OPS 8	Same as Event 60 action
60H	Transition from 801 to 301	Terminate cyclic execution of onorbit user parameter state propagation and user parameter calculations
83	Transition from 201 to OPS 00	Same as Event 60H action
85	Transition from 201 to 301	Same as Event 60H action

Table 4.4-2. Onorbit/Rendezvous User Parameter Processing Sequencer Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
EVENT_60	MSC	ONORBIT_REND_UPP_SEQ	TLM	
EVENT_60A	MSC	ONORBIT_REND_UPP_SEQ	TLM	
EVENT_E1	MSC	ONORBIT_REND_UPP_SEQ	TLM	
EVENT_60B	MSC	ONORBIT_REND_UPP_SEQ	TLM	
EVENT_84	MSC	ONORBIT_REND_UPP_SEQ	TLM	
OPS_2_OR_8_INITIALIZE_COMPLETE	Onorbit/Rendezvous Nav Seq	ONORBIT_REND_UPP_SEQ		
EVENT_60H	MSC	ONORBIT_REND_UPP_SEQ	TLM	
EVENT_83	MSC	ONORBIT_REND_UPP_SEQ	TLM	
EVENT_85	MSC	ONORBIT_REND_UPP_SEQ	TLM	

#### 4.4.1 Onorbit/Rendezvous User Parameter Processing Sequencer Tables (4.198)

The IDD inputs and outputs are listed in Table 4.4.1-1 and 4.4.1-2 respectively. 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 4.4.1-3. K-loads are listed in Table 4.4.1-4. Constants are listed in Table 4.4.1-5, and a principal function cross-reference listing is presented below:

Onorbit/Rendezvous User Parameter Processing Sequencer Principal Function (4.198) Cross-Reference Listing	
Local Name	Source Name
OPS_2_OR_8_INITIALIZE_COMPLETE	OPS_2_OR_8_INITIALIZE_CPLT

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TABLE 4.4.1-1. INPUT FUNCTIONAL PARAMETERS FOR ORBIT/USER PARAMETER PROCESSING SEQUENCER (G4.198)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
OPS_2_INDICATOR	V90X8633X	OPS 2 IND	MSC				90837G	
OPS_2_OR_8_INITIALIZE_CPLT	V90X1242X	NAV INITIALIZATION COMPLETE FLAG	ORB/RND NAV SEQ				90885D	
	V90X8148X	MM 201 FROM OPS-00 FLAG	MSC				89599C	
	V90X8160X	MM 201 FROM MM 801 FLAG	MSC				89599C	
	V90X8164X	MM 201 FROM MM 301 FLAG	MSC				92354	
	V90X8180X	MM 301 FROM MM 201 FLAG	MSC				89599C	
	V90X8200X	TERMINATE POWERED FLIGHT MODE FLAG	MSC				89599C	
	V90X8644X	MM 301 FROM MM 801 FLAG	MSC				89599C	
	V90X8645X	MM 801 FROM MM 201 FLAG	MSC				92355B	
	V90X8646X	MM 202 FROM MM 201 FLAG	MSC				92355B	
	V90X8655X	MM201 TO OPS 00 TRANS EVENT FLAG	MSC				89599C	

**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**

TABLE 4.4.1-2. OUTPUT FUNCTIONAL PARAMETERS FROM ORBIT/USER PARAMETER PROCESSING SEQUENCER (G4.198)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
-----------	--------	--------------	-------------	-------	--------------	------------------	---------	-------------

NO REQUIREMENTS

**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**

**Rate Codes: (HDR Only) 1 = 1 sample/sec 2 = 5 samples/sec 3 = 12.5 samples/sec 4 = 25 samples/sec 5 = 100 samples/sec**  
**(HDR and LDR) A = 1 sample/sec B = 5 samples/sec C = 12.5 samples/sec D = 25 samples/sec E = 100 samples/sec**



TABLE 4.4.1-3. ORBIT/USER PARAMETER PROCESSING SEQUENCER (G4.198) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
DEL_TIME_STEP	V97U6548C	SEC	F	S	D	P	G4.127 G4.144 G4.15 G4.198 G4.205	01 03	ZFT ZFT	93045A	

**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**

TABLE 4.4.1-4. ORBIT/USER PARAMETER PROCESSING SEQUENCER (G4.198) K-LOADS

FSSR NAME DESCRIPTION	MSID	MC	KLOAD VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
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NO REQUIREMENTS

**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**

TABLE 4.4.1-5. ORBIT/USER PARAMETER PROCESSING SEQUENCER (G4.198) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
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NO REQUIREMENTS

**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**

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#### 4.5 USER PARAMETER PROCESSING PRINCIPAL FUNCTION

This principal function shall serve as the interface between navigation and users of navigation-related data during the onorbit operational sequence. This function shall maintain the vehicle state within the User Parameter State Propagation subfunction and shall:

- Provide this state to users who require vehicle state parameters in M50 coordinates (see User Parameter State Propagation, Section 4.5.1, and Onorbit User Parameter Calculations, Section 4.5.2).
- Provide the software to transform this state for users who require nav state-related parameters (see User Parameter Calculations, Section 4.5.2).

Table 4.5 presents the parameter interface to local modules for this principal function. Interface parameters between this principal function and other GN&C principal functions are presented in Table 4.5.3-1 and 4.5.3-2. Other available parameter tables include I-loads in Table 4.5.3-3, K-loads in Table 4.5.3-4, constants in Table 4.5.3-5, and a parameter cross-reference list.

Table 4.5. User Parameter Processing Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
$\bar{A}$ _SENSED			TLM	ONORBIT_REND_USER_PARAM_STATE_PROP
$\bar{DEL}$ _R_TARG			Universal Pointing, TLM	ONORBIT_USER_PARAMETER_CALCULATIONS
$\bar{DEL}$ _V_TARG			Universal Pointing, TLM	ONORBIT_USER_PARAMETER_CALCULATIONS
DOING_REND_NAV	ONORBIT_REND_NAV SEQUENCER	ONORBIT_REND_USER_PARAM_STATE_PROP, ONORBIT_USER_PARAMETER_CALCULATIONS		
FILT_UPDATE	Onorbit/Rendezvous Nav, Onorbit/ Rendezvous Nav Seq	ONORBIT_REND_USER_PARAM_STATE_PROP		
IMU_NAV_ACCEL_THRESH	IMU_ALIGN_DISPLAY	ONORBIT_REND_USER_PARAM_STATE_PROP		
PWRD_FLT_NAV	REL_NAV DISPLAY, FCS/DED DISP c/o DISPLAY, Onorbit Rendezvous Navigation Sequencer	ONORBIT_REND_USER_PARAM_STATE_PROP		
$\bar{R}$ _AVGG			Onorbit Guidance, Startracker SOP, REL NAV SPEC FUNC, Rendezvous Targeting, ATT PROC, Orbit Maneuver DIP, TLM, GN&C/ SM-PL	ONORBIT_REND_USER_PARAM_STATE_PROP
$\bar{R}$ _EF			GN&C/SM-PL	ONORBIT_USER_PARAMETER_CALCULATIONS
$\bar{R}$ _RESET	Onorbit/Rendezvous Nav, Onorbit/ Rendezvous Nav Seq	ONORBIT_REND_USER_PARAM_STATE_PROP		

Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
$\bar{R}$ _TARGET			Star Tracker SOP, Rend Target, REL NAV SPEC FUNC, TLM	ONORBIT_REND_USER_PARAM_STATE_PROP
$\bar{R}$ _TV_RESET	Onorbit/Rendezvous Nav, Onorbit/ Rendezvous Nav Seq	ONORBIT_REND_USER_PARAM_STATE_PROP		
$\bar{S}$ EL_V_M50_CG	IMU RM	IMU DATA SNAP		
T_IMU			TLM	ONORBIT_REND_USER_PARAM_STATE_PROP
T_IMUS	IMU INT PROC	IMU DATA SNAP		
T_RESET	Onorbit/Rendezvous Nav, Onorbit/ Rendezvous Nav Seq	ONORBIT_REND_USER_PARAM_STATE_PROP		
T_SEC_GMT			GN&C/SM-PL	ONORBIT_USER_PARAMETER_CALCULATIONS
T_STATE			Rendezvous Targeting, Onorbit Guidance, Orbit Maneuver DIP, TLM	ONORBIT_REND_USER_PARAM_STATE_PROP
UPP_USE_IMU_DATA			TLM	ONORBIT_REND_USER_PARAM_STATE_PROP
$\bar{V}$ _AVGG			Attitude Proc, Orbit Maneuver DIP, TLM, Star Tracker SOP, Rendezvous Targeting, Onorbit Guidance, GN&C/SM-PL	ONORBIT_REND_USER_PARAM_STATE_PROP
$\bar{V}$ _AVGG_DP			REL NAV SPEC FUNC	ONORBIT_REND_USER_PARAM_STATE_PROP
$\bar{V}$ _IMU_OLD			Onorbit Guidance, Orbit Maneuver DIP	ONORBIT_REND_USER_PARAM_STATE_PROP
$\bar{V}$ _IMU_RESET	Onorbit/Rendezvous Nav, Onorbit/ Rendezvous Nav Seq	ONORBIT_REND_USER_PARAM_STATE_PROP		

Table 4.5. User Parameter Processing Principal Function Parameter Interface to Local Modules				
Variable Name	Principal Function Source	Local Destination	Principal Function Destination	Local Source
$\bar{V}$ _RESET	Onorbit/Rendezvous Nav, Onorbit/ Rendezvous Nav Seq	ONORBIT_REND_ USER_PARAM_ STATE_PROP	GN&C/SM-PL	ONORBIT_USER_ PARAMETER_ CALCULATIONS
$\bar{V}$ _RHO_EF				
$\bar{V}$ _TARGET				
$\bar{V}$ _TV_RESET	Onorbit/Rendezvous Nav, Onorbit/ Rendezvous Nav Seq	ONORBIT_REND_ USER_PARAM_ STATE_PROP	Rendezvous Targeting, REL NAV SPEC FUNC, TLM	ONORBIT_REND_ USER_PARAM_ STATE_PROP
$\bar{V}$ _IMU_SNAP			TLM	ONORBIT_REND_ USER_PARAM_ STATE_PROP



#### 4.5.1 User Parameter State Propagation (ONORBIT\_REND\_USER\_PARAM\_STATE\_PROP)

The Onorbit and Rendezvous Navigation State Propagation subfunctions advance the navigation state vector at relatively large intervals, at the end of which external measurement data processed by the filter are incorporated when appropriate. Users, such as guidance and displays, require a knowledge of the state vector at shorter intervals. The Onorbit and Rendezvous User Parameter State Propagation subfunction will satisfy the requirements of such users by integrating the equations of motion within the intervals of the navigation propagation with use of a simplified computation of the gravitational acceleration in conjunction with a small step size.

The integration of the orbiter and target state vectors is to be performed by an average-g process, using a modeled acceleration that contains a simplified Earth gravitational force model. In the case of the orbiter, if the acceleration derived in the UPP state propagator from the IMU sensed velocities is above a certain threshold level, this acceleration is to be used in the integration process. If the sensed acceleration falls below the threshold level, only the modeled acceleration is to be utilized in the integration. The IMU-sensed velocity has been corrected in the IMU RM to reference the orbiter center of gravity instead of NAV base.

In the rendezvous phases it is also necessary to propagate the target vehicle state. There being no IMU's in this vehicle, only the modeled acceleration is to be used in the integration.

This process will be restarted after each filter update with the filter states. The values of the filter updated position and velocity vectors, together with their time tag and the total accumulated IMU velocity, are stored (at each navigation cycle) in special locations for use by the User Parameter State Propagation subfunction. This prevents the errors resulting from use of a less accurate integrating scheme from becoming too large and, at the same time, provides a synchronization between the propagation tasks.

A. Detailed Requirements. A capability shall be provided for a fast computation of the position and velocity of the orbiter during all phases of OPS 2 and OPS 8, and of the position and velocity of the target vehicle during all rendezvous phases OPS 2. This computation shall provide the required state vectors in an M50 coordinate system by the integration of the equations of motion that include gravity accelerations and, for the orbiter, the IMU sensed velocities, if they give a significant contribution.

The following steps shall be performed (in the order indicated):

1. Snap the IMU-accumulated sensed velocity and time tag:

$\text{SNAP}(\bar{V}_{\text{IMU\_SNAP}}, T_{\text{IMU}})$

(see Section 4.2.2.1)

2. In the case of the orbiter, the value of the state that is to be advanced (integrated forward in time) may be from one of two sources (the one used depends on the tested value of the flag (FILT\_UPDATE), which indicates the availability of a filter updated state):
  - a. If an update from the filter is available (FILT\_UPDATE = ON), the navigation filter updated state, together with its time tag and associated IMU accumulated sensed velocity, is to replace the previous propagated state, time tag, and accumulated velocity. The filter updated values are  $\bar{R}_{\text{RESET}}$ ,  $\bar{V}_{\text{RESET}}$ ,  $T_{\text{RESET}}$ , and  $\bar{V}_{\text{IMU\_RESET}}$ ; the vectors maintained by the user parameter state propagator are  $\bar{R}_{\text{AVGG}}$ ,  $\bar{V}_{\text{AVGG}}$ , and

$\bar{V}_{AVGG\_DP}$ . The time tag is  $T\_STATE$ . Thus, if  $FILT\_UPDATE = ON$ , the following will be done:

$$\begin{aligned}\bar{R}_{AVGG} &= \bar{R}_{RESET} \\ \bar{V}_{AVGG\_DP} &= \bar{V}_{RESET} \\ \bar{V}_{IMU\_OLD} &= \bar{V}_{IMU\_RESET} \\ T\_STATE &= T\_RESET\end{aligned}$$

- b. If an update from the filter is not available ( $FILT\_UPDATE = OFF$ ), the propagated state, saved from the previous cycle, is to be advanced. The value of the IMU-accumulated sensed velocity saved from the previous cycle is available for state advancement purposes.
3. Compute the interval over which advancement is required:

$$DT\_IMU = T\_IMU - T\_STATE$$

4. Test the  $PWRD\_FLT\_NAV$  flag.

- a. If the flag is ON,

$$(1) \text{ Set } \bar{A}_{SENSED} = \frac{\bar{V}_{IMU\_SNAP} - \bar{V}_{IMU\_OLD}}{DT\_IMU} \quad F3$$

F3 This equation shall be protected against division by zero (reference 3.5).

- (2) Compute the IMU threshold value by first converting the  $IMU\_NAV\_ACCEL\_THRESH$  value (design-dependent constant or crew input) from micro-g's to feet per second squared, and then normalizing the threshold value as a function of the propagation interval ( $DT\_IMU$ ).

$$\begin{aligned}DA\_THRESHOLD\_IMU &= IMU\_NAV\_ACCEL\_THRESH \\ &(\text{GO } 10^{-6}) / DT\_IMU\end{aligned}$$

- (3) Test the magnitude of the sensed acceleration ( $\bar{A}_{SENSED}$ ) for this UPP cycle against the computed IMU threshold.

$$|\bar{A}_{SENSED}| > DA\_THRESHOLD\_IMU$$

If  $|\bar{A}_{SENSED}| > DA\_THRESHOLD\_IMU$ , set a flag to ON for telemetry

$$UPP\_USE\_IMU\_DATA = ON$$

Otherwise, turn the telemetry flag OFF, and set the acceleration value to zero.

$$UPP\_USE\_IMU\_DATA = OFF$$

$$\bar{A}_{SENSED} = \bar{0}.$$

- b. If the  $PWRD\_FLT\_NAV$  flag is OFF, turn the telemetry flag to OFF, and set the acceleration value to zero.

UPP\_USE\_IMU\_DATA = OFF

$\bar{A}_{SENSED} = \bar{0}$ .

5. The position and velocity vectors of the orbiter and the noncentral body gravitational acceleration vector shall then be obtained.

- a. Call the user parameter state integrator (see section 4.5.1.1).

CALL: AVERAGE\_G\_INTEGRATOR

IN LIST:  $\bar{R}_{AVGG}$ ,  $\bar{V}_{AVGG\_DP}$ , DT\_IMU,  $\bar{A}_{SENSED}$ , T\_STATE, T\_IMU

OUT LIST:  $\bar{R}_{AVGG}$ ,  $\bar{V}_{AVGG\_DP}$ , \*\*\*, \*\* (See Section 4.5.1.1)

\*\* Orbiter full acceleration not used

\*\*\* Orbiter non-central body gravity not used

The calculations performed up to this point refer to the orbiter's state. Propagation of the target state is required only during the rendezvous phases. A flag (DOING\_REND\_NAV), which has the value ON only during these phases, shall then be consulted by the user parameters state propagator.

- b. Save a single precision copy of  $\bar{V}_{AVGG\_DP}$  for other UPP principal functions.

$\bar{V}_{AVGG} = \bar{V}_{AVGG\_DP}$

6. Test the DOING\_REND\_NAV flag. If it is found to be ON, perform the following steps:

- a. Test the FILT\_UPDATE flag to determine if a target state is available from NAV.

If FILT\_UPDATE = ON, set

$\bar{R}_{TARGET} = \bar{R}_{TV\_RESET}$

$\bar{V}_{TARGET} = \bar{V}_{TV\_RESET}$

where  $\bar{R}_{TARGET}$  and  $\bar{V}_{TARGET}$  represent the position and velocity vectors of the target vehicle advanced by the user parameter state propagator, and  $\bar{R}_{TV\_RESET}$  and  $\bar{V}_{TV\_RESET}$  represent the target state vectors from the navigation filter.

- b. Advance the target state by a call to the integrator. In this call, the vector that contains the sensed acceleration shall be set to zero.

$\bar{A}_{SENSED} = \bar{0}$ .

CALL: AVERAGE\_G\_INTEGRATOR

IN LIST:  $\bar{R}_{TARGET}$ ,  $\bar{V}_{TARGET}$ , DT\_IMU,  
 $\bar{A}_{SENSED}$ , T\_STATE, T\_IMU

OUT LIST:  $\bar{R}_{TARGET}$ ,  $\bar{V}_{TARGET}$ , \* (see Section 4.5.1.1),  
 $\bar{G}_{TARGET}$

\* Target noncentral gravity acceleration not used.

After the state vector updates have been completed, the following steps are to be executed:

7. Save the time tag output for use in the next cycle:

$$T\_STATE = T\_IMU$$

8. Save the latest IMU-accumulated sensed velocity:

$$\bar{V}_{IMU\_OLD} = \bar{V}_{IMU\_SNAP}$$

9. Set the FILT\_UPDATE flag to OFF.

This completes the sequence of calculations of a user parameter state propagation cycle.

B. Interface Requirements. The input and output variables are listed in Table 4.5.1.

C. Processing Requirements. None

D. Constraints. The following variables must be implemented in a downlist time-homogeneous data set:

$$\bar{R}_{AVGG}, \bar{V}_{AVGG}, T\_STATE$$

$$\bar{R}_{TARGET}, \bar{V}_{TARGET}$$

These following parameters will be initialized as such:

$$\bar{R}_{AVGG} \text{ must be initialized to } (21824624.2, 0.0, 0.0)$$

$$\bar{V}_{AVGG} \text{ must be initialized to } (0.0, 22330.0, 12124.2)$$

$$\bar{V}_{AVGG\_DP} \text{ must be initialized to } (0.0, 22330.0, 12124.2)$$

Note: This represents a nearly circular orbit ( $e = 0.001$ ), with semi-major axis of 3595.4667 nautical miles and inclination of 28.5 degrees.

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart is found in Section 5.4 under the name ONORBIT\_REND\_USER\_PARAM\_STATE\_PROP.

Table 4.5.1. ONORBIT_REND_USER_PARAM_STATE_PROP Input/Output		
Variable Name	Input Source	Output Destination
DOING_REND_NAV	**	
FILT_UPDATE	**	
$\bar{R}$ _RESET	**	
$\bar{R}$ _TV_RESET	**	
T_IMU		**, AVERAGE_G_INTEGRATOR
T_RESET	**	
UPP_USE_IMU_DATA		**
$\bar{V}$ _IMU_SNAP		**
$\bar{V}$ _IMU_RESET	**	
$\bar{V}$ _RESET	**	
$\bar{V}$ _TV_RESET	**	
$\bar{A}$ _SENSED		**, AVERAGE_G_INTEGRATOR
DT_IMU		AVERAGE_G_INTEGRATOR
$\bar{R}$ _AVGG	AVERAGE_G_INTEGRATOR	**, AVERAGE_G_INTEGRATOR, ONORBIT_USER_PARAMETER_ CALCULATIONS
$\bar{R}$ _TARGET	AVERAGE_G_INTEGRATOR	**, AVERAGE_G_INTEGRATOR, ONORBIT_USER_PARAMETER CALCULATIONS
GO	***	
$\bar{G}$ _TARGET	AVERAGE_G_INTEGRATOR	**
PWRD_FLT_NAV	**	
T_STATE		**, AVERAGE_G_INTEGRATOR, ONORBIT_USER_PARAMETER_ CALCULATIONS
$\bar{V}$ _AVGG	AVERAGE_G_INTEGRATOR	**, ONORBIT_USER_PARAMETER_ CALCULATIONS
$\bar{V}$ _AVGG_DP	AVERAGE_G_INTEGRATOR	**, AVERAGE_G_INTEGRATOR
$\bar{V}$ _IMU_OLD		**
$\bar{V}$ _TARGET	AVERAGE_G_INTEGRATOR	**, AVERAGE_G_INTEGRATOR, ONORBIT_USER_PARAMETER_ CALCULATIONS

\*\* User parameter processing principal function, see Tables 4.5.3-1 and 4.5.3-2.  
\*\*\* Initialization parameter, see section 4.7.

#### 4.5.1.1 Integration (AVERAGE\_G\_INTEGRATOR)

The Integration subfunction is called by the User Parameter State Propagation subfunction to propagate the Shuttle and target state vectors to current time.

A. Detailed Requirements. This subfunction is called with the following internal variables in the IN LIST and OUT LIST:

IN LIST:  $\bar{R}_{AV}$ ,  $\bar{V}_{AV}$ , DTIME,  $\bar{AC}$ , T\_STATE, T\_IMU

OUT LIST:  $\bar{R}_{AV}$ ,  $\bar{V}_{AV}$ ,  $\bar{G}_{NONCENTRAL}$ ,  $\bar{GR1}$

where

$\left. \begin{array}{l} \bar{R}_{AV} \\ \bar{V}_{AV} \end{array} \right\}$	user parameter state vector
DTIME	interval to propagate state vector over
$\bar{AC}$	acceleration vector
T_STATE	user parameter time tag
T_IMU	current time
$\bar{G}_{NONCENTRAL}$	noncentral body gravitational acceleration vector
$\bar{GR1}$	gravitational acceleration vector

The following steps shall be performed (in the order indicated):

1. By means of a call to the acceleration function, compute the gravitational acceleration for the input state vector and corresponding time tag (see Section 4.2.4.1.1):

$$\bar{GR} = \bar{ACCEL\_ONORBIT} (GM\_DEG\_LOW, GM\_ORD\_LOW, DFL\_AVG, VFLTV\_PRED, ATFL\_OV, \bar{R}_{AV}, \bar{V}_{AV}, T\_STATE)$$

2. Advance the position vector by the average-g method:

$$\bar{R}_{AV} = \bar{R}_{AV} + DTIME [\bar{V}_{AV} + .5 DTIME (\bar{AC} + \bar{GR})]$$

3. Use this updated position vector and the current time to find a new value of the gravitational acceleration (see Section 4.2.4.1.1):

$$\bar{GR1} = \bar{ACCEL\_ONORBIT} (GM\_DEG\_LOW, GM\_ORD\_LOW, DFL\_AVG, VFLTV\_PRED, ATFL\_OV, \bar{R}_{AV}, \bar{V}_{AV}, T\_IMU)$$

4. Advance the velocity vector by the average-g method:

$$\bar{V}_{AV} = \bar{V}_{AV} + \text{DTIME} [\bar{AC} + .5 (\bar{GR} + \bar{GR1})]$$

The quantities GM\_DEG\_LOW, GM\_ORD\_LOW, VFLTV\_PRED, DFL\_AVG, and ATFL\_OV are pad-loaded values of the various acceleration constants, designed for high usage rates (see Section 4.7 for values).

5. Compute the noncentral body gravitational acceleration vector, G, required by the Onorbit Guidance principal function:

$$\bar{G}_{NONCENTRAL} = \bar{G} R1 - \bar{G}_{CENTRAL}$$

The vector  $\bar{G}_{CENTRAL}$  is the central body gravity acceleration computed in the ACCEL\_ONORBIT function.

- B. Interface Requirements. The input and output variables are listed in Table 4.5.1.1.
- C. Processing Requirements. None
- D. Constraints. Outputs should be protected time-homogeneous parameters.
- E. Supplementary Information. A suggested implementation in the form of a detailed flow chart is found in Section 5.4 under the name

AVERAGE\_G\_INTEGRATOR

Table 4.5.1.1. AVERAGE\_G\_INTEGRATOR Input/Output

Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
$\bar{A}C$	$\bar{A}_{SENSED}$	ONORBIT_REND_USER_PARAM_STATE_PROP	
DTIME	DT_IMU	ONORBIT_REND_USER_PARAM_STATE_PROP	
$\bar{R}_{AV}$	$\bar{R}_{AVGG}$	ONORBIT_REND_USER_PARAM_STATE_PROP	
T_IMU	T_IMU	ONORBIT_REND_USER_PARAM_STATE_PROP	
T_STATE	T_STATE	ONORBIT_REND_USER_PARAM_STATE_PROP	
$\bar{V}_{AV}$	$\bar{V}_{AVGG\_DP}$	ONORBIT_REND_USER_PARAM_STATE_PROP	
$\bar{A}C$	$\bar{A}_{SENSED}$	ONORBIT_REND_USER_PARAM_STATE_PROP	
DTIME	DT_IMU	ONORBIT_REND_USER_PARAM_STATE_PROP	
$\bar{R}_{AV}$	$\bar{R}_{TARGET}$	ONORBIT_REND_USER_PARAM_STATE_PROP	
T_IMU	T_IMU	ONORBIT_REND_USER_PARAM_STATE_PROP	
T_STATE	T_STATE	ONORBIT_REND_USER_PARAM_STATE_PROP	
$\bar{V}_{AV}$	$\bar{V}_{TARGET}$	ONORBIT_REND_USER_PARAM_STATE_PROP	
$\bar{R}_{AV}$	$\bar{R}_{AVGG}$		ONORBIT_REND_USER_PARAM_STATE_PROP
$\bar{V}_{AV}$	$\bar{V}_{AVGG\_DP}$		ONORBIT_REND_USER_PARAM_STATE_PROP
$\bar{R}_{AV}$	$\bar{R}_{TARGET}$		ONORBIT_REND_USER_PARAM_STATE_PROP
$\bar{V}_{AV}$	$\bar{V}_{TARGET}$		ONORBIT_REND_USER_PARAM_STATE_PROP



Table 4.5.1.1.(1) AVERAGE\_G\_INTEGRATOR Input/Output

Variable Name	Input Source	Output Destination
ATFL_OV	**	$\overline{\text{ACCEL\_ONORBIT}}$
DFL_AVG	**	$\overline{\text{ACCEL\_ONORBIT}}$
$\overline{\text{G\_NONCENTRAL}}$		ONORBIT_REND_USER_ PARAM_STATE_PROP
$\overline{\text{G\_CENTRAL}}$	$\overline{\text{ACCEL\_ONORBIT}}$	
GM_DEG_LOW	**	$\overline{\text{ACCEL\_ONORBIT}}$
GM_ORD_LOW	**	$\overline{\text{ACCEL\_ONORBIT}}$
$\overline{\text{GR1}}$	$\overline{\text{ACCEL\_ONORBIT}}$	ONORBIT_REND_USER_ PARAM_STATE_PROP
VFLTV_PRED	**	$\overline{\text{ACCEL\_ONORBIT}}$
†	$\overline{\text{ACCEL\_ONORBIT}}$	
$\overline{\text{R\_AV}}$		$\overline{\text{ACCEL\_ONORBIT}}$
$\overline{\text{V\_AV}}$		$\overline{\text{ACCEL\_ONORBIT}}$
T_STATE		$\overline{\text{ACCEL\_ONORBIT}}$
T_IMU		$\overline{\text{ACCEL\_ONORBIT}}$
** Initialization parameters, see Section 4.7.		
† Value returned from the function.		

#### 4.5.2 Onorbit User Parameter Calculations (ONORBIT\_USER\_PARAMETER\_CALCULATIONS)

This subfunction contains software to compute quantities required by the GN&C/SM-PL interface and the Universal Pointing principal function. These calculations are required during OPS 2 and OPS 8.

A. Detailed Requirements. The following steps shall be performed (in the order indicated):

1. If the rendezvous nav flag is set on (DOING\_REND\_NAV = ON), the delta position and velocity vectors in the M50 system are computed. These vectors represent position and velocity vectors from the Shuttle to the rendezvous target.

$$\overline{\text{DEL\_R\_TARG}} = \overline{\text{R\_TARGET}} - \overline{\text{R\_AVGG}}$$

$$\overline{\text{DEL\_V\_TARG}} = \overline{\text{V\_TARGET}} - \overline{\text{V\_AVGG}}$$

2. The M50 to Greenwich-true-of-date transformation matrix is computed at the time of the state vectors, T\_STATE.

$$\text{M50\_TO\_EF} = \text{EARTH\_FIXED\_TO\_M50\_COORD}(\text{T\_STATE})^T$$

3. The Shuttle state vector ( $\overline{\text{R\_AVGG}}$ ,  $\overline{\text{V\_AVGG}}$ ) is transformed into the Greenwich-true-of-date, and the Earth's rotational effects are added to the X and Y components to yield the Earth-relative velocity vector.

$$\overline{\text{R\_EF}} = \text{M50\_TO\_EF} \overline{\text{R\_AVGG}}$$

$$\overline{\text{V\_EF}} = \text{M50\_TO\_EF} \overline{\text{V\_AVGG}}$$

$$\text{V\_RHO\_EF}_1 = \text{V\_EF}_1 + \text{EARTH\_RATE} \text{R\_EF}_2$$

$$\text{V\_RHO\_EF}_2 = \text{V\_EF}_2 - \text{EARTH\_RATE} \text{R\_EF}_1$$

$$\text{V\_RHO\_EF}_3 = \text{V\_EF}_3$$

4. The Greenwich mean time associated with the position and velocity vectors is then saved:

$$\text{T\_SEC\_GMT} = \text{T\_STATE}$$

B. Interface Requirements. Input and output parameters for this subfunction are shown in Table 4.5.2.

C. Processing Requirements. Processing requirements for this subfunction are specified in the ONORBIT\_REND\_UPP\_SEQUENCER.

D. Constraints. Outputs should be protected time homogeneous parameters.

E. Supplemental Information. A suggested implementation in the form of a detailed flow chart can be found in Section 5.4 under the name:

ONORBIT\_USER\_PARAMETR\_CALCULATIONS

Table 4.5.2. ONORBIT_USER_PARAMETER_CALCULATIONS Input/Output		
Variable Name	Input Source	Output Destination
EARTH_RATE	**	
$\bar{R}_{AVGG}$	ONORBIT_REND_USER_PARAM_STATE_PROP	
DOING_REND_NAV	***	
$\bar{R}_{TARGET}$	ONORBIT_REND_USER_PARAM_STATE_PROP	
T_STATE	ONORBIT_REND_USER_PARAM_STATE_PROP	
$\bar{V}_{AVGG}$	ONORBIT_REND_USER_PARAM_STATE_PROP	
$\bar{V}_{TARGET}$	ONORBIT_REND_USER_PARAM_STATE_PROP	
†	EARTH_FIXED_TO_M50_COORD	
$\bar{DEL}_R\_TARG$		***
$\bar{DEL}_V\_TARG$		***
T_SEC_GMT		***
$\bar{V}_{RHO\_EF}$		***
$\bar{R}_{EF}$		***
† Value returned from the function. ** Initialization parameters, see Section 4.7. *** User Parameter Processing principal function, see Tables 4.5.3-1 and 4.5.3-2.		

**4.5.3 Onorbit/Rendezvous User Parameter Processing Tables (4.22)**

The IDD inputs and outputs are listed in Table 4.5.3-1 and 4.5.3-2 respectively. 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 4.5.3-3. K-loads are listed in Table 4.5.3-4. Constants are listed in Table 4.5.3-5, and a principal function cross-reference listing is presented below:

Onorbit/Rendezvous User Parameter Processing Principal Function (4.22) Cross-Reference Listing	
Local Name	Source Name
T_IMU $\bar{V}$ _IMU_SNAP	T_IMUS SEL_V_M50_CG(1) SEL_V_M50_CG(2) SEL_V_M50_CG(3)

TABLE 4.5.3-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT USER PARAMETER PROCESSING (G4.22)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
DOING_REND_NAV	V90X4765X	RENDZ NAV ACTIVE FLAG	ORB/RND NAV SEQ		BD		93017G	*
EARTH_POLE(1)	V90U0190C	X-COMP UNIT VCTR ALONG EARTH AXIS	RNP MAT COMP	ND	DPL		93090E	
EARTH_POLE(2)	V90U0191C	Y-COMP UNIT VCTR ALONG EARTH AXIS	RNP MAT COMP	ND	DPL		93090E	
EARTH_POLE(3)	V90U0192C	Z-COMP UNIT VCTR ALONG EARTH AXIS	RNP MAT COMP	ND	DPL		93090E	
FILT_UPDATE	V90X0224XF	FLAG IND NAV FILTER PROC COMPLETE	ORB/RND NAV					
FILT_UPDATE	V90X0224XI	FLAG IND NAV FILTER PROC COMPLETE	ORB/RND NAV SEQ					
IMU_NAV_ACC_THRESH	V93A6710C	IMU NAV ACCEL THRESHOLD	IMU ALIGN DISP	MICROG	VAR		89813B	
M_M50TOEF_AT_EPOCH(1,1)	V97U5738C	M50 TO EF TRANS MATRIX ELEM 1,1	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(1,2)	V97U5739C	M50 TO EF TRANS MATRIX ELEM 1,2	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(1,3)	V97U5740C	M50 TO EF TRANS MATRIX ELEM 1,3	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(2,1)	V97U5741C	M50 TO EF TRANS MATRIX ELEM 2,1	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(2,2)	V97U5742C	M50 TO EF TRANS MATRIX ELEM 2,2	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(2,3)	V97U5743C	M50 TO EF TRANS MATRIX ELEM 2,3	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(3,1)	V97U5744C	M50 TO EF TRANS MATRIX ELEM 3,1	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(3,2)	V97U5745C	M50 TO EF TRANS MATRIX ELEM 3,2	RNP MAT COMP	ND	DPL		93090E	
M_M50TOEF_AT_EPOCH(3,3)	V97U5746C	M50 TO EF TRANS MATRIX ELEM 3,3	RNP MAT COMP	ND	DPL		93090E	
PWRD_FLT_NAV	V93X5408XA	PWR FLT NAV AVG G ON/OFF CMD	ORB/RND NAV SEQ					
PWRD_FLT_NAV	V93X5408XB	PWR FLT NAV AVG G ON/OFF CMD	FCS/DED DISP					
PWRD_FLT_NAV	V93X5408XC	PWR FLT NAV AVG G ON/OFF CMD	REL NAV DISP					
R_RESET(1)	V90H0235CG	SEL X-COMP OF UPDATED POS VCTR RST	ORB/RND NAV	FT	DPL			
R_RESET(1)	V90H0235CI	SEL X-COMP OF UPDATED POS VCTR RST	ORB/RND NAV SEQ	FT	DPL			
R_RESET(2)	V90H0236CG	SEL Y-COMP OF UPDATED POS VCTR RST	ORB/RND NAV	FT	DPL			
R_RESET(2)	V90H0236CI	SEL Y-COMP OF UPDATED POS VCTR RST	ORB/RND NAV SEQ	FT	DPL			
R_RESET(3)	V90H0237CG	SEL Z-COMP OF UPDATED POS VCTR RST	ORB/RND NAV	FT	DPL			
R_RESET(3)	V90H0237CI	SEL Z-COMP OF UPDATED POS VCTR RST	ORB/RND NAV SEQ	FT	DPL			
R_TV_RESET(1)	V90H1383CA	X-COMP OF CURR TARGET POS VCT RST	ORB/RND NAV	FT	DPL			
R_TV_RESET(1)	V90H1383CB	X-COMP OF CURR TARGET POS VCT RST	ORB/RND NAV SEQ	FT	DPL			
R_TV_RESET(2)	V90H1384CA	Y-COMP OF CURR TARGET POS VCT RST	ORB/RND NAV	FT	DPL			
R_TV_RESET(2)	V90H1384CB	Y-COMP OF CURR TARGET POS VCT RST	ORB/RND NAV SEQ	FT	DPL			
R_TV_RESET(3)	V90H1385CA	Z-COMP OF CURR TARGET POS VCT RST	ORB/RND NAV	FT	DPL			
R_TV_RESET(3)	V90H1385CB	Z-COMP OF CURR TARGET POS VCT RST	ORB/RND NAV SEQ	FT	DPL			
SEL_V_M50_CG(1)	V90L2607C	SEL TOTAL X VEL M50 AT CG	IMU RM	FT/S				
SEL_V_M50_CG(2)	V90L2608C	SEL TOTAL Y VEL M50 AT CG	IMU RM	FT/S				
SEL_V_M50_CG(3)	V90L2609C	SEL TOTAL Z VEL M50 AT CG	IMU RM	FT/S				
T_EPOCH	V97W5528C	TIME TAG FOR M_M50TOEF_AT_EPOCH	RNP MAT COMP	S	DPL		93090E	
T_IMUS	V95W0002C	IMU INPUT TRANS TIME TAG	IMU INT PROC	S	DPL		93017G	*
T_RESET	V90W0534CG	TIME OF FILTER STATE VCTR	ORB/RND NAV	S			92834C	
T_RESET	V90W0534CH	TIME OF FILTER STATE VCTR	ORB/RND NAV SEQ	S			92834C	
V_IMU_RESET(1)	V90L0247CG	SEL X-COMP OF ACCUM SENSED VEL RST	ORB/RND NAV	FT/S			93017G	*
V_IMU_RESET(1)	V90L0247CI	SEL X-COMP OF ACCUM SENSED VEL RST	ORB/RND NAV SEQ	FT/S			93017G	*
V_IMU_RESET(2)	V90L0248CG	SEL Y-COMP OF ACCUM SENSED VEL RST	ORB/RND NAV	FT/S			93017G	*
V_IMU_RESET(2)	V90L0248CI	SEL Y-COMP OF ACCUM SENSED VEL RST	ORB/RND NAV SEQ	FT/S			93017G	*
V_IMU_RESET(3)	V90L0249CG	SEL Z-COMP OF ACCUM SENSED VEL RST	ORB/RND NAV	FT/S			93017G	*
V_IMU_RESET(3)	V90L0249CI	SEL Z-COMP OF ACCUM SENSED VEL RST	ORB/RND NAV SEQ	FT/S			93017G	*
V_RESET(1)	V90L0239CG	SEL X-COMP OF UPDATED VEL VCTR RST	ORB/RND NAV	FT/S				
V_RESET(1)	V90L0239CI	SEL X-COMP OF UPDATED VEL VCTR RST	ORB/RND NAV SEQ	FT/S				

TABLE 4.5.3-1. INPUT FUNCTIONAL PARAMETERS FOR ONORBIT USER PARAMETER PROCESSING (G4.22)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
V_RESET(2)	V90L0240CG	SEL Y-COMP OF UPDATED VEL VCTR RST	ORB/RND NAV	FT/S				
V_RESET(2)	V90L0240CI	SEL Y-COMP OF UPDATED VEL VCTR RST	ORB/RND NAV SEQ	FT/S				
V_RESET(3)	V90L0241CG	SEL Z-COMP OF UPDATED VEL VCTR RST	ORB/RND NAV	FT/S				
V_RESET(3)	V90L0241CI	SEL Z-COMP OF UPDATED VEL VCTR RST	ORB/RND NAV SEQ	FT/S				
V_TV_RESET(1)	V90L1380CA	X-COMP OF CURR TARGET VEL VCT RST	ORB/RND NAV	FT/S				
V_TV_RESET(1)	V90L1380CB	X-COMP OF CURR TARGET VEL VCT RST	ORB/RND NAV SEQ	FT/S				
V_TV_RESET(2)	V90L1381CA	Y-COMP OF CURR TARGET VEL VCT RST	ORB/RND NAV	FT/S				
V_TV_RESET(2)	V90L1381CB	Y-COMP OF CURR TARGET VEL VCT RST	ORB/RND NAV SEQ	FT/S				
V_TV_RESET(3)	V90L1382CA	Z-COMP OF CURR TARGET VEL VCT RST	ORB/RND NAV	FT/S				
V_TV_RESET(3)	V90L1382CB	Z-COMP OF CURR TARGET VEL VCT RST	ORB/RND NAV SEQ	FT/S				

**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**

TABLE 4.5.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT USER PARAMETER PROCESSING (G4.22)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
A_SENSED(1)	V95A0902C	SENSED ACCELERATION X-COMP	DL FMT 22/1 DL FMT 32/1	FT/S2	DPL		93017G	*
A_SENSED(2)	V95A0903C	SENSED ACCELERATION Y-COMP	DL FMT 22/1 DL FMT 32/1	FT/S2	DPL		93017G	*
A_SENSED(3)	V95A0904C	SENSED ACCELERATION Z-COMP	DL FMT 22/1 DL FMT 32/1	FT/S2	DPL		93017G	*
DEL_R_TARG(1)	V95H0855C	X-COMP OF ORBITER/TGT REL POS VCTR	DL FMT 22/1 UNIV POINT PROC	FT	DPL		93017G	*
DEL_R_TARG(2)	V95H0856C	Y-COMP OF ORBITER/TGT REL POS VCTR	DL FMT 22/1 UNIV POINT PROC	FT	DPL		93017G	*
DEL_R_TARG(3)	V95H0857C	Z-COMP OF ORBITER/TGT REL POS VCTR	DL FMT 22/1 UNIV POINT PROC	FT	DPL		93017G	*
DEL_V_TARG(1)	V95L0858C	X-COMP OF ORBITER/TGT REL VEL VCTR	DL FMT 22/1 UNIV POINT PROC	FT/S	DPL		93017G	*
DEL_V_TARG(2)	V95L0859C	Y-COMP OF ORBITER/TGT REL VEL VCTR	DL FMT 22/1 UNIV POINT PROC	FT/S	DPL		93017G	*
DEL_V_TARG(3)	V95L0860C	Z-COMP OF ORBITER/TGT REL VEL VCTR	DL FMT 22/1 UNIV POINT PROC	FT/S	DPL		93017G	*
G_TARGET(1)	V95A0073C	X-COMP OF CURRENT TARGET ACC VCTR	REL NAV SPEC	FT/S2	DPL		92688B	
G_TARGET(2)	V95A0074C	Y-COMP OF CURRENT TARGET ACC VCTR	REL NAV SPEC	FT/S2	DPL		92688B	
G_TARGET(3)	V95A0075C	Z-COMP OF CURRENT TARGET ACC VCTR	REL NAV SPEC	FT/S2	DPL		92688B	
R_AVGG(1)	V95H0185CF	X-COMP OF CUR SHUTTLE POS VCTR M50	DL FMT 22/1 DL FMT 32/1 GN&C/SM-PL IF ORB ATT PROC ORB GUID ORB MNVR DIP ORB TGT SPEC REL NAV SPEC STAR TRCK SOP	FT	DPL		93017G	*
R_AVGG(2)	V95H0186CF	Y-COMP OF CUR SHUTTLE POS VCTR M50	DL FMT 22/1 DL FMT 32/1 GN&C/SM-PL IF ORB ATT PROC ORB GUID ORB MNVR DIP ORB TGT SPEC REL NAV SPEC STAR TRCK SOP	FT	DPL		93017G	*

TABLE 4.5.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT USER PARAMETER PROCESSING (G4.22)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
R_AVGG(3)	V95H0187CF	Z-COMP OF CUR SHUTTLE POS VCTR M50	DL FMT 22/1 DL FMT 32/1 GN&C/SM-PL IF ORB ATT PROC ORB GUID ORB MNVR DIP ORB TGT SPEC REL NAV SPEC STAR TRCK SOP	FT	DPL		93017G	*
R_EF(1)	V95H0155CF	ORBITER X POSITION EF(TOD)	GN&C/SM-PL IF	FT	DPL		92025B	
R_EF(2)	V95H0156CF	ORBITER Y POSITION EF(TOD)	GN&C/SM-PL IF	FT	DPL		92025B	
R_EF(3)	V95H0157CF	ORBITER Z POSITION EF(TOD)	GN&C/SM-PL IF	FT	DPL		92025B	
R_TARGET(1)	V95H0862C	X-COMP OF CURRENT TARGET POS VCTR	DL FMT 22/1 ORB TGT SPEC REL NAV SPEC STAR TRCK SOP	FT	DPL		93017G	*
R_TARGET(2)	V95H0863C	Y-COMP OF CURRENT TARGET POS VCTR	DL FMT 22/1 ORB TGT SPEC REL NAV SPEC STAR TRCK SOP	FT	DPL		93017G	*
R_TARGET(3)	V95H0864C	Z-COMP OF CURRENT TARGET POS VCTR	DL FMT 22/1 ORB TGT SPEC REL NAV SPEC STAR TRCK SOP	FT	DPL		93017G	*
T_IMU	V95W0901C	TIME OF SNAPPED SENSED VEL	DL FMT 22/1	S	DPL		93017G	*
T_SEC_GMT	V95W3890CC	TIME TAG EF STATE(TOD)	DL FMT 32/1 GN&C/SM-PL IF	S			92297B	
T_STATE	V95W0200CF	TIME TAG ASSOC WITH CURRENT STATE	DL FMT 22/1 DL FMT 32/1 ORB GUID ORB MNVR DIP ORB TGT SPEC	S			93017G	*
UPP_USE_IMU_DATA	V95X0889X	UPP IMU DATA USE FLAG	DL FMT 22/1 DL FMT 32/1		BD		93017G	*
V_AVGG(1)	V95L0190CF	X-COMP OF CUR SHUTTLE VEL VCTR M50	DL FMT 22/1 DL FMT 32/1 GN&C/SM-PL IF ORB ATT PROC ORB GUID ORB MNVR DIP ORB TGT SPEC STAR TRCK SOP	FT/S	SPL		93017G	*



TABLE 4.5.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT USER PARAMETER PROCESSING (G4.22)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
V_AVGG(2)	V95L0191CF	Y-COMP OF CUR SHUTTLE VEL VCTR M50	DL FMT 22/1 DL FMT 32/1 GN&C/SM-PL IF ORB ATT PROC ORB GUID ORB MNVR DIP ORB TGT SPEC STAR TRCK SOP	FT/S	SPL		93017G	*
V_AVGG(3)	V95L0192CF	Z-COMP OF CUR SHUTTLE VEL VCTR M50	DL FMT 22/1 DL FMT 32/1 GN&C/SM-PL IF ORB ATT PROC ORB GUID ORB MNVR DIP ORB TGT SPEC STAR TRCK SOP	FT/S	SPL		93017G	*
V_AVGG_DP(1)	V95L0142CF	X-COMP CUR SHUT VEL VCT M50 (DP)	REL NAV SPEC	FT/S	DPL		92748B	
V_AVGG_DP(2)	V95L0143CF	Y-COMP CUR SHUT VEL VCT M50 (DP)	REL NAV SPEC	FT/S	DPL		92748B	
V_AVGG_DP(3)	V95L0144CF	Z-COMP CUR SHUT VEL VCT M50 (DP)	REL NAV SPEC	FT/S	DPL		92748B	
V_IMU_OLD(1)	V95L0210CD	X-COMP OF CURRENT ACCUM IMU VEL	ORB GUID ORB MNVR DIP	FT/S	DPL		92843B	
V_IMU_OLD(2)	V95L0211CD	Y-COMP OF CURRENT ACCUM IMU VEL	ORB GUID ORB MNVR DIP	FT/S	DPL		92843B	
V_IMU_OLD(3)	V95L0212CD	Z-COMP OF CURRENT ACCUM IMU VEL	ORB GUID ORB MNVR DIP	FT/S	DPL		92843B	
V_IMU_SNAP(1)	V95L0898C	SNAPPED TOT X ACCUM SENSED VEL	DL FMT 22/1 DL FMT 32/1	FT/S	DPL		93017G	*
V_IMU_SNAP(2)	V95L0899C	SNAPPED TOT Y ACCUM SENSED VEL	DL FMT 22/1 DL FMT 32/1	FT/S	DPL		93017G	*
V_IMU_SNAP(3)	V95L0900C	SNAPPED TOT Z ACCUM SENSED VEL	DL FMT 22/1 DL FMT 32/1	FT/S	DPL		93017G	*
V_RHO_EF(1)	V95L3884CE	X VELOCITY VECTOR EF(TOD)	GN&C/SM-PL IF	FT/S			92025B	
V_RHO_EF(2)	V95L3885CE	Y VELOCITY VECTOR EF(TOD)	GN&C/SM-PL IF	FT/S			92025B	
V_RHO_EF(3)	V95L3886CE	Z VELOCITY VECTOR EF(TOD)	GN&C/SM-PL IF	FT/S			92025B	
V_TARGET(1)	V95L0867C	X-COMP OF CURRENT TARGET VEL VCTR	DL FMT 22/1 ORB TGT SPEC REL NAV SPEC	FT/S	DPL		93017G	*
V_TARGET(2)	V95L0868C	Y-COMP OF CURRENT TARGET VEL VCTR	DL FMT 22/1 ORB TGT SPEC REL NAV SPEC	FT/S	DPL		93017G	*
V_TARGET(3)	V95L0869C	Z-COMP OF CURRENT TARGET VEL VCTR	DL FMT 22/1 ORB TGT SPEC REL NAV SPEC	FT/S	DPL		93017G	*
	V95M2881P	CGNB_UPP_USE_IMU_DATA	DL FMT 22/1 DL FMT 32/1				93017G	*

TABLE 4.5.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM ONORBIT USER PARAMETER PROCESSING (G4.22)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
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**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**

**Rate Codes: (HDR Only) 1 = 1 sample/sec 2 = 5 samples/sec 3 = 12.5 samples/sec 4 = 25 samples/sec 5 = 100 samples/sec  
(HDR and LDR) A = 1 sample/sec B = 5 samples/sec C = 12.5 samples/sec D = 25 samples/sec E = 100 samples/sec**

TABLE 4.5.3-3. ONORBIT USER PARAMETER PROCESSING (G4.22) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
IMU_NAV_ACCEL_THRESH	V93A6710C	UG	I	D	D	P	G4.126 G4.22	00	ZPA	DC0617	

**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**

TABLE 4.5.3-4. ONORBIT USER PARAMETER PROCESSING (G4.22) K-LOADS

FSSR NAME DESCRIPTION	MSID	MC	KLOAD VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
GM_DEG_LOW	V96U9118C	00	+2	ND	I	S	P	G4.126 G4.22	59953	
GM_ORD_LOW	V96U9120C	00	+0	ND	I	S	P	G4.126 G4.22	59953	

**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**

TABLE 4.5.3-5. ONORBIT USER PARAMETER PROCESSING (G4.22) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
ATFL_OV CONTROLS USE OF CURRENT ORB ATTITUDE IN DRAG COMPUTE	V97U6102C	00	+0	ND	I		S	C G4.126 G4.148 G4.18 G4.21 G4.22	91051K	
DFL_AVG DRAG FLAG USED IN AVG-G INTEGRATION	V97U6123C	00	OFF	ND	D		C	G4.22	90374C	
EARTH_RATE EARTH'S ROTATIONAL RATE	V97U4379C	00	+7.29211514646E-05	RAD/SEC	F		D	C A6.9 G4.126 G4.127 G4.139 G4.144 G4.148 G4.15 G4.17 G4.19 G4.20 G4.205 G4.21 G4.213 G4.22 G4.236 G4.237 G4.4 G5.26	93090E	
GO EARTH GRAV ACCEL CONSTANT	V90A7622C	00	+3.2174049	E+01 FT/SEC**2	F		S	P A6.9 G4.10 G4.105 G4.126 G4.204 G4.208 G4.22 G4.220 G4.227 G4.234 G4.237 G4.36 G4.8 G4.9 G5.27 V4.10 V4.11 V4.11B V4.11C V4.9A	93090E	

TABLE 4.5.3-5. ONORBIT USER PARAMETER PROCESSING (G4.22) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
VFL_TV_PRED VENTING FLAG FOR TARGET PREDICTION FOR UPP STATE PROPAGATION	V97U6139C	00	+0	ND	I		S	P G4.148 G4.22	90374C	

**NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.**

## 4.6 Deleted

## 4.7 INITIALIZATION OF SPECIFIC OPS 2 NAVIGATION PARAMETERS

It is required that initial values for certain specific parameters be made available for use by the navigation flight software. These parameters can be divided into seven categories:

1. Level A Constants – Those parameters with values that are not mission related nor design dependent. These parameters and values are defined in Level A CPDS (SS-P-0002-170).
2. Mission-Dependent Parameters – Those parameters with values that may change from mission to mission. These parameters and their values are defined in an I-loads Requirement Document (ILRD) (JSC 19350).
3. Design-Dependent Parameters – Those parameters whose values are considered to be a part of the software design. These parameters are defined in this book.
4. Hard-Codeable Parameters – Those parameters whose values must be defined but are neither mission dependent nor design dependent and are not defined by the Level A CPDS.
5. Other required initial values – Those parameters whose values do not fit in any of the four above categories.
6. OPS Transition Parameters – Those parameters whose values are needed by the OPS 2 or OPS 8 navigation flight software, or calculated by OPS 2 for an OPS transition to OPS 8, OPS 3, or OPS 00, or calculated by OPS 8 for an OPS transition to OPS 2, OPS 3, or OPS 00.
7. K-Load Parameters - Former mission-dependent parameters which have become hard-coded.

These seven categories of initialization parameters are denoted in the Initialization Category column of variable lists in Section 5 by the following abbreviations:

- C – Level A constants
- MD – Mission-dependent parameters
- DD – Design-dependent parameters
- HC – Hard-codeable parameters
- IV – Other required initial values
- OPS – OPS transition parameters
- K-load – A former I-load which has become hard-coded

Additional information on the initialization of specific OPS 2 or 8 navigation parameters can be obtained from the I-load, K-load, and constant tables located at the end of each principal function description in Section 4. The variable lists in Section 5 provide initialization information for all parameters used in each principal function.

#### **4.8 DOWNLIST REQUIREMENTS**

Downlist requirements for the Onorbit/Rendezvous (OPS 2) operations computer load are given in the Computer Program Development Specification (CPDS) Vol.1, Book 4, Downlist/Uplink Software Requirements (SS-P-0002-140). Data that will be available for downlist may be found in the principal function output tables marked with TLM as output destination. They may also be found in the variable lists of Sections 5.1, 5.3, and 5.4 indicated by the word “downlist” in the Uplink/Downlist column of the variable lists.



## 4.9 UPLINK REQUIREMENTS

The following subsections identify uplink requirements to support the orbital operations computer load onboard navigation software. Each subsection identifies a specific set of parameters which are candidates for uplink and details the structure of the formatted load, specifies any OP\_CODE checking and/or special processing required as a result of the occurrence of the particular uplinked data, and describes any special constraints involved. All navigation related uplink parameter requirements are grouped into the following categories:

- Orbiter state vector uplink parameters (Section 4.9.1)
- Rendezvous vehicle state vector uplink parameters (Section 4.9.2)
- Vent/RCS thrust body force vector uplink parameters (Section 4.9.3)
- Drag model scale factors uplink parameters (Section 4.9.4)
- Covariance matrix uplink parameters (Section 4.9.5)
- RNP Matrix Time Parameters Load (Section 4.9.6)

### 4.9.1 Orbiter State Vector Uplink Parameters (ORBITER\_STATE\_VECTOR\_UPLINK)

The parameters to be candidates for change via command uplink associated with the orbiter state vector update include the orbiter M50 position and velocity vectors, and the associated time tag. These data are used by the Onorbit/ Rendezvous Navigation principal function during OPS 2 and OPS 8.

A. Detailed Requirements. The orbiter M50 position and velocity vectors with the associated time tag (GMT) can be changed via a formatted load structured as described in Table 4.9.1–1. The following high-rate special processing is required upon receipt of an orbiter state vector command uplink load:

1. A bit-string (OP\_CODE) shall have been set to the “orbiter state vector uplink” OP\_CODE value (0001001) by the ground uplink processing software when data are received from the ground.
2. The bit-string (OP\_CODE) shall first be tested by the special processing software to determine if it equals the value specified for an orbiter state uplink:

OP\_CODE = 0001001

3. If the above is true, a flag (DO\_OV\_UPLINK) shall be set to ON, and the uplinked orbiter state vector with associated time tag shall be stored in special locations:

DO\_OV\_UPLINK = ON  
 $\overline{R\_GND} = \overline{BUFFER\_R}$   
 $\overline{V\_GND} = \overline{BUFFER\_V}$   
T\_GND = BUFFER\_T

and the OP\_CODE shall be nulled.  
OP\_CODE = 0000000

Once the special high-rate special processing has been performed by the ground uplink software, additional low-rate special processing is required to be performed at a particular point during execution of the next navigation cycle. Detailed requirements for the low-rate special processing requirements are presented in Section 4.2.3.1.

B. Interface Requirements. The input/output required for the high-rate special processing software are listed in Table 4.9.1-2. Required input and output for low-rate special processing software are listed in Table 4.2.3.1.

C. Processing Requirements. The high rate special processing detailed in this section shall be performed at a fast enough rate so that if two command uplinks (orbiter and target) are transmitted between navigation cycles, both sets of data (including the DO\_OV\_UPLINK and DO\_TV\_UPLINK flags) will be available to the low-rate (NAV) special processing software. The low-rate special processing (Section 4.2.3.1) shall be performed during a navigation cycle prior to the Normal State Vector Propagation and, during rendezvous navigation phases, Covariance Matrix Propagation subfunctions.

D. Constraints. Because of a system software requirement to clear uplink data buffers in a relatively short amount of time, and because of the relatively slow rate at which the Onorbit/Rendezvous Navigation principal function will be operating, a fast-rate special processing function is required to buffer off the data and set flags. There is also a requirement to be able to update both the orbiter and the target states in a single navigation cycle, if such data has been uplinked.

E. Supplementary Information. A suggested implementation of the orbiter state vector formatted load special processing requirements in the form of detailed flow charts, are presented in Section 5.5 under:

ORBITER\_STATE\_VECTOR\_UPLINK (high-rate special processing)

Table 4.9.1-1. Orbiter State Vector Uplink Data Format					
Level B Mnemonic	Uplink Buffer Data		Command Word	Data Type	Units
	Name	Description			
	BUFFER_R <sub>1</sub>	X-Position in M50 coord	CW3, CW4	DF	ft
	BUFFER_R <sub>2</sub>	Y-Position in M50 coord	CW5, CW6	DF	ft
	BUFFER_R <sub>3</sub>	Z-Position in M50 coord	CW7, CW8	DF	ft
	BUFFER_V <sub>1</sub>	X-Velocity in M50 coord	CW9	SF	ft/sec
	BUFFER_V <sub>2</sub>	Y-Velocity in M50 coord	CW10	SF	ft/sec
	BUFFER_V <sub>3</sub>	Z-Velocity in M50 coord	CW11	SF	ft/sec
	BUFFER_T	Time Tag in GMT	CW1, CW2	DF	sec

Table 4.9.1-2.Orbiter State Vector Uplink Input/Output

Variable Name	Input Source	Output Destination
$\overline{\text{BUFFER\_R}}$	GROUND UPLINK PROCESSOR	
$\overline{\text{BUFFER\_V}}$	GROUND UPLINK PROCESSOR	
$\text{BUFFER\_T}$	GROUND UPLINK PROCESSOR	
$\text{DO\_OV\_UPLINK}$		NAV_ONORBIT_RENDEZVOUS
$\overline{\text{R\_GND}}$		ONORBIT_REND_AUTO_INFLIGHT_UPDATE
$\text{T\_GND}$		ONORBIT_REND_AUTO_INFLIGHT_UPDATE
$\overline{\text{V\_GND}}$		ONORBIT_REND_AUTO_INFLIGHT_UPDATE

#### 4.9.2 Rendezvous Vehicle State Vector Uplink Parameters (RENDEZVOUS\_STATE\_VECTOR\_UPLINK)

The parameters to be candidates for change via command uplink associated with the rendezvous vehicle state vector update include the rendezvous vehicle M50 position and velocity vectors, and the associated time tag.

A. Detailed Requirements. The rendezvous vehicle M50 position and velocity vectors can be changed via a formatted load structured as described in Table 4.9.2-1. Each load contains a time tag (GMT) associated with the state vector. The following high-rate special processing is required upon receipt of a rendezvous vehicle state vector command uplink load.

1. A bit-string (OP\_CODE) shall have been set to the “rendezvous vehicle state vector” OP\_CODE value (0001010) by the ground uplink processing software when data are received from the ground.
2. The bit string (OP\_CODE) shall first be tested by the special processing software to determine if it equals the value specified for the rendezvous vehicle state uplink,

OP\_CODE = 0001010

3. If the above is true, a flag (DO\_TV\_UPLINK), shall be set to ON, and the rendezvous vehicle state vector and associated time tag shall be stored in special locations:

DO\_TV\_UPLINK = ON  
 $\bar{R}_{TV\_GND} = \bar{BUFFER\_RT}$   
 $\bar{V}_{TV\_GND} = \bar{BUFFER\_VT}$   
T\_TV\_GND = BUFFER\_TT

and the OP\_CODE shall be nulled signifying that the state vector has been transferred to the locations:

OP\_CODE = 0000000

Once the above high-rate special processing has been performed by the ground uplink software, additional low-rate special processing is required to be performed at a particular point during execution of the next navigation cycle. This latter class of special processing will actually reinitialize the rendezvous vehicle state vector using the uplinked data.

Detailed requirements for this (low-rate) portion of the special processing requirements are presented in Section 4.2.3.1.

B. Interface Requirements. The input and output required for the high-rate special processing software are listed in Table 4.9.2-2. Input and output for the low-rate special processing software are listed in Table 4.2.3.1.

C. Processing Requirements. The high-rate special processing detailed in this section shall be performed at a fast enough rate so that if two command uplinks (orbiter and/or target) are transmitted between navigation cycles, both data sets (including the DO\_OV\_UPLINK and DO\_TV\_UPLINK flags) will be available to the low-rate (NAV) special processing software. The low-rate special processing (Section 4.2.3.1) shall be performed during a navigation cycle prior to Normal State Vector Propagation and, during rendezvous, Covariance Matrix Propagation subfunctions.

D. Constraints. Because of a system software requirement to clear uplink data buffers in a relatively short amount of time, and because of the relatively slow rate at which the Onorbit/Rendezvous Navigation principal function will be operating, a fast-rate special processing function is required to buffer off the data and set flags. There is also a requirement to be able to update both the orbiter and rendezvous vehicle state vectors on a single navigation cycle if such data have been uplinked.

E. Supplementary Information. A suggested implementation of the formatted rendezvous vehicle state vector load special processing requirements, in the form of detailed flow charts are presented in Section 5.5 under:

RENDEZVOUS\_STATE\_VECTOR\_UPLINK (high-rate special processing)

Table 4.9.2-1. Rendezvous Vehicle State Vector Uplink Data Format					
Level B Mnemonic	Uplink Buffer Data		Command Word	Data Type	Units
	Name	Description			
	BUFFER_RT <sub>1</sub>	X-Position in M50 coord	CW3, CW4	DF	ft
	BUFFER_RT <sub>2</sub>	Y-Position in M50 coord	CW5, CW6	DF	ft
	BUFFER_RT <sub>3</sub>	Z-Position in M50 coord	CW7, CW8	DF	ft
	BUFFER_VT <sub>1</sub>	X-Velocity in M50 coord	CW9	SF	ft/sec
	BUFFER_VT <sub>2</sub>	Y-Velocitiy in M50 coord	CW10	SF	ft/sec
	BUFFER_VT <sub>3</sub>	Z-Velocity in M50 coord	CW11	SF	ft/sec
	BUFFER_TT	Time Tag in GMT	CW1, CW2	DF	sec

Table 4.9.2-2. Rendezvous Vehicle State Vector Uplink Input/Output		
Variable Name	Input Source	Output Destination
$\overline{\text{BUFFER\_RT}}$	GROUND UPLINK PROCESSOR	
$\overline{\text{BUFFER\_VT}}$	GROUND UPLINK PROCESSOR	
BUFFER_TT	GROUND UPLINK PROCESSOR	
DO_TV_UPLINK		NAV_ONORBIT_RENDEZVOUS
$\overline{\text{R\_TV\_GND}}$		ONORBIT_REND_AUTO_INFLIGHT_UPDATE
$\overline{\text{V\_TV\_GND}}$		ONORBIT_REND_AUTO_INFLIGHT_UPDATE
T_TV_GND		ONORBIT_REND_AUTO_INFLIGHT_UPDATE

### 4.9.3 Vent/RCS Body Force Vector Uplink Parameters (VENT\_RCS\_MODEL\_PARAM\_UPLINK)

The parameters to be candidates for change via the vent/RCS thrusting uplink command load include a body contact force  $\bar{V}FORCE$ , to account for venting and uncoupled RCS thrusting and other body contact forces if desired, and the associated action ON/OFF times (TFON and TFOFF). These data are specified by permission I-load values (see Section 4.7) or uplinked to be used by the Onorbit/Rendezvous Navigation principal function in both OPS 2 and OPS 8.

#### ONORBIT\_RENDEZVOUS\_NAV

A. Detailed Requirements. The values of the body contact force ( $\bar{V}FORCE$ ) and associated on-off times (TFON and TFOFF) may be changed via a formatted command load structured as described in Table 4.9.3-1. The following processing will be initiated upon receipt of a Vent/RCS uplink from the ground.

1. A bit-string (OP\_CODE) shall have been set to the “vent/RCS body force vector uplink” OP\_CODE value (0101001) by the ground uplink processing software when data are received from the ground.
2. The bit-string (OP\_CODE) shall first be tested by the processing software to determine if it equals the value specified for a vent/RCS uplink:

OP\_CODE = 0101001

3. If the above is true, the vent/RCS body contact force vector,  $\bar{V}FORCE$ , and ON/OFF action times (TFON/TFOFF) shall be stored in special locations:

$\bar{V}FORCE = \bar{BUFFER}_B$   
TFON = BUFFER\_O<sub>1</sub>  
TFOFF = BUFFER\_O<sub>2</sub>

and the OP\_CODE shall be nulled.  
OP\_CODE = 0000000

B. Interface Requirements. The input and output required for a vent/RCS uplink are shown in Table 4.9.3-2.

C. Processing Requirements. The uplink vent/RCS command load will cause revision of all entries; i.e.,

$\bar{V}FORCE$   
TFON  
TFOFF

For this reason, all entries of the vent/RCS command load shall be filled with their desired values (those values desired immediately after the completion of the uplink) even if some of the entries are to remain the same.

D. Constraints. None

E. Supplementary Information. A suggested implementation of the vent/RCS body contact force parameter uplink in the form of a detailed flow chart (VENT\_RCS\_MODEL\_PARAM\_UPLINK) is presented in Section 5.5.

Table 4.9.3-1. Vent/RCS Body Force Vector Uplink Data Format						
Level B Mnemonic	Uplink Buffer Data			Command Word	Data Type	Units
	Name	Description				
	BUFFER_B <sub>1</sub>	Vent/RCS X–Body force	in	CW5	SF	lb
	BUFFER_B <sub>2</sub>	Vent/RCS Y–Body force	body	CW6	SF	lb
	BUFFER_B <sub>3</sub>	Vent/RCS Z–Body force	coord	CW7	SF	lb
	BUFFER_O <sub>1</sub>	Vent/RCS ON time		CW1, CW2	DF	sec
	BUFFER_O <sub>2</sub>	Vent/RCS OFF time		CW3, CW4	DF	sec

Table 4.9.3-2. Vent/RCS Body Force Vector Uplink Input/Output		
Variable Name	Input Source	Output Destination
$\bar{B}$ UFFER_B	GROUND UPLINK PROCESSOR	
BUFFER_O <sub>1</sub>	GROUND UPLINK PROCESSOR	
BUFFER_O <sub>2</sub>	GROUND UPLINK PROCESSOR	
$\bar{V}$ FORCE		$\bar{A}$ CCEL_ONORBIT
TFON		$\bar{A}$ CCEL_ONORBIT
TFOFF		$\bar{A}$ CCEL_ONORBIT

#### 4.9.4 Drag Model Scale Factors Uplink Parameters (DRAG\_MODEL\_PARAM\_UPLINK)

The Orbiter and rendezvous target drag model scale factors, KFACTOR and TARGET\_KFACTOR, can be changed via uplink. Command load uplink of these parameters provides a means to adjust, if necessary, the Orbiter and/or target vehicle drag model coefficients during their respective state propagation modes. The drag model is used by the Onorbit/Rendezvous Navigation principal function during OPS 2 and OPS 8 for the Orbiter and OPS 2 for the target.

##### ONORBIT\_RENDEZVOUS\_NAV

A. Detailed Requirements. The values of the Orbiter and rendezvous target drag model scale factors (KFACTOR and TARGET\_KFACTOR) can be changed via a command load structured as described in Table 4.9.4-1. The following processing shall be initiated upon receipt of a drag model scale factors uplink from the ground.

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1. A bit-string (OP\_CODE) shall have been set to the “drag model scale factors uplink” OP\_CODE (0101010) by the ground uplink processing software when data are received from the ground.
2. The bit-string (OP\_CODE) shall first be tested by the processing software to determine if it equals the value specified for a drag model scale factors uplink.

OP\_CODE = 0101010

3. If the above is true, the uplinked Orbiter and target drag model scale factors shall be stored in special locations:

KFACTOR = BUFFER\_K  
TARGET\_KFACTOR = BUFFER\_K\_TGT

and the OP\_CODE shall be nulled.  
OP\_CODE = 0000000

B. Interface Requirements. The input and output required for a drag model scale factors uplink are shown in Table 4.9.4-2.

C. Processing Requirements. None

D. Constraints. None

E. Supplementary Information. A suggested implementation of the drag model scale factors update capability is presented in Section 5.5 in the form of a detailed flow chart, DRAG\_MODEL\_PARAM\_UPLINK. The Drag Model Scale Factors uplink is valid in OPS 2 and OPS 8, but the TARGET\_KFACTOR is not used in OPS 8, as the target state is available only in OPS 2. Uplinked Drag Model Scale Factors are not carried across OPS 2 - 8 or OPS 8 - 2 transitions. New values, if required, must be re-uplinked following these OPS transitions.



Table 4.9.4-1. Drag Model Scale Factors Uplink Data Format					
Level B Mnemonic	Uplink Buffer Data		Command Word	Data Type	Units
	Name	Description			
	BUFFER_K	Orbiter Drag Model Scale Factor	CW1	SF	n.d.
	BUFFER_K_TGT	Target Drag Model Scale Factor	CW2	SF	n.d.

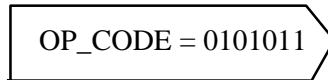
Table 4.9.4-2. Drag Model Scale Factors Uplink Input/Output		
Variable Name	Input Source	Output Destination
BUFFER_K	GROUND UPLINK PROCESSOR	$\overline{\text{ACCEL\_ONORBIT}}$ $\overline{\text{ACCEL\_ONORBIT}}$
BUFFER_K_TGT	GROUND UPLINK PROCESSOR	
KFACTOR		
TARGET_KFACTOR		

#### 4.9.5 Covariance Matrix Uplink Parameters (COV\_MATRIX\_PARAM\_UPLINK)

The parameters to be candidates for change via uplink associated with the covariance matrix update include diagonal elements (standard deviations) of the filter state covariance matrix in UVW coordinates and selected correlation coefficients.

A. Detailed Requirements. Values of the prestored (I-load) UVW covariance matrix can be changed via a formatted command load structured as described in Table 4.9.5-1. Each load will contain data entries to replace the values of the UVW standard deviations (SIG\_UPDATE). Detailed descriptions of these parameters can be found in Section 4.1.2.2.1.1 and Section 4.7. The following processing is required upon receipt of the covariance matrix uplink command load.

1. A bit-string (OP\_CODE) shall have been set to the “covariance matrix uplink” OP\_CODE (0101011) by the ground uplink processing software when data are received from the ground.
2. The bit-string (OP\_CODE) shall first be tested by the processing software to determine if it equals the value specified for a covariance matrix uplink:



3. If the above is true, the standard deviations (SIG\_UPDATE) and correlation coefficients (COV\_COR\_UPDATE) shall be stored in special locations:

SIG\_UPDATE = BUFFER\_S

COV\_COR\_UPDATE = BUFFER\_C

and the OP\_CODE shall be nulled.

OP\_CODE = 0000000

B. Interface Requirements. The input and output required for covariance matrix parameters uplink can be found in Table 4.9.5-2.

C. Processing Requirements. Changes to SIG\_UPDATE and COV\_COR\_UPDATE will be made each time the covariance matrix parameters uplink is performed.

D. Constraints. The user shall perform the covariance matrix uplink prior to the state vector uplink when rendezvous navigation is active and it is desired that the uplinked covariance matrix parameters be incorporated along with an uplinked state vector.

E. Supplementary Information. A suggested implementation of the covariance matrix parameters uplink in the form of a detailed flow chart (COV\_MATRIX\_PARAM\_UPLINK) is presented in Section 5.5.

Table 4.9.5-1. Covariance Matrix Uplink Data Format					
Level B Mnemonic	Uplink Buffer Data		Command Word	Data Type	Units
	Name	Description			
	BUFFER_S <sub>1</sub>	U position standard deviation	CW1	SF	ft
	BUFFER_S <sub>2</sub>	V position standard deviation	CW2	SF	ft
	BUFFER_S <sub>3</sub>	W position standard deviation	CW3	SF	ft
	BUFFER_S <sub>4</sub>	U velocity standard deviation	CW4	SF	ft/sec
	BUFFER_S <sub>5</sub>	V velocity standard deviation	CW5	SF	ft/sec
	BUFFER_S <sub>6</sub>	W velocity standard deviation	CW6	SF	ft/sec
	BUFFER_C <sub>1</sub>	U-V correlation coeff	CW7	SF	-
	BUFFER_C <sub>2</sub>	U- $\dot{U}$ correlation coeff	CW8	SF	-
	BUFFER_C <sub>3</sub>	U- $\dot{V}$ correlation coeff	CW9	SF	-
	BUFFER_C <sub>4</sub>	V- $\dot{U}$ correlation coeff	CW10	SF	-
	BUFFER_C <sub>5</sub>	V- $\dot{V}$ correlation coeff	CW11	SF	-
	BUFFER_C <sub>6</sub>	W- $\dot{W}$ correlation coeff	CW12	SF	-
	BUFFER_C <sub>7</sub>	$\dot{U}$ - $\dot{V}$ correlation coeff	CW13	SF	-

Table 4.9.5-2. Covariance Matrix Uplink Input/Output		
Variable Name	Input Source	Output Destination
BUFFER_S	GROUND UPLINK PROCESSOR	COVINIT_UVW COVINIT_UVW
BUFFER_C	GROUND UPLINK PROCESSOR	
SIG_UPDATE		
COV_COR_UPDATE		

#### 4.9.6 RNP Matrix Time Parameters Uplink (OP\_CODE = 0111011)

The flight software shall provide the capability to update the RNP Matrix time parameters via uplink in OPS 9, MM201, and MM301. When an RNP Matrix Time Parameters uplink is received, the RNP Matrix I-Loads LAUNCH\_YEAR and RNP\_DAY shall be replaced by their uplinked values, the uplink OP\_CODE shall be reset, and the RNP\_TIME\_UL flag shall be set ON so that Orbit Navigation will call the RNP MAT COMP function to compute new values for the RNP matrix data.

A. Detailed Requirements. Check to see if the RNP Matrix Time Parameters have been uplinked (indicated by the uplink OP\_CODE being set to 0111011). If so, the following actions shall be taken. The

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I-Load parameters LAUNCH\_YEAR and RNP\_DAY shall be set equal to their uplinked values. The uplink OP\_CODE shall be set to 0000000 to prevent repeated processing of the uplink. Finally, the RNP\_TIME\_UL flag shall be set ON, indicating that the RNP MAT COMP function must be called by Orbit Navigation to re-compute the RNP matrix data (M\_M50TOEF\_AT\_EPOCH, T\_EPOCH, and EARTH\_POLE) based on the uplinked values for LAUNCH\_YEAR and RNP\_DAY.

```
IF OP_CODE = 0111011 THEN
  LAUNCH_YEAR = LAUNCH_YEAR_UL
  RNP_DAY = RNP_DAY_UL
  OP_CODE = 0000000
  RNP_TIME_UL = ON
```

B. Interface Requirements. The following list of parameters may be uplinked:

RNP Matrix Time Parameters Load			
M/S ID No.	FSSR Name	Nomenclature	Type
V97U5383C	LAUNCH_YEAR_UL	LAUNCH YEAR FOR RNP MATRIX CALC	INT
V97U5384C	RNP_DAY_UL	DAY OF YEAR FOR RNP MATRIX CALC	INT

The following table contains the input/output data for the RNP Matrix Time Parameters uplink:

RNP Matrix Time Parameters Uplink Input/Output		
Variable Name	Input Source	Output Destination
OP_CODE	GROUND UPLINK PROCESSOR	GROUND UPLINK PROCESSOR RNP MAT COMP (G4.16) RNP MAT COMP (G4.16) ORB/RNDZ NAV (G4.126)
LAUNCH_YEAR_UL	GROUND UPLINK PROCESSOR	
RNP_DAY_UL	GROUND UPLINK PROCESSOR	
OP_CODE		
LAUNCH_YEAR		
RNP_DAY		
RNP_TIME_UL		

C. Processing Requirements. The flag RNP\_TIME\_UL is initially set OFF.

D. Constraints. The RNP matrix time parameters uplink processing is only supported in OPS 9, MM201 and MM301.

E. Supplementary Information. A suggested implementation of these requirements is illustrated as a flowchart (RNP\_MATRIX\_TIME\_UPLINK\_PROCESSING) in Section 5.5.

**4.9.7 Deleted**

**4.9.8 Deleted**

## 4.10 COORDINATE TRANSFORMATIONS

These nine subfunctions provide the capability for transforming parameters specified (or computed) in one coordinate system to another coordinate system. Coordinate system definitions are provided in Section 5.3.

Each of the nine subfunctions described in Sections 4.10.2 through 4.10.10 may be executed separately. With two exceptions, these subfunctions do not actually perform the coordinate transformation; only the rotation matrix is computed. The two exceptions convert between Earth-fixed coordinates and geodetic parameters.

For consistency, it is assumed that all coordinate systems located on the surface of the Earth are specified in terms of geodetic parameters (i.e., geodetic latitude, longitude, and altitude above the reference ellipsoid) and that all azimuth angles are referenced to true (not magnetic) north.

### 4.10.1 Deleted

### 4.10.2 Earth-Fixed to M50 (EARTH\_FIXED\_TO\_M50\_COORD)

The purpose of this subfunction is to propagate the matrix  $M\_M50TOEF\_AT\_EPOCH$  from the last epoch time to the time of interest. This propagation accounts for the Earth's daily rotation effects only. (The nutation and precession computations are lengthy.)

Note:  $M\_M50TOEF\_AT\_EPOCH$  is also referred to as the RNP matrix. It is the transformation from the mean equator and equinox of 1950 to the true equator and Greenwich meridian of date. This transformation accounts for the earth's rotation, nutation, and precession from the beginning of the Besselian year 1950 to the Julian date derived from  $T\_EPOCH$  and the year of launch. The RNP matrix and its  $T\_EPOCH$  are computed by the RNP Matrix Computation principal function (G4.16) during GN&C OPS 9 and made available to the remaining GN&C OPS sequences via the Major Function Base (MFB). The MFB contains data and code that are not part of the OPS overlay. If necessary, the RNP matrix and  $T\_EPOCH$  may be re-computed in GN&C OPS 9 following a MFB overlay, or during GN&C OPS 2 or GN&C OPS 3 initialization for inflight GPC recovery where the MFB has been overlaid. The RNP matrix data must also be recomputed by executing the RNP MAT COMP function following an uplink of the RNP Matrix Time parameters (see section 6.3.65) of SS-P-0002-140, the Downlist/Uplink CPDS). Section 4.11 of FSSR STS 83-0005, Ascent/RTLS Navigation contains a detailed description of the RNP MAT COMP principal function.

The Earth-fixed coordinate frame of the time of interest is rotated about its Z-axis to obtain the Earth-fixed coordinate frame of the time of the  $M\_M50TOEF\_AT\_EPOCH$  matrix. The angle of rotation is the product of the Earth's mean rotational rate relative to the mean of data system and the difference between the matrix's time tag and the time of interest. A matrix that represents this Z-axis rotation is calculated. The matrix that represents the transformation from the Earth-fixed frame of the last epoch time to the mean of 1950 frame is the  $M\_M50TOEF\_AT\_EPOCH$  matrix's transpose. Then the desired Earth-fixed-to-mean of 1950 matrix is the product of the transpose of the  $M\_M50TOEF\_AT\_EPOCH$  matrix postmultiplied by the Z-axis rotation matrix.

A. Detailed Requirements. This function is designated in calling routines as

EARTH\_FIXED\_TO\_M50\_COORD(TIME)

where TIME — time of interest measured from the beginning of the particular mission year

EARTH\_FIXED\_TO\_M50\_COORD — Earth fixed to mean of 1950 coordinate transformation matrix of the time of interest

The following steps shall be performed (in the order indicated):

1. The time difference from the epoch time to the current time is calculated:

$$\text{DELTA} = \text{TIME} - \text{T\_EPOCH}$$

(T\_EPOCH is the epoch time).

2. The angle of rotation about the Earth-fixed axis is obtained.

$$\text{LAM} = \text{EARTH\_RATE DELTA}$$

3. The Earth-fixed Z-axis rotation matrix is then defined:

F9

$$M = \begin{pmatrix} \cos(\text{LAM}) & -\sin(\text{LAM}) & 0 \\ \sin(\text{LAM}) & \cos(\text{LAM}) & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

F9 This equation shall be protected against return value sine or cosine with magnitude greater than unity (reference 3.5).

4. The Earth-fixed to mean of 1950 coordinate transformation matrix is then computed as follows:

$$\text{EARTH\_FIXED\_TO\_M50\_COORD} = M\_M50TOEF\_AT\_EPOCH^T M$$

Because of the sparseness of the matrix M, both core and execution time will be conserved by use of the following formulation: For notational convenience, let N denote the matrix M\_M50TOEF\_AT\_EPOCH. The sine and cosine of LAM will be computed once and denoted by CLAM = COS (LAM) and SLAM = SIN (LAM). Then EARTH\_FIXED\_TO\_M50\_COORD will be computed as follows:

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{1,1} = N_{1,1} \text{ CLAM} + N_{2,1} \text{ SLAM}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{1,2} = -N_{1,1} \text{ SLAM} + N_{2,1} \text{ CLAM}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{1,3} = N_{3,1}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{2,1} = N_{1,2} \text{ CLAM} + N_{2,2} \text{ SLAM}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{2,2} = -N_{1,2} \text{ SLAM} + N_{2,2} \text{ CLAM}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{2,3} = N_{3,2}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{3,1} = N_{1,3} \text{ CLAM} + N_{2,3} \text{ SLAM}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{3,2} = -N_{1,3} \text{ SLAM} + N_{2,3} \text{ CLAM}$$

$$\text{EARTH\_FIXED\_TO\_M50\_COORD}_{3,3} = N_{3,3}$$

B. Interface Requirements. The input and output data are shown in Table 4.10.2.

C. Processing Requirements. This function may be executed as needed. The time (TIME) at which the output transformation matrix (EARTH\_FIXED\_TO\_M50\_COORD) is desired must be supplied by the user in elapsed seconds from the beginning of the year of mission commencement.

A valid M\_M50TOEF\_AT\_EPOCH must be available before this subfunction can be executed.

D. Constraints. None

E. Supplementary Information. The Aries mean of 1950 and the Earth-fixed coordinate systems are shown in Section 5.3. A suggested implementation in the form of a detailed flow chart may be found in Section 5.3 under the name:

EARTH\_FIXED\_TO\_M50\_COORD FUNCTION

Table 4.10.2. EARTH_FIXED_TO_M50_COORD Function Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
TIME	T	ACCEL_ONORBIT FUNCTION ONORBIT_USER_PARAMETER_ CALCULATIONS	
TIME	T_STATE		
Variable Name		Input Source	Output Destination
EARTH_RATE		**	ACCEL_ONORBIT FUNCTION, ONORBIT_USER_PARAMETER_ CALCULATIONS
M_M50TOEF_AT_EPOCH		RNP MAT COMP	
T_EPOCH		RNP MAT COMP	
†			
† Only the values of EARTH_FIXED_TO_M50_COORD's elements are passed to output destination.			
** Initialization parameters, see Section 4.7			

### 4.10.3 Geodetic to Earth-Fixed (GEODETTIC\_TO\_EF)

This submodule accepts the geodetic parameters of a point and computes the Earth-fixed Cartesian coordinates of that point.

A. Detailed Requirements. This function is addressed in calling modules as

GEODETTIC\_TO\_EF(LAT\_GEOD,LON,ALT)

This function is referred to internally as

GEODETTIC\_TO\_EF(LAT\_GEOD,LON,ALT) =  $\bar{R}_{EF}$

where

ALT	—	altitude above reference ellipsoid of point of interest
LAT_GEOD	—	geodetic latitude of point of interest
LON	—	longitude of point of interest
$\bar{R}_{EF}$	—	Earth-fixed position vector of point of interest

These equations shall transform the geodetic parameters to Earth-fixed coordinates:

$$R_{EF1} = \left[ \frac{EARTH\_RADIUS\_EQUATOR}{[\cos^2(LAT\_GEOD) + (1 - ELLIPT)^2 \sin^2(LAT\_GEOD)]^{1/2}} + ALT \right] \bullet$$

F3  
F9, F4

$$\cos(LAT\_GEOD) \cos(LON)$$

$$R_{EF2} = \left[ \frac{EARTH\_RADIUS\_EQUATOR}{[\cos^2(LAT\_GEOD) + (1 - ELLIPT)^2 \sin^2(LAT\_GEOD)]^{1/2}} + ALT \right] \bullet$$

F3  
F9, F4

$$\cos(LAT\_GEOD) \sin(LON)$$

$$R_{EF3} = \left[ \frac{(1 - ELLIPT)^2 EARTH\_RADIUS\_EQUATOR}{[\cos^2(LAT\_GEOD) + (1 - ELLIPT)^2 \sin^2(LAT\_GEOD)]^{1/2}} + ALT \right] \bullet$$

F3  
F9, F4

$$\sin(LAT\_GEOD)$$

F3 This equation shall be protected against division by zero (reference 3.5).

F4 This equation shall be protected against square roots of a negative number (reference 3.5).

F9 This equation shall be protected against return value of sine or cosine with magnitude greater than unity (reference 3.5).

B. Interface Requirements. The input and output data are shown in table 4.10.3.

C. Processing Requirements. The input angles must be in radians.



D. Constraints. None

E. Supplementary Information. The geodetic parameter set and the Earth-fixed coordinate system are illustrated in Section 5.3. A suggested implementation in the form of a detailed flow chart may be found in Section 5.3 under the name:

GEODETTIC\_TO\_EF FUNCTION

Table 4.10.3. GEODETTIC_TO_EF Function Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
ALT		Various Users	
LAT_GEOD		Various Users	
LON		Various Users	
$\bar{R}_{EF}$	†		Various Users
Variable Name		Input Source	Output Destination
EARTH_RADIUS_EQUATOR		**	
ELLIPT		**	
† Only the values of $\bar{R}_{EF}$ 's components are passed to output destination. ** Initialization parameters, see Section 4.7.			

**4.10.4 Earth-Fixed to Topodetic (EF\_TO\_TOPDET)**

This subfunction accepts the geodetic latitude and longitude of a point in radians and computes the rotation matrix from Earth-fixed coordinates to a topodetic coordinate system for the input location.

Formulation: This subfunction creates the rotation matrix as an Euler Z, Y sequence through the longitude angle (LON) and the geodetic latitude angle plus 90 degrees ( $LAT\_GEOD + \pi/2$ ), respectively.

A. Detailed Requirements. Calling modules address this function as

EF\_TO\_TOPDET(LAT\_GEOD, LON)

This function is referred to internally as

EF\_TO\_TOPDET(LAT\_GEOD, LON) = M

where

LAT_GEOD	—	geodetic latitude of point of interest
LON	—	longitude of point of interest
M	—	desired Earth-fixed to topodetic coordinate transformation matrix

The transformation matrix shall be calculated as shown here:

$$M = \begin{bmatrix} (-\cos LON \sin LAT\_GEOD) & (-\sin LON \sin LAT\_GEOD) & (\cos LAT\_GEOD) \\ (-\sin LON) & (\cos LON) & 0 \\ (-\cos LON \cos LAT\_GEOD) & (-\sin LON \cos LAT\_GEOD) & (-\sin LAT\_GEOD) \end{bmatrix} \quad F9$$

F9 This equation shall be protected against return value of sine or cosine with magnitude greater than unity (reference 3.5).

B. Interface Requirements. The input and output data are shown in Table 4.10.4.

C. Processing Requirements. The input variables must be in radians.

D. Constraints. None.

E. Supplementary Information. The Earth-fixed and topodetic coordinate systems, and a suggested implementation of this module are provided in Section 5.3. A suggested implementation in the form of a detailed flow chart may be found in Section 5.3 under the name:

EF\_TO\_TOPDET FUNCTION

Table 4.10.4. EF_TO_TOPDET Function Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
LAT_GEOD	LAT_GEOD	EF_TO_RUNWAY FUNCTION	EF_TO_RUNWAY FUNCTION
LON	LON	EF_TO_RUNWAY FUNCTION	
M	*		
* Only the values of M's elements are passed to output destination.			

#### 4.10.5 Earth-Fixed to Runway (EF\_TO\_RUNWAY)

This subfunction accepts the geodetic latitude, longitude, and azimuth of the runway and computes the rotation matrix from the Earth-fixed coordinate system to the runway coordinate system.

Formulation: The Earth-fixed to Topodetic subfunction is used to obtain an Earth-fixed to topodetic rotation matrix. Then the Earth-fixed to topodetic matrix is multiplied by an Euler Z rotation matrix through the runway azimuth angle (AZ), measured from true north to the +X-axis of the runway.

A. Detailed Requirements. Other routines designate this function as

EF\_TO\_RUNWAY(LAT\_GEOD,LON,AZ)

in which	LAT_GEOD	— runway's geodetic latitude
	LON	— runway's longitude
	AZ	— runways azimuth
	EF_TO_RUNWAY	— desired Earth-fixed to runway coordinate transformation matrix

The following steps shall be performed (in the order indicated):

1. The Euler Z rotation matrix is calculated.

$$M = \begin{bmatrix} (\cos AZ) & (\sin AZ) & 0 \\ (-\sin AZ) & (\cos AZ) & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad F9$$

F9 This equation shall be protected against return value of sine or cosine with magnitude greater than unity (reference 3.5).

2. The Earth-Fixed to Topodetic subfunction is called and its rotation matrix is premultiplied by the Euler Z rotation matrix to produce the Earth-fixed to runway rotation matrix.

EF\_TO\_RUNWAY = M EF\_TO\_TOPDET(LAT\_GEOD, LON)

B. Interface Requirements. The input and output data are shown in Table 4.10.5.

C. Processing Requirements. Input angles must be in radians.

D. Constraints. None.

E. Supplementary Information. The Earth-fixed, runway, and topodetic coordinate systems are shown in Section 5.3. A suggested implementation in the form of a detailed flow chart may be found in Section 5.3 under the name:

EF\_TO\_RUNWAY FUNCTION

Table 4.10.5. EF_TO_RUNWAY Function Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
AZ	AZ	EF_TO_SCANNER FUNCTION	
LAT_GEOD	LAT_GEOD	EF_TO_SCANNER FUNCTION	
LON	LON	EF_TO_SCANNER FUNCTION	
Variable Name		Input Source	Output Destination
	†	EF_TO_TOPDET(LAT_GEOD,LON)	
	†		EF_TO_SCANNER FUNCTION
† Only EF_TO_TOPDET's element values are passed from input source, and only values of EF_TO_RUNWAY's elements are passed to output destination.			

#### 4.10.6 Earth-Fixed to Scanner (EF\_TO\_SCANNER)

The purpose of this subfunction is to compute the rotation matrix from Earth-fixed to scanner coordinates.

Formulation: The Earth-Fixed to Runway subfunction is executed, with use of the geodetic latitude and longitude of the scanner and the azimuth of the scanner boresight (AZ) from the true north, to obtain a rotation matrix.

The rotation matrix is then multiplied by a rotation matrix representing a 180-degree rotation about the X-axis.

A. Detailed Requirements. This function is designated.

EF\_TO\_SCANNER(LAT\_GEOD,LON,AZ)

in calling routines.  
where

LAT_GEOD	—	geodetic latitude of scanner
LON	—	longitude of scanner
AZ	—	azimuth of scanner boresight
EF_TO_SCANNER	—	desired Earth-fixed to scanner coordinate transformation matrix

This step shall be performed:

This evaluation of the Earth-Fixed to Runway subfunction is premultiplied by the 180 degree X-axis rotation matrix

$$M = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{pmatrix}$$

to obtain the Earth-fixed to scanner rotation matrix.

EF\_TO\_SCANNER = M EF\_TO\_RUNWAY(LAT\_GEOD, LON, AZ)

B. Interface Requirements. The input and output data are given in Table 4.10.6.

C. Processing Requirements. Input angles must be in radians.

D. Constraints. None.

E. Supplementary Information. The scanner, runway, topodetic, and Earthfixed coordinate systems are shown in Section 5.3. A suggested implementation in the form of a detailed flow chart may be found in Section 5.3 under the name:

EF\_TO\_SCANNER FUNCTION

Table 4.10.6. EF_TO_SCANNER Function Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
AZ		Various Users	
LAT_GEOD		Various Users	
LON		Various Users	
Variable Name		Input Source	Output Destination
	†	EF_TO_RUNWAY(LAT_GEOD,LON,AZ)	
	†		Various Users
† Only the values of EF_TO_RUNWAY's elements are passed from input source; and only the values of EF_TO_SCANNER's elements are passed to output destination.			

#### 4.10.7 Transformation From Structural Body to M50 Coordinates (SBODY\_TO\_M50)

The transformation matrix from structural body to M50 coordinates (MAT) is computed by postmultiplying the transformation matrix from body to M50 coordinates by a matrix representing a 180-degree rotation about the Y-axis.

The transformation from body to M50 coordinates is the transpose of the matrix derived from the quaternion Q\_FIFTY\_BODY by employing the special-purpose matrix function QUAT\_TO\_MAT.

A. Detailed Requirements. This subfunction is called with the following internal variables in the IN LIST and the OUT LIST:

IN LIST: Q\_FIFTY\_BODY

OUT LIST: MAT

where Q\_FIFTY\_BODY mean of 1950 to body rotation quaternion

MAT desired structural body to mean of 1950 coordinate transformation matrix.

The following steps shall be performed (in the order indicated):

1. The special-purpose matrix function QUAT\_TO\_MAT is called to obtain a mean of 1950 to body rotation matrix.

$$\text{MATRIX} = \text{QUAT\_TO\_MAT} (\text{Q\_FIFTY\_BODY})$$

2. Rotate the transpose of the output matrix 180° about the Y-axis.

$$\begin{aligned} \text{MAT}_{1,1} &= -\text{MATRIX}_{1,1} \\ \text{MAT}_{1,2} &= \text{MATRIX}_{2,1} \\ \text{MAT}_{1,3} &= -\text{MATRIX}_{3,1} \\ \text{MAT}_{2,1} &= -\text{MATRIX}_{1,2} \\ \text{MAT}_{2,2} &= \text{MATRIX}_{2,2} \\ \text{MAT}_{2,3} &= -\text{MATRIX}_{3,2} \\ \text{MAT}_{3,1} &= -\text{MATRIX}_{1,3} \\ \text{MAT}_{3,2} &= \text{MATRIX}_{2,3} \\ \text{MAT}_{3,3} &= -\text{MATRIX}_{3,3} \end{aligned}$$

B. Interface Requirements. Input and output parameters are listed in Table 4.10.7.

C. Processing Requirements. This subfunction may be executed as needed.

D. Constraints. None.

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart can be found in Section 5.3 under the name:

SBODY\_TO\_M50



Table 4.10.7. SBODY_TO_M50 Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
Q_FIFTY_BODY MAT		Various Users	Various Users
Variable Name		Input Source	Output Destination
†		QUAT_TO_MAT (Q_FIFTY_BODY)	
† Only the values of QUAT_TO_MAT's elements are passed from input source.			

#### 4.10.8 Conversion of a Quaternion to a Matrix (QUAT\_TO\_MAT)

The special-purpose matrix function QUAT\_TO\_MAT computes the transformation matrix, A, associated with a quaternion, Q, as  $QUAT\_TO\_MAT(Q) = A$ .

A. Detailed Requirements. Calling modules designate this function

$$QUAT\_TO\_MAT(Q)$$

This function is referred to internally as

$$QUAT\_TO\_MAT(Q) = A$$

where

Q – quaternion

A – corresponding transformation matrix

The following steps shall be performed (in the order indicated).

$$P2 = Q_2 + Q_2$$

$$P3 = Q_3 + Q_3$$

$$P4 = Q_4 + Q_4$$

$$P5 = P2 Q_2$$

$$P6 = P4 Q_4$$

$$TEMP = 1.0 - P3 Q_3$$

$$A_{1,1} = TEMP - P6$$

$$A_{2,2} = 1.0 - P5 - P6$$

$$A_{3,3} = TEMP - P5$$

$$P5 = P2 Q_3$$

$$P6 = P4 Q_1$$

$$A_{1,2} = P5 - P6$$

$$A_{2,1} = P5 + P6$$

$$P5 = P2 Q_4$$

$$P6 = P3 Q_1$$

$$A_{1,3} = P5 + P6$$

$$A_{3,1} = P5 - P6$$

$$P5 = P3 Q_4$$

$$P6 = P2 Q_1$$

$$A_{2,3} = P5 - P6$$

$$A_{3,2} = P5 + P6$$

B. Interface Requirements. Input and output parameters are listed in Table 4.10.8.

C. Processing Requirements. None.

D. Constraints. None.

E. Supplementary Information. A suggested implementation in the form of a detailed flow chart can be found in Section 5.3 under the name:

QUAT\_TO\_MAT FUNCTION

Table 4.10.8. QUAT_TO_MAT Function Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
Q	Q_M50BODY_IMU	NAV_ONORBIT_RENDEZVOUS	NAV_ONORBIT_RENDEZVOUS, RR_ANGLE_NAV, SBODY_TO_M50, REND_NAV_INTERP
Q	Q_M50BODY_RR	RR_ANGLE_NAV, REND_NAV_INTERP	
Q	Q_FIFTY_BODY	SBODY_TO_M50	
A	*		
* Only values of A's components are passed to output destination.			

#### 4.10.9 Earth-Fixed to Geodetic (EF\_TO\_GEODETTIC)

This function is required to transform a Cartesian position vector in the Earth-fixed (Greenwich) coordinate system to the geodetic parameters: geodetic altitude, longitude, and geodetic latitude.

A. Detailed Requirements. This subfunction is called with the following internal variables in the IN LIST and the OUT LIST:

IN LIST:  $\bar{R}_{EF}$

OUT LIST: LAT\_GEOD, LON, ALT

where

$\bar{R}_{EF}$  Cartesian position vector

LAT\_GEOD geodetic latitude

LON geodetic longitude

ALT geodetic altitude

The following steps shall be performed (in the order indicated):

1. The computation for longitude is:

$$LON = ARCTAN2 (R_{EF2} , R_{EF1} ), 0 \leq LON < 2 \pi \quad F7$$

2. Computations for geodetic latitude, LAT\_GEOD, and height above the reference ellipsoid, ALT, are as follows:

$$R_{XY} = R_{EF1}^2 + R_{EF2}^2$$

$$R = (R_{XY} + R_{EF3}^2)^{1/2} \quad F4$$

FLATCON = 1.0 - (1.0\_ELLIPT)<sup>2</sup>, where ELLIPT = flattening of the reference ellipsoid

$$SIN_P = R_{EF3}/R \quad F3$$

$$COS_P = (R_{XY})^{1/2}/R \quad F3,F4$$

$$RAD_P = \frac{EARTH\_RADIUS\_EQUATOR}{\sqrt{1.0 + FLATCON \sin^2 P / (1.0 - FLATCON)}} \quad F3, F4$$

F3 This equation shall be protected against division by zero (reference 3.5).

F4 This equation shall be protected against square roots of a negative number (reference 3.5).

F7 This equation shall be protected against arc tangents with both arguments equal to zero (reference 3.5).

$$\text{DEL} = \frac{\text{FLATCON} \sin_P \cos_P}{1.0 - \text{FLATCON} \cos_P^2} \quad \text{F3}$$

$$\text{DEL\_LAT} = \frac{\text{RAD\_P} \text{ DEL}}{\text{R}} \quad \text{F3}$$

$$\text{PHI} = \text{ARCTAN} (\text{SIN\_P}/\text{COS\_P}), -\pi/2 \leq \text{PHI} \leq \pi/2 \quad \text{F3, F7}$$

$$\text{LAT\_GEOD} = \text{PHI} + \text{DEL\_LAT} \text{ (in radians)}$$

and

$$\text{ALT} = (\text{R} - \text{RAD\_P}) (1.0 - 0.50 \text{ DEL DEL\_LAT}) \text{ (in feet)}$$

F3 This equation shall be protected against division by zero (reference 3.5).

F7 This equation shall be protected against arc tangents with both arguments equal to zero (reference 3.5).

B. Interface Requirements. The input and output data are shown in Table 4.10.9.

C. Processing Requirements. This subfunction may be executed on demand.

D. Constraints. None.

E. Supplementary Information. The Earth-fixed coordinate system and geodetic parameters are defined in Section 5.3. A suggested implementation in the form of a detailed flow chart may be found in Section 5.3 under the name:

EF\_TO\_GEODETTIC

Table 4.10.9. EF_TO_GEODETTIC Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
R̄_EF		Various Users	Various Users Various Users Various Users
ALT			
LAT_GEOD			
LON			
Variable Name		Input Source	Output Destination
EARTH_RADIUS_EQUATOR		**	
ELLIPT		**	
** Initialization parameters, see Section 4.7.			

#### 4.10.10 UVW to M50 (UVW\_TO\_M50)

The purpose of this subfunction is to compute the transformation matrix from UVW coordinates to Aries M50 coordinates, given the position and velocity of the vehicle.

The orientation of the U, V, W system is determined by the orbiter inertial position and velocity vectors ( $\bar{\mathbf{R}}$ ,  $\bar{\mathbf{V}}$ ) at the point (or time) of interest.

A. Detailed Requirements. Users of this function designate it:

$$\text{UVW\_TO\_M50}(\bar{\mathbf{R}}, \bar{\mathbf{V}})$$

where

$\bar{\mathbf{R}}$  — position vector (mean of 1950)

$\bar{\mathbf{V}}$  — velocity vector (mean of 1950)

UVW\_TO\_M50 — UVW to mean of 1950 coordinate transformation matrix

The following steps shall be performed (in the order indicated):

1. The UVW coordinate frame axes unit vectors in mean of 1950 coordinates are determined. ( $\bar{\mathbf{Z}}$  represents the V-axis unit vector to avoid confusion with the velocity vector.)

$$\bar{\mathbf{U}} = \bar{\mathbf{R}} / |\bar{\mathbf{R}}| \quad \text{F3}$$

$$\bar{\mathbf{W}} = (\bar{\mathbf{R}} \times \bar{\mathbf{V}}) / |\bar{\mathbf{R}} \times \bar{\mathbf{V}}| \quad \text{F3}$$

$$\bar{\mathbf{Z}} = \bar{\mathbf{W}} \times \bar{\mathbf{U}}$$

F3 This equation shall be protected against division by zero (reference 3.5).

2. The transformation matrix from UVW coordinates to Aries mean of 1950 is then given by

$$\text{UVW\_TO\_M50} = \bar{\mathbf{U}} \bar{\mathbf{Z}} \bar{\mathbf{W}}$$

B. Interface Requirements. The input and output data are given in Table 4.10.10.

C. Processing Requirements. All computations are to be performed in double precision.

D. Constraints. None.

E. Supplementary Information. The UVW coordinate system and the Aries M50 system are defined in Section 5.3. A suggested implementation in the form of a detailed flow chart may be found in Section 5.3 under the name

UVW\_TO\_M50 FUNCTION

Table 4.10.10. UVW_TO_M50 Function Input/Output			
Inlist/Outlist		Input Source	Output Destination
Internal Name	External Name		
$\bar{R}$	$\bar{R}_{\text{FILT}}$	REND_BIAS_AND_COV_PROP	
$\bar{R}$	$\bar{R}_{\text{TV}}$	REND_BIAS_AND_COV_PROP	
$\bar{R}$	$\bar{R}$	U_A_BIAS_AND_COVINIT	
$\bar{V}$	$\bar{V}_{\text{FILT}}$	REND_BIAS_AND_COV_PROP	
$\bar{V}$	$\bar{V}_{\text{TV}}$	REND_BIAS_AND_COV_PROP	
$\bar{V}$	$\bar{V}$	U_A_BIAS_AND_COVINIT	
Variable Name		Input Source	
†			REND_BIAS_AND_COV_PROP, U_A_BIAS_AND_COVINIT

† Only the values of UVW\_TO\_M50's components are passed to output destination.

#### 4.10.11 Coordinate Transformations Table

The constants for coordinates transformations are presented in Table 4.10.11-1.

Table 4.10.11-1. Coordinate Transformations Constant Parameters							
FSSR Name	MSID	Description	Value	Units	Data Type	Precision	PF Ref
EARTH_RADIUS_EQUATOR	V97U5324C	Earth's Equatorial Radius	20925741.4698	ft	F	D	*
EARTH_RATE	V97U4379C	Earth's Rotation Rate	72.9211514646E-6	rad/sec	F	D	*
ELLIPT	V97U5332C	Earth's Ellipticity Constant	3.352329869E-3	-	F	D	*

\* See function reference data in Table 4.2.11-5.

4.11 Deleted

4.12 Deleted

4.13 Deleted

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## **5.0 SUPPLEMENTAL MATERIAL**

The material in this section is provided for information only. It is divided by major function as follows:

- Basic On–Orbit Navigation (Sections 5.1 and 5.2)
- General Requirements (Section 5.3)
- User Parameter Processing (Section 5.4)
- Navigation Uplink Processing (Section 5.5)
- Interface Diagrams for On–Orbit/Rendezvous Navigation (Section 5.6)

## 5.1 GENERAL REQUIREMENTS FUNCTION

The supplemental material provided in this section provides a list of variable definitions that describes the characteristics associated with the parameters, and Table 5.1-1 which is a list of the total navigation variables for the basic navigation functions.

### VARIABLES LIST DEFINITIONS

#### Code used for variable data type

- F: floating point quantity. An n-dimensional floating point vector will be denoted F(n). Similarly, a nxm floating point matrix will be denoted by F(n,m).
- I: integer quantity; I(n) will denote an n-dimensional integer vector
- B: bit, i.e., data having only values of 0 or 1
- C: character; C(n) will denote an n-dimensional character string

#### Code used for variable precision

- D: double precision
- S: single precision; integer quantities are assumed single precision unless otherwise specified

#### Variable location

- Compool: Variable value located in common storage, accessible by all functions
- Local: Variable is used by one function only, and usable to other functions through call argument only

#### Variable initialization category

- blank: display is vacant
- C: constant (unchanging)
- DD: design dependent
- HC: hard coded
- MD: mission dependent (I-LOAD)
- OPS: OPS transition parameter
- IV: other required initial values
- K-load: a former I-load that has become hard-coded

Variable initial value

initial operation sequence computer inputs

Variable uplink and downlink status

UPLINK: variable is an uplink item

DOWNLIST: variable is a downlist item

Units definitions

deg: angular measurement, degrees

ft: feet

lb: pounds

n.d.: nondimensional

rad: radian

sec: time measurement, seconds

slugs: mass measurement, slugs

vary: units have different values which depend on variable use

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
A	DF(5,2)	local	—	—	—	—	Legendre functions array in gravitational acceleration calculation.
$\bar{A}BM$ (V96U9061C-66C)	SF(3,2)	local	MD	—	—	n.d	Variable used in $\bar{A}CCEL\_ONORBIT$ atmospheric density code (nighttime vertical calibration coefficients).
ACC_MIN (V96U9067C)	I	local	DD	—	—	—	Minimum number of sequential marks accepted by the residual edit test to blank the display edit status indicator (DISP_EDIT).
AFH	SF	local	—	—	—	—	Density model night time vertical coefficient.
ALT_SS (V90H4945C)	SF	compool	—	—	downlist	ft	Altitude of the Shuttle for downlist.
ALT	SF	local	—	—	—	ft	Altitude above reference ellipsoid used in $\bar{A}CCEL\_ONORBIT$ .
ALT_L (V96U9068C)	SF	local	MD	—	—	ft	Density model upper bound of lower layer used in $\bar{A}CCEL\_ONORBIT$ drag model.
ANGLES_AIF (V93J6237C)	I	compool	—	—	—	—	Auto/Inhibit/Force switch associated with the currently enabled angles data set.
ANGLES_AIF_DISPLAY (V90J1361C)	I	compool	—	—	downlist	—	Flag indicating to display that the angles auto/inhibit/force flag (ANGLES_AIF) has been acknowledged by navigation.
ANGLES_AIF_LAST	I	local	IV	2(inhibit)	—	—	The last nonforce value of the ANGLES_AIF flag.
ANGLES_ENABLE_DISPLAY (V90J1416C)	I	compool	—	—	downlist	—	Positive feedback flag to the display indicating the angle set currently enabled.
ANGLES_MANUAL_EDIT_OVERRIDE	B	local	—	—	—	—	Local value of the manual edit override flag.
ANGLES_STAT_FLAG	B	local	—	—	—	—	Local value of the stat flag.
AREA	SF	local	—	—	—	ft <sup>2</sup>	Area used in $\bar{A}CCEL\_ONORBIT$ drag model.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description						
$\bar{A}$ _RESID	DF(3)	local	—	—	—	ft/sec <sup>2</sup>	Acceleration of the orbiter interpolated to a specified measurement time (M50).						
ATFL_OV	I	compool	HC	0	—	—	Flag controlling use or nonuse of current attitude of orbiter.						
ATFL_TV	I	compool	HC	2	—	—	Flag controlling use of mass, area, and drag coefficient of target vehicle.						
ATM	I	local	—	—	—	—	Flag indicating if current or prestored configuration constants are to be used in drag computations within $\bar{A}$ CCCEL_ONORBIT.						
ATMP (V94J3999C)	I	compool	—	—	downlist	—	Flag indicating target or orbiter CD, mass and area for prediction.						
$\bar{A}$ _TV_RESID	DF(3)	local	—	—	—	ft/sec <sup>2</sup>	Acceleration of the target vehicle interpolated to a specified measurement time (M50).						
AUXILIARY	DF	local	—	—	—	1/sec <sup>2</sup>	Scalar variable used in gravitational acceleration model in $\bar{A}$ CCCEL_ONORBIT.						
A1 A2 A3 A4 A5 A6 A7 A8 A9	}	local	—	—	—	ft <sup>-2</sup> sec/ft <sup>2</sup> sec/ft <sup>2</sup> sec <sup>2</sup> /ft <sup>2</sup> sec <sup>2</sup> /ft <sup>2</sup> sec <sup>3</sup> /ft <sup>2</sup> sec <sup>-1</sup> /ft <sup>-2</sup> ft <sup>-2</sup> sec/ft <sup>2</sup>	Temporary variables in mean conic partial transition matrix computations.						
$\bar{B}$						DF(13)		compool	—	—	—	vary	Partial derivative of the measurement with respect to the filter vehicle state.
BFH						SF		local	—	—	—	—	Atmospheric density model diurnal coefficient used in $\bar{A}$ CCCEL_ONORBIT.

Table 5.1-1. Variable List - On-orbit Navigation							
Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
BIAS_COV_VAR	SF(2)	local	—	—	—	vary	Copy of the bias variance terms for the covariance matrix of the sensor data currently being processed.
BIAS_INIT	SF(2)	local	—	—	—	vary	Copy of the initial sensor bias of the sensor data currently being processed.
BIAS_VAR	SF(2)	local	—	—	—	vary	Copy of the sensor bias variances for the sensor data currently being processed.
BIAS_VAR_COAS_ANGLES (V96U9069C-70C)	SF(2)	local	DD	—	—	rad <sup>2</sup>	Variance of the COAS angle biases.
BIAS_VAR_RR_ANGLES (V96U9071C-2C)	SF(2)	local	DD	—	—	rad <sup>2</sup>	Variance of the rendezvous radar angle biases.
BIAS_VAR_RRDOT (V96U9073C-4C)	SF(2)	local	DD	—	—	ft <sup>2</sup> , ft <sup>2</sup> /sec <sup>2</sup>	Variance of the rendezvous radar range and range rate biases.
BIAS_VAR_ST_ANGLES (V96U9075C-6C)	SF(2)	local	DD	—	—	rad <sup>2</sup>	Variance of the star tracker angle biases.
$\bar{B}M$ (V96U9077C-9C)	SF(3)	local	MD	—	—	nd ft <sup>-1</sup> ft	Atmospheric density model diurnal coefficients used in $\bar{A}CCEL\_ONORBIT$ .
BT_E_B	DF	local	—	—	—	vary	Variable used to store the dot product of $\bar{B}$ and $\bar{E}B$
$\bar{C}$	DF(9)	local	C	—	—	—	Tesseral harmonics coefficients used in $\bar{A}CCEL\_ONORBIT$ Earth gravity code.
CBD1 (V96U9087C)	SF	local	K-load	+1.4036 E-05	—	ft** <sup>-1</sup>	Coefficient used in $\bar{A}CCEL\_ONORBIT$ atmospheric density seasonal latitudinal effect.
CBD2 (V96U9088C)	SF	local	K-load	-1.3716 E-05	—	ft** <sup>-1</sup>	Coefficient used in $\bar{A}CCEL\_ONORBIT$ atmospheric density seasonal latitudinal effect.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
CBM1	SF	local	—	—	—	—	Coefficient used in $\overline{ACCEL\_ONORBIT}$ atmospheric density seasonal latitudinal effect.
CBM2 (V97U5281C)	SF	local	MD	—	—	—	Coefficient used in $\overline{ACCEL\_ONORBIT}$ atmospheric density seasonal latitudinal effect.
CD	SF	local	—	—	—	—	Vehicle drag coefficient used in $\overline{ACCEL\_ONORBIT}$ drag acceleration calculations.
CDA (V97U5281C)	DF	local	DD	—	—	—	Constant used to model drag coefficient used in $\overline{ACCEL\_ONORBIT}$ .
CDEC1	DF	compool	—	—	—	—	Cosine of solar declination used in $\overline{ACCEL\_ONORBIT}$ density calculations.
C_DENSEA (V96U9094C)	SF	local	DD	—	—	ft	Constant used in $\overline{ACCEL\_ONORBIT}$ density model.
CDF (V97U6002C)	DF	local	DD	—	—	—	Constant used in $\overline{ACCEL\_ONORBIT}$ drag coefficient calculation.
CDN (V97U5282C)	DF	local	DD	—	—	—	Constant used in $\overline{ACCEL\_ONORBIT}$ drag coefficient calculation.
CDS (V97U6010C)	DF	local	DD	—	—	—	Constant used in $\overline{ACCEL\_ONORBIT}$ drag coefficient calculation.
COAS_ANGLES_BIAS_INIT (V96U9084C-5C)	SF(2)	local	MD	—	—	rad	Initial value of the COAS angle bias slots in the state vector.
COAS_ANGLES_EDIT_OVERRIDE	B	local	—	—	—	—	Flag used to override (ON) the residual edit test for the COAS angles data.
COAS_ANGLES_STAT	B	local	—	—	—	—	Flag indicating that COAS angles data are to be processed for statistical display purpose only (ON).

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
COAS_DATA_GOOD (V90X4849X)	B	compool	—	—	downlist	—	Snapped COAS flag indicating the use of COAS to track a target. This is used by navigation as a DATA_GOOD flag. (STAR TRCK SOP HAL name NAV_SIGHT, M/SID# V95X4779X).
COAS_ENABLE (V93X6225X)	B	compool	—	—	downlist	—	COAS angle ENABLE flag not used in the software but is included here for downlist notification.
COAS_ID (V90J4854C)	I	compool	—	—	downlist	—	Snapped COAS selection flag (STAR TRCK SOP HAL name AXN, M/S ID# V95X4972X).
COAS_MARK_NUM (V90J4827C)	I	compool	IV	0	downlist	—	COAS measurement mark counter.
CONST	DF	local	—	—	—	sec <sup>3</sup> /ft <sup>2</sup>	Temporary variable used in transition matrix computation.
CONT_ACC (V90A4944C)	SF	compool	—	—	downlist	ft/sec <sup>2</sup>	Contact acceleration (magnitude of the IMU sensed acceleration) used to determine whether IMU data and/or measurement data are to be used.
COS_LAG (V96U9086C)	SF	local	DD	—	—	—	Cosine of atmospheric bulge lag angle used in $\bar{A}CCEL\_ONORBIT$ density model.
COS_PSI	SF	local	—	—	—	—	Variable used in $\bar{A}CCEL\_ONORBIT$ atmospheric density model.
COS_SOL_RA	DF	compool	—	—	—	—	Cosine of solar right ascension used in $\bar{A}CCEL\_ONORBIT$ density model.
$\bar{C}OV\_ACCEL\_UVW\_INIT$ (V90H4930C-32C)	SF(3)	compool	—	—	—	ft <sup>2</sup> /sec <sup>4</sup>	Vector of unmodeled acceleration bias error variances in UVW coordinates.
$\bar{C}OV\_COR\_UPDATE$ (V96H1290C-6C)	SF(7)	compool	MD	—	uplink	—	Vector of correlation coefficients associated with UVW standard deviations (SIG_UPDATE) used for Orbiter/target covariance initialization (ground update).



Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
COV_POS_SIG (V90H0438C)	SF	compool	—	—	downlist	ft	Square root of the sum of the position diagonal elements of the covariance matrix.
COV_VEL_SIG (V90L0439C)	SF	compool	—	—	downlist	ft/sec	Square root of the sum of the velocity diagonal elements of the covariance matrix.
COV_PWRD_FLT (V90X4936X)	B	compool	DD	—	—	—	Flag indicating that the IMU use flag has been turned on at least once since the last COV prop.
COV_PWRD_FLT_LAST (V90X4845X)	B	compool	—	—	—	—	The last value of COV_PWRD_FLT.
$\overline{\text{COV}}_U_A_{\text{COAST}}$ (V96U9095C-7C)	SF(3)	compool	DD	—	—	ft <sup>2</sup> /sec <sup>4</sup>	Unmodeled acceleration bias variances for coasting flight.
$\overline{\text{COV}}_U_A_{\text{PWRD\_FLT}}$ (V96U9098C-100C)	SF(3)	local	DD	—	—	ft <sup>2</sup> /sec <sup>4</sup>	Unmodeled acceleration bias variances for powered flight.
COV_USE_IMU_DATA	B	compool	—	—	—	—	Flag indicating if delta velocities will be incorporated into covariance propagation matrix.
CSFST	SF	local	—	—	—	ft	Variable used in $\overline{\text{ACCEL}}_{\text{ONORBIT}}$ atmospheric density model.
CSSND	SF	local	—	—	—	ft	Variable used in $\overline{\text{ACCEL}}_{\text{ONORBIT}}$ atmospheric density model.
CURR_ORB_MASS (V90U1961C)	SF	compool	—	—	—	slugs	Current orbiter mass
C1	DF	local	—	—	—	sec/ft	Scratch variable used in mean conic partials calculations.
C1	DF	local	—	—	—	—	Auxiliary variable used in F and G series computations and in Pines method.
C2	SF	local	—	—	—	sec <sup>2</sup> /ft <sup>2</sup>	Scratch variable used in mean conic partials calculations.
C2	DF	local	—	—	—	—	Auxiliary variable used in Pines method.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
$\bar{D}$	SF(3)	local	—	—	—	ft/sec <sup>2</sup>	Variable used in $\bar{ACCEL\_ONORBIT}$ to define vehicle drag acceleration.
DA_THRESHOLD (V90A4747C)	I	compool	—	—	downlist	micro G's	Threshold value for magnitude of sensed acceleration.
DA_THRESHOLD_TEST	SF	local	—	—	—	ft/sec <sup>2</sup>	Threshold test value for magnitude of sensed acceleration.
DAP_JET (V90X2349X)	B	compool	IV	OFF	—	—	RCS jet firing indication flag.
DEG_PER_RAD	SF	compool	C	—	—	deg/rad	Conversion factor from radians to degrees.
DELQ	DF	compool	—	—	—	vary	Measurement residuals.
DELTA_RESID_RATIO (V96U9107C)	SF	local	DD	—	—	—	Increment on the residual edit test ratio when data is forced.
DELTAT	DF	local	—	—	—	sec	Time interval between two positions in a conic (F and G series).
DELTAT_COAS	SF	local	—	—	—	sec	Time since last COAS measurement processing.
DELTAT_COAS_MAX (V96U9108C)	SF	local	DD	—	—	sec	Maximum age of COAS measurement before navigation will not process it.
DELTAT_COAS_MIN (V96U9109C)	SF	local	DD	—	—	sec	Minimum change in COAS time tag before it is considered by navigation to be a new measurement.
DELTAT_GO	DF	compool	—	—	—	sec	Time interval between two positions in a conic.
DELTAT_ST	SF	local	—	—	—	sec	Time difference between current star tracker measurement time and last star tracker measurement time.
DELTAT_ST_MIN (V96U9110C)	SF	local	DD	—	—	sec	Minimum change in star tracker time tag needed to verify that the star tracker data has changed
DELTIM	DF	local	—	—	—	sec	Time interval for the mean conic partial transition matrix calculation.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/ Downlist	Units	Description
D_FIN	DF	local	—	—	—	ft <sup>2</sup> /sec	Dot product of final position and velocity vectors in F and G.
D_FIN_TEMP	DF	compool	HC	0.	—	ft <sup>2</sup> /sec	Temporary storage for D_FIN (Pines method).
DFL	B	compool	HC	1	—	—	Flag indicating activation (1) or deactivation of drag model.
DIAG	DF	local	—	—	—	sec	Scratch variable used in computation of state transition matrix for COV prop.
DID_COVAR_REINIT (V90X1415X)	B	compool	IV	OFF	downlist	—	Positive feedback flag indicating (ON) that a covariance reinitialization has been performed.
DID_FILTERED_TO_PROP (V90X4984X)	B	compool	—	—	downlist	—	Positive feedback flag indicating (ON) that a state vector transfer has been performed (backup propagated state = filtered state).
DID_ORB_TO_TGT (V90X1413X)	B	compool	IV	OFF	downlist	—	Positive feedback flag indicating (ON) that a state vector transfer has been performed (TGT = ORB).
DID_PROP_TO_FILTERED (V90X4985X)	B	compool	—	—	downlist	—	Positive feedback flag indicating (ON) that a state vector transfer has been performed (filtered state = backup propagated state).
DID_TGT_TO_ORB (V90X1414X)	B	compool	IV	OFF	downlist	—	Positive feedback flag indicating (ON) that a state vector transfer has been performed (ORB = TGT).
DID_SV_SOURCE_FOR_UPP (V90X4986X)	C(4)	compool	—	—	downlist	—	Positive feedback flag indicating whether the filtered state (“1”) or the backup state (“0”) is to be sent by nav to users.
D_IN	DF	local	—	—	—	ft <sup>2</sup> /sec	Dot product of initial position and velocity used in F and G series.
DISP_DELQ (V90H0212C,14C,21C,V90A0711C)	SF(4)	compool	—	—	downlist	vary	Display measurement residual.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
$\overline{\text{DISP\_EDIT}}$ (V90X0213X,15X,23X,0712X)	C(4)	compool	IV	“blank”	downlist	—	Display edit status indicator.
$\overline{\text{DISP\_SIG}}$ (V90U0216C,17C,22C,713C)	SF(4)	compool	—	—	downlist	—	Display residual edit ratio.
DM	B	local	IV	OFF	—	—	Flag indicating use of or nonuse of drag model in $\overline{\text{ACCEL\_ONORBIT}}$ .
D_MN_AN	DF	local	—	—	—	rad	Difference in mean anomalies used to solve Kepler’s equations, used in F and G series.
DMP (V94X3969X)	B	compool	—	—	—	—	Flag indicating use or nonuse of drag acceleration in prediction.
DNM	DF	local	—	—	—	—	Local variable used in $\overline{\text{ACCEL\_ONORBIT}}$ gravitational acceleration computation.
DO_COAS_ANGLES_NAV (V90X4880X)	B	local	—	—	downlist	—	On-off switch indicating (ON) that COAS angles data have been selected for processing.
DO_COAS_ANGLES_NAV_LAST (V90X4725X)	B	compool	—	—	—	—	On-off switch indicating (ON) that COAS angles data were selected for processing in the last filter cycle.
DO_COVAR_REINIT (V93X6233X)	B	compool	—	—	—	—	Flag indicating (ON) the performance of covariance matrix reinitialization.
DO_FILTERED_TO_PROP (V90X4987X)	B	compool	—	—	—	—	Flag indicating (ON) crew – requested state vector transfer (filtered state to backup propagated state).
DO_PROP_TO_FILTERED (V90X4968X)	B	compool	—	—	—	—	Flag indicating (ON) crew – requested state vector transfer (backup propagated state to filtered state).

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
DOING_MEAS_ENABLE (V90X1417X)	B	compool	IV	OFF	downlist	—	Flag indicating (ON) measurement data are being processed and (OFF) measurement data are not being processed. Provides positive feedback to REL_NAV DISPLAY.
DOING_PWRD_FLT_NAV (V90X1289X)	B	compool	IV	OFF	downlist	—	Flag indicating (ON) that a powered flight navigation phase is currently active and (OFF) a nonpowered flight nav phase is active. Provides positive feedback to REL_NAV DISPLAY.
DOING_REND_NAV (V90X4765X)	B	compool	IV	OFF	downlist	—	Flag indicating (ON) a rendezvous navigation phase is active and (OFF) a non-rendezvous navigation phase is active. Provides positive feedback to REL_NAV DISPLAY.
DOING_ST_RR_COAS (V90J4872C)	I	compool	IV	1	downlist	—	Integer indicating the angle set selected 1 – ST TRK ANGLES 2 – RR ANGLES 3 – COAS ANGLES
D_ONE	DF	local	—	—	—	ft <sup>2</sup> /sec	Dot product of position and velocity vectors for transition matrix computation and F and G series.
DO_ORB_TO_TGT (V93X6215X)	B	compool	—	—	—	—	Flag indicating (ON) state vector transfer (TGT = ORB).
DO_OV_UPLINK (V90X4754X)	B	compool	IV	OFF	—	—	Flag indicating (ON) that data have been uplinked for orbiter state vector update.
DO_RR_ANGLES_NAV (V90X4866X)	B	local	—	—	downlist	—	Flag indicating (ON) that rendezvous radar angles data have been selected for processing.
DO_RR_ANGLES_NAV_LAST (V90X4726X)	B	compool	—	—	—	—	Flag indicating (ON) that rendezvous radar angles data were selected for processing in the last filter cycle.
DO_RRDOT_NAV_LAST (V90X4727X)	B	compool	—	—	—	—	Flag indicating (ON) that rendezvous radar range and range rate data were selected for processing in the last filter cycle.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
DO_ST_ANGLES_NAV (V90X4868X)	B	compool	—	—	downlist	—	Switch indicating (ON) that star tracker angles data have been selected for processing.
DO_ST_ANGLES_NAV_LAST (V90X4728X)	B	compool	—	—	—	—	Flag indicating (ON) that star tracker angles data were selected for processing in the last filter cycle.
DO_ST_RR_COAS (V93J6236C)	I	compool	IV	1	—	—	Integer indicating the angle set selected: 1 – ST TRK ANGLES SELECTED 2 – RR ANGLES SELECTED 3 – COAS ANGLES SELECTED
DO_TGT_TO_ORB (V93X6216X)	B	compool	—	—	—	—	Flag indicating (ON) state vector transfer (ORB = TGT).
DO_TV_UPLINK (V90X4757X)	B	compool	IV	OFF	—	—	Flag indicating (ON) that data have been uplinked for target state vector update.
$\bar{D}$ _SAVE (V95L0804C-06C)	DF(3)	compool	—	—	—	ft/sec <sup>2</sup>	Drag acceleration saved for ORB_TGTING.
$\bar{D}$ _SS (V90U4842C-44C)	SF(3)	compool	—	—	downlist	ft/sec <sup>2</sup>	Drag of Shuttle for downlist.
DT_COV (V90W1366C)	DF	compool	—	—	downlist	ft/sec	Change in velocity since the last COV propagation.
DT_FILT (V90W4946C)	DF	compool	—	—	—	sec	Interval over which to propagate the state vector.
DT_LIM (V96U9579C)	I	local	K-load	600	—	sec	Maximum prediction internal allowed in OPS_2_OR_8_INITIALIZE.
DT_NAV_STATE_PROP (V96U8683C)	I	compool	DD	—	—	sec	Onorbit/rendezvous nav state vector propagation rate.
DT_STEP	DF	local	—	—	—	sec	Integration step size for prediction or propagation.
D_TWO	DF	local	—	—	—	ft <sup>2</sup> /sec	Dot product of the position and velocity vectors for the transition matrix computation and F and G series.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
$\bar{D}V\_COV$ (V90L4772C, 891C, 892C)	SF(3)	compool	—	—	downlist	ft/sec	Change in velocity since the last COV propagation.
DV_COUNT (V90J5184C)	I	compool	IV	0	downlist	—	Number of cycles IMU data accepted into NAV during maneuvering.
$\bar{D}V\_DISP$ (V90L5181C-83C)	SF(3)	compool	IV	0.,0.,0.	downlist	ft/sec	Accumulated IMU sensed velocities accepted by NAV.
$\bar{D}V\_FILT$ (V90L4953C-55C)	SF(3)	compool	—	—	—	ft/sec	Difference between accumulated sensed IMU readings on the present cycle and the previous cycle (M50).
$\bar{D}V\_IN$	SF(3)	local	—	—	—	ft/sec	Input change in velocity used in SUPER_G integrator.
$\bar{D}V\_SUM$	SF(3)	compool	IV	0.,0.,0.	—	ft/sec	Accumulated values of $\bar{D}V\_FILT$ during thrust ON.
E (V90U4006C -09C V90U4011C -19C V90U4026C -38C V90U4045C -57C V90U4064C -76C V90U4083C -95C V90U4103C -15C V90U4122C -34C V90U4141C -53C V90U4160C -72C V90U4179C -91C V90U4198C -200C V90U4202C -11C V90U4218C -30C V90U4237C -49C)	DF (13,13)	compool	—	—	downlist (diagonal element only)	vary	Filter covariance matrix.
EARTH_MU	DF	compool	C	—	—	ft <sup>3</sup> /sec <sup>2</sup>	Gravitational constant of the Earth.
$\bar{E}$ ARTH_POLE	DF(3)	compool	—	0,0,1	—	—	Unit vector in direction of Earth's axis of rotation.
EARTH_RADIUS_EQUATOR	DF	compool	C	—	—	ft	Earth's equatorial radius.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
EARTH_RADIUS_GRAV	DF	local	C	—	—	ft	Earth's radius used for gravitational accelerations in ACCEL_ONORBIT.
EARTH_RATE	DF	compool	C	—	—	rad/sec	Earth's angular rotation rate.
EB_COPY	DF(13)	local	—	—	—	vary	Covariance matrix times the partials vector.
EDIT_FLAG	C	compool					Five valued flag used to indicate the status of the sensor measurement processing: OFF – not suitable for processing ON – edited by the residual edit test STAT – processed for statistical display only PROCESSED – processed normally FORCED – processed through force command
ELLIPT	DF	compool	C	—	—	—	Earth's ellipticity constant.
EPS_TIME (V96U9115C)	SF	local	DD	—	—	sec	Minimum time separation for state vector interpolation.
ERR	DF	local	—	—	—	rad	Auxiliary variable used in F and G series (conic solution) calculations.
EVENT_E1 (V90X8164X)	B	compool	IV	OFF	—	—	OPS 3 to MM201
EVENT_60 (V90X8189X)	B	compool	IV	OFF	—	—	MM106 to MM201
EVENT_60A (V90X8160X)	B	compool	IV	OFF	—	—	OPS 8 to MM201
EVENT_60B (V90X8645X)	B	compool	IV	OFF	—	—	MM201 to OPS 8
EVENT_60H (V90X8644X)	B	compool	IV	OFF	—	—	OPS 8 to OPS 3
EVENT_67 (V90X8646X)	B	compool	IV	OFF	—	—	MM201 to MM202



Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
EVENT_73 (V90X8200X)	B	compool	IV	OFF	—	—	MM202 to MM201
EVENT_83 (V90X8655X)	B	compool	IV	OFF	—	—	MM201 to OPS 00
EVENT_84 (V90X8148X)	B	compool	IV	OFF	—	—	OPS 00 to MM201
EVENT_85 (V90X8180X)	B	compool	IV	OFF	—	—	MM201 to OPS 3
EXP_SHAPE_FACTOR (V97U5334C)	DF	local	DD	—	—	—	Constant used in drag model drag coefficient calculation.
F	DF	local	—	—	—	—	Closed form version of the F time series.
FALSE_TARG (V90X1422X)	B	compool	IV	OFF	—	—	Flag indicating false target is being tracked by star tracker.
FDOT	DF	local	—	—	—	sec <sup>-1</sup>	Closed form version of the time derivative of F series.
FIFTY	DF(3,3)	local	—	—	—	—	Transformation matrix Earth-fixed to M50 used in $\overline{\text{ACCEL\_ONORBIT}}$ .
FILT_UPDATE (V90X0224X)	B	compool	IV	OFF	—	—	Flag indicating (ON) that current navigation cycle is complete.
FM1	DF	local	—	—	—	—	Auxiliary variable for F minus 1.
F1 F2 F3 F4	DF	local	—	—	—	—	Auxiliary variables in gravitational acceleration calculations used in $\overline{\text{ACCEL\_ONORBIT}}$ .
G							
$\overline{G}$							
$\overline{G\_CENTRAL}$							
	DF	local	—	—	—	sec	Closed form version of the G time series.
	DF(3)	local	—	—	—	ft/sec <sup>2</sup>	Gravitational acceleration in $\overline{\text{ACCEL\_ONORBIT}}$ .
	DF(3)	compool	—	—	—	ft/sec <sup>2</sup>	Gravitational acceleration due to Earth as a point mass.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
GDI	SF	local	—	—	—	—	Atmospheric density diurnal coefficient used in <u>ACCEL_ONORBIT</u> .
GDIE (V96U9116C)	SF	local	DD	—	—	—	Exponent of atmospheric density diurnal coefficient used in <u>ACCEL_ONORBIT</u> .
GDM1	DF	local	—	—	—	—	Auxiliary variable for GDOT minus 1.
GDOT	DF	local	—	—	—	—	Closed form version of the time derivative of the G series.
$\bar{G}_{INT}$	DF(3)	local	—	—	—	ft/sec <sup>2</sup>	Intermediate value of acceleration used in SUPER_G integration.
GMD	I	local	—	—	—	—	Flag indicating degree of gravitational potential model in <u>ACCEL_ONORBIT</u> .
GM_DEG (V96U9117C)	I	compool	K-load	+4	—	—	Flag indicating the degree of gravitational potential model.
GM_DEG_LOW (V96U9118C)	I	compool	K-load	+2	—	—	Lowest degree of potential model in calls to the acceleration function; used for sensed velocity, powered flight integration.
GMDP (V94J3975C)	I	compool	—	—	—	—	Flag indicating the degree of gravitational potential model for prediction.
GMO	I	local	—	—	—	—	Flag indicating order of gravitational potential model to be used in <u>ACCEL_ONORBIT</u> .
GMOP (V94J3963C)	I	compool	—	—	—	—	Flag indicating the order of the gravitational potential model to be used for prediction.
GM_ORD (V96U9119C)	I	compool	K-load	+4	—	—	Flag indicating the order of the gravitational potential model.
GM_ORD_LOW (V96U9120C)	I	compool	K-load	+0	—	—	Lowest order of potential model in calls to the acceleration function; used for sensed velocity powered flight integration.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
$\bar{G}_{NEW}$ (V90U4940C-42C)	DF(3)	compool	—	—	downlist	ft/sec <sup>2</sup>	Orbiter acceleration vector (M50).
GO	SF	compool	C	—	—	ft/sec <sup>2</sup> /g	Earth gravity acceleration constant.
$\bar{G}_{ONE}$	DF(3)	local	—	—	—	ft/sec <sup>2</sup>	Acceleration vector in transition matrix calculation.
$\bar{G}_{OUT}$	DF(3)	local	—	—	—	ft/sec <sup>2</sup>	Acceleration vector used in SUPER_G.
$\bar{G}_{PROP}$	DF(3)	local	—	—	—	ft/sec <sup>2</sup>	Dummy variable used to accept the acceleration vector returned by SUPER_G when propagating the backup state vector.
$\bar{G}_{TV}$ (V90L4961C-63C)	DF(3)	compool	—	—	downlist	ft/sec <sup>2</sup>	Target vehicle acceleration vector (M50).
$\bar{G}_{TV\_LAST}$ (V90A4796C, 97C, 88C)	DF(3)	compool	—	—	—	ft/sec <sup>2</sup>	Target vehicle acceleration vector, last value (M50).
$\bar{G}_{TWO}$	DF(3)	local	—	—	—	ft/sec <sup>2</sup>	Acceleration vector in transition matrix calculation.
G_2_FPS2	SF	compool	C	—	—	lb/slug	Mass to weight conversion.
HORIZ	SF	local	—	—	—	rad	Filter estimate of the horizontal angle measurement.
I	I	local	—	—	—	—	Counter.
IATM	I	local	—	—	—	—	Attitude mode flag that controls the use or nonuse of prestored average area, mass, and drag coefficient of orbiter or target vehicle.
I_CYCLE (V90J4889C)	I	compool	—	—	downlist	—	Counter for the navigational cycle.
IDM	B	local	—	—	—	—	Flag indicating the activation (1) or deactivation (0) of the drag model.
ID_MATRIX_3X3	SF(3,3)	local	HC	$\begin{bmatrix} 1.0.0. \\ 0.1.0. \\ 0.0.1. \end{bmatrix}$	—	—	3 X 3 identity matrix.

Table 5.1-1. Variable List - On-orbit Navigation							
Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
IDRAG (V90X4950X)	B	compool	—	—	—	—	Drag model flag used by state prop.
IGD (V90J4947C)	I	compool	—	—	—	—	Temporary storage for the potential model degree used by state prop.
IGO (V90J4948C)	I	compool	—	—	—	—	Temporary storage for the potential model order used by state prop.
$\bar{I}_N$	SF(3)	local	—	—	—	—	Raw vector of M50 to sensor transformation matrix used in angles partials calculation.
$\bar{I}_{RHO}$	SF(3)	compool	—	—	—	—	Unit line-of-sight vector.
IMU_NAV_ACCEL_THRESH (V93A6710C)	I	compool	MD, OPS	—	—	micro-g's	Crew-selected acceleration threshold value for incorporating IMU data into nav.
IVENT (V90X4951X)	B	compool	—	—	—	—	Temporary value of venting model flag used in state propagator.
IVM	B	local	—	—	—	—	Flag indicating activation (1) or deactivation (0) of the venting and RCS uncoupled thrusting model.
J	I	local	—	—	—	—	Counter.
K	I	local	—	—	—	—	Counter.
KFACTOR (V96U8173C)	SF	compool	MD	—	uplink	—	Orbiter drag model scale factor used in $\bar{ACCEL}_{ONORBIT}$ .
K_ANG (V99U7430C)	SF	local	DD	—	—	rad	Angle between the body x-axis and antenna shaft axis.
K_RESID_EDIT (V96U9121C)	SF	local	DD	—	—	—	Residual edit test scale factor.
K_UND_WGT (V97U5350C)	SF	local	DD	—	—	—	Filter underweighing factor.
L	I	local	—	—	—	—	Counter.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
LOC (V96U9122C)	DF	local	MD	—	—	rad	Coefficient used in $\overline{\text{ACCEL\_ONORBIT}}$ solar ephemeris model.
LOS	DF	local	—	—	—	rad	Longitude of the Sun in M50 coordinates.
LOSK1 (V96U9123C)	DF	local	MD	—	—	—	Coefficient used in $\overline{\text{ACCEL\_ONORBIT}}$ solar ephemeris model.
LOSK3 (V96U9124C)	DF	local	MD	—	—	—	Coefficient used in $\overline{\text{ACCEL\_ONORBIT}}$ solar ephemeris model.
LOS_R (V96U9125C)	DF	local	K-load	+1.990986594 E-07	—	rad/sec	Coefficient used in $\overline{\text{ACCEL\_ONORBIT}}$ solar ephemeris model.
LOS_ZERO (V96U9126C)	DF	local	MD	—	—	rad	Coefficient used in $\overline{\text{ACCEL\_ONORBIT}}$ solar ephemeris model.
MANUAL_EDIT_ OVERRIDE	B	compool	—	—	—	—	Copy of the manual edit override flag of sensor data type currently being processed that is sent to the filter.
MASS_INIT (V90U4938C)	SF	compool	OPS	—	—	slugs	Used for OPS 2, 8, 0 initialization of current orbiter mass.
MAT	SF(3,3)	local	—	—	—	—	UVW to M50 transformation matrix for the filtered vehicle in COV prop.
MAX_TIME_TOL (V96U8685C)	SF	local	K-load	+5.4 E+04	—	sec	Maximum time threshold for the state vector prediction task. If the absolute value of the difference between current filter time and the state vector exceeds this threshold, no state vector prediction will take place.
M_BODYM50	SF(3,3)	compool	—	—	—	—	Body to M50 transformation matrix.
M_BODY_TO_COAS (V96U9127C-44C)	SF (3,3,2)	local	DD	—	—	—	Body to COAS coordinates transformation matrix.
M_BODY_TO_RR (V96U9145C-53C)	SF(3,3)	compool	DD	—	—	—	Body to RR coordinates transformation matrix.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
MEAS_ENABLE (V93X6232X)	B	compool	IV	OFF	—	—	Flag indicating that measurement processing is enabled during MM202.
MEAS_STAT	B	local	—	—	—	—	Temporary flag used in measurement selection.
MEAS_THRESHOLD (V96U9154C)	SF	compool	DD	—	—	ft/sec <sup>2</sup>	Threshold value for the magnitude of sensed accelerations for nonuse of measurement data.
MM_CODE (V90X8656X)	I	compool	—	—	—	—	Major mode 202 indicator.
M_M50_TO_BODY_COAS (V90U4857C -65C)	SF(3,3)	compool	—	—	downlist	—	Snapped variable for the M50 to body coordinates transformation matrix at the time of COAS data snap (STAR TRCK SOP HAL name T_M50_BODY, M/S ID# V95U4809-17C).
M_M50TOEF_AT_EPOCH (V97U5738C - 46C)	DF(3,3)	compool	—	—	—	—	Transformation matrix from M50 to earth-fixed at T_EPOCH
M_M50_TO_SENSOR	SF(3,3)	compool	—	—	—	—	M50 to sensor coordinates transformation matrix for the sensor type being processed.
M_M50_TO_ST (V90U4920C -28C)	SF(3,3)	compool	—	—	downlist	—	Snapped variable for M50 to star tracker coordinate transformation matrix (STAR TRCK SOP HAL name T_M50_ST, M/S ID# V95U4800-8C).
MS_DELQ	DF	local	—	—	—	vary	Estimated variance of the computed sensor measurement.
MS_POS_UND_WGT (V97U5411C)	SF	local	DD	—	—	ft <sup>2</sup>	Threshold of the Shuttle position variance for filter underweighing.
M_UVW_M50	DF(3,3)	compool	—	—	—	—	UVW to M50 transformation matrix.
N	I	local	—	—	—	—	Counter.
N_ACCEPT (V90J1402C, 03C, 00C, 01C)	I(4)	compool	IV	0	downlist	—	Counter for the number of data marks that have been used to update the navigation state vector.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
NAV_ANGLES_AIF (V90J4253C)	I	compool	—	—	downlist	—	Auto/Inhibit/Force switch used in nav for the currently enabled angles data set.
NAV_CURR_ORB_MASS (V90U4254C)	SF	compool	—	—	downlist	slugs	Current orbiter mass used in nav.
NAV_DAP_JET (V90X5185X)	B	compool	—	—	downlist	—	Nav flag indicating RCS jet firing.
NAV_DO_COVAR_REINIT (V90X4256X)	B	compool	—	—	downlist	—	Nav flag tested to determine when to reinitialize the covariance matrix.
NAV_DO_FILTERED_TO_PROP (V90X4975X)	B	compool	—	—	downlist	—	Nav flag indicating (ON) crew-requested state vector transfer (filtered state to backup propagated state).
NAV_DO_ORB_TO_TGT (V90X4258X)	B	compool	—	—	downlist	—	Nav flag indicating (ON) crew – requested state vector transfer (orbiter to target).
NAV_DO_OV_UPLINK (V90X4260X)	B	compool	—	—	downlist	—	Nav flag indicating (ON) orbiter state vector uplink has occurred.
NAV_DO_PROP_TO_FILTERED (V90X4976X)	B	compool	—	—	downlist	—	Nav flag indicating (ON) crew-requested state vector transfer (backup propagated state to filtered state).
NAV_DO_TGT_TO_ORB (V90X4259X)	B	compool	—	—	downlist	—	Nav flag indicating (ON) crew – requested state vector transfer transfer (target to orbiter).
NAV_DO_TV_UPLINK (V90X4261X)	B	compool	—	—	downlist	—	Nav flag indicating (ON) target state vector uplink has occurred.
NAV_FALSE_TARG (V90X4300X)	B	compool	—	—	downlist	—	Copy of FALSE_TARG for TLM and star tracker SOP.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
NAV_MEAS (V90X4967X)	B	compool	IV	OFF	downlist	—	Flag indicating (ON) that sensor measurements are to be processed.
NAV_MEAS_ENABLE (V90X4262X)	B	compool	—	—	downlist	—	Nav flag indicating (ON) that measurement processing is enabled in MM 202.
NAV_MM_CODE (V90X4263X)	I	compool	—	—	downlist	—	Major mode indicator for NAV.
NAV_PWRD_FLT_NAV (V90X4264X)	B	compool	—	—	downlist	—	Flag indicating (ON) to NAV that powered flight navigation should be exercised.
NAV_RANGE_AIF (V90J4268C)	I	compool	—	—	downlist	—	Auto/Inhibit/Force switch used in NAV in processing the rendezvous radar range measurements.
NAV_RDOT_AIF (V90J4269C)	I	compool	—	—	downlist	—	Auto/Inhibit/Force switch used in NAV in processing the rendezvous radar range rate measurements.
NAV_RR_ANGLES_ENABLE (V90X4273X)	B	compool	—	—	downlist	—	Rendezvous radar angles enable flag for downlist.
NAV_SIG	SF(4)	compool	—	—	—	—	Copy of the residual edit test ratios for the sensor measurements processed.
NAV_ST_ENABLE (V90X4274X)	B	compool	—	—	downlist	—	Star tracker angles enable flag for NAV.
NAV_ST_RR_COAS	I	compool	IV	1	—	—	Integer indicating the angle set selected for navigation processing: 1 – ST TRK ANGLES 2 – RR ANGLES 3 – COAS ANGLES
NAV_SV_SOURCE_FOR_UPP (V90X4977X)	B	compool	—	—	downlist	—	Snapped value of flag indicating whether the filtered state (“1”) or the propagated backup state (“0”) is to be sent to users by NAV.



Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
N_CYCLE_SUB (V96U8681C)	I	compool	DD	—		—	Frequency at which measurements are to be processed and the covariance matrix propagated.
N_EDIT	I	compool	—	0		—	Counter indicating number of sequential measurements edited prior to setting FALSE_TARG.
N_MAX_EDIT (V96U9537C)	I	local	DD	—		—	Maximum number of sequential star tracker measurements to be edited before FALSE_TARG is set to 1.
NOISY_NAV_MEAS (V90X4937X)	B	—	IV	OFF		—	Flag indicating (ON) that the sensed acceleration is above MEAS_THRESHOLD and measurement data are not to be used.
N_REJECT (V90J1407C, 08C, 05C, 06C)	I(4)	compool	IV	0	downlist	—	Counter for the number of data marks that have been edited by the navigation filter.
NUM_KEP_ITER	I	local	HC	5	—	—	Maximum number of iterations in the solution of Kepler's equation (F and G).
N1	I	local	—	—	—	—	Variable used in $\overline{ACCEL\_ONORBIT}$ Earth gravitational code.
OMEG_C (V96U9157C)	DF	local	K-load	+1.990968715 E-07	—	rad/sec	Coefficient used in $\overline{ACCEL\_ONORBIT}$ solar ephemeris model.
$\overline{OMEGA}$	DF(13)	local	—	—	—	vary	Kalman gains vector.
ONEMRIN	DF	local	—	—	—	—	Auxiliary variable used in solving Kepler's equation (F and G series).
OPS_2_OR_8_INITIALIZE_COMPLETE (V90X1242X)	B	compool	—	—	—	—	Signal to MSC indicating that initialization of user parameter state propagation quantities is complete.
ORB_PROP_SV	B	compool	IV	OFF	—	—	Flag indicating (ON) that the backup propagated state vector for the Shuttle is being propagated.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
OV_PREDICT_FAIL (V90X4770X)	B	compool	—	—	downlist	—	Flag which indicates that the time threshold, MAX_TIME_TOL, has been exceeded and consequently no orbiter state vector prediction will take place.
PHASE_C (V96U9158C)	DF	local	MD	—	—	rad	Coefficient used in ACCEL_ONORBIT solar ephemeris model.
PHI	DF(6,9)	local	IV	0.	—	vary	State transition matrix from previous filter time to current time.
PHI_BIAS	DF(4)	local	—	—	—	—	Diagonal elements of the sensor bias portion of the state transition matrix.
PHI_MC	DF(6,6)	local	—	—	—	vary	Patch transition matrix computed by mean conic partials.
PHI_PATCH	DF(6,6)	compool	—	—	—	vary	Transition matrix for converting from time of measurement to current time.
PHI_UNMOD_ACC	DF	local	—	—	—	—	Scalar stored in diagonal elements of the unmodeled acceleration portion of the state transition matrix.
PI	DF	local	C	—	—	—	Transcendental constant which is the ratio of the circumference of a circle to its diameter.
PITCH	SF	local	—	—	—	rad	Q_RR_PITCH expressed in radians.
PREC_STEP_PRED (V98U8726C)	DF	compool	K-load	+3.00 E+02	—	sec	Integration step size for precise prediction.
PRED_ENA_FLAG (V90X4266X)	B	compool	—	—	—	—	Signal from Nav Sequencer to terminate current use of predictor when events to leave OPS 2 or OPS 8 are initiated.
PRED_ORB_AREA (V93U6955C)	SF	compool	—	—	downlist	ft <sup>2</sup>	Orbiter's cross-sectional area for use in prediction.
PRED_ORB_CD (V93U6954C)	SF	compool	—	—	downlist	—	Orbiter's drag coefficient for use in prediction.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
PRED_ORB_MASS (V93U6953C)	SF	compool	—	—	downlist	slugs	Orbiter mass used in prediction.
PRED_STEP (V90W3964C)	SF	compool	—	—	downlist	sec	Prediction step size.
PRED_STEP_OPS_INIT (V96U8686C)	DF	local	K-load	+6.10 E+02	—	sec	Initial predictor step size used in OPS_2_OR_8_INITIALIZE.
PRED_TASK_COMPLETE	B	local	—	—	—	—	A flag, local to the state vector prediction task, indicating that the prediction task is complete.
PRED_USE (V90J4768CA)	I	compool	IV	0	downlist	—	A flag, having values 0 through 9, which indicates to the user of the state vector prediction task the status of prediction task.
PWRD_FLT_NAV (V93X5408X)	B	compool	—	—	downlist	—	Flag indicating use of powered flight propagation (ON) or coasting flight propagation (OFF).
Q_COAS_HORIZ (V90U4847C)	SF	compool	—	—	downlist	rad	Snapped variable for the COAS horizontal angle measurement (STAR TRCK SOP HAL name COAS_HORIZ, M/S ID# V95U4969C [-Z] or V95U4968 [+X]).
Q_COAS_VERT (V90U4848C)	SF	compool	—	—	downlist	rad	Snapped variable for the COAS vertical angle measurement (STAR TRCK SOP HAL name COAS_VERT, M/S ID# V95U4992C [-Z] or V95U4993C [+X]).
Q_HORIZ	SF	local	—	—	—	rad	Measurement from horizontal measurement sensor.
$\bar{Q}$ _M50BODY_IMU (V95U0873C -6C)	SF(4)	compool	—	—	downlist	—	Snapped variable for the Shuttle M50 to body attitude quaternion at the time of the IMU data snap (ORB ATT PROC HAL name Q_BOD_M50, M/S ID# V90U2240-3C).
$\bar{Q}$ _M50BODY_RR (V90U4829C -32C)	SF(4)	compool	—	—	downlist	—	Snapped Shuttle M50 to body attitude quaternion at the time of the rendezvous radar data snap (RR SOP HAL name Q_M50BODY_RR, M/S ID# V95U4312 -15C).

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
Q_RR_RNG (V90U4895C)	SF	compool	—	—	downlist	ft	Snapped variable for the rendezvous radar range measurement (RR SOP HAL name RR_RANGE0, M/S ID# V95H4287C).
Q_RR_RNG_DOT (V90U4896C)	SF	compool	—	—	downlist	ft/sec	Snapped variable for the rendezvous radar range rate measurement (RR SOP HAL name RR_RNGRO, M/S ID# V95R4288C).
Q_RR_ROLL (V90U4893C)	SF	compool	—	—	downlist	deg	Snapped variable for the rendezvous radar roll angle measurement (RR SOP HAL name RR_ROLLO, M/S ID# V95H4284C).
Q_RR_PITCH (V90U4894C)	SF	compool	—	—	downlist	deg	Snapped variable for the rendezvous radar pitch angle measurement (RR SOP HAL name RR_PITCHO, M/S ID# V95H4284C).
Q_ST_HORIZ (V90U4833C)	SF	compool	—	—	downlist	rad	Snapped variable for the star tracker horizontal angle measurement (STAR TRCK SOP HAL name H_NAV, M/S ID# V95H4753C).
Q_ST_VERT (V90U4834C)	SF	compool	—	—	downlist	rad	Snapped variable for the star tracker vertical angle measurement (STAR TRCK SOP HAL name V_NAV, M/S ID# V95H4754C).
Q_VERT	SF	local	—	—	—	rad	Measurement from vertical measurement sensor.
$\bar{R}$	DF(3)	local	—	—	—	ft	Temporary M50 position vector used in $\bar{ACCEL\_ONORBIT}$ .
RAD_PER_DEG	SF	compool	C	—	—	rad/deg	Conversion factor from degrees to radians.
RANGE_AIF (V93J6241C)	I	compool	—	—	—	—	Auto/inhibit/force switch associated with the rendezvous radar range measurement.
RANGE_AIF_DISPLAY (V90J1362C)	I	compool	—	—	downlist	—	Flag indicating to displays that the range auto/inhibit/force flag has been processed.
RANGE_AIF_LAST	I	local	IV	2 (inhibit)	—	—	Last value of RANGE_AIF.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/ Downlist	Units	Description
RANGE_EDIT_OVERRIDE	B	local	—	—	—	—	Flag indicating (ON) that the crew wishes to force rendezvous radar range measurement.
RANGE_STAT	B	local	—	—	—	—	Flag indicating (ON) that rendezvous radar range data is to be processed for statistical display only.
$\bar{R}$ _CORR	DF(3)	local	—	—	—	ft	The filter correction for position.
RDOT_AIF (V93J6247C)	I	compool	—	—	—	—	Auto/inhibit/force switch associated with the rendezvous radar range rate measurement.
RDOT_AIF_DISPLAY (V90J1368C)	I	compool	—	—	downlist	—	Flag indicating to displays that the range rate auto/inhibit/force flag has been processed.
RDOT_AIF_LAST	I	local	IV	2 (inhibit)	—	—	Last value of RDOT_AIF.
RDOT_DATA_GOOD (V90X4900X)	B	compool	—	—	downlist	—	Snapped data validity flag for the rendezvous radar range rate measurement (RR SOP HAL name RR_RNGR_DG, M/S ID# V95X4294X).
RDOT_EDIT_OVERRIDE	B	local	—	—	—	—	Flag indicating (ON) that the crew wishes to force rendezvous radar range rate measurement.
RDOT_STAT	B	local	—	—	—	—	Flag indicating (ON) that rendezvous radar range rate data is to be processed for statistical display only.
RNP_TIME_UL (V90X0441X)	B	compool	—	OFF	—	—	Flag indicating (ON) that new values for the RNP matrix time parameters have been uplinked.
$\bar{R}$ _EF	DF(3)	local	—	—	—	ft	Earth-fixed position vector used in $\bar{A}$ CCEL_ONORBIT.
REF_ORB_AREA (V96U9160C)	SF	compool	DD	—	—	ft <sup>2</sup>	Orbiter reference cross sectional area used in propagating drag calculations.
REF_ORB_CD (V96U9161C)	SF	compool	K-load	+2.0 E+00	—	—	Orbiter reference drag coefficient.
REND_NAV_INIT_PRED	B	compool	IV	OFF	—	—	Flag indicating prediction task in progress as scheduled by REND_NAV_INIT.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
REJ_MAX (V96U9162C)	I	local	DD	—	—	—	Maximum number of sequential marks; rejected by the residual edit test, before DISP_EDIT for the corresponding measurement is set to .
REND_NAV_FLAG (V93X6220X)	B	compool	IV	OFF	downlist	—	Flag indicating whether rendezvous navigation (ON) or onorbit navigation (OFF) is in operation.
REND_NAV_FLAG_LAST	B	local	IV	OFF	—	—	Last value of REND_NAV_FLAG.
RESID_RATIO_OLD	SF	compool	—	—	—	—	Value of residual ratio from the previous cycle for the measurement being processed.
RESID_TEST	SF	local	—	—	—	vary	Scaled value of the estimated measurement variance for comparison with the measurement deviation squared in the residual edit test.
RESID_TEST_RATIO	SF	compool	—	—	—	—	Ratio of the magnitude of the measurement residual and scale value of the estimated measurement standard deviation to be used in the residual edit test.
$\bar{R}$ _FILT (V90H0584C-6C)	DF(3)	compool	—	—	—	ft	Orbiter position vector (M50).
$\bar{R}$ _FILT_DISP (V90H5040C-5042C)	DF(3)	compool	—	—	—	kft	M50 orbiter position vector for display.
$\bar{R}$ _FILT_INIT (V90H1276C-8C)	DF(3)	compool	OPS	—	—	ft	Orbiter position vector saved across memory reconfiguration and used for navigation initialization.
$\bar{R}$ _FILT_TLM (V90H4277C-79C)	DF(3)	compool	—	—	downlist	ft	Orbiter position vector for downlist (M50).
$\bar{R}$ _FIN	DF(3)	local	—	—	—	ft	Position vector at the end of a time interval in M50. Used in F and G series and in SUPER_G.
R_FIN_INV	DF	local	—	—	—	ft <sup>-1</sup>	Reciprocal of the magnitude of R_FIN.
R_FIN_TEMP_INV	DF	local	—	—	—	ft <sup>-1</sup>	Dummy variable used in the call to F_AND_G.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
R_FMP_DISP (V90H4997C)	SF	compool	—	—	downlist	kft	RSS of the filtered position vector minus the backup propagated position vector.
$\bar{R}$ _GND (V96H3500C-02C)	DF(3)	compool	—	—	uplink	ft	Uplink orbiter position vector in M50.
RHO	SF	local	—	—	—	slugs/ft <sup>3</sup>	Atmospheric density used in $\bar{A}CCEL\_ONORBIT$ drag model.
$\bar{R}HO\_PLANE$	SF(3)	local	—	—	—	ft	In-plane component of the line of sight.
$\bar{R}$ _IN	DF(3)	local	—	—	—	ft	Position vector at the beginning of a time interval in M50. Used in F & G series and in SUPER_G.
R_IN_INV	DF	local	—	—	—	ft <sup>-1</sup>	Reciprocal of the magnitude of $\bar{R}$ _IN.
R_INV	DF	local	—	—	—	ft <sup>-1</sup>	Inverse of M50 position used in $\bar{A}CCEL\_ONORBIT$ .
$\bar{R}$ _LAST (V90H4782C-4C)	DF(3)	compool	—	—	—	ft	Position vector of the orbiter at the end of the last filter cycle (M50).
RNG	SF	local	—	—	—	ft	Computed range measurement.
RNG_DATA_GOOD (V90X4899X)	B	compool	—	—	downlist	—	Snapped data validity flag for range measurement (RR SOP HAL name RR_RNG_DG, M/S ID# V95X4293X).
RNG_DOT	SF	local	—	—	—	ft/sec	Computed range rate measurement.
RNG_MIN (V96U9163C)	SF	local	DD	—	—	ft	Minimum separation between the orbiter and the target.
$\bar{R}$ _OFFSET_BODY (V99U7431C-3C)	SF(3)	compool	DD	—	—	ft	Vector from the Shuttle navigation reference point to the rendezvous radar antenna, represented in body coordinates.
R_OFFSET_CALC	B	compool	IV	OFF	—	—	Flag (ON) requesting REND_NAV_INTERP to calculate a relative position vector taking into account the radar antenna offset with respect to the Shuttle navigation reference point (i.e., center of gravity).

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
R_OFFSET_M50	SF(3)	compool	—	—	—	ft	Representation of $\bar{R}_{\text{OFFSET\_BODY}}$ in M50 coordinate system.
$\bar{R}_{\text{MEAS}}$	SF(3)	compool	—	—	—	ft	Accumulated vector of filter corrections to position.
R_MEAS_RSS (V90H4999C)	SF	compool	—	—	downlist	kft	RSS of the total filter correction to position for a cycle.
ROLL	SF	local	—	—	—	rad	Q_RR_ROLL expressed in radians.
RO_N	DF	local	—	—	—	ft/sec <sup>2</sup>	Distance term used in $\bar{ACCEL\_ONORBIT}$ gravitational acceleration model.
$\bar{R}_{\text{ONE}}$	DF(3)	local	—	—	—	ft	Position vector at the beginning of an interpolation interval (M50). Also used to generate a transition matrix.
R_ONE_INV	DF	compool	—	—	—	ft <sup>-1</sup>	Reciprocal of the magnitude of $\bar{R}_{\text{ONE}}$ .
RO_ZERO	DF	local	—	—	—	—	Distance term in $\bar{ACCEL\_ONORBIT}$ gravitational acceleration model.
$\bar{R}_{\text{PRED\_FINAL}}$ (V95H0811C-3C)	DF(3)	compool	—	—	downlist	ft	Position vector as output from precise state predictor (M50).
$\bar{R}_{\text{PRED\_INIT}}$ (V94H4002C-4C)	DF(3)	compool	—	—	downlist	ft	Position vector input for prediction (M50).
$\bar{R}_{\text{PROP}}$ (V90H4991C-93C)	DF(3)	compool	—	—	—	ft	Backup propagated position vector.
$\bar{R}_{\text{PROP\_TLM}}$ (V90H4978-80C)	DF(3)	compool	—	—	downlist	ft	Copy of backup position state vector for downlist.
RR_ANGLE_DATA_GOOD (V90X4901X)	B	compool	—	—	downlist	—	Snapped data validity flag for the rendezvous radar angles measurement (RR SOP HAL name RR_ANG_DG, M/S ID# V95X4295X).
RR_ANGLE_MARK_NUM (V90J4824C)	I	compool	IV	0	downlist	—	Rendezvous radar angle (shaft plus trunnion) mark counter.



Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
RR_ANGLES_BIAS_INIT (V96U9164C-5C)	SF(2)	local	MD	—	—	rad	Initial value for the rendezvous radar angles bias slot of the state vector.
RR_ANGLES_EDIT_OVERRIDE	B	local	—	—	—	—	Flag indicating (ON) that the crew wishes to force rendezvous radar angles data.
RR_ANGLES_STAT	B	local	—	—	—	—	Flag indicating (ON) that rendezvous radar angles data is to be processed for statistical display only.
RRDOT_BIAS_INIT (V96U9166C-7C)	SF(2)	local	MD	—	—	ft, ft/sec	Initial value for the rendezvous radar range and range rate bias slots of the state vector.
RRDOT_MARK_NUM (V90J4825C)	I	compool	IV	0	downlist	—	Range and range rate data mark counter.
RREF (V96U9168C)	DF	local	K-Load	+2.3769016 E-03	—	slugs/ ft**3	Constant used to define units of density in ACCEL_ONORBIT drag model.
$\bar{R}$ _RESET (V90H0235C-7C)	DF(3)	compool	—	—	—	ft	Orbiter position vector reserved for the reset of user parameter state propagation position vector (M50).
$\bar{R}$ _RESID	DF(3)	local	—	—	—	ft	Orbiter position vector interpolated to measurement time (M50).
$\bar{R}$ _RHO	SF(3)	compool	—	—	—	ft	Line of sight (M50) between orbiter and target.
R_RHO_MAG	SF	compool	—	—	—	ft	Magnitude of the relative position vector.
$\bar{R}$ _TEMP	SF(3)	local	HC	22,126, 000; 0; 0	—	ft	Initial value for orbiter position vector when an OPS 0 to OPS 2 transition occurs.
$\bar{R}$ _TV (V90H0307C-9C)	DF(3)	compool	MD	—	—	ft	Target vehicle M50 position vector.
$\bar{R}$ _TV_GND (V96H1277C-9C)	DF(3)	compool	—	—	uplink	ft	Uplink target position vector in M50.
$\bar{R}$ _TV_LAST (V90H4789C-91C)	DF(3)	compool	—	—	—	ft	Target position vector at the end of last filter cycle (M50).

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
$\bar{R}_{TV\_RESET}$ (V90H1383C-5C)	DF(3)	compool	—	—	—	ft	Target position vector reserved for the reset of user parameter state propagation position vector (M50).
$\bar{R}_{TV\_RESID}$	DF(3)	local	—	—	—	ft	Target position vector interpolated to measurement time (M50).
$\bar{R}_{TV\_TLM}$ (V90H4287C-89C)	DF(3)	compool	—	—	downlist	ft	Target position vector for downlist (M50).
$\bar{R}_{TWO}$	DF(3)	local	—	—	—	ft	Position vector at the end of the interpolation interval (M50). Also used to generate a transition matrix.
R_TWO_INV	DF	local	—	—	—	ft <sup>-1</sup>	Reciprocal of the magnitude of $\bar{R}_{TWO}$ .
$\bar{S}$	DF(9)	local	C	—	—	—	Tesseral harmonics coefficients used in $\bar{ACCEL\_ONORBIT}$ gravitational acceleration.
S	DF(6,6)	local	IV	0	—	vary	State noise matrix for the covariance propagation.
SA	SF	local	—	—	—	—	Square of the sine of the angle of attack used in $\bar{ACCEL\_ONORBIT}$ drag model.
SB	SF	local	—	—	—	—	Absolute value of the sine of side slip angle used in $\bar{ACCEL\_ONORBIT}$ drag model.
S_BIAS	DF(4)	local	—	—	—	(rad <sup>2</sup> , rad <sup>2</sup> , ft <sup>2</sup> , ft <sup>2</sup> /sec <sup>2</sup> )	State noise terms for the sensor bias slots.
SDEC	DF	compool	—	—	—	—	Sine of solar declination used in $\bar{ACCEL\_ONORBIT}$ atmospheric density model.
SELF_TEST_FLAG (V90X4888X)	B	compool	—	—	downlist	—	Snapped flag indicating that rendezvous radar is in the self-test mode. (RR SOP HAL name RR_SELF_TEST, M/S ID# V95X4309X).
$\bar{SENSOR\_BIAS}$	SF(4)	compool	IV	0,0,0,0	—	rad,rad, ft,ft/sec	Sensor biases, part of state vector (M50).

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
$\bar{S}$ ENSOR_BIAS_TLM (V90U4295C-98C)	SF(4)	compool	—	—	downlist	rad,rad, ft,ft/sec	Sensor biases (part of state vector) for TLM (M50).
$\bar{S}$ ENSOR_DELQ	SF(4)	compool	—	—	—	vary	Measurement residuals.
SENSOR_DELTA (V96U9766C)	SF	local	K-load	+5.773503 E-1	—	—	An increment used to adjust the relative unit vector for measurement processing.
SENSOR_EDIT (V90U8841C, V90J8880C-82C)	C(4)	compool	—	—	downlist	—	Five-valued parameter defining use of measurement data by the navigation filter.. <ul style="list-style-type: none"> <li>ON — rejected by the residual edit test</li> <li>OFF — no processing attempted</li> <li>PROCESSED — accepted by residual edit test and used to update the state vector.</li> <li>STAT — used to generate display parameters</li> <li>FORCED — used to update state vector as a result of manual edit override.</li> </ul>
SENSOR_EPS (V96U9765C)	SF	local	K-load	+1.0 E+0	—	ft	Minimum allowable distance between target and shuttle for measurement processing.
SEQ_ACCEPT (V90J4732C,33C, 30C, 31C)	I(4)	compool	IV	0	downlist	—	Number of sequential sensor marks accepted by the residual edit test for the various sensor measurements.
SEQ_REJECT (V90J4737C, 38C,35C, 36C)	I(4)	compool	IV	0	downlist	—	Number of sequential sensor marks rejected by the residual edit test for the various sensor measurements.
SHAFT	SF	local	—	—	—	rad	Estimate of the rendezvous radar shaft measurement.
SHFT	SF	local	—	—	—	rad	Rendezvous radar shaft angle measurement obtained by transforming the roll and pitch angle outputs Q_RR_ROLL and Q_RR_PITCH.
SHUTTLE_FILTER_FLAG (V90X4952X)	B	compool	—	—	—	—	Flag indicating which vehicle state is to be used by the filter; (ON) Shuttle state (OFF) target state.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
SIFST	SF	local	—	—	—	ft	Variable used in atmospheric density model in $\overline{\text{ACCEL\_ONORBIT}}$ .
SIG_RR_RNG (V96U9775C)	SF	local	DD	—	—	feet	One sigma statistic of rendezvous radar range measurement.
SIG_UPDATE (V96H1284C-9C)	SF(6)	compool	MD	—	uplink	ft, ft/sec	Standard deviations (UVW) for the filter vehicle position/velocity covariance initialization.
SIN_LAG (V96U9169C)	SF	local	DD	—	—	—	Sine of atmospheric density bulge lag angle used in $\overline{\text{ACCEL\_ONORBIT}}$ .
SIN_SOL_RA	DF	compool	—	—	—	—	Sine of solar right ascension used in $\overline{\text{ACCEL\_ONORBIT}}$ density model.
SLOPE_SIG_RR_RNG (V96U9170C)	SF	local	DD	—	—	—	Rate of change of rendezvous radar range statistics with respect to range.
SMA	DF	compool	—	—	—	ft	Semimajor axis of conic.
SQR_EMU (V90U1241C)	DF	compool	—	—	—	ft <sup>3/2</sup> /sec	Square root of EARTH_MU used in onorbit prediction/propagation equations of motion (Pines method).
SSND	SF	local	—	—	—	ft	Variable used in $\overline{\text{ACCEL\_ONORBIT}}$ atmospheric density calculation.
$\overline{\text{ST\_ANGLES\_BIAS\_INIT}}$ (V96U9171C-2C)	SF(2)	local	MD	—	—	rad	Initial value for the star tracker angles bias slots of the state vector.
ST_ANGLES_EDIT_OVERRIDE	B	local	—	—	—	—	Flag used (ON) to override the residual edit test for star tracker angles data.
ST_ANGLES_STAT	B	local	—	—	—	—	Flag indicating (ON) that star tracker angles data are to be processed for statistical display only.
STAT_FLAG	B	compool	—	—	—	—	Copy of the stat flag associated with the measurement type currently being processed.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
ST_DATA_GOOD (V90X4835X)	B	compool	—	—	downlist	—	Snapped data validity flag for star tracker data (STAR TRCK SOP HAL name DATA_GOOD, M/S ID# V95X4771X).
ST_MARK_NUM (V90J4826C)	I	compool	IV	0	downlist	—	Star tracker measurement mark counter.
S_UNMOD_ACC	DF(3,3)	local	—	—	—	ft <sup>2</sup> /sec <sup>4</sup>	Unmodeled acceleration noise terms.
SV_SOURCE_FOR_UPP (V90X4989X)	B	compool	—	—	—	—	Flag indicating whether the filtered state (“1”) or the backup state (“0”) is to be sent by NAV to users.
SV_TIME_TAG_DIFF	SF	local	HC	0.5	—	sec	Time tolerance used to test the time tag of the predicted state against the reset time tag of navigation.
SV_UPDATE	B	local	—	—	—	—	A flag, local to the auto-inflight update subfunction, which indicates (ON) that a state vector update has occurred.
S0 S1 S2 S3	DF	local	—	—	—	— vary vary vary	Auxiliary variables used in F and G series and Pines computations, S1 and S2 also used as auxiliary variables in mean conic partials transition matrix computations.
S2B							
T	DF	local	—	—	—	sec	Time variable (GMT) used in $\bar{ACCEL\_ONORBIT}$ and SOLAR_EPHEMERIS.
TARGET_AREA (V96U9173C)	SF	compool	K-Load	1.0	—	ft <sup>2</sup>	Target vehicle reference cross-sectional area.
TARGET_CD (V96U9174C)	SF	compool	K-Load	2.0	—	—	Target vehicle reference drag coefficient.
TARGET_KFACTOR (V90U4004C)	SF	compool	—	1.0	uplink	—	Target drag model scale factor used in $\bar{ACCEL\_ONORBIT}$ .
TARGET_MASS (V96U9175C)	SF	compool	K-Load	1.0	—	slugs	Target vehicle reference mass.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
TAU	SF(2)	local	—	—	—	sec	Local variable for sensor time constants.
TAU_COAS_ANGLES (V96U9176C-7C)	SF(2)	local	DD	—	—	sec	Time constant for the COAS angles sensor.
TAU_RR_ANGLES (V96U9178C-9C)	SF(2)	local	DD	—	—	sec	Correlation time constant for the rendezvous radar angle measurement.
TAU_RRDOT (V96U9180C-1C)	SF(2)	local	DD	—	—	sec	ECRV correlation time vector for rendezvous radar range and range rate.
TAU_SENS	SF(4)	compool	IV	1.,1.,1.,1.	—	sec	General correlation time constants for sensors.
TAU_ST_ANGLES (V96U9182C-3C)	SF(2)	local	DD	—	—	sec	Correlation time constant for star tracker measurements.
TAU_U_A_COAST (V96U9184C)	SF	compool	DD	—	—	sec	Correlation time constant for unmodeled accelerations during coasting flight.
TAU_U_A_PWRD_FLT (V96U9185C)	SF	local	DD	—	—	sec	Correlation time constant for unmodeled accelerations during powered flight.
TAU_UNMOD_ACC_COV (V90W4929C)	SF	compool	DD	—	—	sec	Correlation time constant for unmodeled accelerations used in covariance propagation.
TAU_UNMOD_ACC_STATE (V96U9186C)	SF	local	DD	—	—	sec	Correlation time constant for unmodeled accelerations used in state propagation.
T_BIAS_COAS (V96U9187C)	SF	local	DD	—	—	sec	Time tag bias associated with COAS measurements.
T_BIAS_REND_RADAR (V96U9188C)	SF	local	DD	—	—	sec	Time tag bias associated with rendezvous radar measurements.
T_BIAS_ST (V96U9189C)	SF	local	DD	—	—	sec	Time tag bias associated with star tracker measurements.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
T_COAS (V90W4853C)	DF	compool	—	—	downlist	sec	Snapped variable for the COAS measurement time tag (STAR TRCK SOP HAL name T_TARLOS, M/S ID# V95W4985C).
T_COAS_LAST	DF	local	IV	0	—	sec	Time of last COAS measurement update.
T_COV_LAST (V90W4771C)	DF	compool	—	—	—	sec	Time tag of last covariance propagation.
T_CURRENT_FILT (V90W4749C)	DF	compool	—	—	downlist	sec	Snapped time tag of the current IMU/ATT data (IMU SOP HAL name T_IMUS_GA, M/S ID# V95W0002C).
$\bar{T}DV\_FILT$	SF(3)	local	HC	0,0,0	—	ft/sec	Dummy vector for target accumulated velocity.
TEMP	DF (13,13)	local	—	—	—	vary	Temporary matrix used during covariance matrix propagation to store the intermediate calculation of $E^T$ during the $E^T + S$ computation.
$\bar{T}EMP$	DF(3)	local	—	—	—	sec/ft	Temporary vector used by the mean conic partial.
T_EPOCH (V97W5528C)	DF	compool	—	—	—	sec	Time tag for M_M50TOEF_AT_EPOCH and EARTH_POLE
TEST_VALUE	SF	local	—	—	—	—	Value against which the residual ratio is tested. If the residual ratio is greater than TEST_VALUE, the measurement is edited.
T_FILT_DAYS (V90W5043C)	I	compool	—	—	—	days	Orbiter state vector GMT days for display.
T_FILT_HRS (V90W5044C)	I	compool	—	—	—	hrs	Orbiter state vector GMT hours for display.
T_FILT_MIN (V90W5045C)	I	compool	—	—	—	min	Orbiter state vector GMT minutes for display.
T_FILT_SECS (V90W5046C)	SF	compool	—	—	—	secs	Orbiter state vector GMT seconds for display.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
T_FILT_INIT (V90W1287C)	DF	compool	OPS	—	—	sec	Time tag of navigation initialization data carried across memory transition.
T_FIN	DF	local	—	—	—	sec	Final time at end of prediction or propagation, used in SUPER_G.
TFOFF (V96W8178C) (V90W4960C)	DF	compool	MD	—	uplink, downlist	sec	Vent/RCS thrust force off time used in $\bar{A}CCEL\_ONORBIT$ .
TFON (V96W8177C) (V90W4959C)	DF	compool	MD	—	uplink, downlist	sec	Vent/RCS thrust force on time used in $\bar{A}CCEL\_ONORBIT$ .
T_GND (V96W3520C)	DF	compool	—	—	uplink	sec	Uplinked time tag of orbiter state vector.
THETA	DF	local	—	—	—	rad	Difference of eccentric anomaly.
THETA_COR	DF	local	—	—	—	rad	Correction to THETA in the solution of Kepler's equation, used in F and G.
THRUST	B	local	—	—	—	—	Flag indicating RCS jet firing or IMU sensed velocity greater than threshold.
T_IN	DF	local	—	—	—	sec	Initial time input for state propagation, used in SUPER_G.
T_LAST_FILT (V90W1252C)	DF	compool	—	—	—	sec	Time tag of $\bar{V}\_LAST\_FILT$ and of filter state at last navigation cycle.
T_LAST_FILT_TLM (V90W4285C)	DF	compool	—	—	downlist	sec	Time tag of orbiter and target state vector at last navigation cycle (for TLM).
T_ORB_STATE_UPDATE (V94W3727C)	DF	compool	MD	—	downlist	sec	Time tag of most recent orbiter state vector update (for TLM).
$\bar{T}OT\_ACC$ (V90A4874C-76C)	DF(3)	compool	—	—	downlist	ft/sec <sup>2</sup>	Orbiter M1950 total acceleration vector.



Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
$\bar{T}OT\_ACC\_LAST$ (V90A1261C-4C)	DF(3)	compool	—	—	—	ft/sec <sup>2</sup>	Value of $\bar{T}OT\_ACC$ at the end of the previous cycle.
T_PRED_FINAL (V94W3979C)	DF	compool	—	—	downlist	sec	Time tag for prediction (associated with $\bar{R}_PRED\_FINAL$ and $\bar{V}_PRED\_FINAL$ ).
T_PRED_INIT (V94W3970C)	DF	compool	—	—	downlist	sec	Time tag for prediction (associated with $\bar{R}_PRED\_INIT$ and $\bar{V}_PRED\_INIT$ ).
T_REND_RADAR (V90W4841C)	DF	compool	—	—	downlist	sec	Snapped time tag of the rendezvous radar measurement (RR SOP HAL name RR_TIM, M/S ID# V95W4292C).
T_RESET (V90W0534C)	DF	compool	—	—	—	sec	Time associated with reserved reset state.
T_RESID	DF	local	—	—	—	sec	Time tag of interpolated state vector.
TRG_TRK_MODE (V90U4836C)	B	compool	—	—	downlist	—	Snapped flag indicating (ON) that the star tracker is in the target tracking mode (STAR TRCK SOP HAL name NAV_TARGET, M/S ID# V95X4778X).
TRUN	SF	local	—	—	—	rad	Estimate of the rendezvous radar trunnion angle measurement.
TRUNNION	SF	local	—	—	—	rad	Rendezvous radar trunnion angle measurement obtained by transforming the pitch and roll angle outputs Q_RR_PITCH and Q_RR_ROLL.
T_STAR_TRACKER (V90W4837C)	DF	compool	—	—	downlist	sec	Snapped variable for the star tracker measurement time tag (STAR TRCK SOP HAL name T_NAV, M/S ID# V95W4760C).
T_ST_LAST	DF	local	IV	0	—	sec	Time of last star tracker measurement.
T_TV (V90W0315C)	DF	compool	MD	—	downlist	sec	Target vehicle state vector time tag.
T_TV_GND (V96W1283C)	DF	compool	—	—	uplink	sec	Uplinked target state time tag.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
T_TV_STATE_UPDATE (V90W4939C)	DF	compool	MD	—	downlist	sec	Time tag of most recent target state vector update (for TLM).
TV_PREDICT_FAIL (V90X4769XA)	B	compool	—	—	downlist	—	Flag which indicates that the time tolerance MAX_TIME_TOL has been exceeded and consequently no target state vector prediction will take place.
$\bar{U}_M$	SF(3)	compool	—	—	—	ft	Line of sight vector in sensor system.
$\bar{U}NMOD\_ACC\_BIAS$ (V90U1265C-7C)	SF(3)	compool	—	—	—	ft/sec <sup>2</sup>	Unmodeled acceleration bias.
$\bar{U}NMOD\_ACC\_BIAS\_TLM$ (V90U4301C-03C)	SF(3)	compool	—	—	downlist	ft/sec <sup>2</sup>	Unmodeled acceleration bias for TLM.
UNMOD_ACC_UPDATE_FLAG (V96U9190C)	B	local	MD	—	—	—	Flag indication (ON) that the unmodeled acceleration bias states are to be updated by the filter.
$\bar{U}R$	DF(3)	local	—	—	—	—	Earth fixed unit vector in $\bar{A}CCEL\_ONORBIT$ drag model.
$\bar{U}_RDOT$	SF(3)	local	—	—	—	1/sec	Local variable used in the calculation of the estimated range rate measurement.
$\bar{U}R\_SUN$ (V90U4872C-4C)	DF(3)	compool	—	—	—	—	Sun unit vector in M50 coordinates.
USE_IMU_DATA (V90X0538X)	B	compool	IV	OFF	downlist	—	Flag indicating (ON) the usage of IMU data by the powered flight propagator.
USE_IMU_DATA_LAST	B	local	IV	OFF	—	—	Flag indicating (ON) the usage of IMU data by the powered flight propagator during the last NAV cycle.
$\bar{V}$	DF(3)	local	—	—	—	ft/sec	Vehicle M50 velocity used in $\bar{A}CCEL\_ONORBIT$ .
VAR	SF	compool	—	—	—	vary	Copy of variance associated with measurement currently being processed.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
$\bar{V}AR\_COAS\_ANGLES$ (V96U9191C-2C)	SF(2)	local	DD	—	—	rad <sup>2</sup>	COAS angles measurement bias variables used to initialize the covariance matrix.
VAR_COAS_HORIZ (V96U9193C)	SF	local	DD	—	—	rad <sup>2</sup>	Variance of the COAS horizontal measurement.
VAR_COAS_VERT (V96U9194C)	SF	local	DD	—	—	rad <sup>2</sup>	Variance of the COAS vertical measurement.
VAR_HORIZ	SF	local	—	—	—	rad <sup>2</sup>	Variance of the horizontal measurement sensor.
VAR_IMU_ALIGN (V96U9195C)	SF	local	DD	—	—	rad <sup>2</sup>	Variance of platform misalignment added as process noise in the covariance matrix.
VAR_RANGE_DOT (V96U9196C)	SF	local	DD	—	—	ft <sup>2</sup> /sec <sup>2</sup>	Variance of the rendezvous radar range rate sensor measurement.
VAR_RR_ANGLES (V96U9197C-8C)	SF(2)	local	DD	—	—	rad <sup>2</sup>	Rendezvous radar angles measurement bias variances used to initialize the covariance matrix.
VAR_RRDOT (V96U9199C-200C)	SF(2)	local	DD	—	—	ft <sup>2</sup> , ft <sup>2</sup> /sec <sup>2</sup>	Rendezvous radar range and range rate measurement bias variance used to initialize the covariance matrix.
VAR_RR_RNG_MIN (V96U9201C)	SF	local	DD	—	—	ft <sup>2</sup>	Minimum value for computation of rendezvous radar range variance.
VAR_SENS	SF(4)	compool	—	—	—	vary	General measurement bias filter variance used in adding process noise to the sensor bias portion of covariance.
VAR_SHAFT (V96U9202C)	SF	local	DD	—	—	rad <sup>2</sup>	Variance of the rendezvous radar shaft angle measurement.
VAR_ST_ANGLES (V96U9203C-4C)	SF(2)	local	DD	—	—	rad <sup>2</sup>	Star tracker angles measurement bias variances used to initialize the covariance matrix.
VAR_ST_HORIZ (V96U9205C)	SF	local	DD	—	—	rad <sup>2</sup>	Variance of star tracker horizontal angle measurement.
VAR_ST_VERT (V96U9206C)	SF	local	DD	—	—	rad <sup>2</sup>	Variance of star tracker vertical angle measurement.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
VAR_TRUN (V96U9207C)	SF	local	DD	—	—	rad <sup>2</sup>	Variance of the rendezvous radar trunnion angle measurement.
$\bar{V}$ AR_U_A_COAST (V96U9208C-10C)	SF(3)	compool	DD	—	—	ft <sup>2</sup> /sec <sup>4</sup>	Variance of unmodeled accelerations during coasting flight.
$\bar{V}$ AR_U_A_PWRD_FLT (V96U9211C-13C)	SF(3)	local	DD	—	—	ft <sup>2</sup> /sec <sup>4</sup>	Variance of unmodeled accelerations during powered flight.
$\bar{V}$ AR_UNMOD_ACC (V90A4933C-35C)	SF(3)	compool	—	—	—	ft <sup>2</sup> /sec <sup>4</sup>	Variance of unmodeled accelerations.
VAR_VERT	SF	local	—	—	—	rad <sup>2</sup>	Variance of the vertical measurement sensor.
$\bar{V}$ _CORR	DF(3)	local	—	—	—	ft/sec	Filter correction to the velocity.
$\bar{V}$ _CURRENT_FILT (V90L8927C-9C)	DF(3)	compool	—	—	downlist	ft/sec	Snapped variable for the total accumulated IMU sensed velocity (IMU RM HAL name $\bar{S}$ EL_V_M50_CG, MSID# V90L2607C-09C).
VEH_MASS	SF	local	—	—	—	slugs	Vehicle mass used in $\bar{A}$ CCEL_ONORBIT drag model.
VEL_THRESH (V99U7496C)	SF	compool	DD	—	—	ft/sec	Test value to determine whether to incorporate sensed velocities during RCS burns.
$\bar{V}$ ENT	SF(3)	local	—	—	—	ft/sec <sup>2</sup>	Vent/RCS thrust acceleration used in $\bar{A}$ CCEL_ONORBIT.
$\bar{V}$ ENT_SS (V90U4964C-66C)	SF(3)	compool	—	—	downlist	ft/sec <sup>2</sup>	Orbiter vent vector for downlist.
VERT	SF	local	—	—	—	rad	Filter estimated vertical angle measurement.
$\bar{V}$ _FILT (V90L0624C-6C)	DF(3)	compool	—	—	—	ft/sec	Orbiter M1950 velocity vector.
$\bar{V}$ _FILT_DISP (V90L5047C-5049C)	DF(3)	compool	—	—	—	kft/sec	M50 orbiter velocity vector for display.
$\bar{V}$ _FILT_INIT (V90L1279C-81C)	DF(3)	compool	OPS	—	—	ft/sec	Orbiter velocity vector saved across memory reconfiguration and used for navigation initialization.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
$\bar{V}$ _FILT_TLM (V90L4281C-83C)	DF(3)	compool	—	—	downlist	ft/sec	Orbiter velocity vector for TLM (M50).
$\bar{V}$ _FIN	DF(3)	local	—	—	—	ft/sec	Orbiter or target velocity vector at T_FIN, used in SUPER_G.
VFL_OV	B	compool	HC	1	—	—	Flag indicating activation (1) or deactivation (0) of Vent/RCS thrust acceleration models for orbiter propagation.
VFLOV_PRED	B	compool	HC	0	—	—	Flag indicating activation (1) or deactivation (0) of Vent/RCS thrust acceleration model for orbiter prediction.
VFL_TV	B	compool	HC	1	—	—	Flag setting that specifies use of unmodeled acceleration bias for target vehicle propagation.
VFLTV_PRED	B	compool	HC	0	—	—	Flag setting that specifies use of unmodeled acceleration bias for target vehicle prediction.
VFL_TV_PROP	B	local	HC	0	—	—	Flag specifying the vent model to be used when propagating the backup state for the target.
V_FMP_DISP (V90L4998C)	SF	compool	—	—	downlist	ft/sec	RSS of the filtered position vector minus the backup propagated position.
$\bar{V}$ FORCE (V96U8174C-76C) (V90U4956C-58C)	SF(3)	compool	MD	—	uplink, downlist	lb	Vent/RCS thrust force vector in body coordinates used in $\bar{A}$ CCEL_ONORBIT.
$\bar{V}$ _GND (V96L3510C-12C)	DF(3)	compool	—	—	uplink	ft/sec	Uplinked orbiter velocity vector.
$\bar{V}$ _IMU_DIF	DF(3)	local	—	—	—	ft/sec	Difference in current and past accumulated sensed IMU velocities used in state vector interpolation.
$\bar{V}$ _IMU_RESET (V90L0247C-9C)	DF(3)	compool	—	—	downlist	ft/sec	Copy of $\bar{V}$ _LAST_FILT.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
$\bar{V}_{IN}$	DF(3)	local	—	—	—	ft/sec	Initial orbiter or target velocity vector used in F and G or SUPER_G.
$\bar{V}_{LAST}$ (V90L4785C-7C)	DF(3)	compool	—	—	—	ft/sec	Velocity vector of the Shuttle at the end of the last filter subcycle.
$\bar{V}_{LAST\_FILT}$ (V90L0621C-3C)	DF(3)	compool	—	—	—	ft/sec	Total accumulated IMU-sensed velocity.
VM	B	local	—	—	—	—	Flag used in $\bar{ACCEL\_ONORBIT}$ to indicate if vent/RCS model is to be used.
$\bar{V}_{MEAS}$	SF(3)	compool	—	—	—	ft/sec	Accumulated vector of filter corrections to velocity.
$V_{MEAS\_RSS}$ (V90L5000C)	SF	compool	—	—	downlist	ft/sec	RSS of the total filter correction to velocity for a cycle.
VMP (V94X3971X)	B	compool	—	—	—	—	Flag indicating use or nonuse of the vent model in prediction.
$\bar{V}_{ONE}$	DF(3)	local	—	—	—	ft/sec	Velocity vector at the beginning of a time interval used to generate a transition matrix. Also the velocity vector at the beginning of an interpolation interval.
$\bar{V}_{PRED\_FINAL}$ (V95L0814C-6C)	DF(3)	compool	—	—	downlist	ft/sec	Velocity vector as output from precision state predictor.
$\bar{V}_{PRED\_INIT}$ (V94L4006C-8C)	DF(3)	compool	—	—	downlist	ft/sec	Initial velocity vector for prediction.
$\bar{V}_{PROP}$ (V90L4994C-6C)	DF(3)	compool	—	—	—	ft/sec	Backup propagated velocity vector.
$\bar{V}_{PROP\_TLM}$ (V90L4981C-3C)	DF(3)	compool	—	—	downlist	ft/sec	Copy of backup velocity state vector for downlist.
$\bar{V}_R$	SF(3)	local	—	—	—	ft/sec	Velocity of vehicle relative to atmosphere used in $\bar{ACCEL\_ONORBIT}$ drag model in M50 coordinates.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
$\bar{V}$ _REL_BODY	SF(3)	local	—	—	—	ft/sec	Orbiter velocity relative to the atmosphere in body coordinates.
$\bar{V}$ _RESET (V90L0239C -41C)	DF(3)	compool	—	—	—	ft/sec	Orbiter vehicle velocity vector after all navigation updates reserved for reset of user parameter state propagator velocity vector.
$\bar{V}$ _RESID	DF(3)	local	—	—	—	ft/sec	M1950 velocity vector interpolated to the measurement time.
$\bar{V}$ _RHO	SF(3)	compool	—	—	—	ft/sec	Relative M1950 velocity vector.
$\bar{V}$ _TEMP	SF(3)	local	HC	0., 25270., 0.	—	ft/sec	Initial value for orbiter velocity vector when an OPS 0 to OPS 2 transition occurs.
$\bar{V}$ _TV (V90L0310C -12C)	DF(3)	compool	MD	—	—	ft/sec	Target vehicle M1950 velocity vector.
$\bar{V}$ _TV_GND (V96L1280C -2C)	DF(3)	compool	—	—	uplink	ft/sec	Uplinked target velocity vector.
$\bar{V}$ _TV_LAST (V90L4792C -4C)	DF(3)	compool	—	—	—	ft/sec	Last value of the target vehicle velocity vector.
$\bar{V}$ _TV_RESET (V90L1380C -2C)	DF(3)	compool	—	—	—	ft/sec	Target vehicle velocity vector after all navigation updates, reserved for reset of user parameter state propagator velocity vector.
$\bar{V}$ _TV_RESID	DF(3)	local	—	—	—	ft/sec	Velocity vector of the target vehicle at measurement time.
$\bar{V}$ _TV_TLM (V90L4291C -93C)	DF(3)	compool	—	—	downlist	ft/sec	Target velocity vector for TLM (M50).
$\bar{V}$ _TWO	DF(3)	local	—	—	—	ft/sec	Velocity vector at the end of a time interval used to generate a transition matrix. Also the velocity vector at the end of an interpolation interval.
WT_DISP (V93G6940C)	SF	compool	OPS	—	—	lbs	Displayed weight transferred from OPS 1 to OPS 2, or OPS 3 to OPS 2.

Table 5.1-1. Variable List - On-orbit Navigation

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
$\bar{X}$	DF(6)	local	—	—	—	ft,ft,ft, ft/sec, ft/sec, ft/sec	Temporary array for the orbiter or target state vector, used in Pines method.
$\bar{XN}$	DF(7)	local	—	—	—	ft,ft,ft, ft/sec, ft/sec, ft/sec, sec	Array of integrated initial conditions for onorbit prediction and propagation.
$\bar{ZETA\_IMAG}$	DF(5)	local	—	—	—	—	Coefficients used in $\bar{ACCEL\_ONORBIT}$ gravitational acceleration which are longitude dependent.
$\bar{ZETA\_REAL}$	DF(5)	local	—	—	—	—	Coefficients used in $\bar{ACCEL\_ONORBIT}$ gravitational acceleration which are longitude dependent.
$\bar{ZONAL}$	DF(4)	local	C	—	—	—	Zonal harmonics coefficients used in $\bar{ACCEL\_ONORBIT}$ gravitational acceleration.



Table 5.1A-1. Variable List - GPS Related Parameters

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/ Downlist	Units	Description
ATMP (V94J3999C)	I	compool	—	—	downlist	—	Flag indicating target or orbiter CD, mass and area for prediction.
CORR_COEFF_GPS (V90U3068C-74C)	SF(7)	compool	—	—	—	—	Nominal values of the covariance matrix correlation coefficients to be used for reinitializing the navigation Kalman filter covariance at a GPS reset of the navigation filter state.
DOING_REND_NAV (V90X4765X)	B	compool	IV	OFF	downlist	—	Flag indicating (ON) that a powered flight navigation phase is currently active.
DMP (V94X3969X)	B	compool	—	—	—	—	Flag indicating whether drag acceleration should be used by ACCEL_ONORBIT.
E (V90U4006C-09C V90U4011C-19C V90U4026C-38C V90U4045C-57C V90U4064C-76C V90U4083C-95C V90U4103C-15C V90U4122C-34C V90U4141C-53C V90U4160C-72C V90U4179C-91C V90U4198C-220C V90U4202C-11C V90U4218C-30C V90U4237C-49C)	DF (13,13)	compool	—	—	downlist (diagonal elements only)	vary	Filter covariance matrix
FOM (V91H0982C,3C,4C)	I(3)	compool	—	—	—	—	GPS receiver figures of merit.
FOM_SOP (V90H3009C-11C)	I(3)	compool	—	—	—	—	Figure of merit for each GPS receiver from the GPS SOP.
G_COV	DF(6,6)	local	—	—	—	—	Navigation covariance matrix adjustment (UVW).

Table 5.1A-1. Variable List - GPS Related Parameters

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/ Downlist	Units	Description
G_COV_M50	DF(6,6)	local	—	—	—	—	Navigation covariance matrix adjustment rotated to M50 coordinates.
G_GPS_INIT (V90A2619C-21C)	DF(3)	compool	—	—	—	—	Gravity acceleration for GPS REF STATE INIT
G_NEW (V90U4940C-42C)	DF(3)	compool	—	—	downlist	ft/sec *sec	Orbiter acceleration vector (M50).
GMDP (V94J3975C)	I	compool	—	—	—	—	Parameter specifying degree of gravity model to be used by ACCEL_ONORBIT.
GMOP (V94J3963C)	I	compool	—	—	—	—	Parameter specifying order of gravity model to be used by ACCEL_ONORBIT.
GPS_AIF (V93J1200C)	I	compool	—	—	—	—	GPS Auto/Inhibit/Force Flag
GPS_AIF_EXEC (V94X1041X)	B	compool	—	—	—	—	Flag indicating if GPS auto/inhibit/force executed.
GPS_AIF_RCVD (V9331042C)	I	compool	—	—	—	—	Flag indicating which GPS Auto/Inhibit/Force command is in effect.
GPS_DG (V90X3450X,1X,2X)	B(3)	compool	—	—	—	—	GPS data good flag indicating power on with no communications fault, valid data and receiver in NAV mode.
GPS_DG_SF_PREV (V90X3536X-38X)	B(3)	compool	—	—	—	—	Data good for GPS state selection of each valid receiver state from previous navigation cycle.
GPS_DG_SOP (V90X3012X-14X)	B(3)	compool	—	—	—	—	GPS data good indicator.
GPS_FAIL_FOM (V90X3453X,4X,5X)	B(3)	compool	—	—	—	—	FOM failure status of GPS receivers.
GPS_FAIL_FOM_SOP (V90X3015X-17X)	B(3)	compool	—	—	—	—	FOM failure status of GPS receiver.
GPS_LOCKOUT (V97U3563C)	I	compool	MD	—	—	—	Parameter defining permissible GPS incorporation (A/I/F) for different memory configurations.

Table 5.1A-1. Variable List - GPS Related Parameters

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/ Downlist	Units	Description
GPS_NAV_AIF_EXEC (V94X6082X)	B	compool	IV	OFF	—	—	Flag indicating (ON) that the requested GPS to NAV AUTO command could not be honored.
GPS_RATIO_FLAG (V90X0440X)	B	compool	IV	OFF	—	—	Flag indicating (ON) that selected GPS residual ratio exceeded its allowed limit
GPS_REF_INIT_VALID (V90X3642X)	B	compool	IV	ON	—	—	Flag indicating (ON) that a valid reference state has been obtained for aiding the GPS receiver(s).
GPS_SV_SEL_AVAIL (V90X3081X)	B	compool	—	—	—	—	Flag indicating a selected GPS state vector is available.
GPS_TO_GC_AIF (V93J1200C)	I	compool	—	—	—	—	GPS Auto/Inhibit/Force flag.
GPS_TO_NAV_AI (V93X1202X)	I	compool	—	—	—	—	Auto/Inhibit command for GPS resetting the NAV state.
GPS_TO_NAV_AIF (V90J3463C)	I	compool	—	—	—	—	Auto/Inhibit/Force command feedback for GPS resetting the NAV state.
GPS_TO_NAV_FORCE (V93X1201X)	B	compool	—	—	—	—	Command for forcing GPS states into navigation.
GPS_TO_NAV_FORCE_RCVD (V90X3461X)	B	compool	—	—	—	—	A local copy of the command for forcing GPS states into navigation.
GPS_TO_NAV_RCVD (V90X3462X)	I	compool	—	—	—	—	A local copy of the Auto/Inhibit command for GPS incorporation into navigation.
M_ROT	DF(3)	local	—	—	—	—	Matrix for rotating covariance matrix from UVW to M50 coordinate systems.
NAV_RESET (V94X1135XC)	B	compool	—	OFF	—	—	Flag indicating the nav filter states have been reset with the GPS selected state.
NOOP_GPS_GAX_MSGS (V90X3547X)	B	compool	—	—	—	—	Flag to inhibit GPS GAX messages.
Q_M50BODY_IMU (V95U0873C-6C)	SF(4)	compool	—	—	downlist	—	Snapped variable for the shuttle M50 to body attitude quaternion at the time of the IMU drag snap.

Table 5.1A-1. Variable List - GPS Related Parameters

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/ Downlist	Units	Description
$\bar{R}$ _FILT (90H0584C-6C)	DF(3)	compool	—	—	—	ft	Orbiter position vector (M50).
$\bar{R}$ _GPS_ECEF_SOP (V90H3036C-44C)	3xDF(3)	compool	—	—	—	ft	Position vector of GPS data sent to GPS Receiver State Proc.
$\bar{R}$ _PROP (V90H4991C-93C)	DF(3)	compool	—	—	—	ft	Backup propagated position vector.
$\bar{R}$ _RESET (V90H0235C-7C)	DF(3)	compool	—	—	—	ft	Orbiter vehicle position vector reserved for the reset of user parameter state propagator position vector.
$\bar{R}$ _TV (V90H0307C-9C)	DF(3)	compool	MD	—	—	ft	Target vehicle M1950 velocity vector.
R_GPS_ECEF	DF(3)	local	—	—	—	ft	Estimates of shuttle position from GPS receivers in WGS 84.
$\bar{R}$ _GPS_INIT (V90H3476C,7C,8C)	DF(3)	compool	—	—	—	ft	Estimates of shuttle position for GPS reference state initialization.
$\bar{R}$ _GPS_SEL (V90H3082C,3C,4C)	DF(3)	compool	—	—	—	ft	Selected GPS Position vector.
SHUTTLE_FILTER_FLAG (V90X4952X)	B	compool	MD	—	—	—	Flag indicating which vehicle state is to be used by the filter; (ON) shuttle state, (OFF) target state.
SIG_DIAG_GPS (V90H3094C-99C)	DF(6)	compool	—	—	—	—	Square root of diagonal elements for GPS update covariance matrix.
T_CURRENT_FILT (V90W4749C)	DF	compool	—	—	downlist	sec	Snapped time tag of the current IMU/ATT data.
T_GPS_SOP (V90W3045C-47C)	3xDF	compool	—	—	—	sec	Time tag for current GPS receiver data.
T_GPS (V90W3479C,80C,81C)	DF(3)	compool	—	—	—	sec	Time tags of GPS estimates of shuttle state vector.
T_GPS_CYCLE (V94U2926C)	S	compool	DD	—	—	sec	Nominal time between GPS updates of the nav filter state.

Table 5.1A-1. Variable List - GPS Related Parameters

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/ Downlist	Units	Description
T_GPS_INIT (V90W3482C)	DF	compool	—	—	—	sec	Time tags of the estimates of the shuttle state vector for GPS reference initialization.
T_GPS_LAST_UPDATE (V90W3556C)	DF	compool	—	—	—	sec	Time of last GPS update of nav filter state.
T_IMU_SAVE_SOP (V90W3048C-50C)	3xDF	compool	—	—	—	sec	Time tag of IMU data closest to GPS data snap.
T_LAST_FILT (V90W1252C)	DF	compool	—	—	—	sec	Time tag of V_LAST_FILT and of filter state at last navigation cycle.
T_LAST_GPS (V90W3183C,4C,5C)	3xDF	compool	—	—	—	sec	Time tag of IMU data closest to GPS data snap time.
T_RESET (V90W0534C)	DF	compool	—	—	—	sec	Time associated with reserved reset state.
UPLINK_NAV_RESET	B	compool	IV	OFF	—	—	Flag indicating (ON) that the orbiter state has been updated by a ground uplink.
UVW_TO_M50	DF(3,3)	compool	—	—	—	—	Matrix transformation between UVW and M50 coordinate frames.
$\bar{V}$ _CURRENT_FILT (V90L8927C-9C)	DF(3)	compool	—	—	downlist	ft/sec	Snapped variable for the total accumulated IMU sensed velocity.
$\bar{V}$ _FILT (V90L0624C-6C)	DF(3)	compool	—	—	—	ft/sec	Orbiter M1950 velocity vector.
V_GPS_ECEF	SF(3)	local	—	—	—	ft/sec	Estimates of shuttle velocity from GPS receivers in WGS 84.
$\bar{V}$ _GPS_ECEF_SOP (V90L3051C-59C)	3xDF(3)	compool	—	—	—	ft/sec	Velocity vector of GPS data sent to GPS Receiver State Proc.
$\bar{V}$ _GPS_INIT (V90L3475C,6C,7C)	SF(3)	compool	—	—	—	ft/sec	Estimates of shuttle velocity for GPS reference state initialization.
$\bar{V}$ _GPS_SEL (V90L3108C,9C,10C)	DF(3)	compool	—	—	—	ft/sec	Selected GPS Velocity vector.

Table 5.1A-1. Variable List - GPS Related Parameters

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial-ization Category	Initial Value	Uplink/Downlist	Units	Description
$\bar{V}$ _IMU_GPS_INIT (V90L3506C to V90L3514C)	DF(9)	compool	—	—	—	ft/sec	Initial IMU velocity counts assigned to each GPS receiver.
$\bar{V}$ _IMU_RESET (V90L0247C-9C)	DF(3)	compool	—	—	downlist	—	Accumulated IMU velocity counts associated with reset state.
$\bar{V}$ _IMU_SAVE_SOP (V95L0133C-41C)	3xDF(3)	compool	—	—	—	—	IMU counts associated with GPS snapped receiver states.
$\bar{V}$ _LAST_FILT (V90L0621C-3C)	DF(3)	compool	—	—	—	ft/sec	Total accumulated IMU sensed velocity.
$\bar{V}$ _LAST_GPS (V90L3515C to V90L3523C)	DF(9)	compool	—	—	—	ft/sec	IMU velocity counts just prior to time of GPS receiver states snapped by navigation from the GPS SOP.
$\bar{V}$ _PROP (V90L4994C-6C)	DF(3)	compool	—	—	—	ft/sec	Backup propagated velocity vector.
$\bar{V}$ _RESET (V90L0239C-41C)	DF(3)	compool	—	—	—	ft/sec	Orbiter vehicle velocity vector reserved for the reset of user parameter state propagator velocity vector.
$\bar{V}$ _TV (V90L0310C-12C)	DF(3)	compool	MD	—	—	ft/sec	Target vehicle M1950 velocity vector
VMP (V94X3971X)	B	compool	—	—	—	—	Flag indicating whether vent acceleration should be used by ACCEL_ONORBIT.

## 5.2 NAVIGATION SEQUENCER PRINCIPAL FUNCTION AND NAVIGATION PROCESSING PRINCIPAL FUNCTION FLOW CHARTS

The materials provided in this section are suggested flow charts (Figures 5.2–1 through 5.2–49) for the Navigation Sequencer and Basic Navigation principal functions. Flow charts for other functions, such as the precision state predictor, user parameter processor, and uplink processing functions are provided in Sections 5.3 through 5.5. Interface diagrams for the Navigation Sequencer, Basic Navigation and precision state predictor functions are provided in Section 5.6.

These flow charts represent navigation sequencer and navigation processing and are composed of the following modules:

1. ONORBIT\_REND\_NAV\_SEQUENCER (OPS 2)
2. ONORBIT\_REND\_NAV\_SEQUENCER (OPS 8)
3. REND\_NAV\_EXIT
4. NAV\_EXIT
5. OPS\_2\_OR\_8\_INITIALIZE
6. SHUTTLE\_RESET
7. REND\_NAV\_INIT
8. REND\_COV\_INIT
9. COV\_LAST\_RESET
10. DO\_NAV\_LAST\_SETUP CODE
11. COVINIT\_UVW
12. DISPLAY\_COUNT\_INIT
13. TARGET\_RESET
14. NAV\_ONORBIT\_RENDEZVOUS
- 14a. SNAP\_INPUTS CODE
15. COV\_PROP\_SETUP CODE
- 15a. STATE\_VECTOR\_MANAGEMENT CODE
16. ONORBIT\_REND\_AUTO\_INFLIGHT\_UPDATE
17. STATE\_VECTOR\_PREDICT\_TASK
18. REL\_NAV\_DISPLAY\_UPDATES
- 18a. GPS\_UPDATE CODE

- 18b. GPS RESYNCH
- 19. ONORBIT\_REND\_R\_V\_STATE\_PROP
- 20. SUPER\_G
- 21.  $\overline{ACCEL\_ONORBIT}$  FUNCTION
- 22. ACCEL\_EARTH\_GRAV CODE
- 23. ACCEL\_ONORBIT\_VENT\_AND\_THRUST CODE
- 24. SOLAR\_EPHEM
- 25. ONORBIT\_DENSITY CODE
- 26. ACCEL\_ONORBIT\_DRAG CODE
- 27. H\_ELLIPSOID FUNCTION
- 28.  $\overline{V\_REL}$  FUNCTION
- 29. REND\_BIAS\_AND\_COV\_PROP
- 30. UNMOD\_ACC\_REINIT CODE
- 31. PHI\_E\_PHI\_TRANSPOSE CODE
- 32. PWRD\_FLT\_NOISE CODE
- 33. U\_A\_BIAS\_AND\_COVINIT
- 34. MEAN\_CONIC\_PARTIAL\_TRANSITION\_MATRIX\_6x6
- 35. F\_AND\_G
- 36. REND\_SENSOR\_SELECT
- 37. REND\_NAV\_SENSOR\_INIT
- 38. SETUP
- 39. RRDOT\_NAV
- 40. REND\_NAV\_INTERP
- 41. ONORBIT\_SV\_INTERP
- 42. REND\_NAV\_FILTER
- 43. REND\_STATE\_AND\_COV\_UPDATE CODE
- 44. RR\_ANGLE\_NAV



- 45. REND\_ANGLE\_PARTIALS
- 46. STAR\_TRACKER\_NAV
- 47. ANGLE\_NAV
- 48. COAS\_NAV
- 49. MEAS\_PROCESSING\_STATISTICS\_REND

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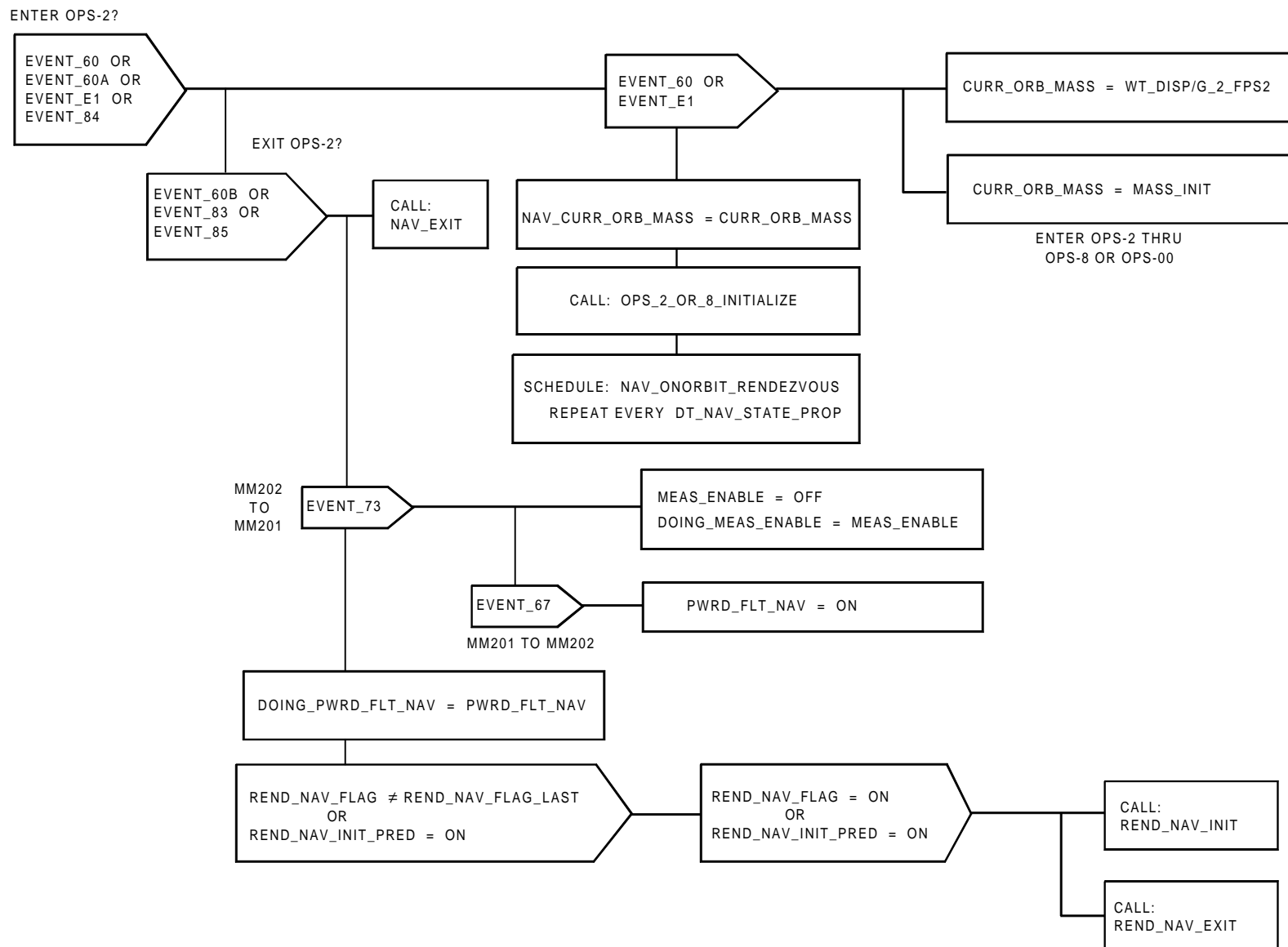


FIGURE 5.2-1. ONORBIT\_REND\_NAV\_SEQUENCER (OPS-2)

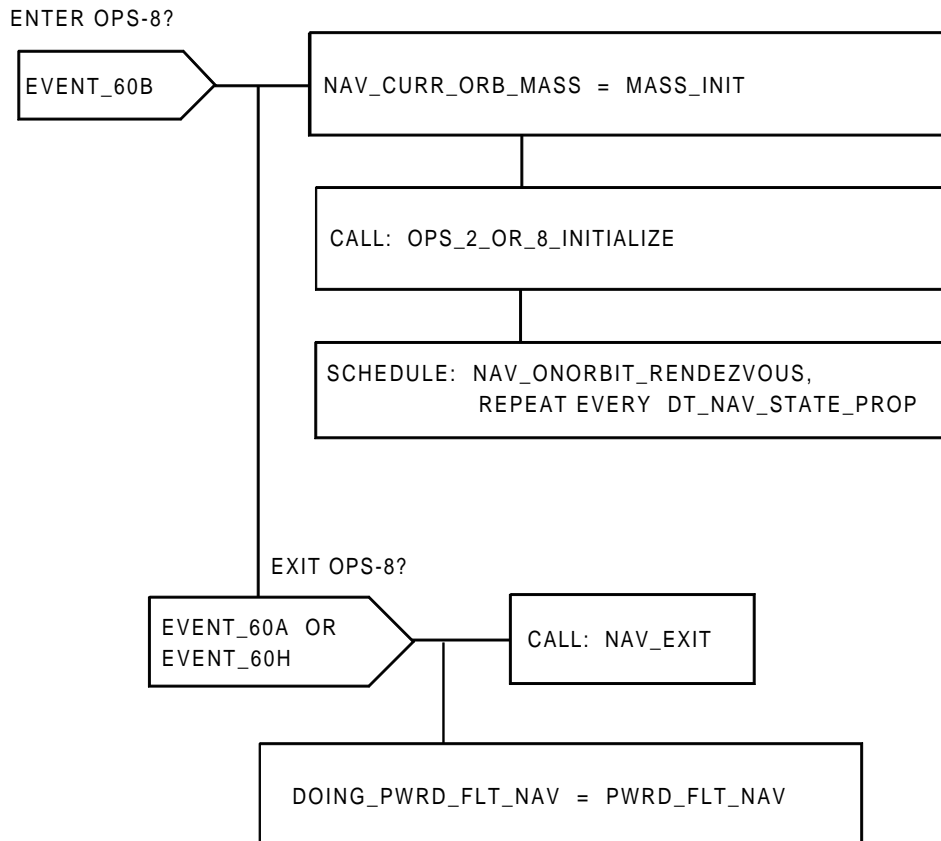


FIGURE 5.2-2. ONORBIT\_REND\_NAV\_SEQUENCER (OPS-8)

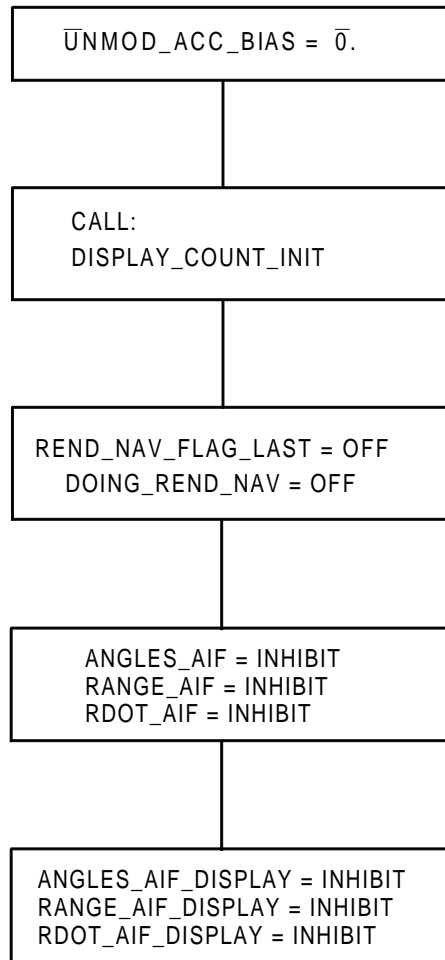
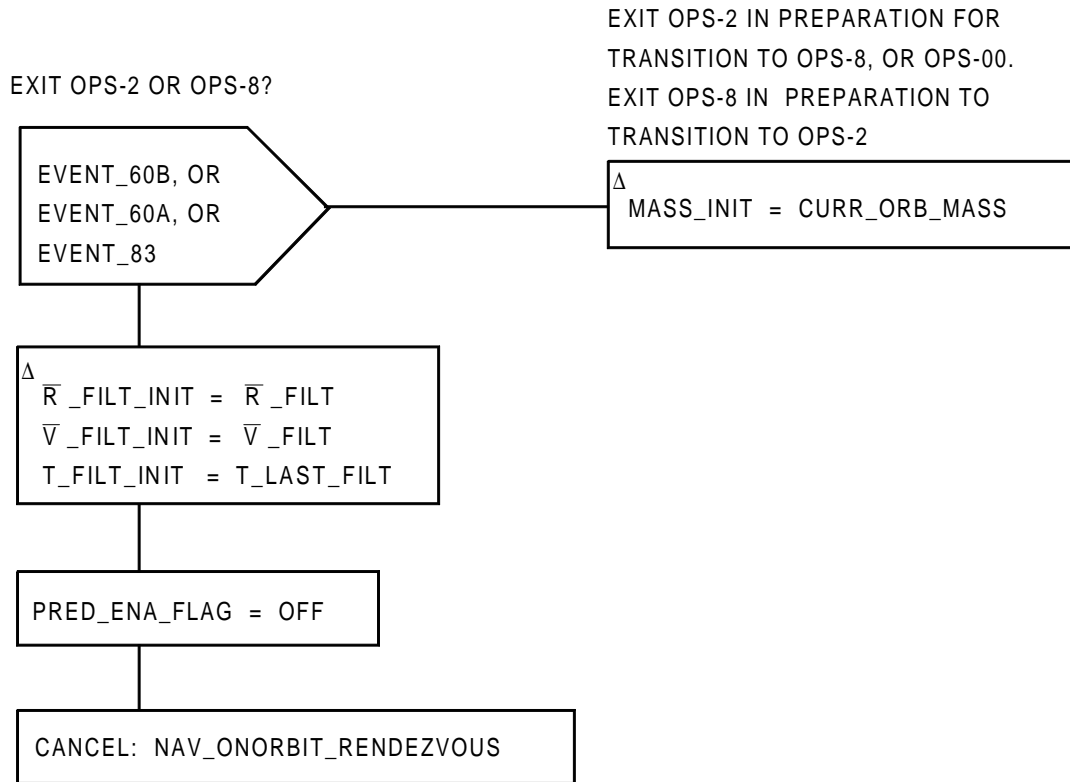


FIGURE 5.2-3. REND\_NAV\_EXIT



$\Delta$  THESE PARAMETERS MUST BE SAVED ACROSS THE MEMORY TRANSITIONS.

FIGURE 5.2-4. NAV\_EXIT

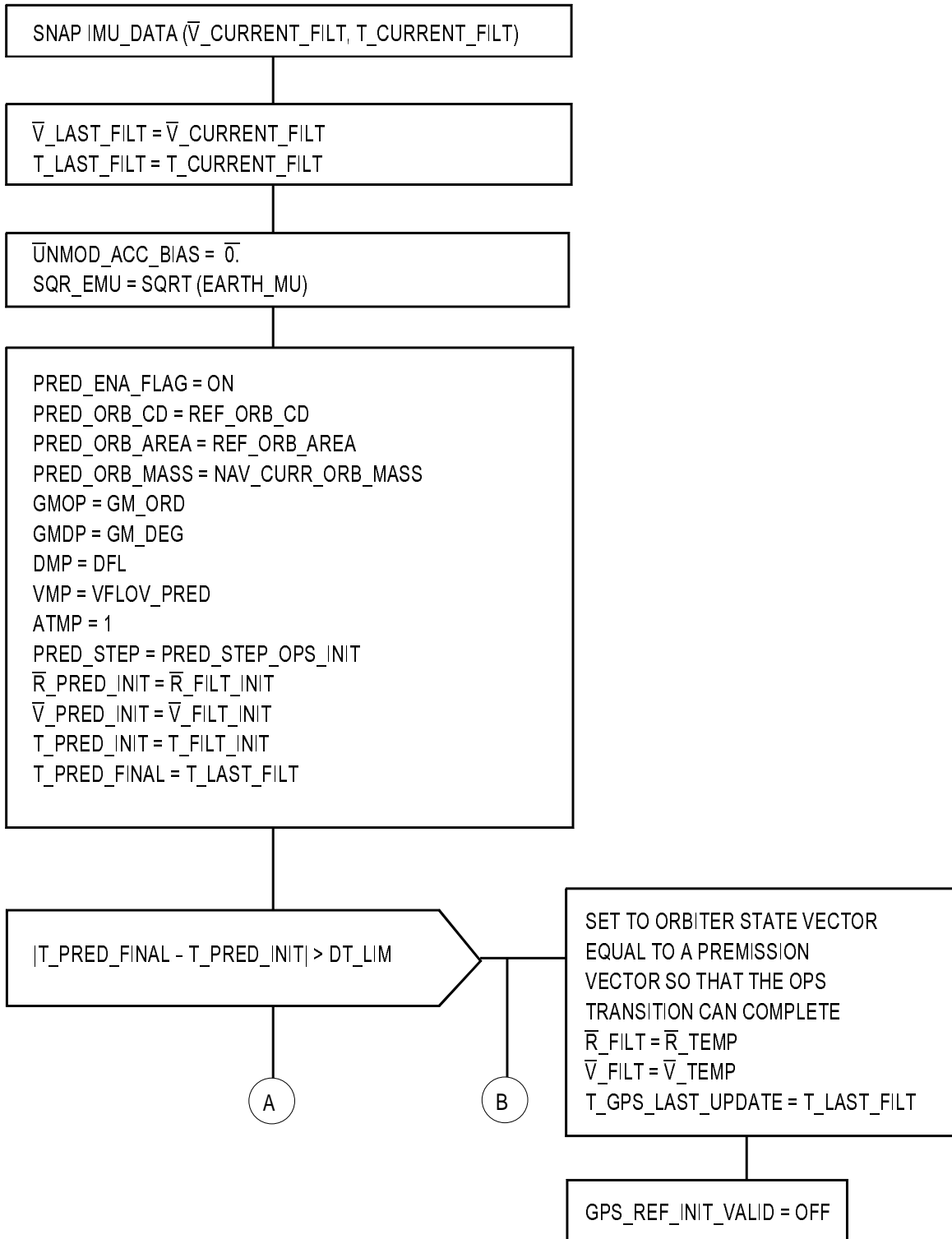


FIGURE 5.2-5.(1) OPS\_2\_OR\_8\_INITIALIZE (Sheet 1 of 2)

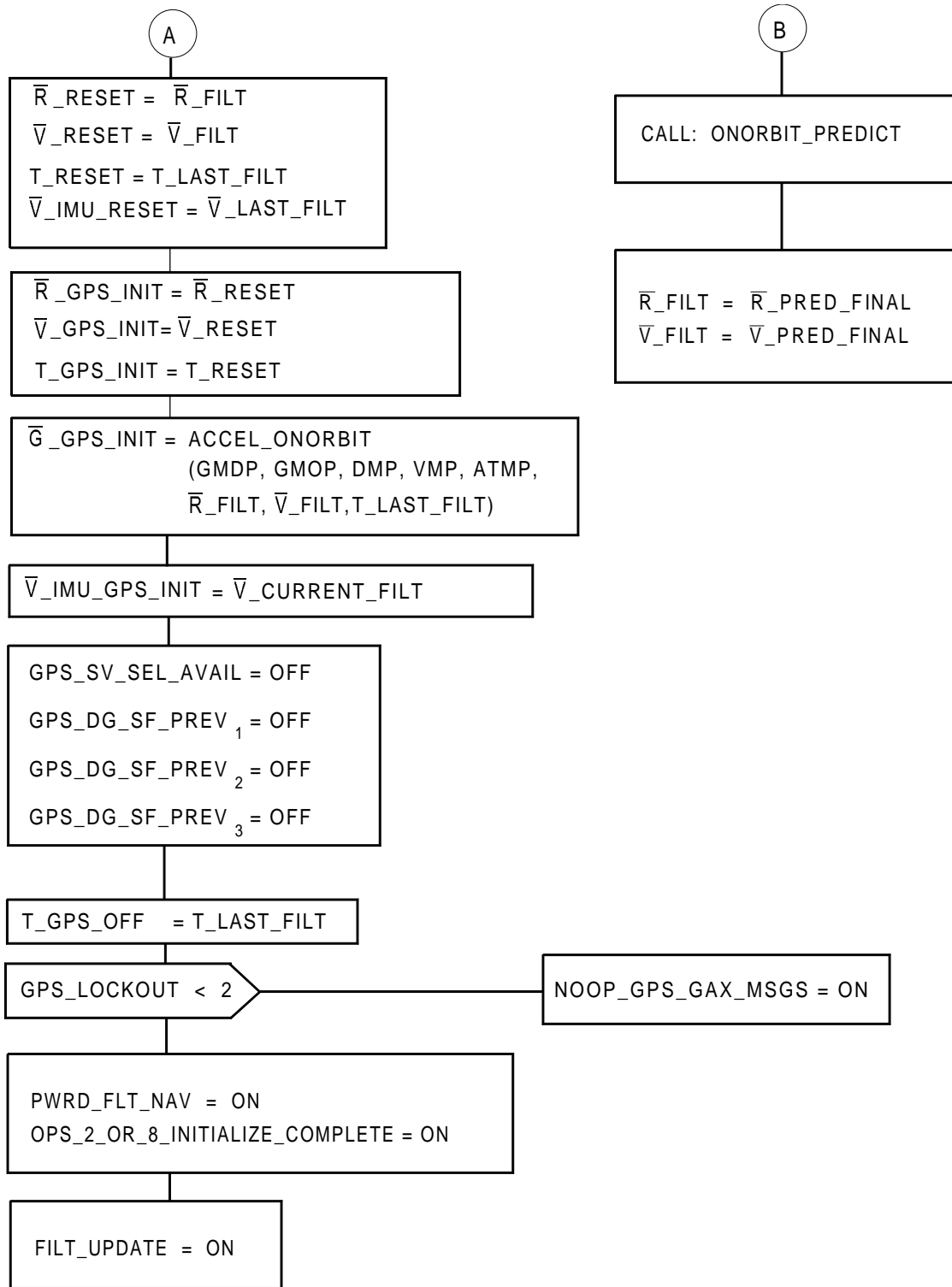


FIGURE 5.2-5.(2) OPS\_2\_OR\_8\_INITIALIZE (Sheet 2 of 2)



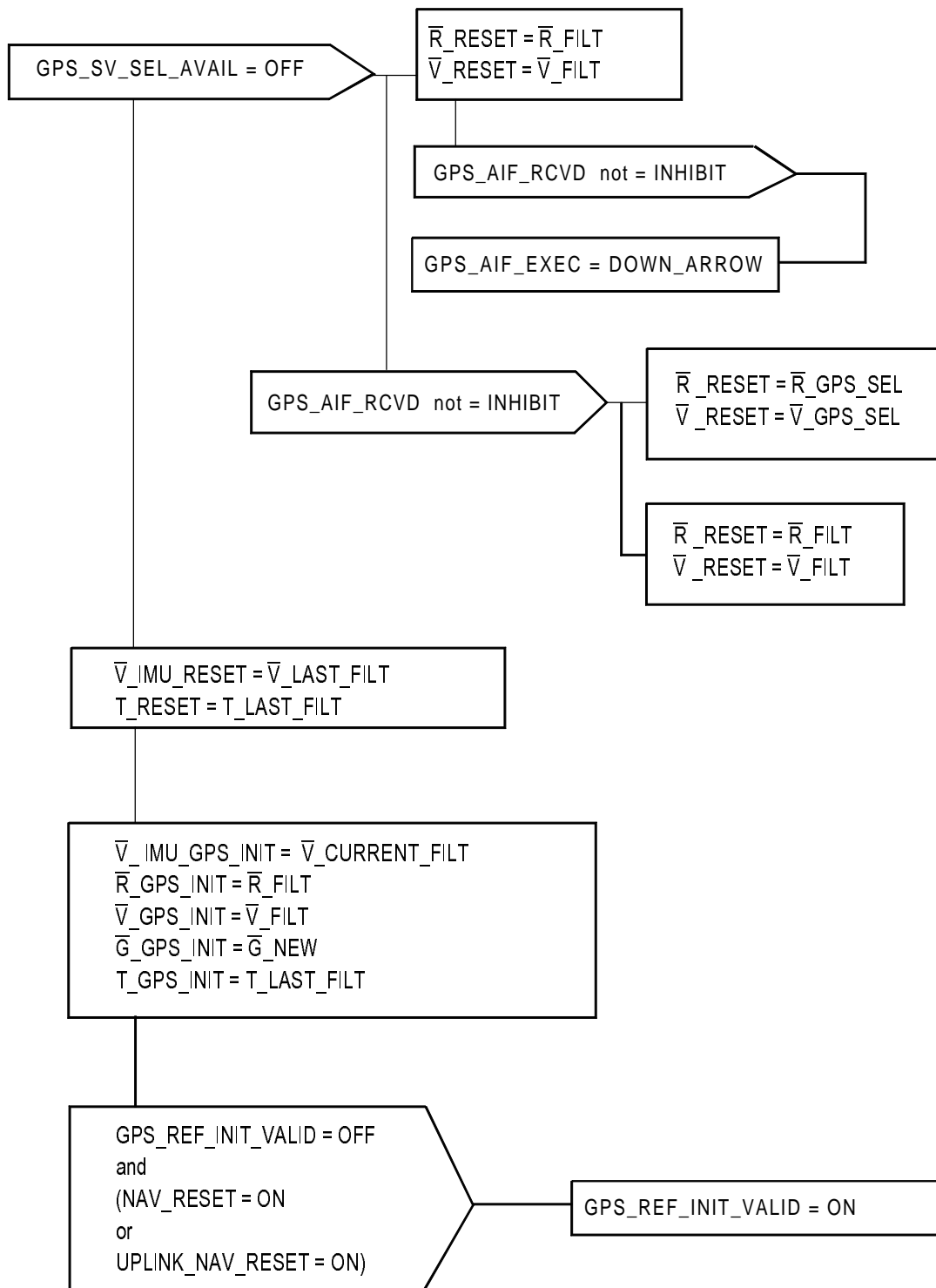


FIGURE 5.2-6. SHUTTLE\_RESET

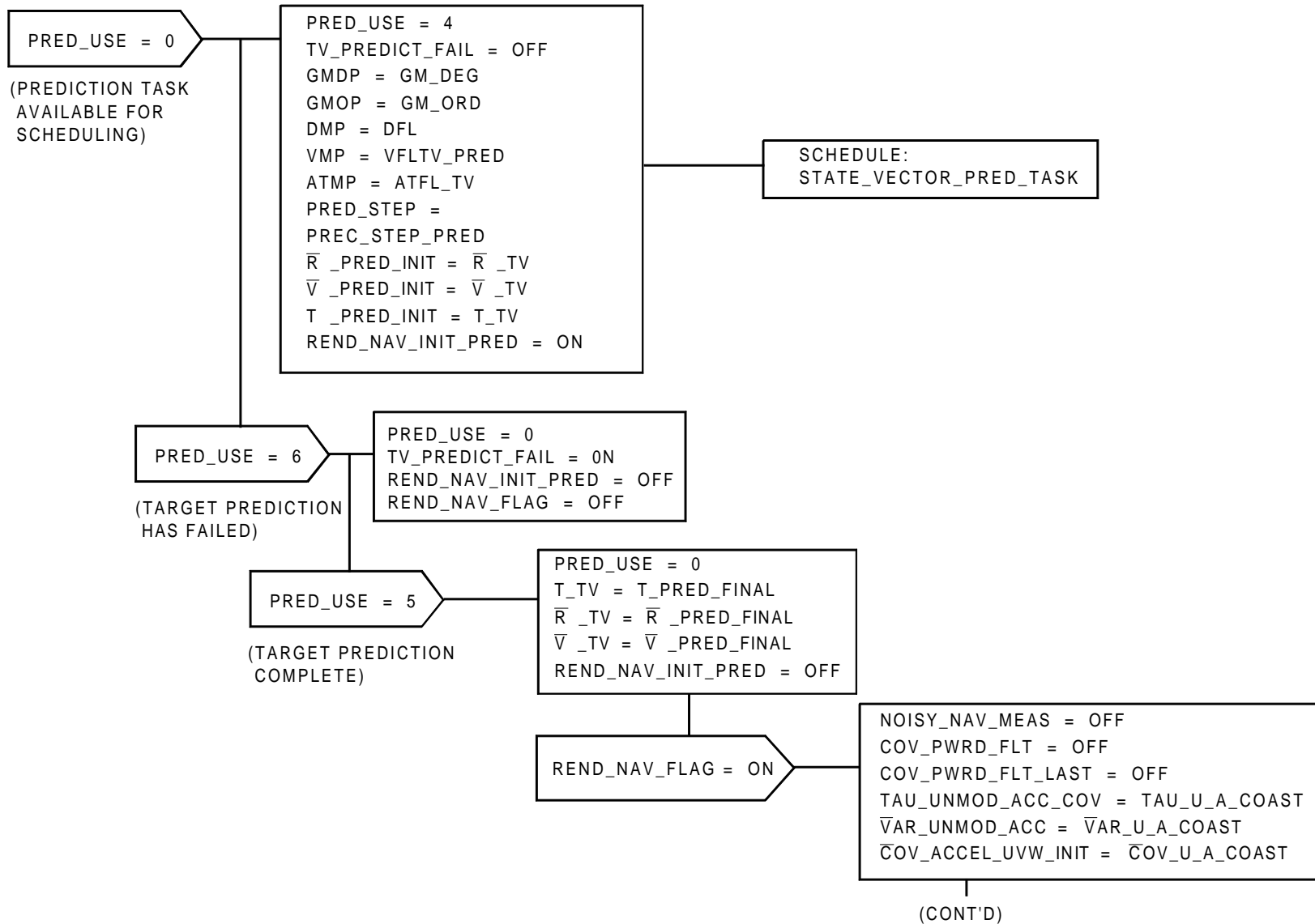
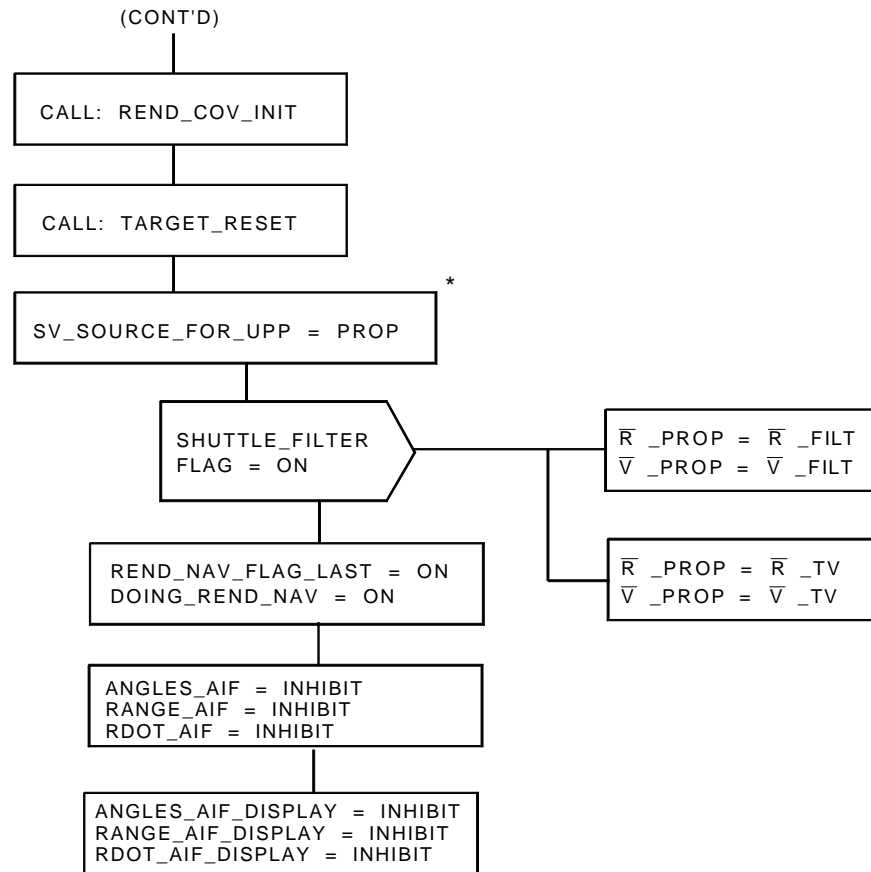


FIGURE 5.2-7.(1) RENDE\_NAV\_INIT (Sheet 1 of 2)



\* IN THE EVENT THAT SV\_SOURCE\_FOR\_UPP IS IMPLEMENTED AS A DISCRETE INSTEAD OF AS A CHARACTER STRING, THEN THE FOLLOWING CONVENTION SHOULD BE FOLLOWED:

PROP = 0  
FILT = 1

FIGURE 5.2-7.(2) REND\_NAV\_INIT (Sheet 2 of 2)

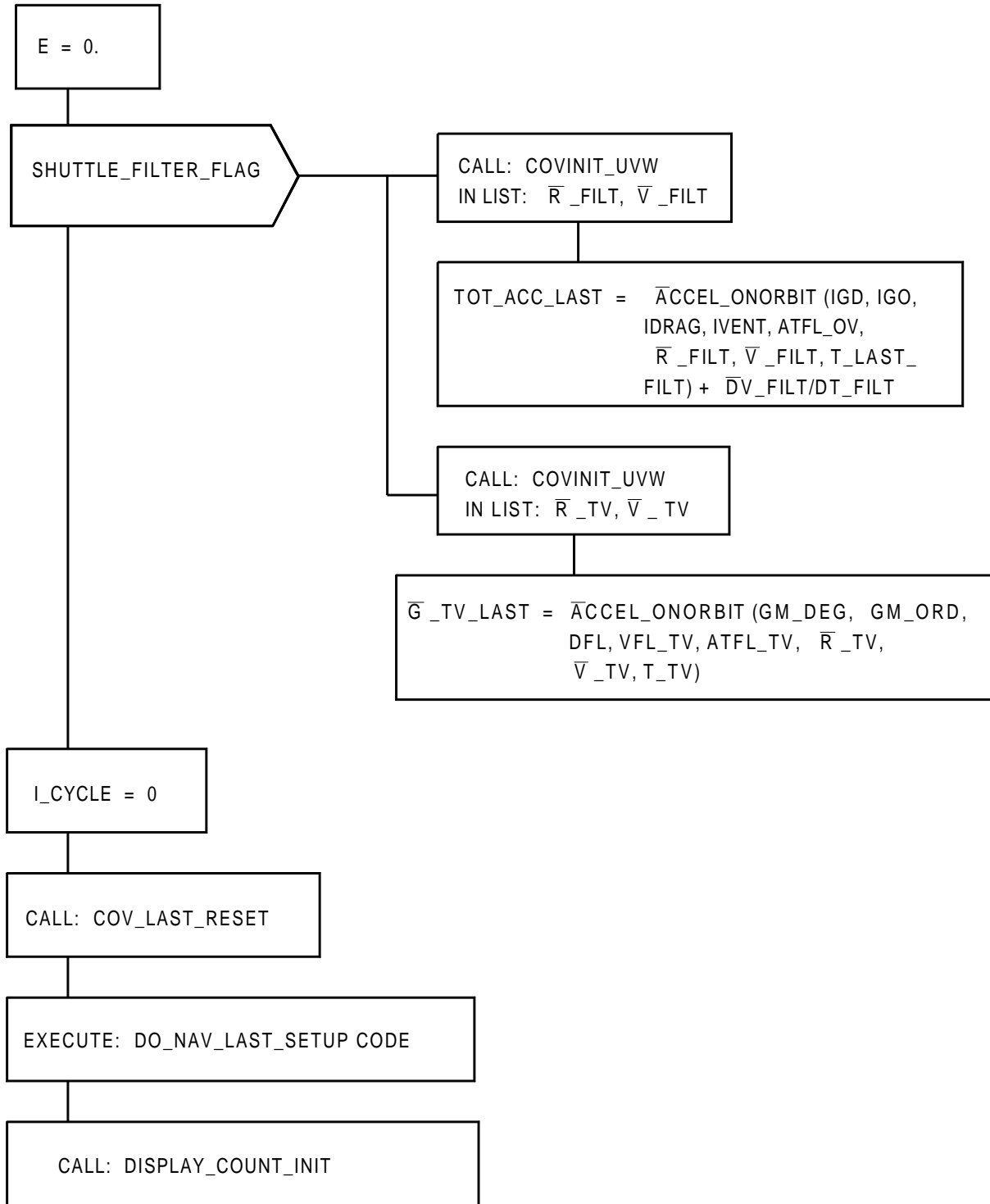


FIGURE 5.2-8. REND\_COV\_INIT

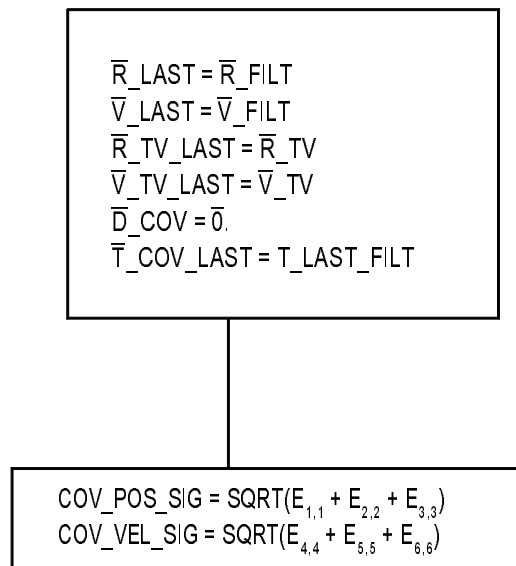


FIGURE 5.2-9. COV\_LAST\_RESET

```
DO_RR_ANGLES_NAV_LAST = OFF  
DO_RRDOT_NAV_LAST = OFF  
DO_ST_ANGLES_NAV_LAST = OFF  
DO_COAS_ANGLES_NAV_LAST = OFF
```

FIGURE 5.2-10. DO\_NAV\_LAST\_SETUP Code

IN LIST:  $\bar{R}, \bar{V}$

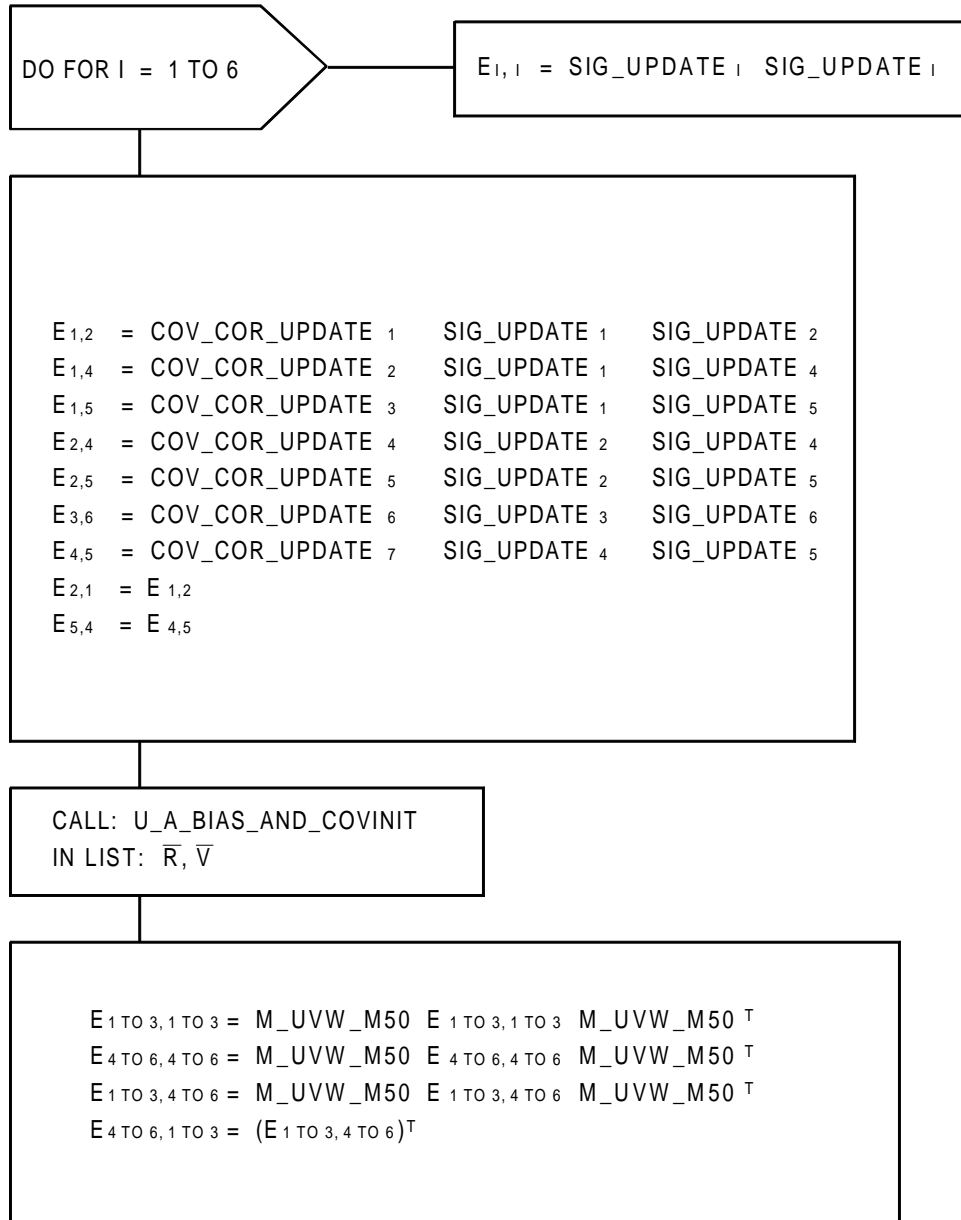


FIGURE 5.2-11. COVINIT\_UVW

```
N_ACCEPT = 0  
N_REJECT = 0  
SEQ_ACCEPT = 0  
SEQ_REJECT = 0
```

FIGURE 5.2-12. DISPLAY\_COUNT\_INIT



$$\begin{aligned}\bar{R}_{TV\_RESET} &= \bar{R}_{TV} \\ \bar{V}_{TV\_RESET} &= \bar{V}_{TV}\end{aligned}$$

FIGURE 5.2-13. TARGET\_RESET

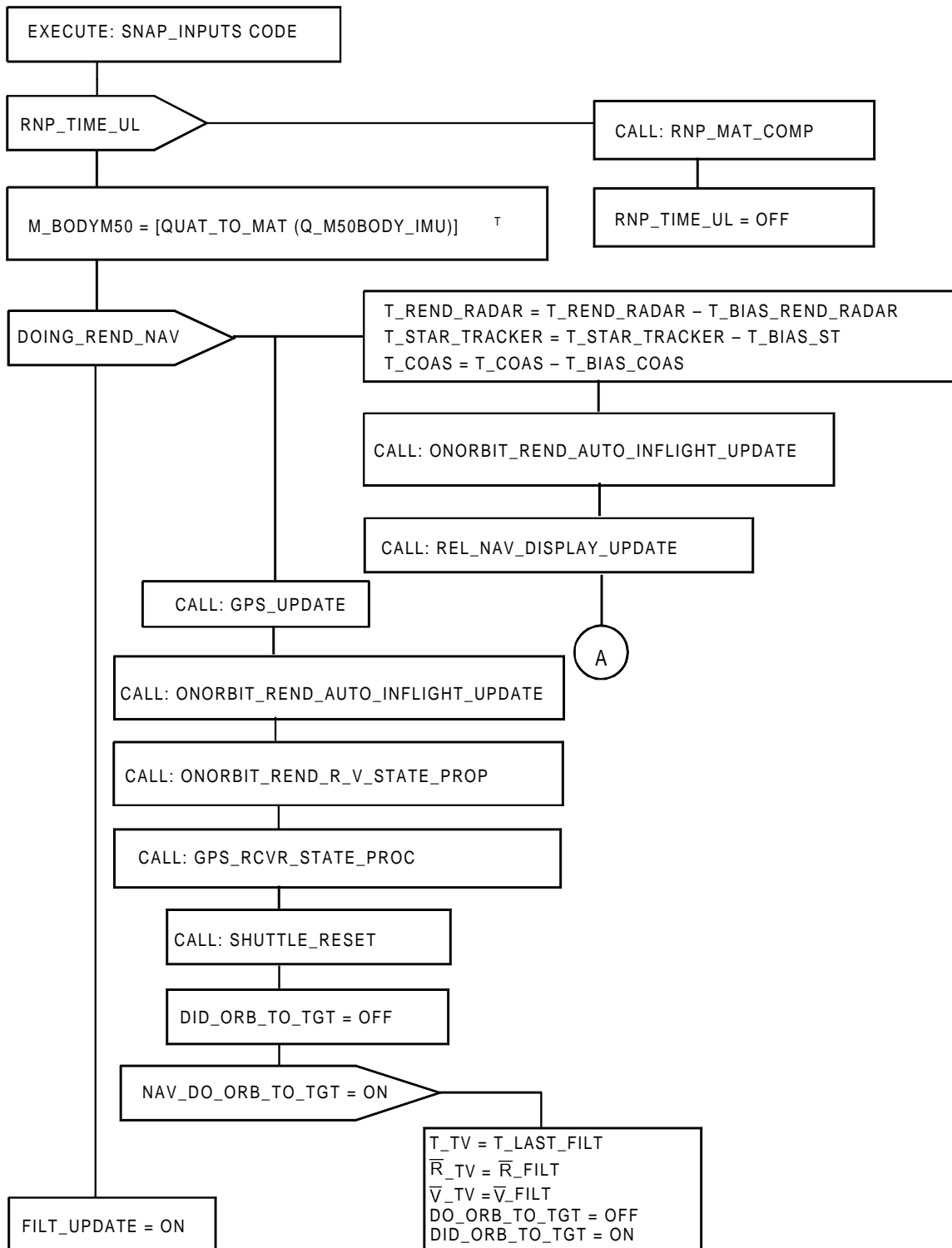


FIGURE 5.2-14.(1) NAV\_ONORBIT\_RENDEZVOUS (Sheet 1 of 4)

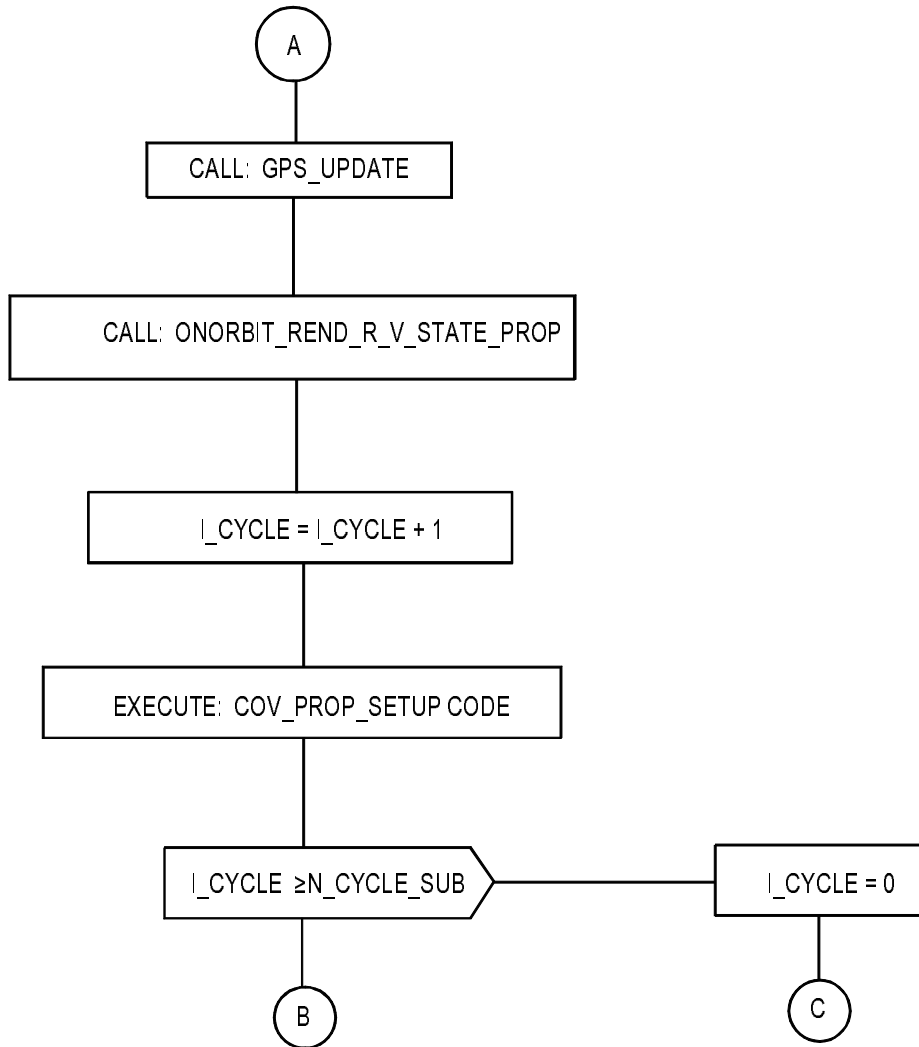


FIGURE 5.2-14.(2) NAV\_ONORBIT\_RENDEZVOUS (Sheet 2 of 4)

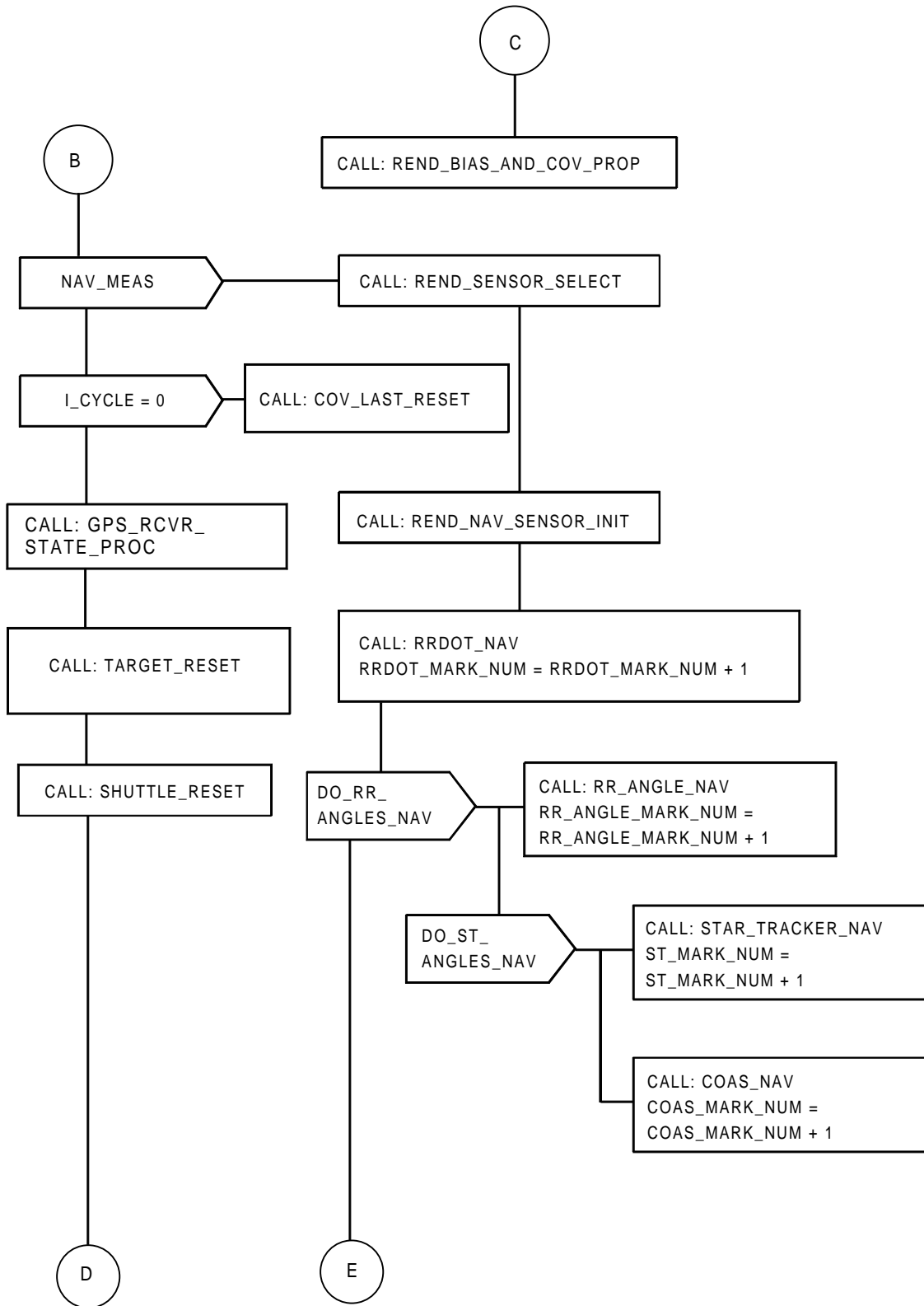


FIGURE 5.2-14.(3) NAV\_ONORBIT\_RENDEZVOUS (Sheet 3 of 4)

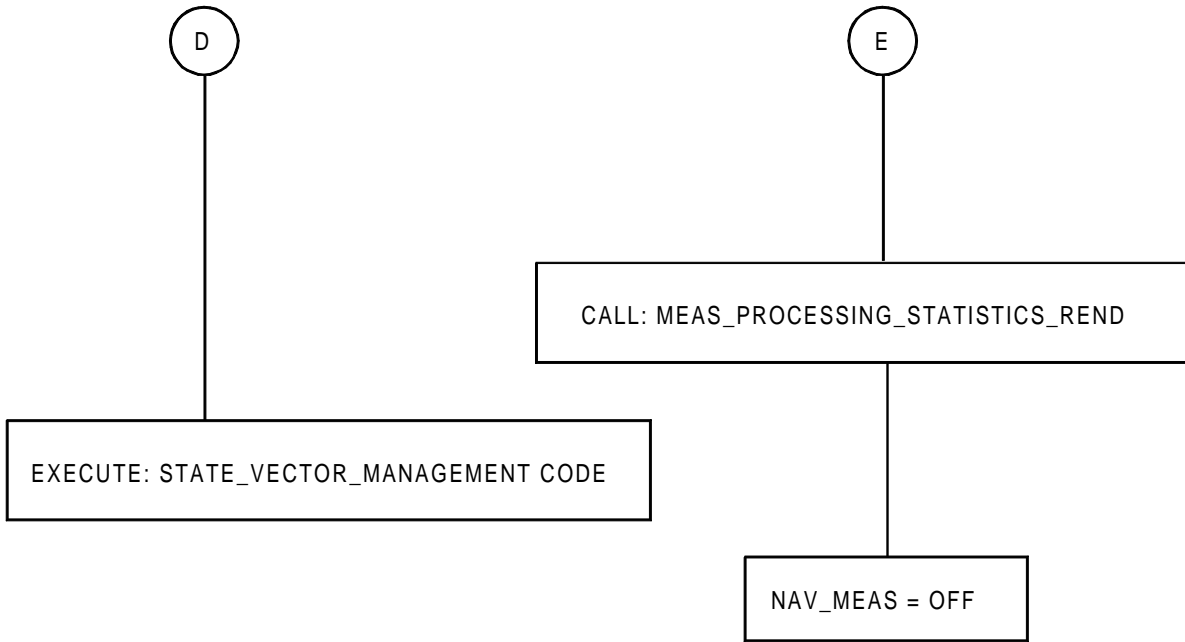


FIGURE 5.2-14.(4) NAV\_ONORBIT\_RENDEZVOUS (Sheet 4 of 4)

SNAP\_INPUTS CODE

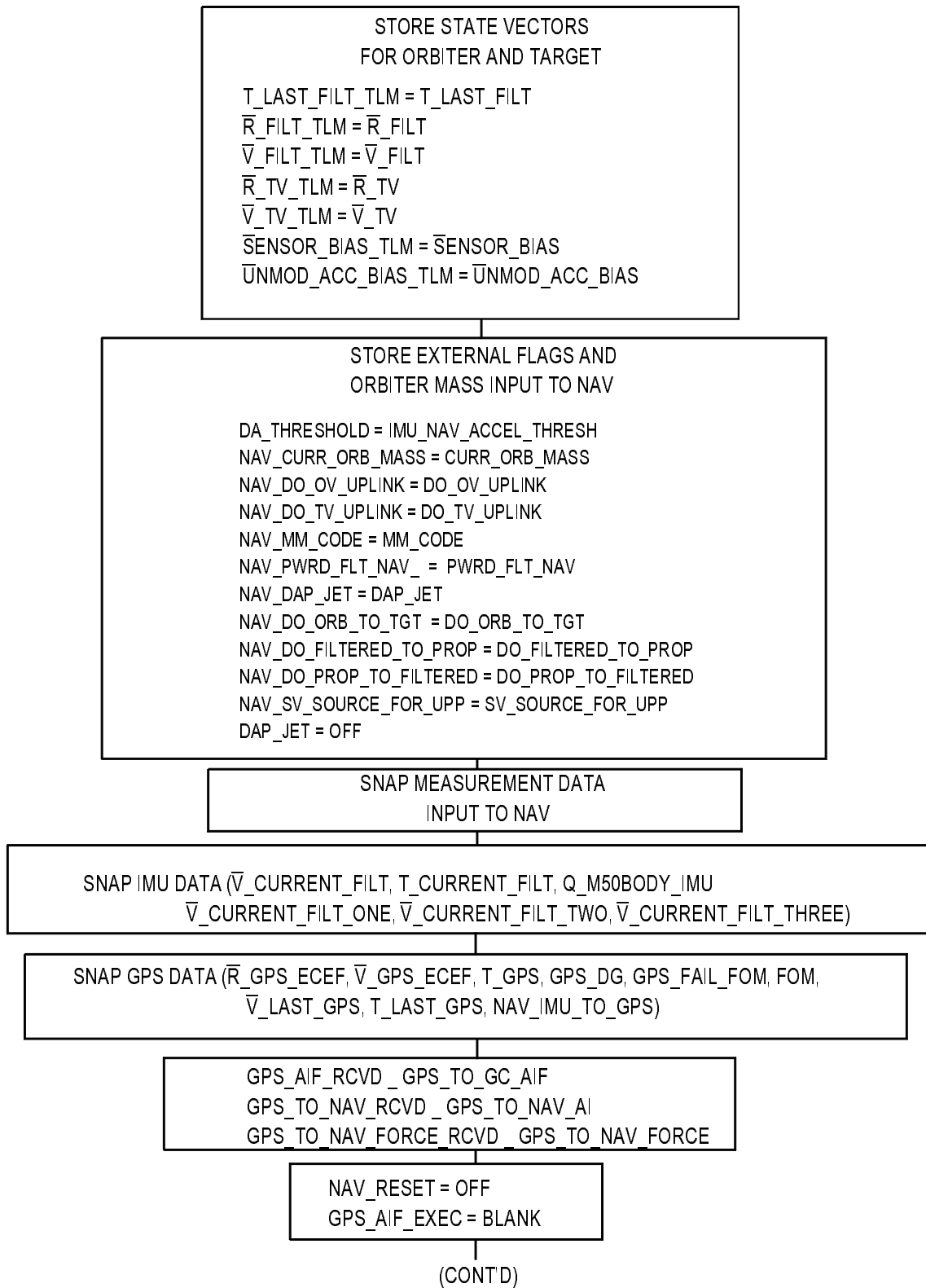


FIGURE 5.2-14A.(1) SNAP\_INPUTS Code (Sheet 1 of 3)

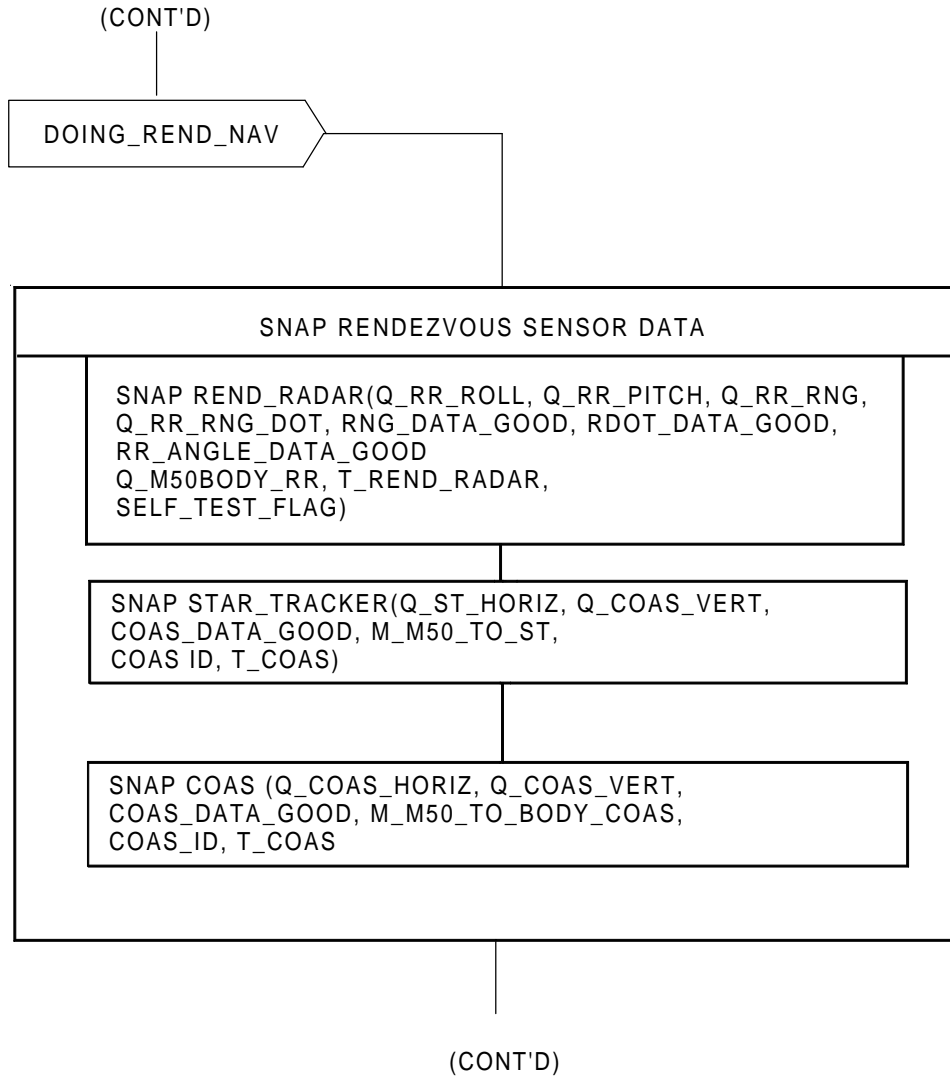


FIGURE 5.2-14A.(2) SNAP\_INPUTS Code (Sheet 2 of 3)

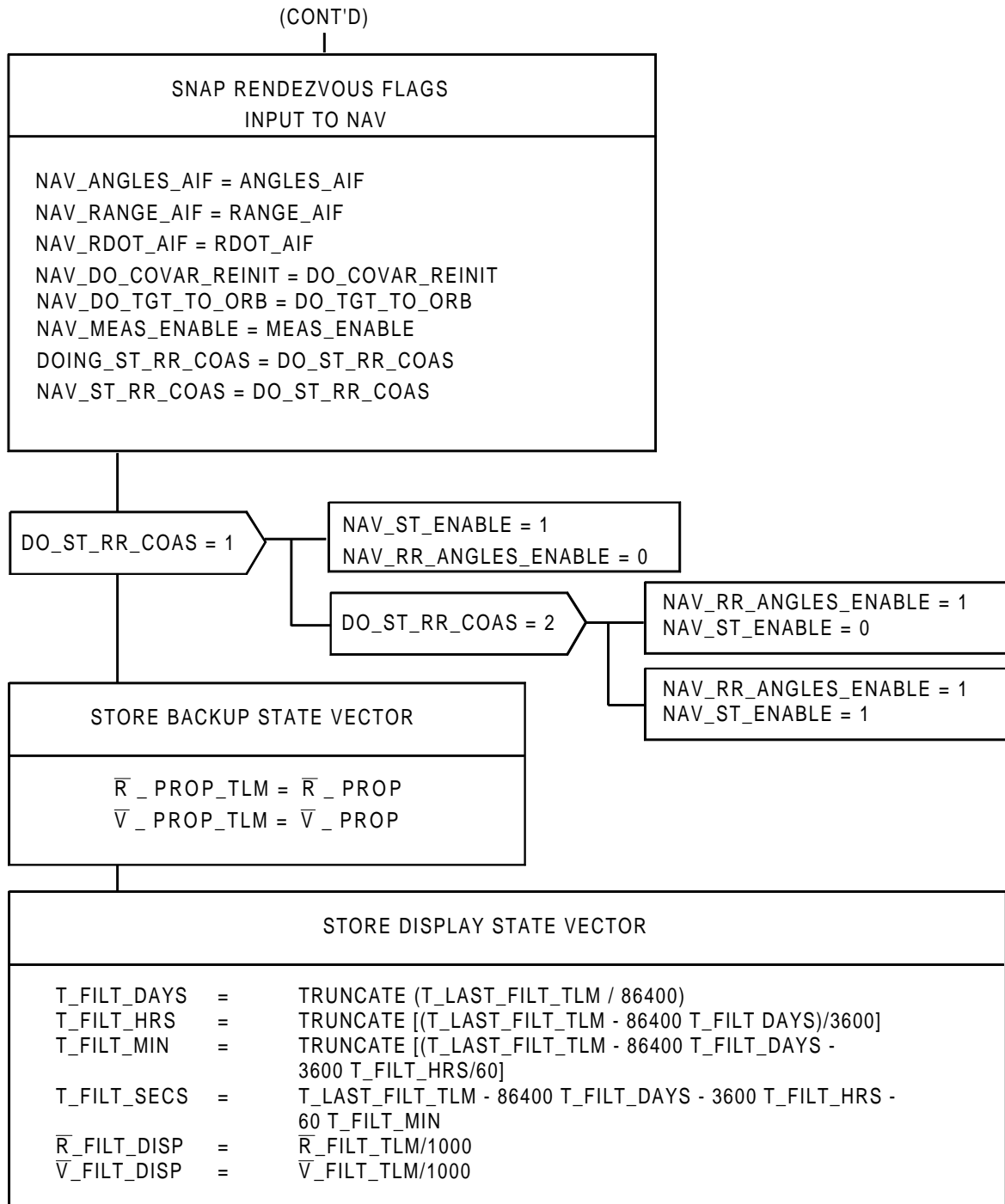


FIGURE 5.2-14A.(3) SNAP\_INPUTS Code (Sheet 3 of 3)



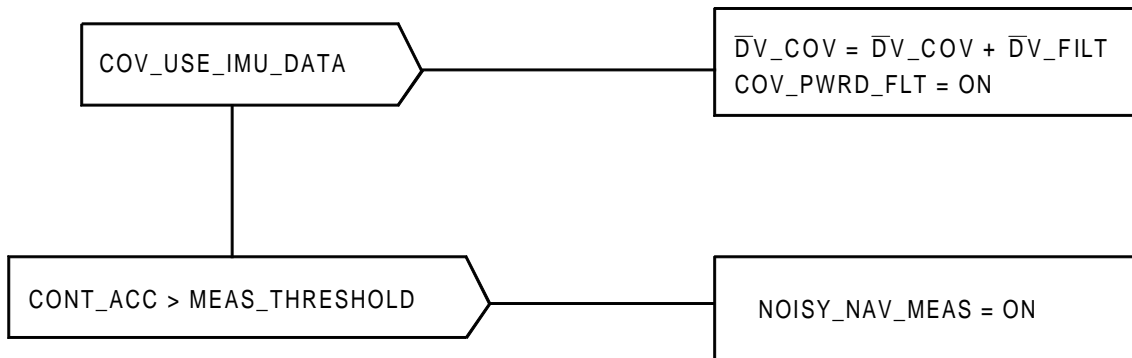
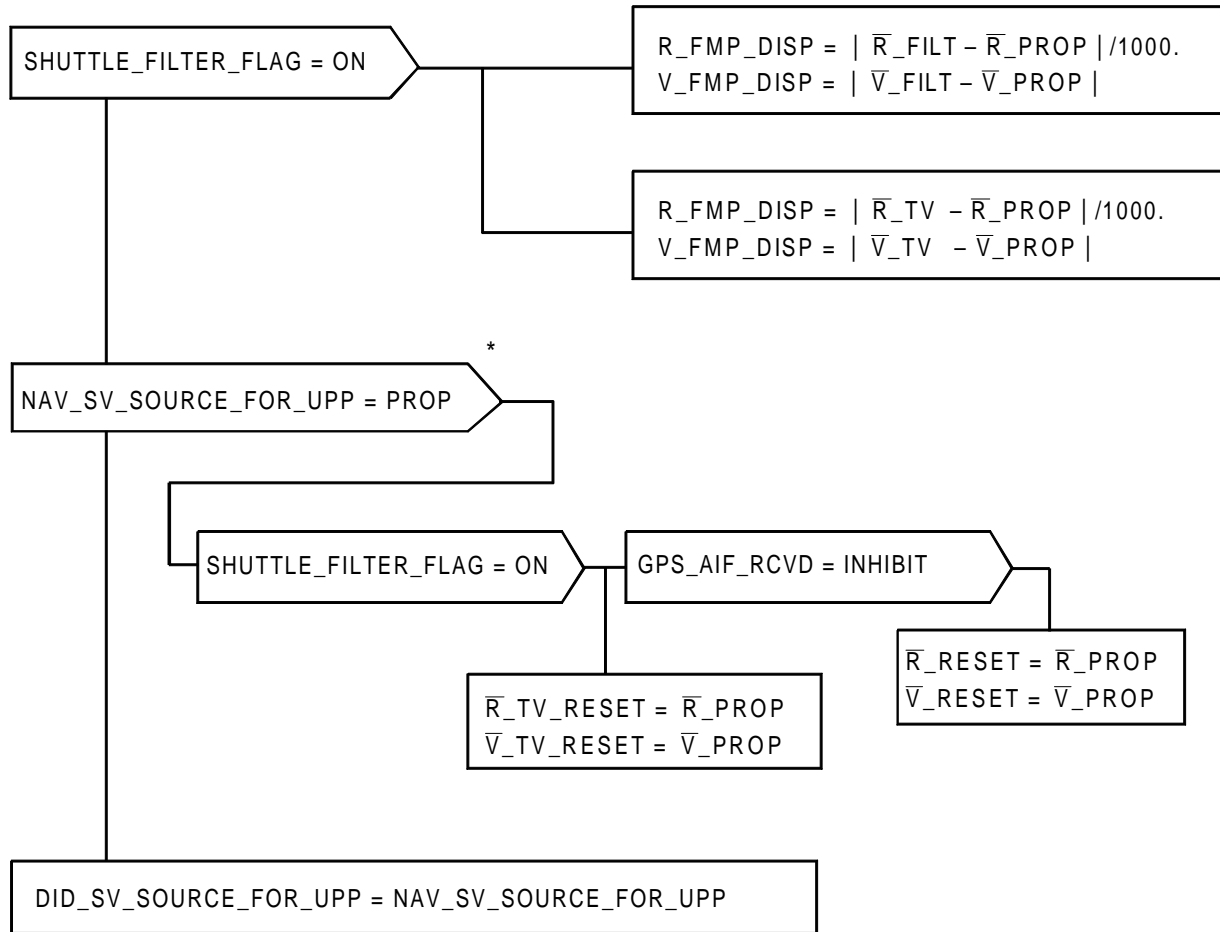


FIGURE 5.2-15. COV\_PROP\_SETUP Code



\* IN THE EVENT THAT NAV\_SV\_SOURCE\_FOR\_UPP IS IMPLEMENTED AS A DISCRETE INSTEAD OF AS A CHARACTER STRING, THEN THE FOLLOWING CONVENTION SHOULD BE FOLLOWED:

PROP = 0  
 FILT = 1

FIGURE 5.2-15A.STATE\_VECTOR\_MANAGEMENT Code

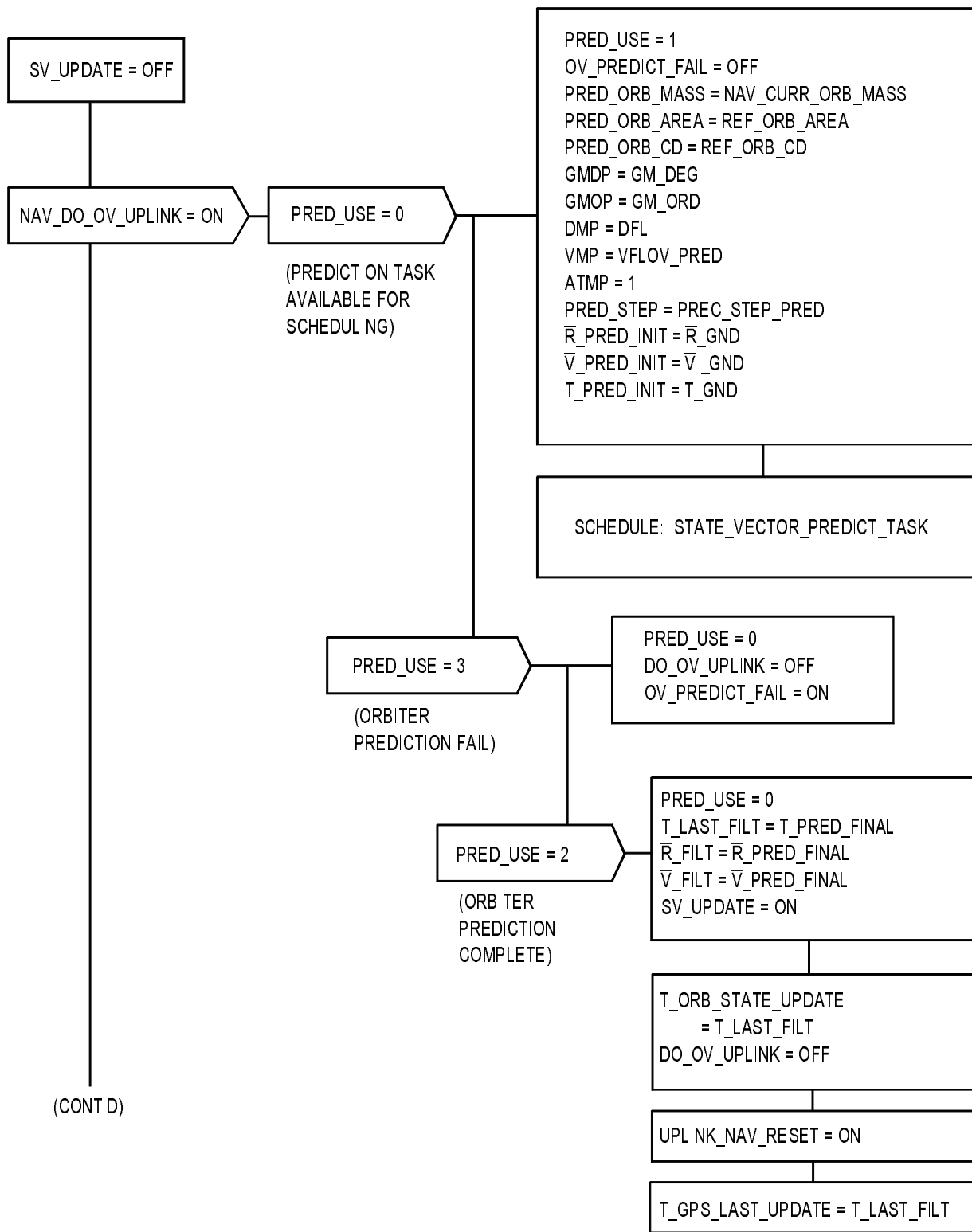


FIGURE 5.2-16.(1) ONORBIT\_REND\_AUTO\_INFLIGHT\_UPDATE (Sheet 1 of 2)

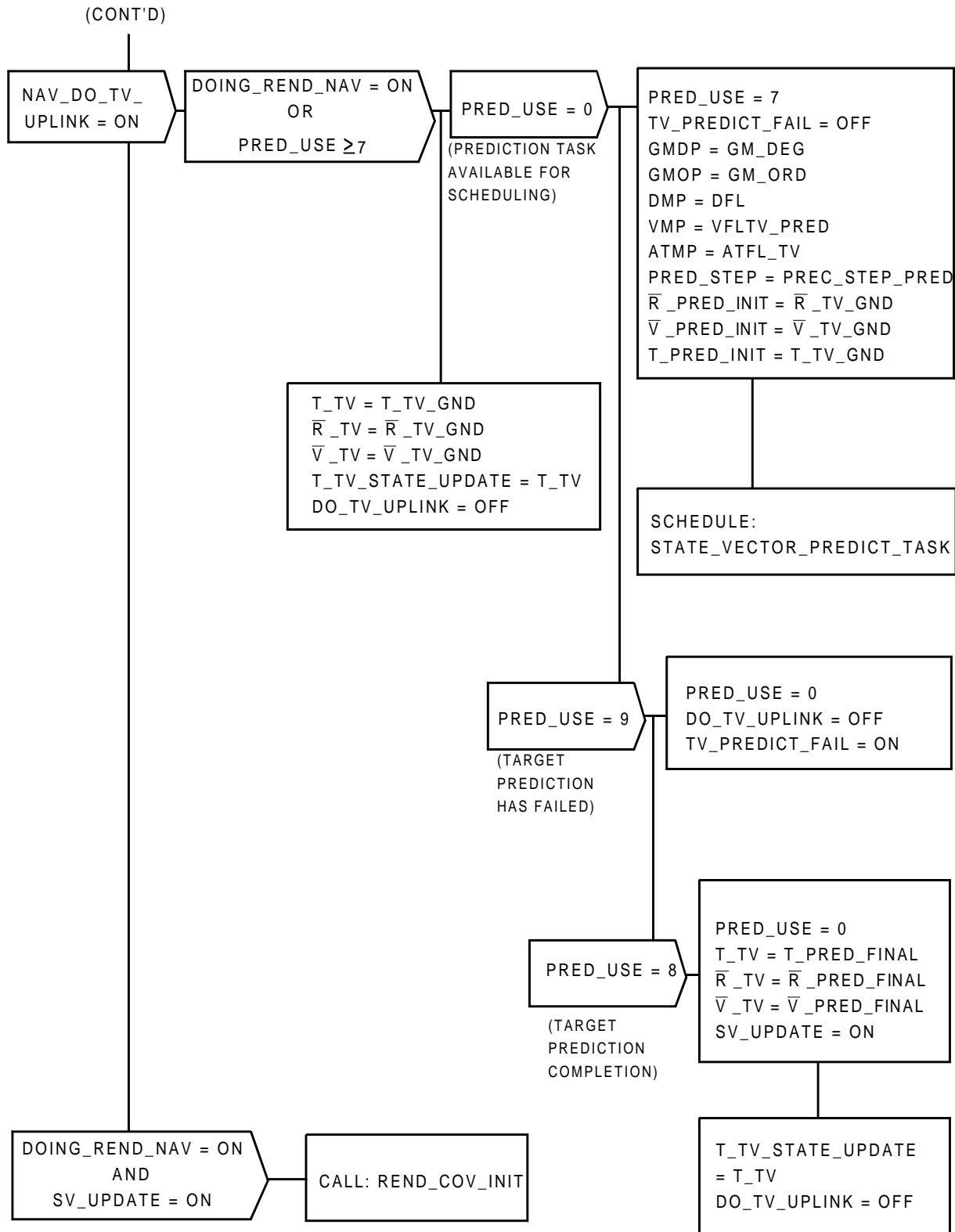


FIGURE 5.2-16.(2) ONORBIT\_REND\_AUTO\_INFLIGHT\_UPDATE (Sheet 2 of 2)

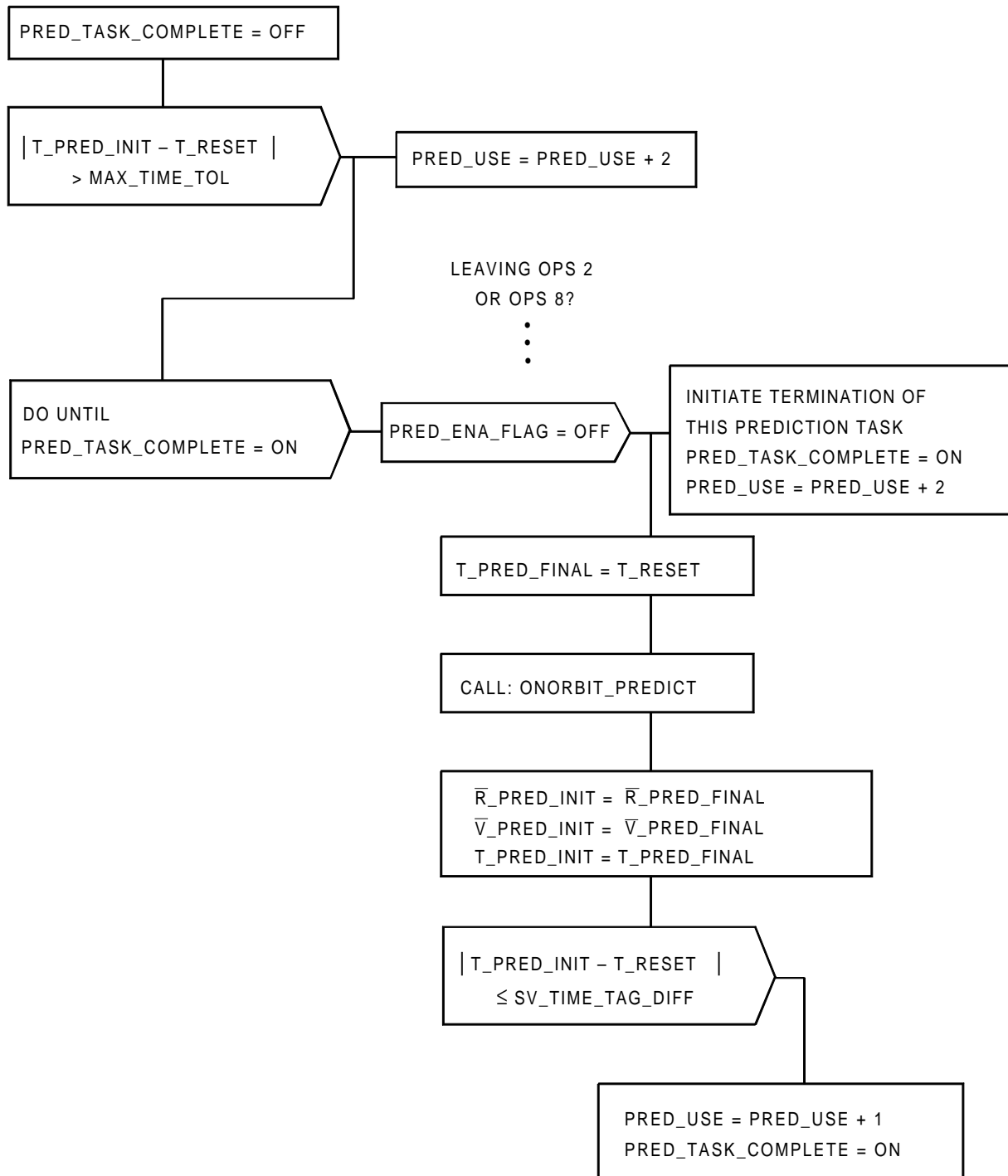
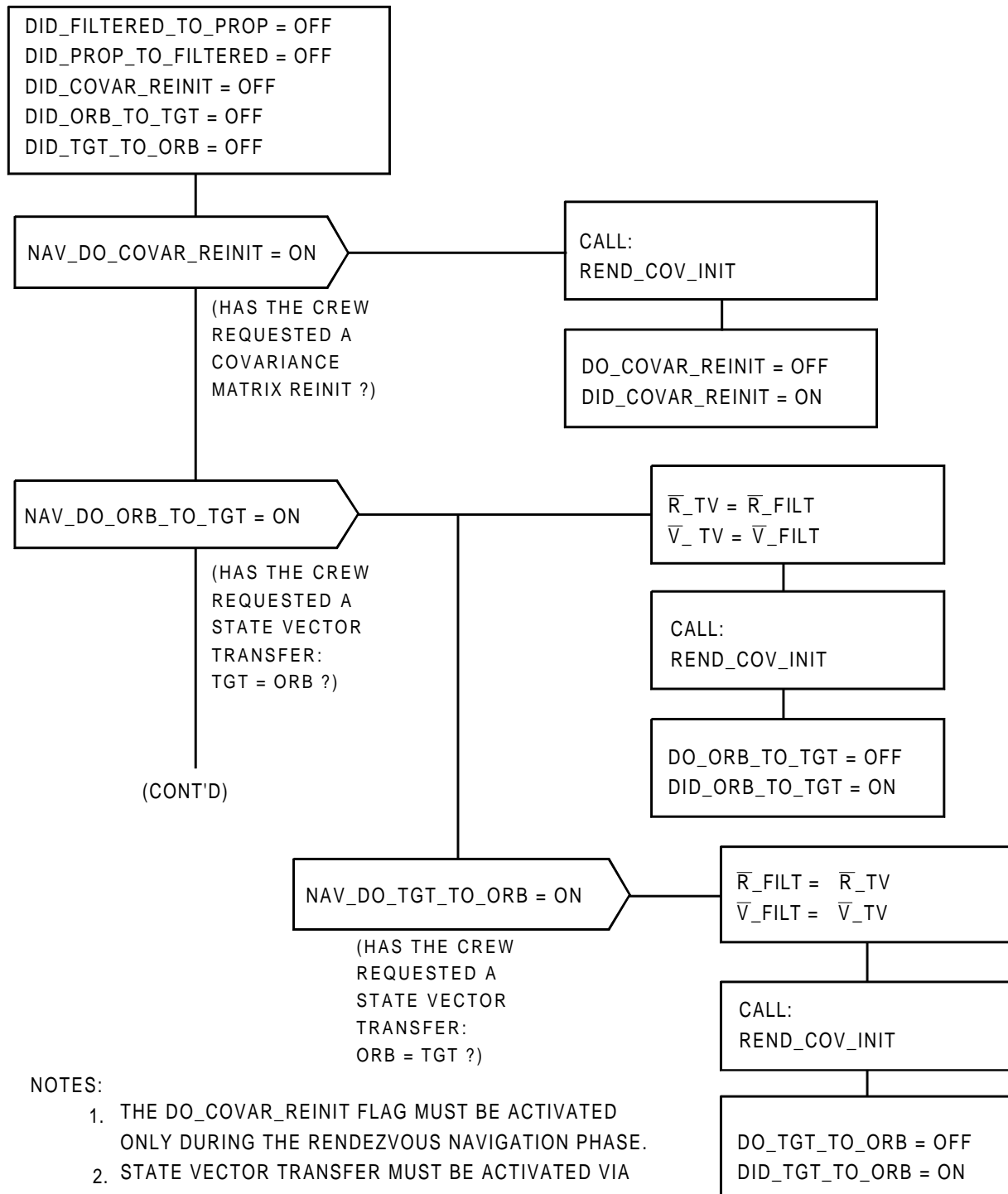


FIGURE 5.2-17. STATE\_VECTOR\_PREDICT\_TASK



NOTES:

1. THE DO\_COVAR\_REINIT FLAG MUST BE ACTIVATED ONLY DURING THE RENDEZVOUS NAVIGATION PHASE.
2. STATE VECTOR TRANSFER MUST BE ACTIVATED VIA CREW INPUT TO THE REL\_NAV DISPLAY AND ONLY DURING THE RENDEZVOUS NAVIGATION PHASE.

FIGURE 5.2-18.(1) REL\_NAV\_DISPLAY Updates (Sheet 1 of 2)

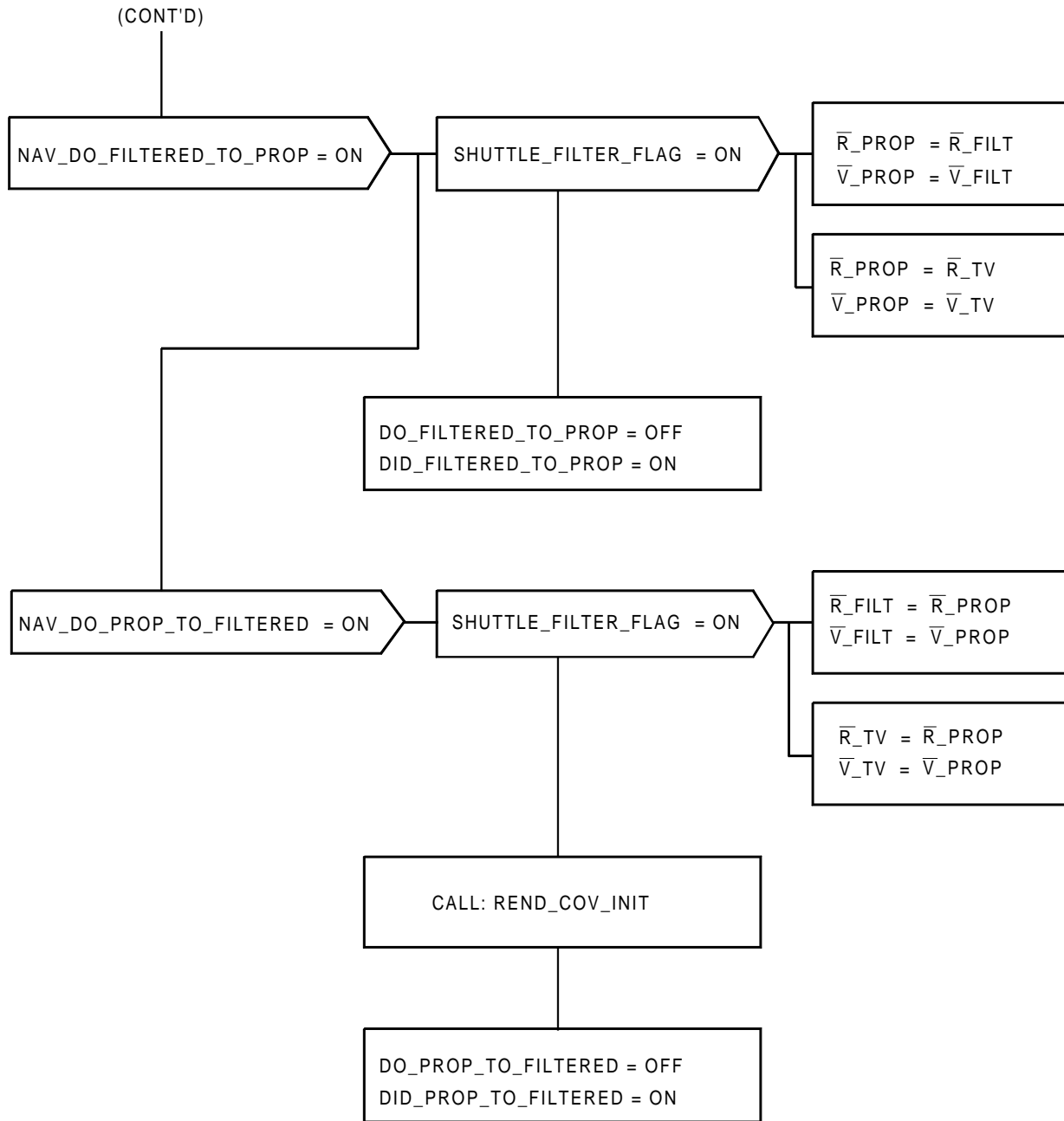


FIGURE 5.2-18.(2) REL\_NAV\_DISPLAY Updates (Sheet 2 of 2)

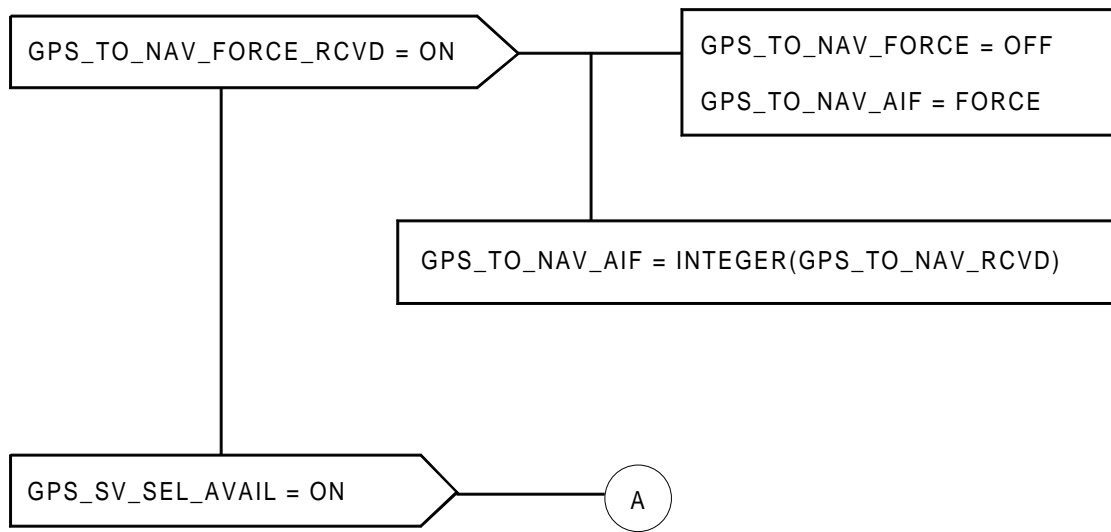


FIGURE 5.2-18A.(1) GPS\_UPDATE (Sheet 1 of 2)



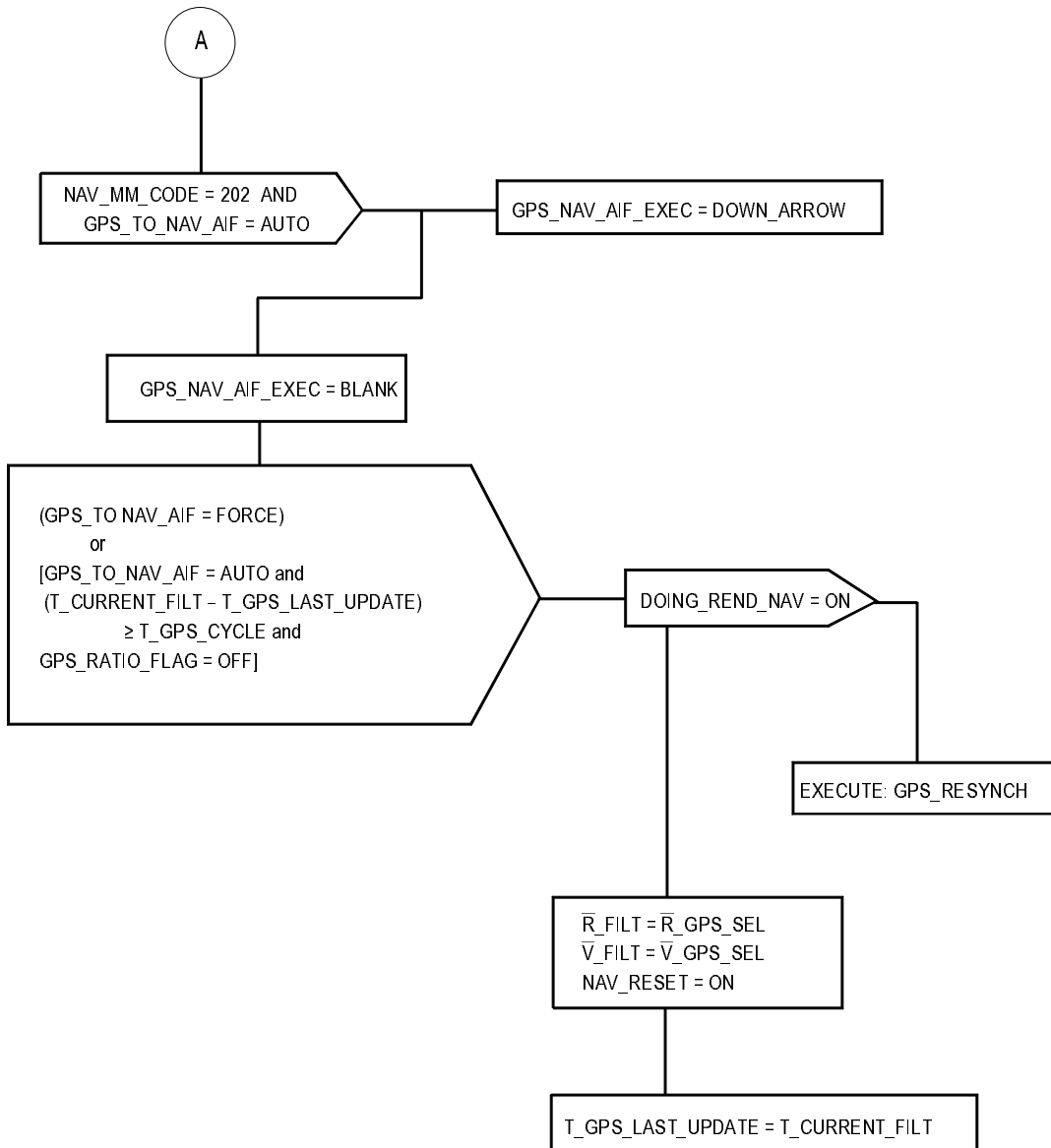


FIGURE 5.2-18A.(2) GPS\_UPDATE (Sheet 2 of 2)

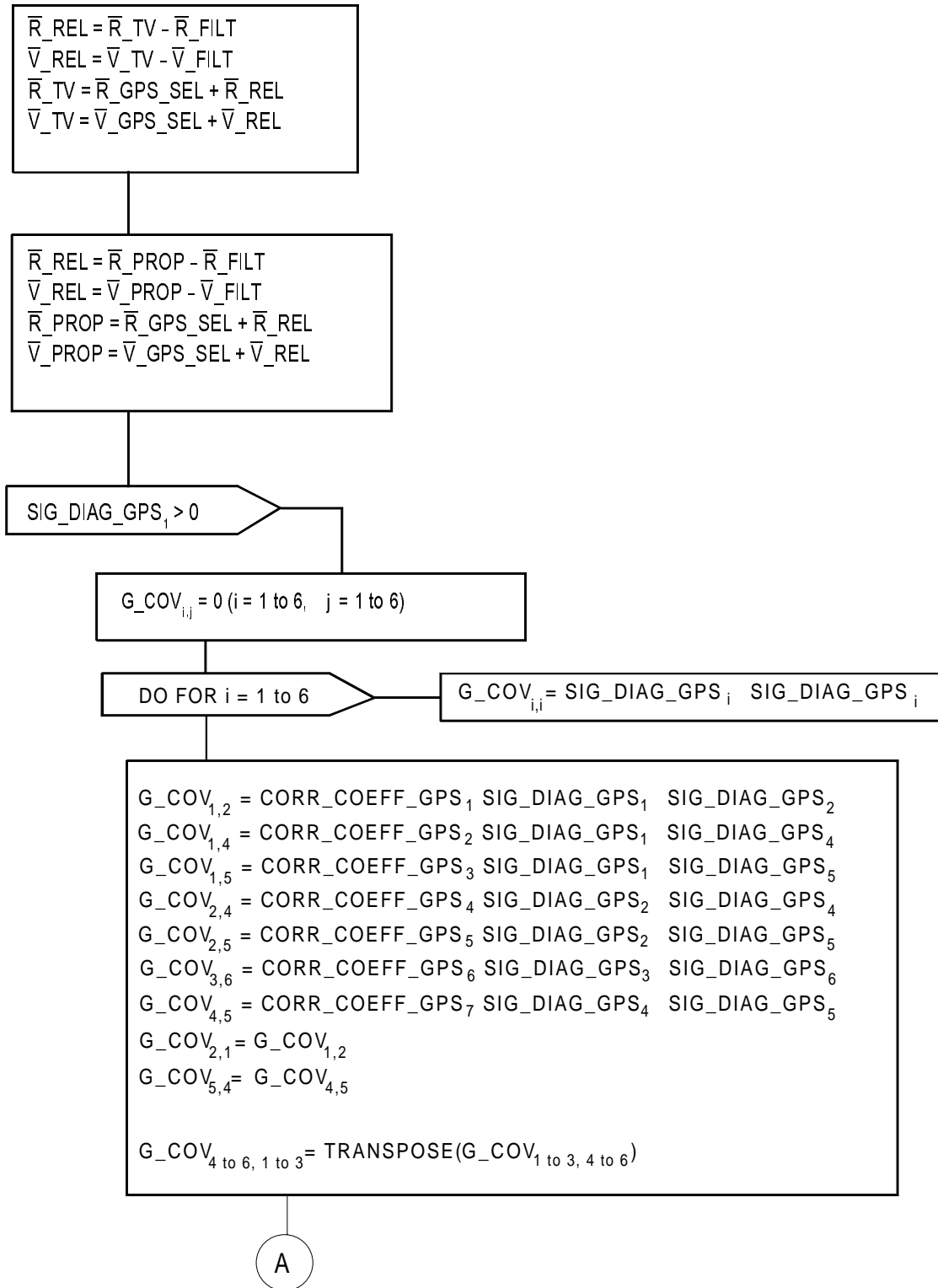


FIGURE 5.2-18B.(1) GPS\_RESYNCH (Sheet 1 of 2)

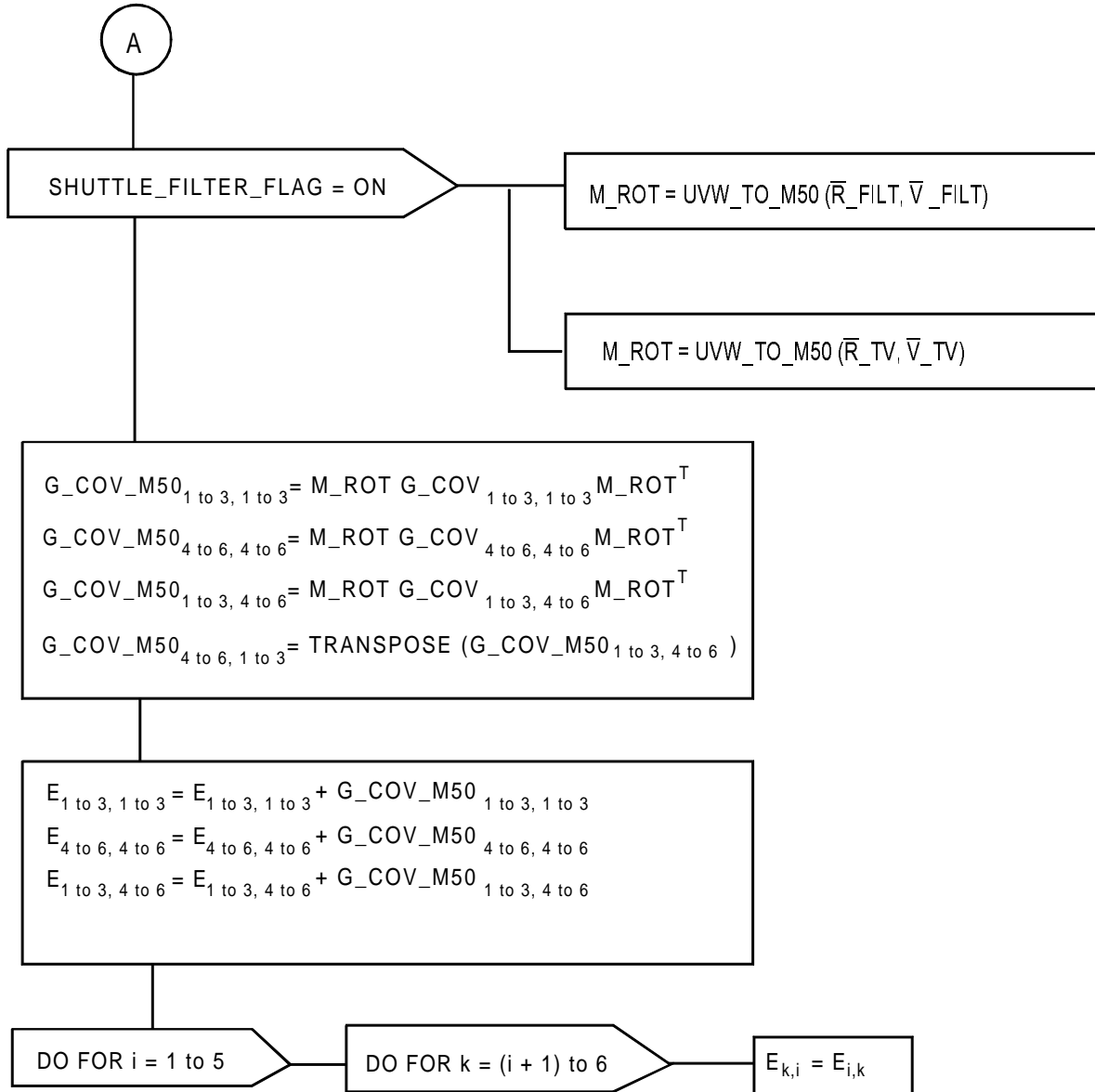


FIGURE 5.2-18B.(2) GPS\_RESYNCH (Sheet 2 of 2)

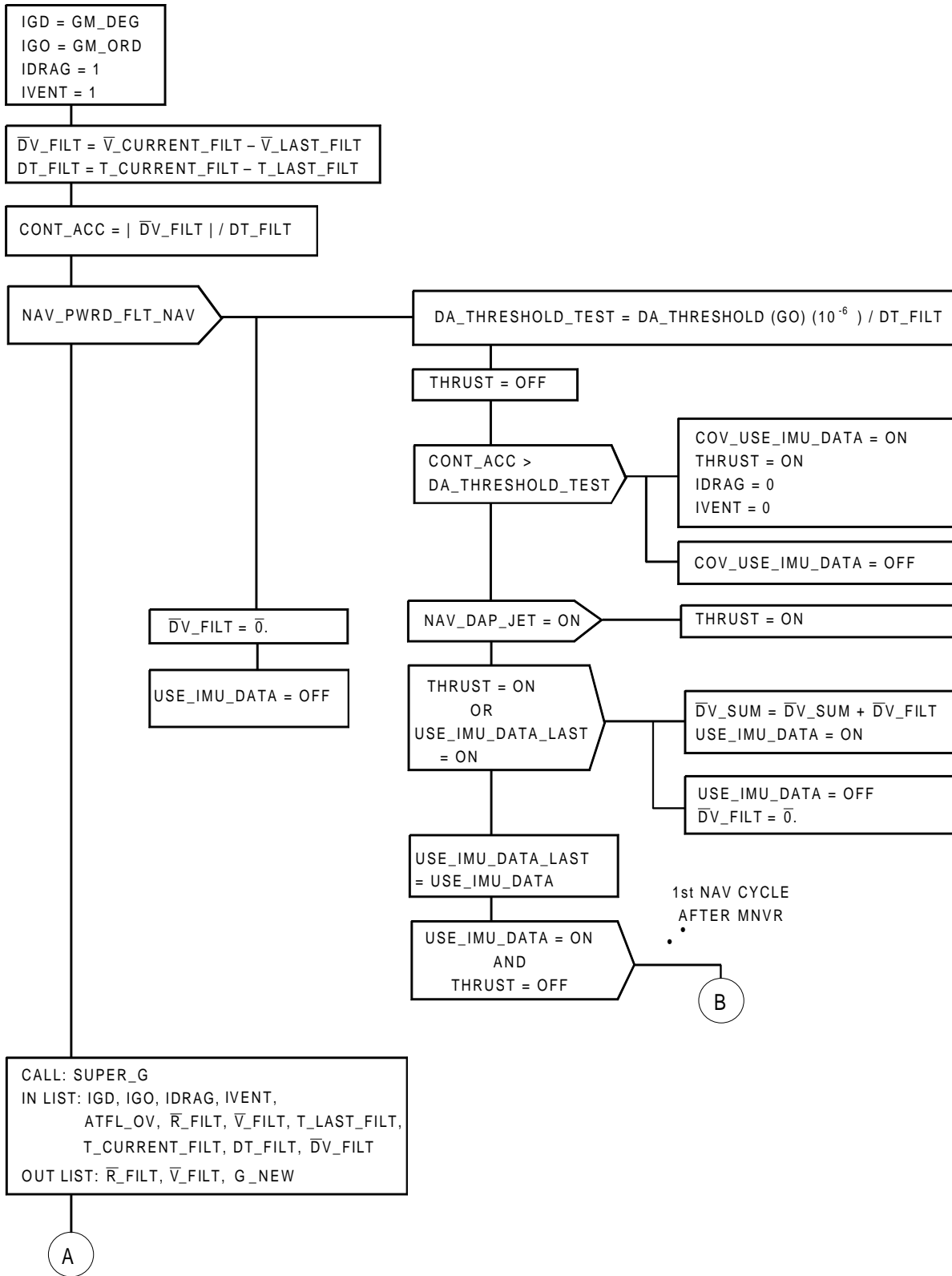
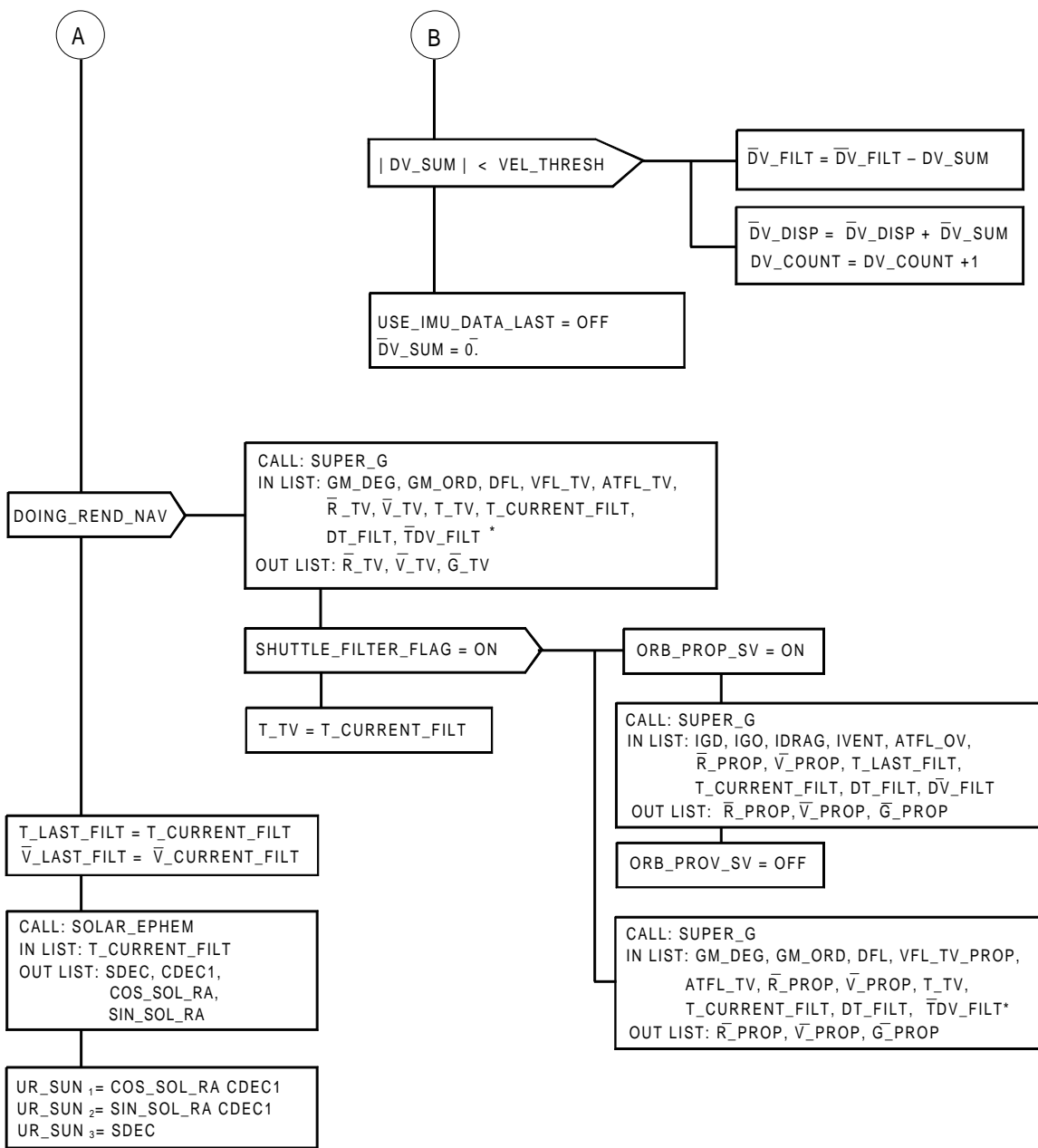


FIGURE 5.2-19.(1) ONORBIT\_REND\_R\_V\_STATE\_PROP (Sheet 1 of 2)



\*TDV\_FILT IS A HARDCODED VECTOR (0., 0., 0.).

FIGURE 5.2-19.(2) ONORBIT\_REND\_R\_V\_STATE\_PROP (Sheet 2 of 2)

IN LIST: GMD, GMO, DM, VM, ATM,  $\bar{R}_{IN}$ ,  $\bar{V}_{IN}$ , T\_IN, T\_FIN, DT\_FILT,  $\bar{D}V_{IN}$   
OUT LIST:  $\bar{R}_{FIN}$ ,  $\bar{V}_{FIN}$ ,  $\bar{G}_{OUT}$

$$\bar{G}_{INT} = \bar{ACCEL\_ONORBIT} (GMD, GMO, DM, VM, ATM, \bar{R}_{IN}, \bar{V}_{IN}, T\_IN)$$

$$\bar{R}_{FIN} = \bar{R}_{IN} + DT\_FILT [ \bar{V}_{IN} + 0.5 ( \bar{D}V_{IN} + DT\_FILT \bar{G}_{INT} ) ]$$

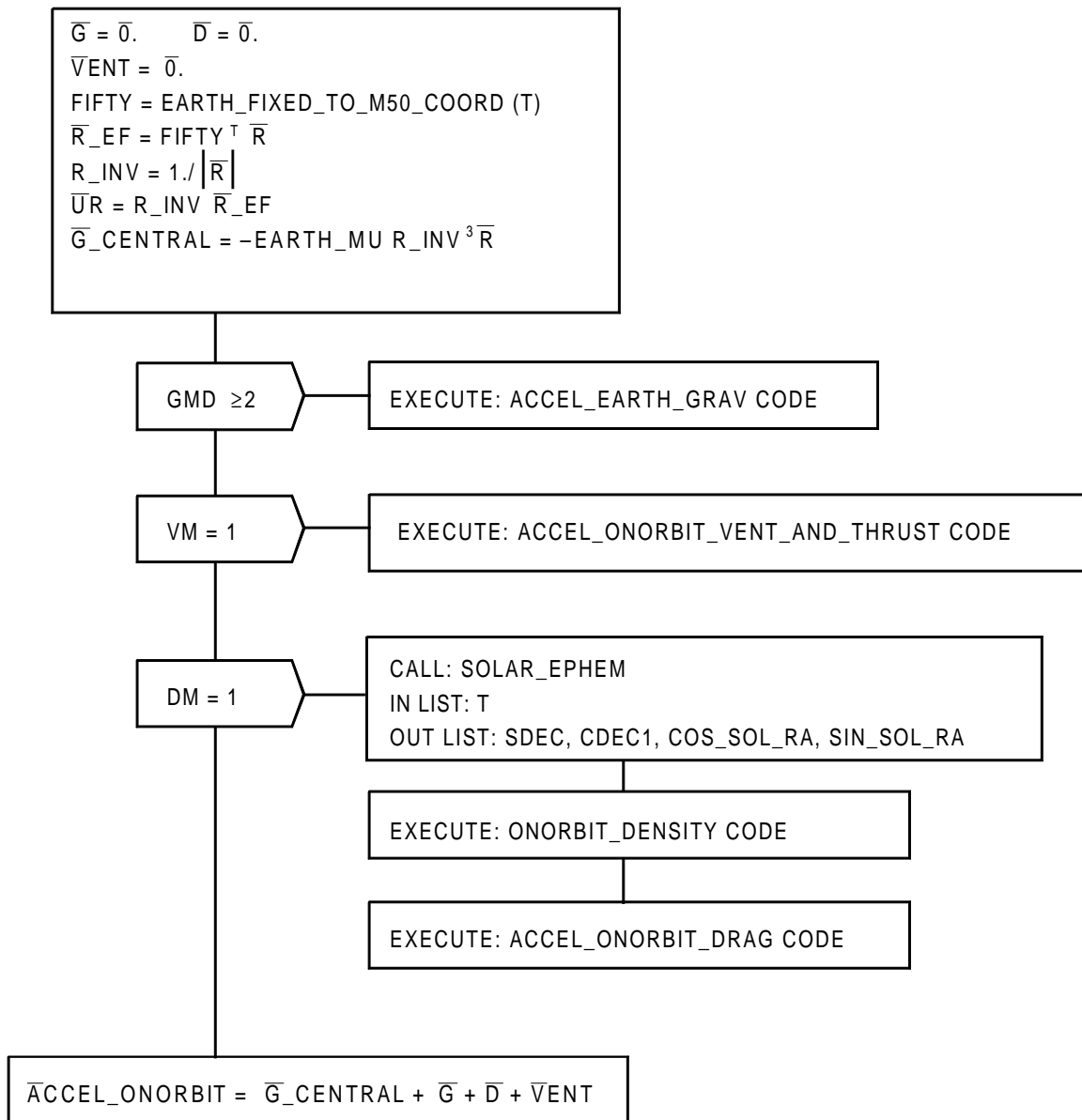
$$\bar{G}_{OUT} = \bar{ACCEL\_ONORBIT} (GMD, GMO, DM, VM, ATM, \bar{R}_{FIN}, \bar{V}_{IN}, T\_FIN)$$

$$\bar{V}_{FIN} = \bar{V}_{IN} + \bar{D}V_{IN} + 0.5 DT\_FILT ( \bar{G}_{INT} + \bar{G}_{OUT} )$$

$$\bar{R}_{FIN} = \bar{R}_{FIN} + [ ( \bar{G}_{OUT} - \bar{G}_{INT} ) DT\_FILT^2 ] / 6.$$

FIGURE 5.2-20. SUPER\_G

IN LIST: GMD, GMO, DM, VM, ATM,  $\bar{R}$ ,  $\bar{V}$ , T



- GMD CONTROLS THE DEGREE OF THE GRAVITY MODEL.  
 GMO CONTROLS THE ORDER OF THE GRAVITY MODEL.  
 DM CONTROLS THE USE OR NONUSE OF DRAG ACCELERATION MODEL.  
 VM CONTROLS THE USE OR NONUSE OF VENTING AND UNCOUPLED THRUSTING MODEL.  
 ATM CONTROLS THE INCORPORATION OF UNMOLDED ACCELERATIONS (IN CONJUNCTION WITH THE SHUTTLE\_FILTER\_FLAG) AND WHEN COMPUTING DRAG, THE VARIOUS DRAG MODEL OPTIONS USED (I.E., CURRENT ATTITUDE, AREA, DRAG COEFFICIENT, ETC.).  
 $\bar{R}$ ,  $\bar{V}$  ARE THE POSITION AND VELOCITY VECTORS OF THE VEHICLE IN M50 COORDINATES.  
 T IS THE TIME IN GMT SECONDS.

FIGURE 5.2-21.  $\bar{ACCEL\_ONORBIT}$  Function

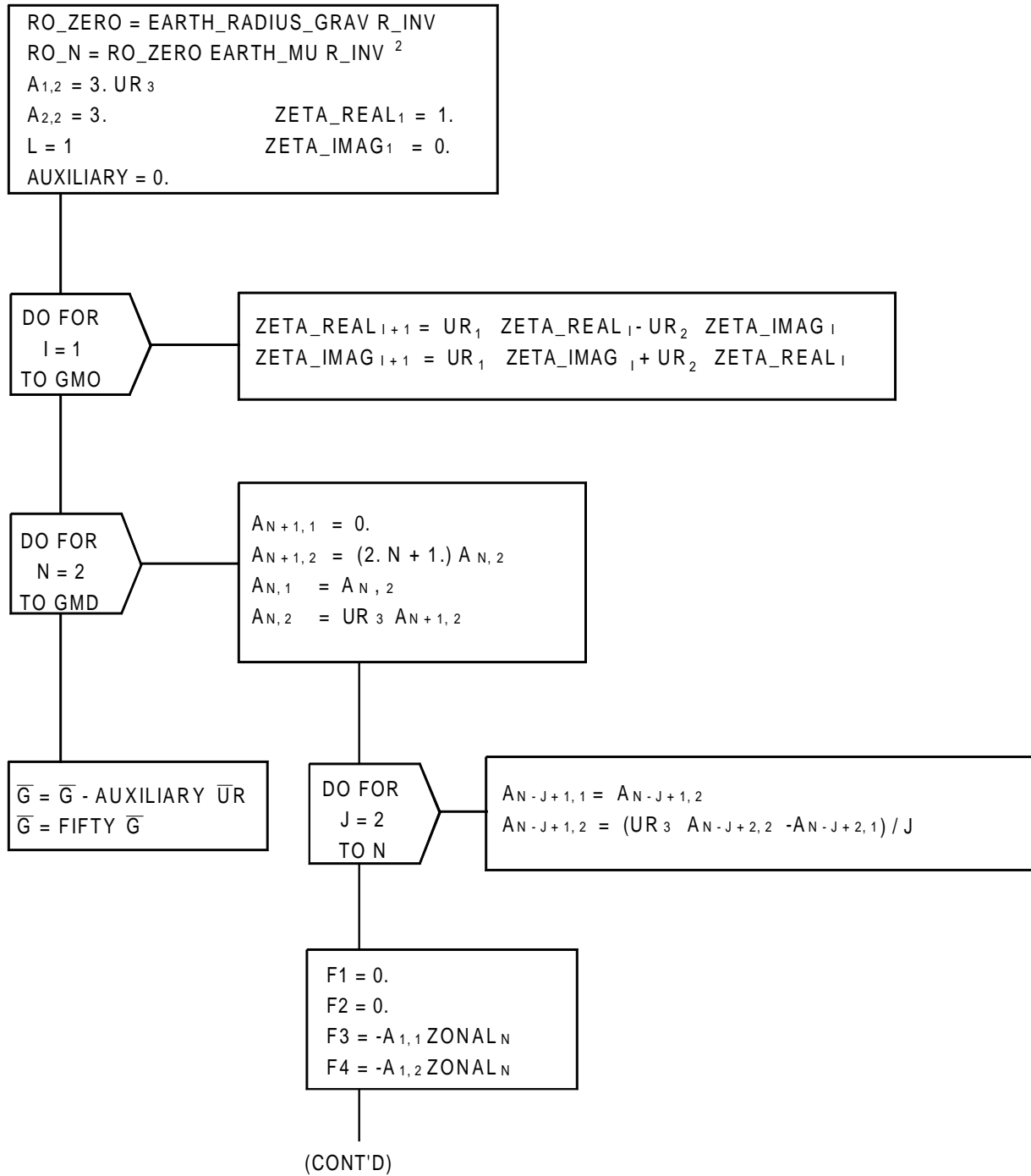


FIGURE 5.2-22.(1) ACCEL\_EARTH\_GRAV Code (Sheet 1 of 2)



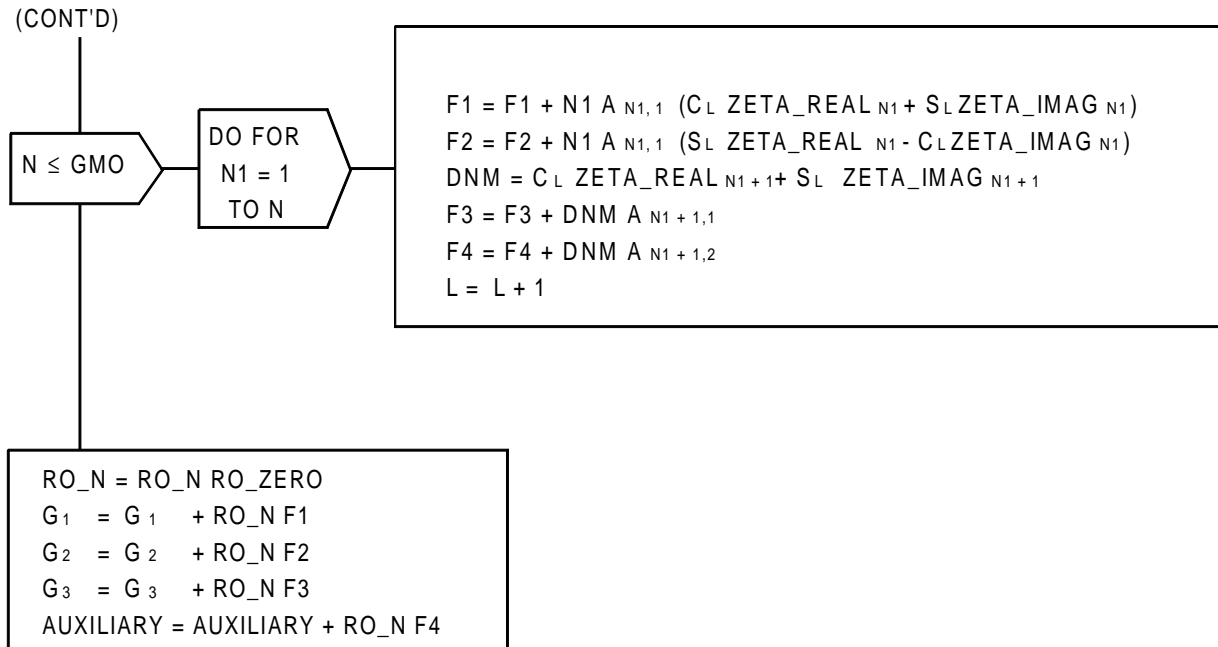


FIGURE 5.2-22.(2) ACCEL\_EARTH\_GRAV Code (Sheet 2 of 2)

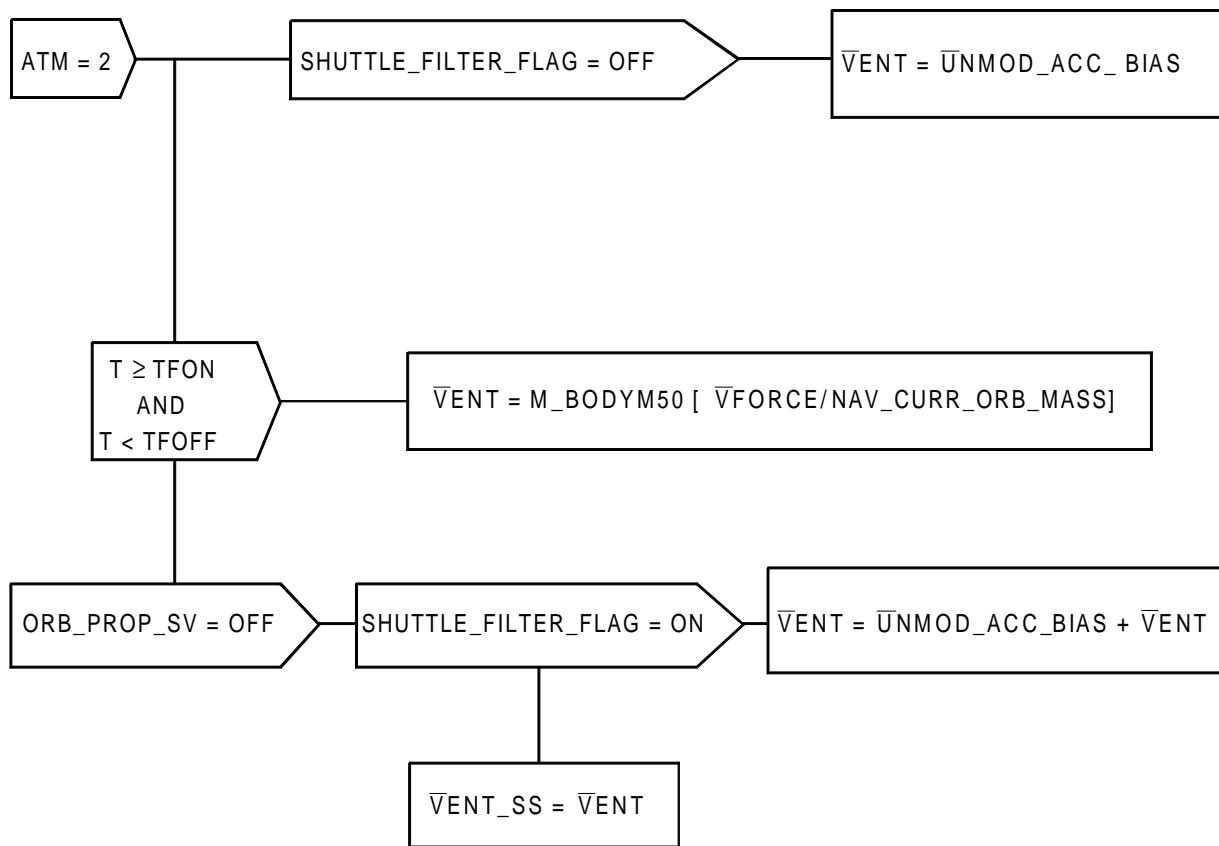


FIGURE 5.2-23. ACCEL\_ONORBIT\_VENT\_AND\_THRUST Code

IN LIST: T  
OUTLIST: SDEC, CDEC1, COS\_SOL\_RA, SIN\_SOL\_RA

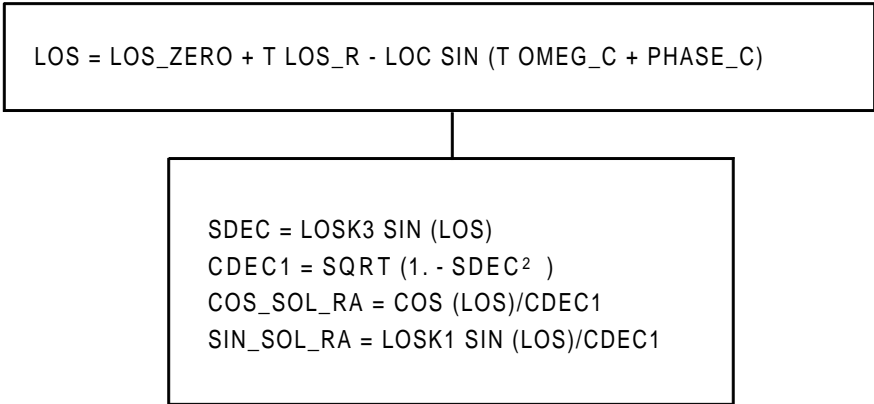


FIGURE 5.2-24. SOLAR\_EPHEM

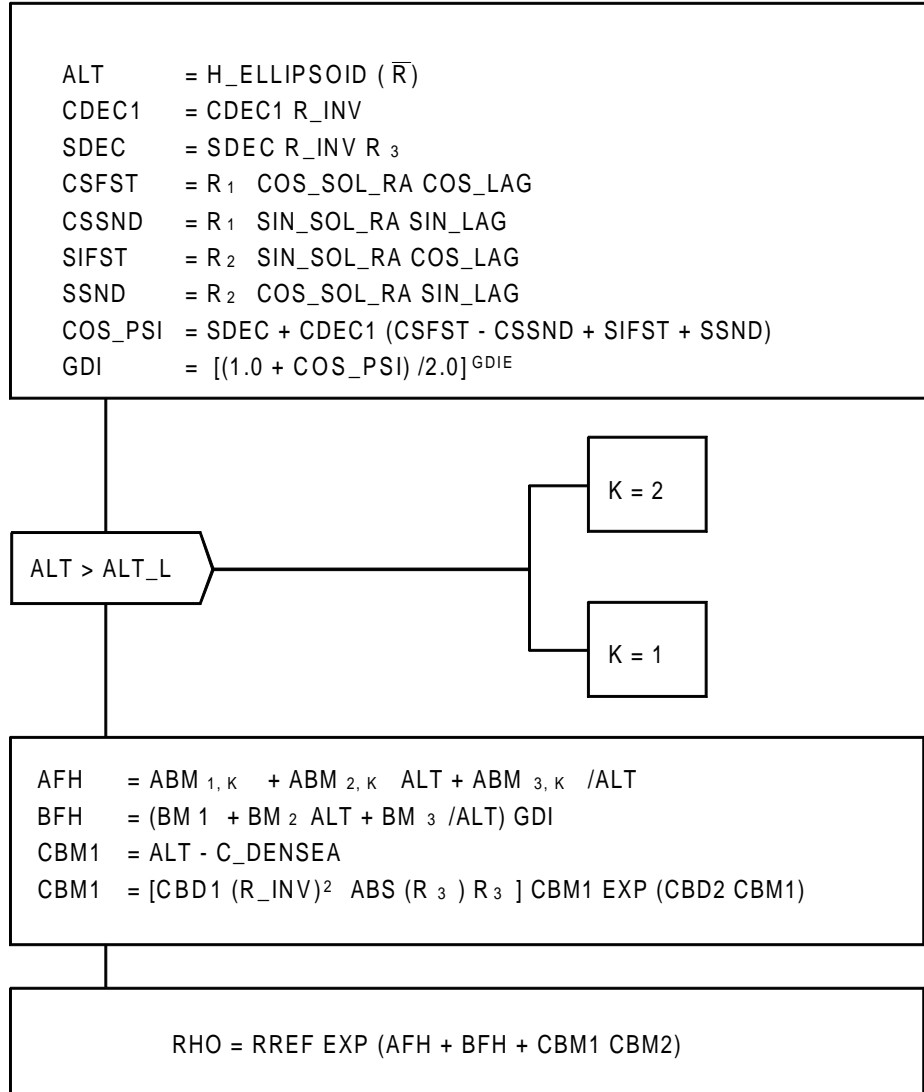


FIGURE 5.2-25. ONORBIT\_DENSITY Code

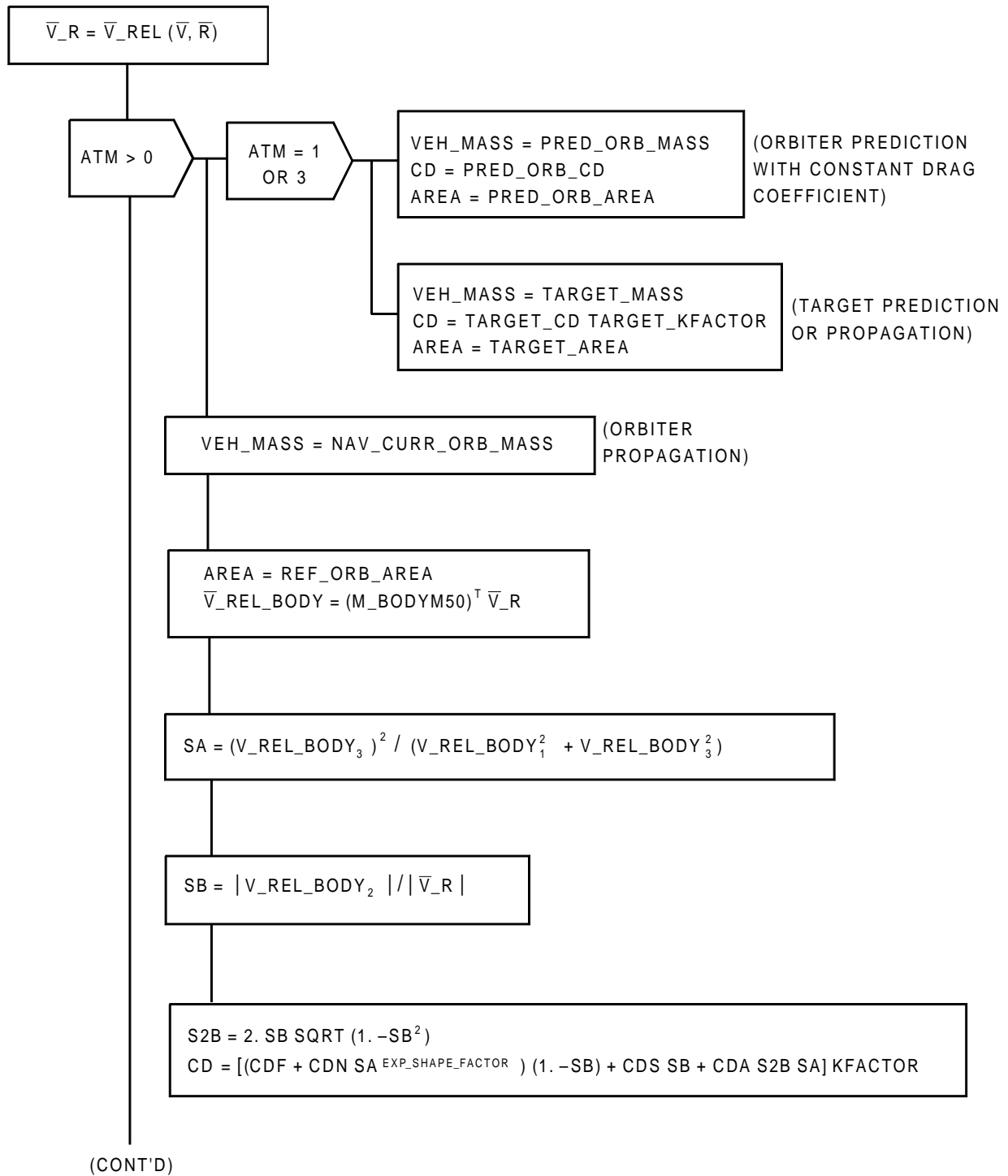


FIGURE 5.2-26.(1) ACCEL\_ONORBIT\_DRAG Code (Sheet 1 of 2)

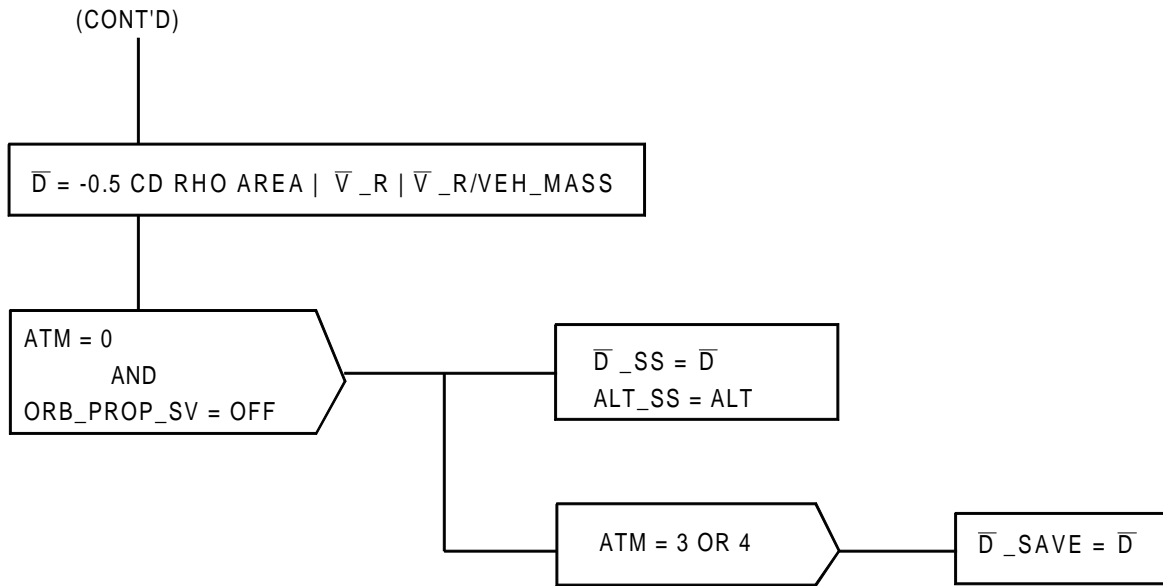


FIGURE 5.2-26.(2) ACCEL\_ONORBIT\_DRAG Code (Sheet 2 of 2)

$$H\_ELLIPSOID(\bar{R}) = |\bar{R}| \cdot \frac{(1 - ELLIPT) \text{ EARTH\_RADIUS\_EQUATOR}}{\sqrt{1 + ((1 - ELLIPT)^2 - 1) (1 - (\bar{UNIT}(\bar{R}) \cdot \bar{EARTH\_POLE})^2)}}$$

FIGURE 5.2-27. H\_ELLIPSOID Function

$$\bar{V}_{REL}(\bar{V}, \bar{R}) = \bar{V} - EARTH\_RATE(\bar{EARTH\_POLE} \times \bar{R})$$

FIGURE 5.2-28.  $\bar{V}_{REL}$  Function



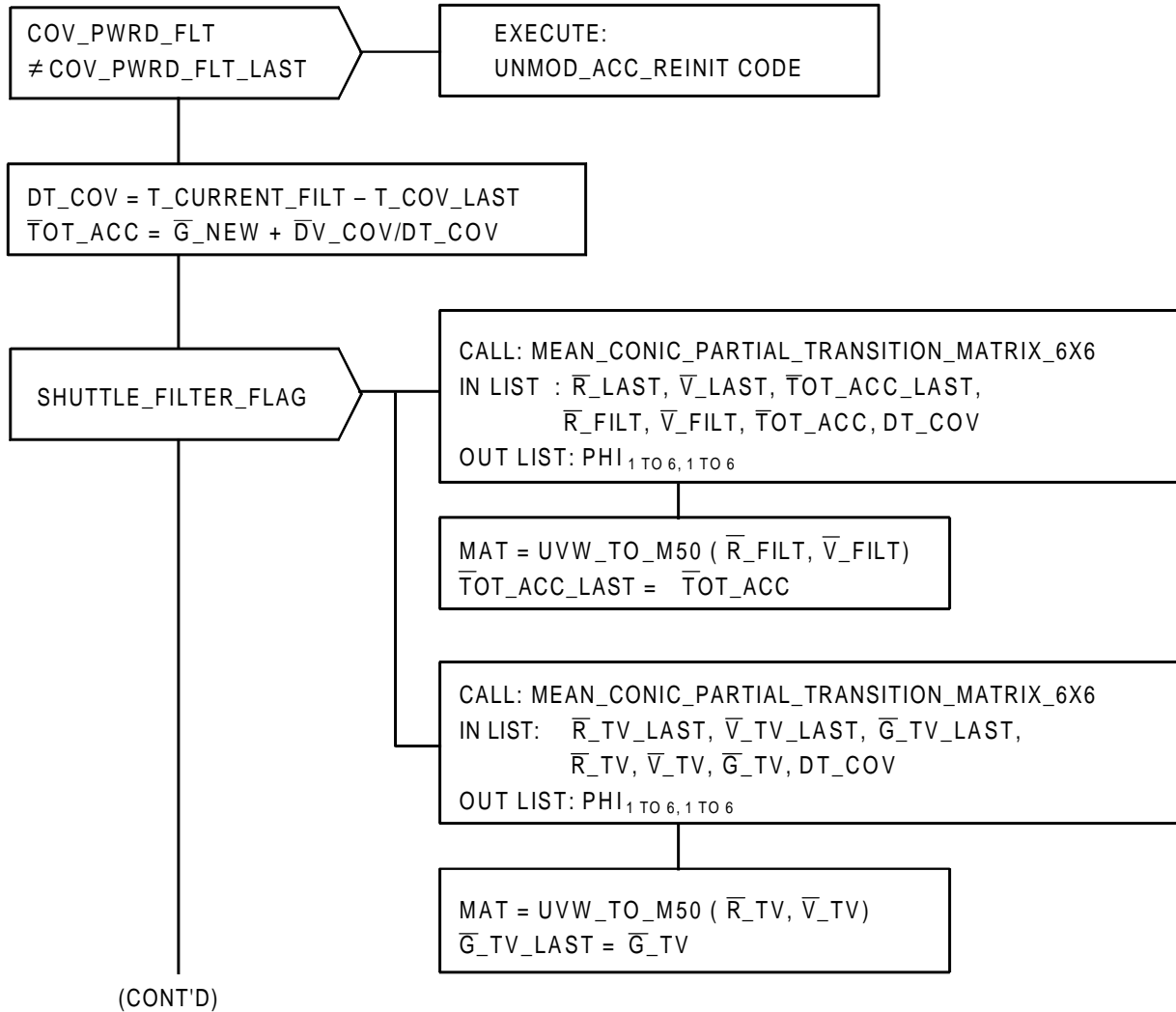


FIGURE 5.2-29.(1) REND\_BIAS\_AND\_COV\_PROP (Sheet 1 of 2)

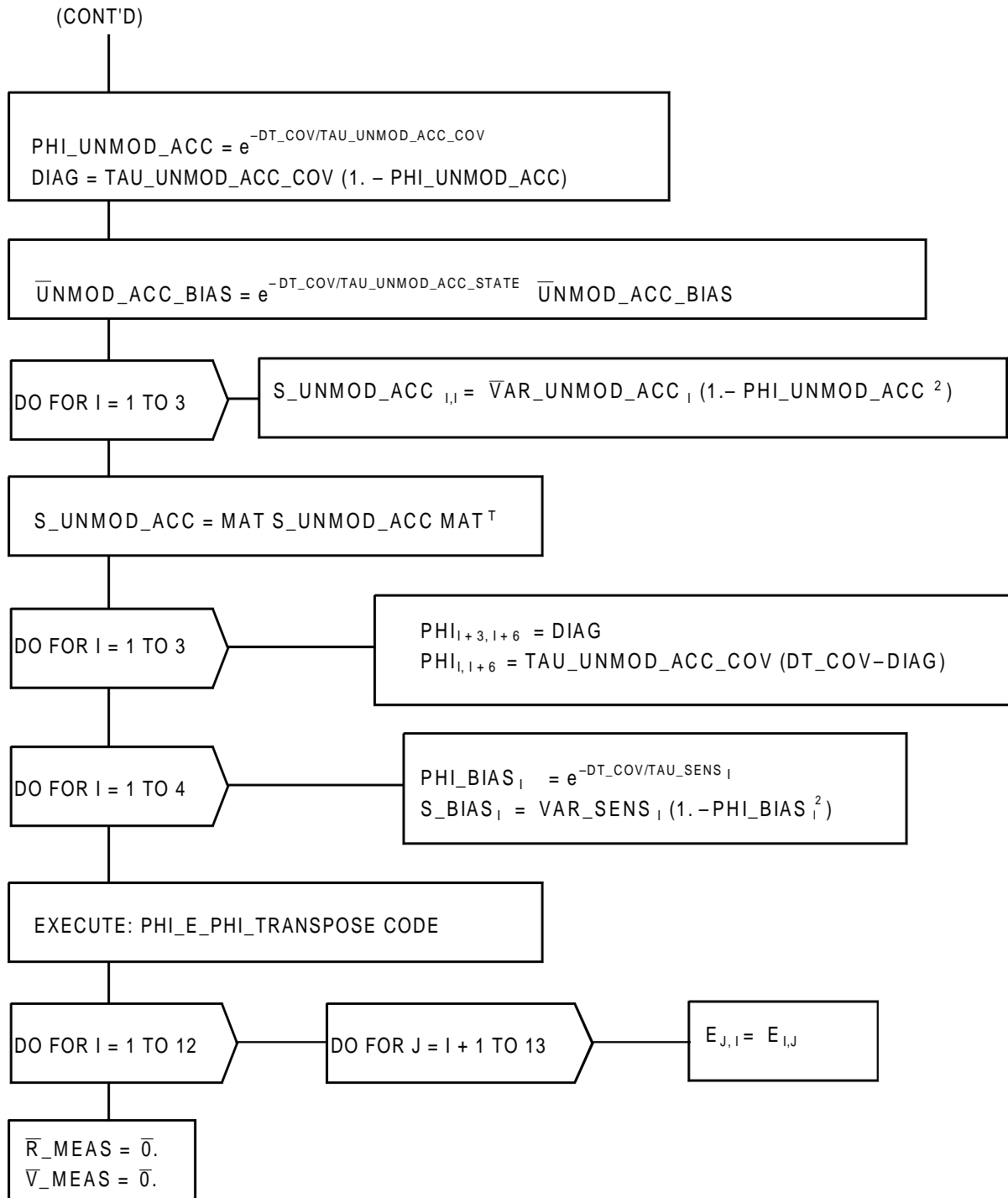


FIGURE 5.2-29.(2) REND\_BIAS\_AND\_COV\_PROP (Sheet 2 of 2)

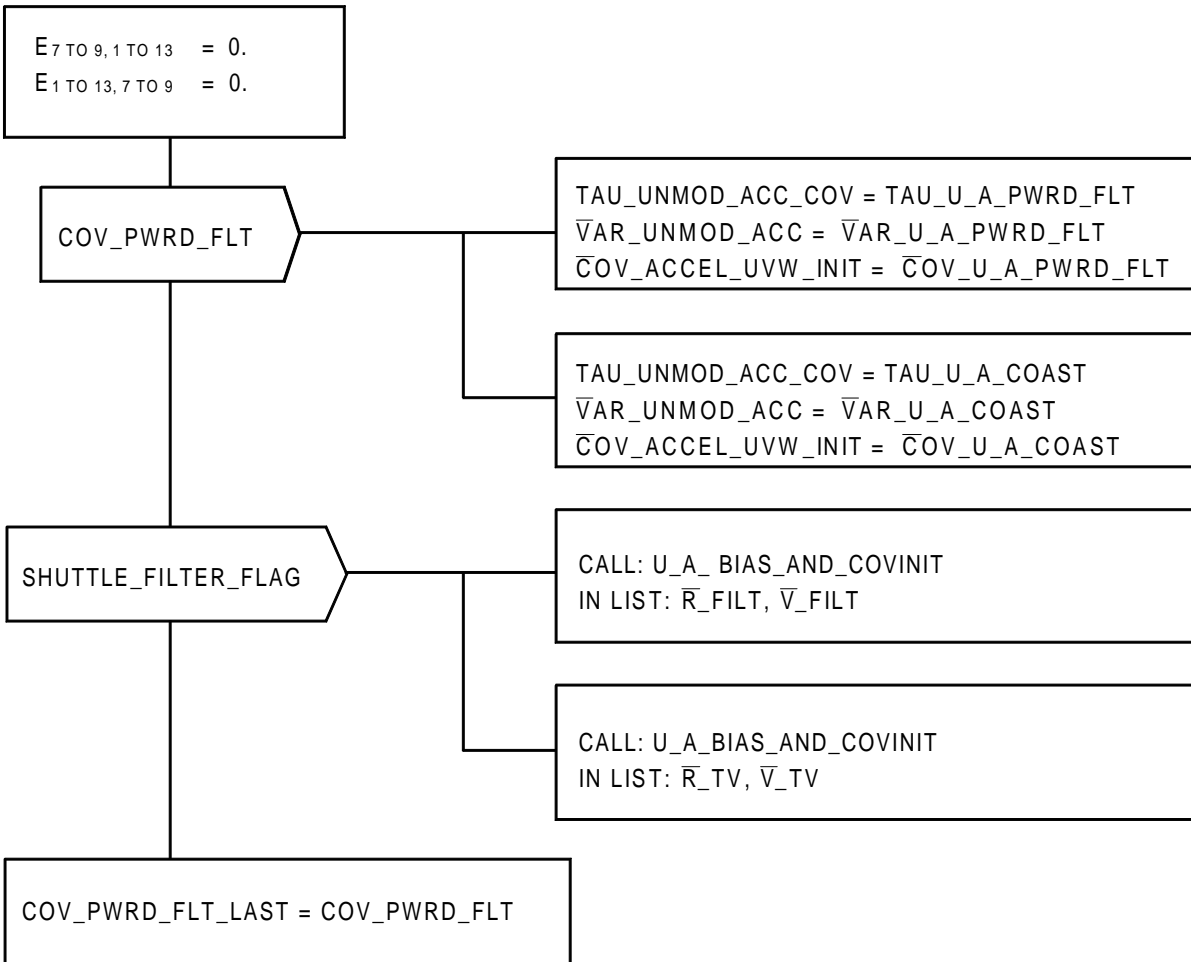


FIGURE 5.2-30. UNMOD\_ACC\_REINIT Code

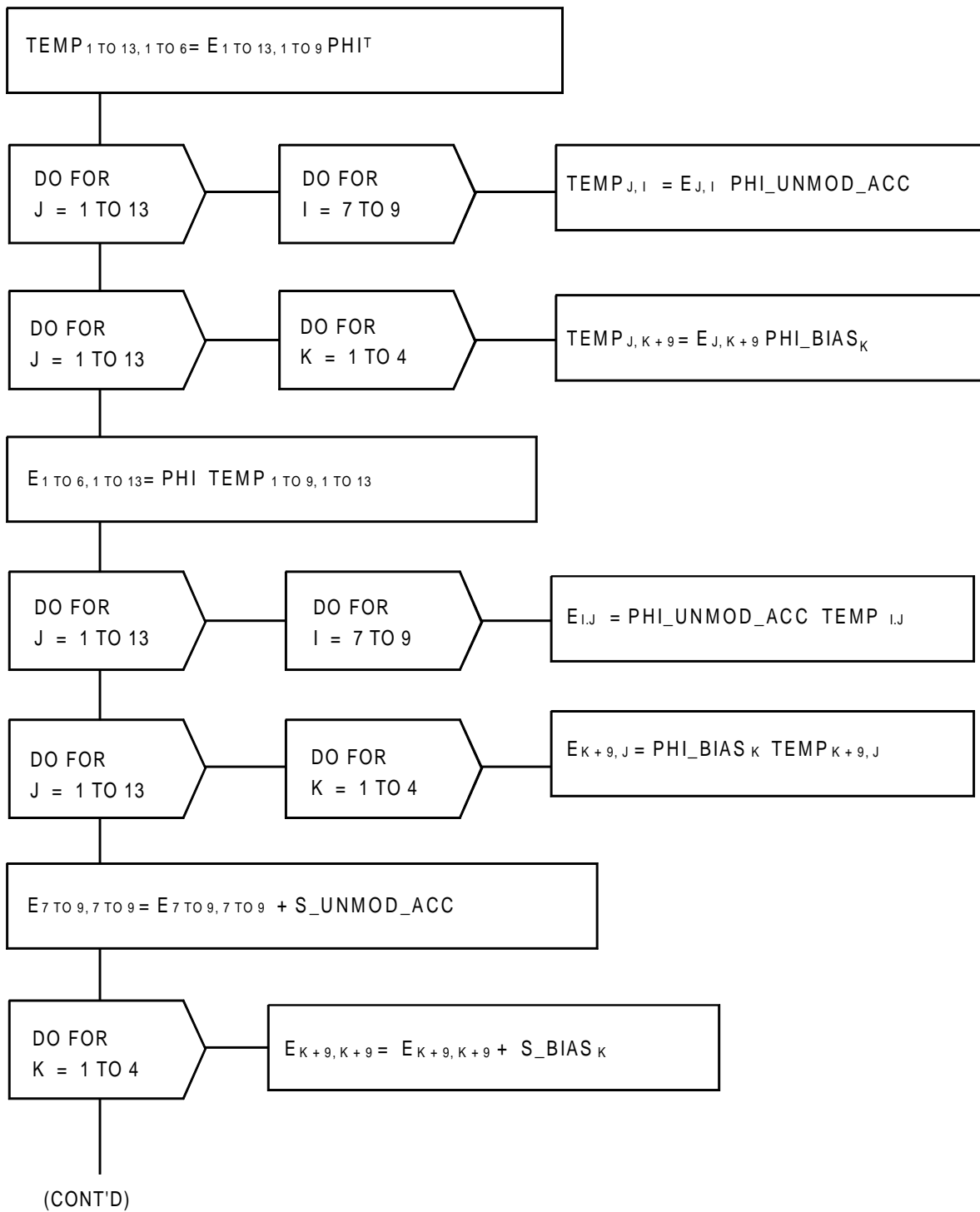


FIGURE 5.2-31.(1) PHI\_E\_PHI\_TRANSPOSE Code (Sheet 1 of 2)

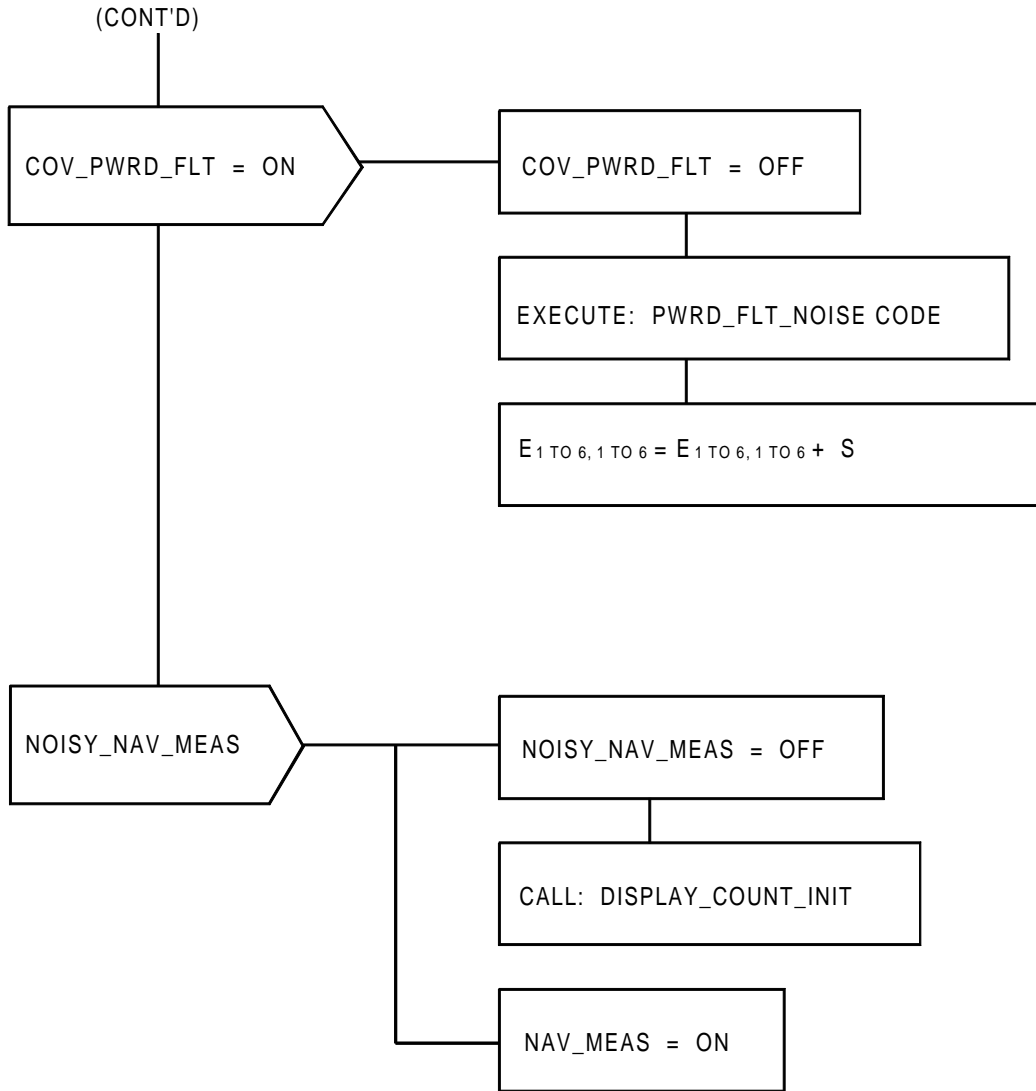


FIGURE 5.2-31.(2) PHI\_E\_PHI\_TRANSPOSE Code (Sheet 2 of 2)

$$\begin{aligned} S_{4,4} &= \overline{DV\_COV}_3^2 + \overline{DV\_COV}_2^2 \\ S_{5,5} &= \overline{DV\_COV}_1^2 + \overline{DV\_COV}_3^2 \\ S_{6,6} &= \overline{DV\_COV}_1^2 + \overline{DV\_COV}_2^2 \\ S_{4,5} &= - \overline{DV\_COV}_1 \overline{DV\_COV}_2 \\ S_{4,6} &= - \overline{DV\_COV}_1 \overline{DV\_COV}_3 \\ S_{5,6} &= - \overline{DV\_COV}_2 \overline{DV\_COV}_3 \\ S_{6,5} &= S_{5,6} \\ S_{6,4} &= S_{4,6} \\ S_{5,4} &= S_{4,5} \\ S_{4\ TO\ 6,\ 4\ TO\ 6} &= (VAR\_IMU\_ALIGN) S_{4\ TO\ 6,\ 4\ TO\ 6} \\ S_{1\ TO\ 3,\ 4\ TO\ 6} &= 0.5 (DT\_COV) S_{4\ TO\ 6,\ 4\ TO\ 6} \\ S_{1\ TO\ 3,\ 1\ TO\ 3} &= 0.5 (DT\_COV) S_{1\ TO\ 3,\ 4\ TO\ 6} \end{aligned}$$

FIGURE 5.2-32. PWRD\_FLT\_NOISE Code

IN LIST:  $\bar{R}$ ,  $\bar{V}$

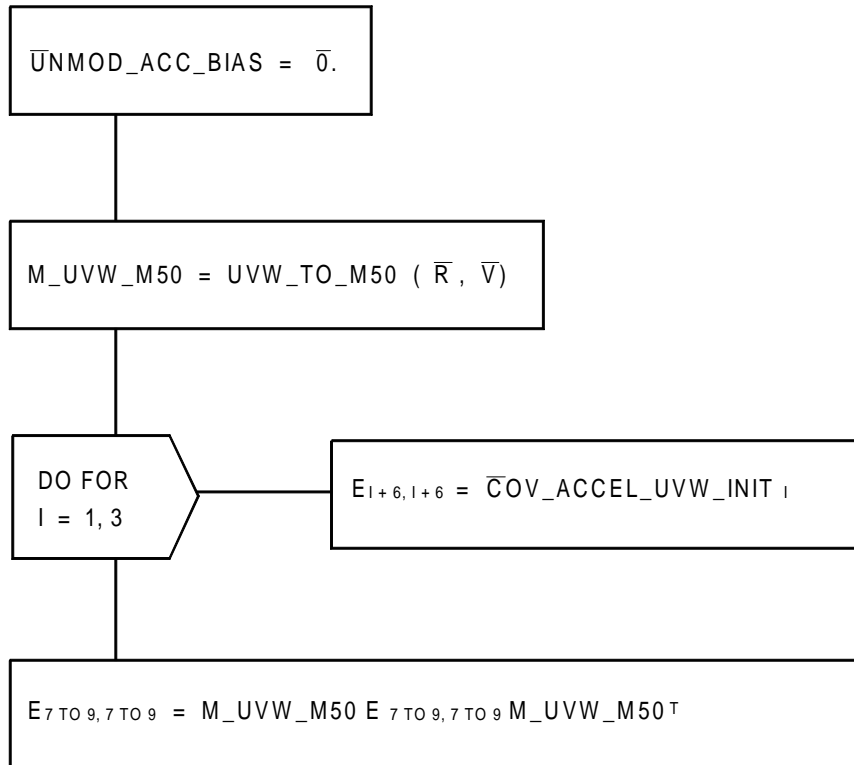


FIGURE 5.2-33. U\_A\_BIAS\_AND\_COVINIT

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IN LIST:  $\bar{R}_{ONE}$ ,  $\bar{V}_{ONE}$ ,  $\bar{G}_{ONE}$ ,  $\bar{R}_{TWO}$ ,  $\bar{V}_{TWO}$ ,  $\bar{G}_{TWO}$ , DELTIM  
 OUT LIST: PHI\_MC

$$R\_ONE\_INV = 1./|\bar{R}_{ONE}| \quad D\_ONE = \bar{R}_{ONE} \cdot \bar{V}_{ONE}$$

$$R\_TWO\_INV = 1./|\bar{R}_{TWO}| \quad D\_TWO = \bar{R}_{TWO} \cdot \bar{V}_{TWO}$$

$$SMA = 1./[R\_ONE\_INV + R\_TWO\_INV - (\bar{V}_{ONE} \cdot \bar{V}_{ONE} + \bar{V}_{TWO} \cdot \bar{V}_{TWO})/(2. \text{EARTH\_MU})]$$

$$C1 = \text{SQRT}(SMA)/\text{SQR\_EMU}$$

CALL: F\_AND\_G  
 IN LIST: SMA, DELTIM, C1,  $\bar{R}_{ONE}$ , R\_ONE\_INV, R\_TWO\_INV,  $\bar{V}_{ONE}$ , D\_ONE, D\_TWO  
 OUT LIST: F, G, FDOT, GDOT, S0, S1, S2, S3,  $\bar{R}_{TWO}$ , R\_TWO\_INV, THETA

$$FM1 = F - 1$$

$$GDM1 = GDOT - 1$$

$$S1 = C1 S1$$

$$C2 = C1^2$$

$$\text{CONST} = C2 [\text{EARTH\_MU} C2 (3. S3 C1 - S1 S2) + G S2]$$

$$S2 = C2 S2$$

$$A1 = (\text{FDOT} S1 + FM1 R\_ONE\_INV) R\_ONE\_INV$$

$$A2 = \text{FDOT} S2$$

$$A3 = FM1 S1 R\_ONE\_INV$$

$$A4 = FM1 S2$$

$$A5 = GDM1 S2$$

$$A6 = G S2$$

$$A7 = \text{FDOT} (S0 R\_ONE\_INV R\_TWO\_INV + R\_ONE\_INV^2 + R\_TWO\_INV^2)$$

$$A8 = (\text{FDOT} S1 + GDM1 R\_TWO\_INV) R\_TWO\_INV$$

$$A9 = GDM1 S1 R\_TWO\_INV$$

(CONT'D)

FIGURE 5.2-34.(1) MEAN\_CONIC\_PARTIAL\_TRANSITION\_MATRIX\_6X6 (Sheet 1 of 2)



(CONT'D)

$$\begin{aligned}
 \text{TEMP} &= A4 \bar{V}_{\text{TWO}} - A2 \bar{R}_{\text{TWO}} \\
 \text{PHI\_MC}_{1\text{TO}3,1\text{TO}3} &= F \text{ID\_MATRIX\_3X3} + \text{CONST } \bar{V}_{\text{TWO}} \bar{G}_{\text{ONE}}^T + \\
 &\quad (A3 \bar{V}_{\text{TWO}} - A1 \bar{R}_{\text{TWO}}) \bar{R}_{\text{ONE}}^T + \text{TEMP } \bar{V}_{\text{ONE}}^T \\
 \\
 \text{PHI\_MC}_{1\text{TO}3,4\text{TO}6} &= G \text{ID\_MATRIX\_3X3} - \text{CONST } \bar{V}_{\text{TWO}} \bar{V}_{\text{ONE}}^T + \\
 &\quad \text{TEMP } \bar{R}_{\text{ONE}}^T + (A6 \bar{V}_{\text{TWO}} - A5 \bar{R}_{\text{TWO}}) \bar{V}_{\text{ONE}}^T \\
 \\
 \text{TEMP} &= A2 \bar{V}_{\text{TWO}} - A8 \bar{R}_{\text{TWO}} \\
 \text{PHI\_MC}_{4\text{TO}6,1\text{TO}3} &= F \text{DOT ID\_MATRIX\_3X3} + \text{CONST } \bar{G}_{\text{TWO}} \bar{G}_{\text{ONE}}^T + \\
 &\quad (A1 \bar{V}_{\text{TWO}} - A7 \bar{R}_{\text{TWO}}) \bar{R}_{\text{ONE}}^T + \text{TEMP } \bar{V}_{\text{ONE}}^T \\
 \\
 \text{PHI\_MC}_{4\text{TO}6,4\text{TO}6} &= G \text{DOT ID\_MATRIX\_3X3} - \text{CONST } \bar{G}_{\text{TWO}} \bar{V}_{\text{ONE}}^T + \\
 &\quad \text{TEMP } \bar{R}_{\text{ONE}}^T + (A5 \bar{V}_{\text{TWO}} - A9 \bar{R}_{\text{TWO}}) \bar{V}_{\text{ONE}}^T
 \end{aligned}$$

FIGURE 5.2-34.(2) MEAN\_CONIC\_PARTIAL\_TRANSITION\_MATRIX\_6X6 (Sheet 2 of 2)

IN LIST: SMA, DELTAT, C1,  $\bar{R}_{IN}$ , R\_IN\_INV, R\_FIN\_INV,  $\bar{V}_{IN}$ , D\_IN, D\_FIN

OUT LIST: F, G, FDOT, GDOT, S0, S1, S2, S3,  $\bar{R}_{FIN}$ , R\_FIN\_INV, THETA  
 (SOLVE KEPLER'S EQUATION FOR PINES METHOD OR SV\_INTERP)

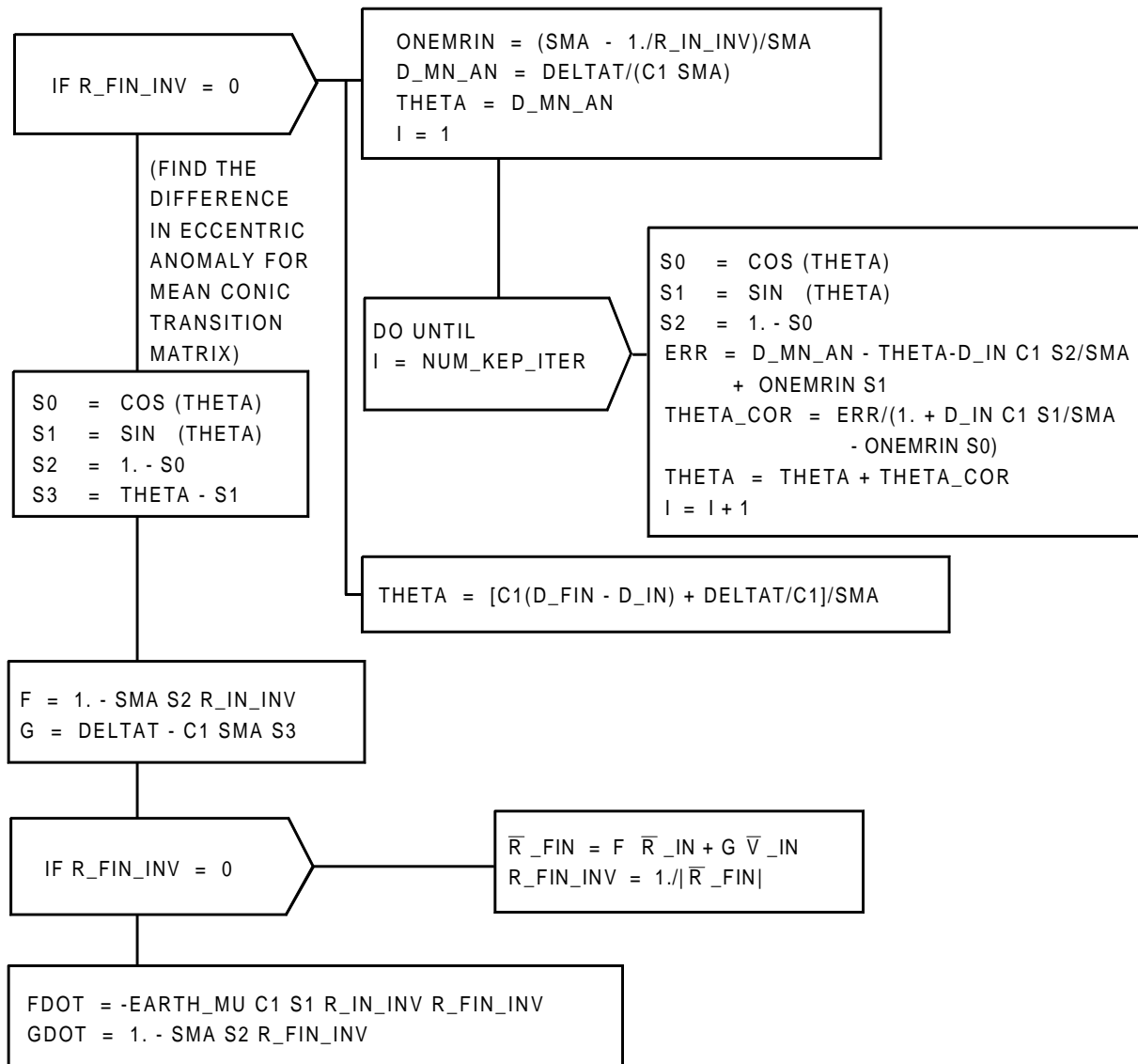


FIGURE 5.2-35. F\_AND\_G

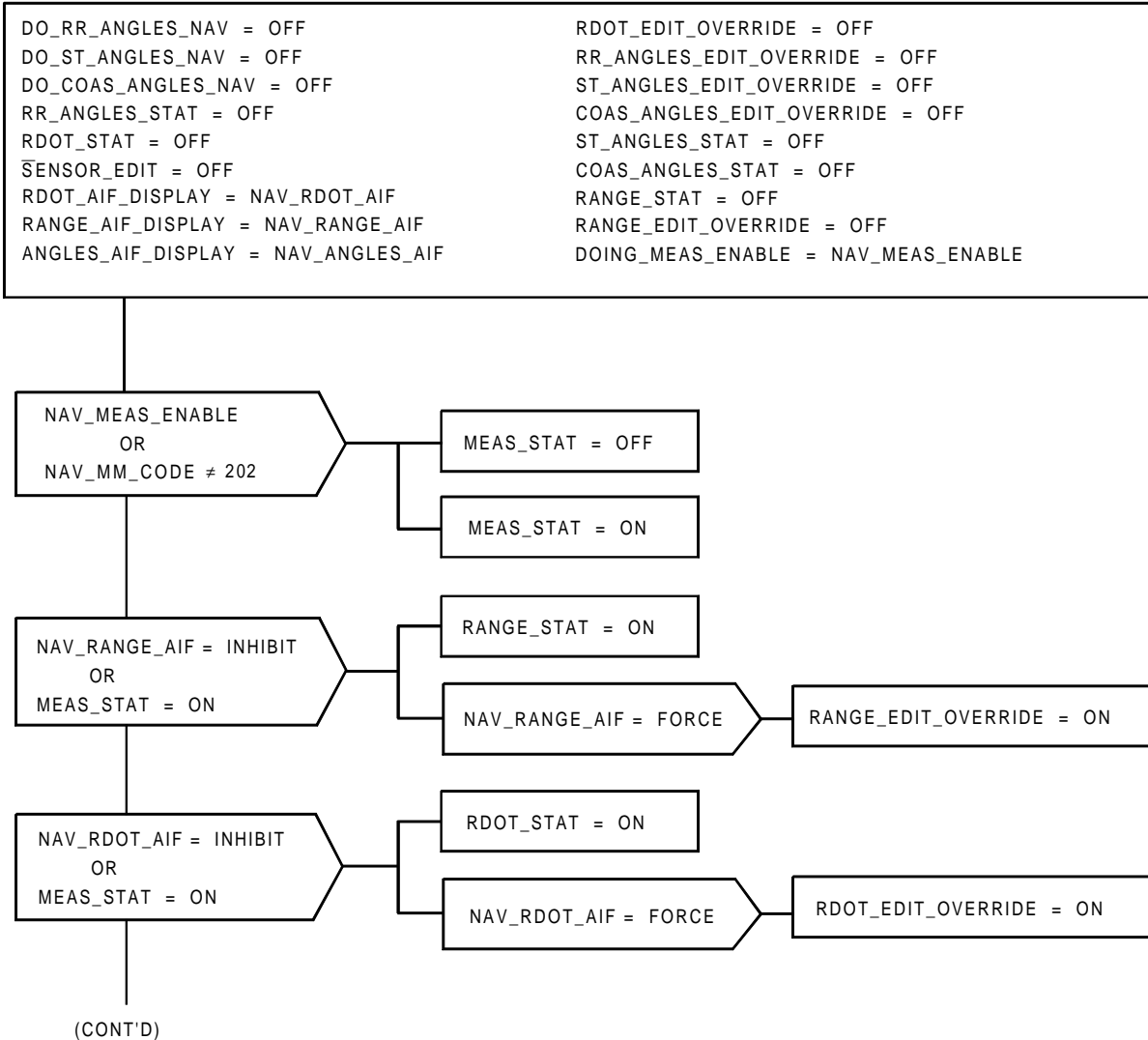


FIGURE 5.2-36.(1) REND\_SENSOR\_SELECT (Sheet 1 of 3)

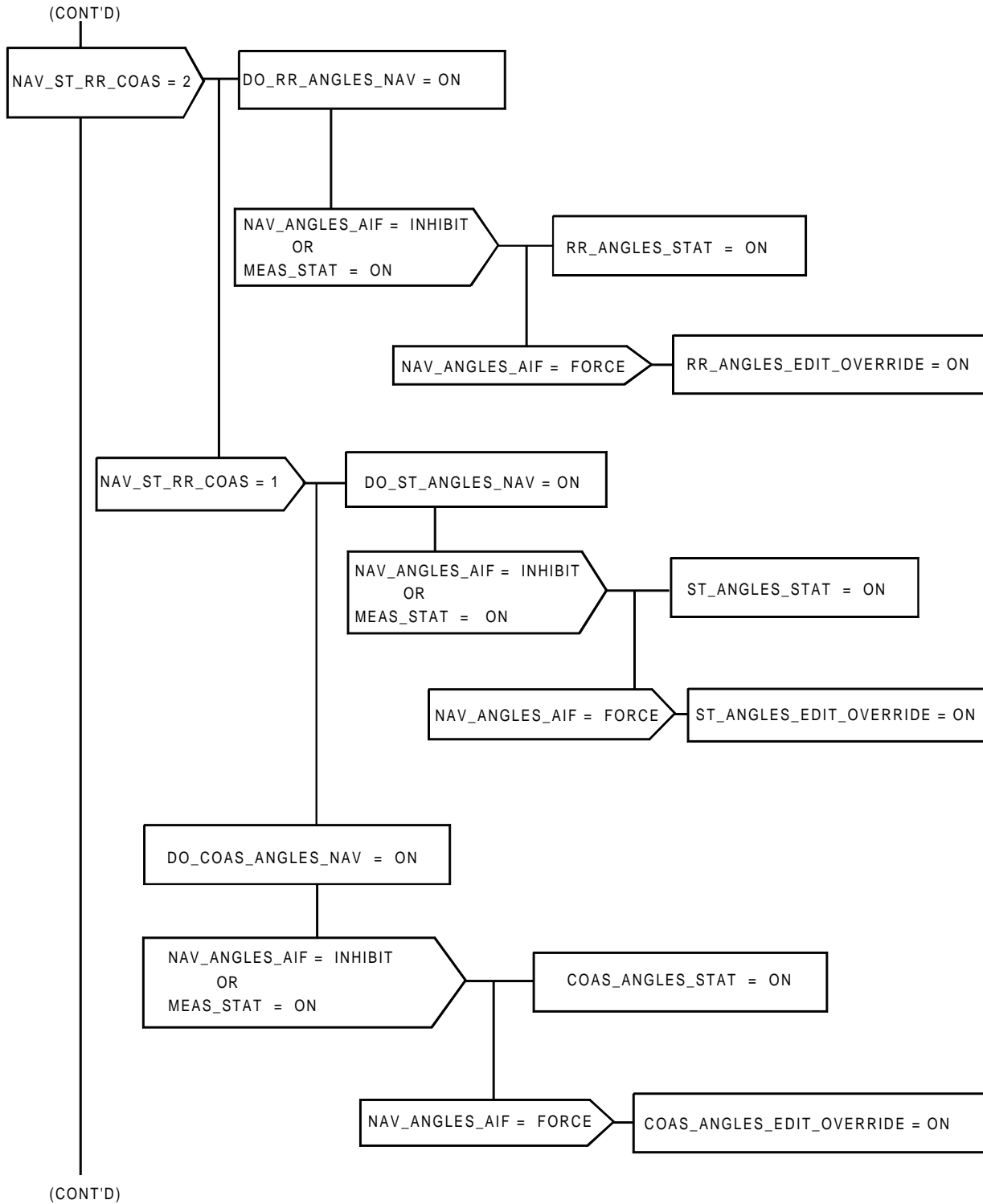


FIGURE 5.2-36.(2) REND\_SENSOR\_SELECT (Sheet 2 of 3)

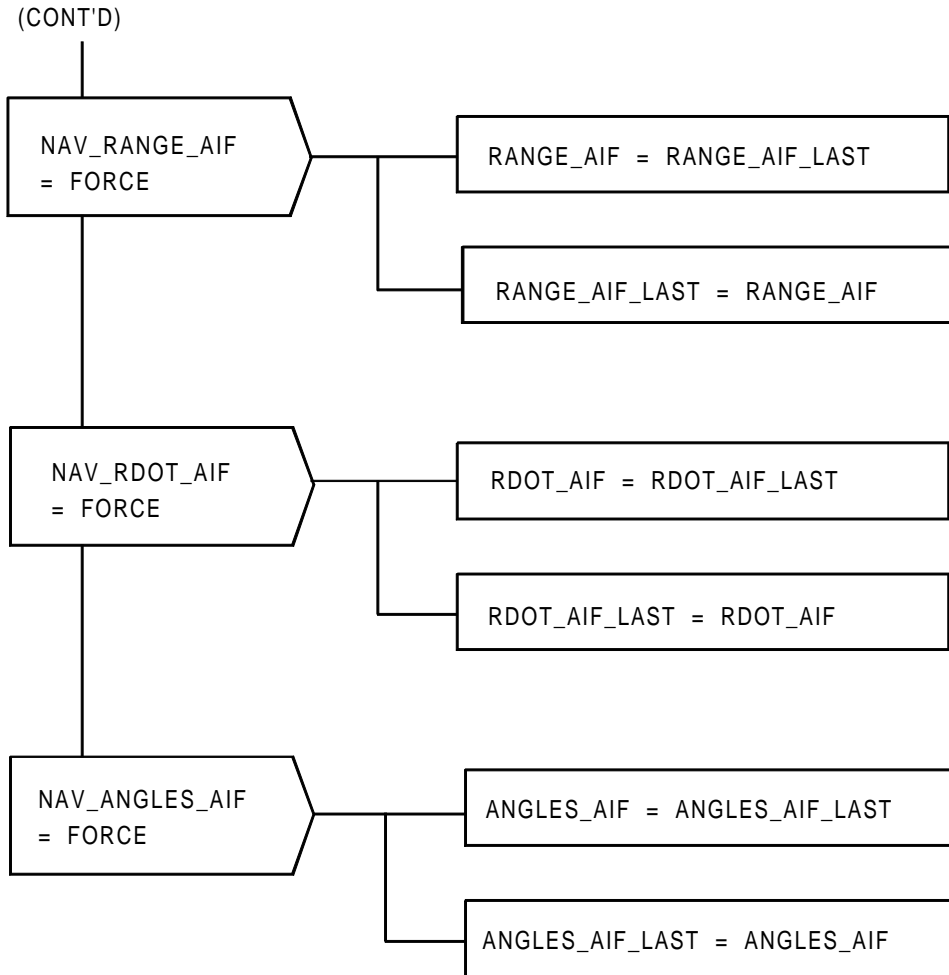


FIGURE 5.2-36.(3) REND\_SENSOR\_SELECT (Sheet 3 of 3)

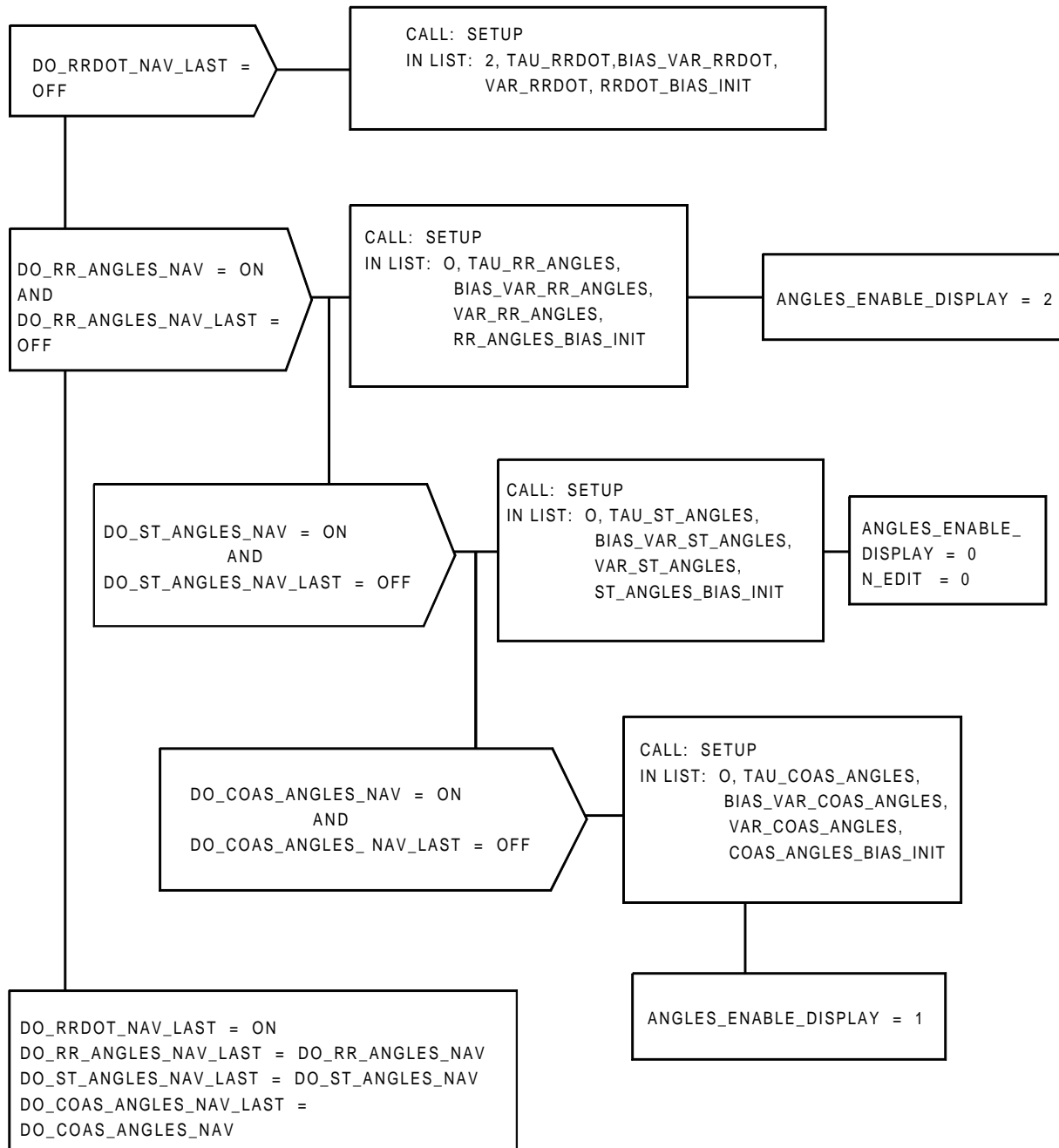


FIGURE 5.2-37. REND\_NAV\_SENSOR\_INIT

IN LIST: I, TAU, BIAS\_VAR, BIAS\_COV\_VAR, BIAS\_INIT

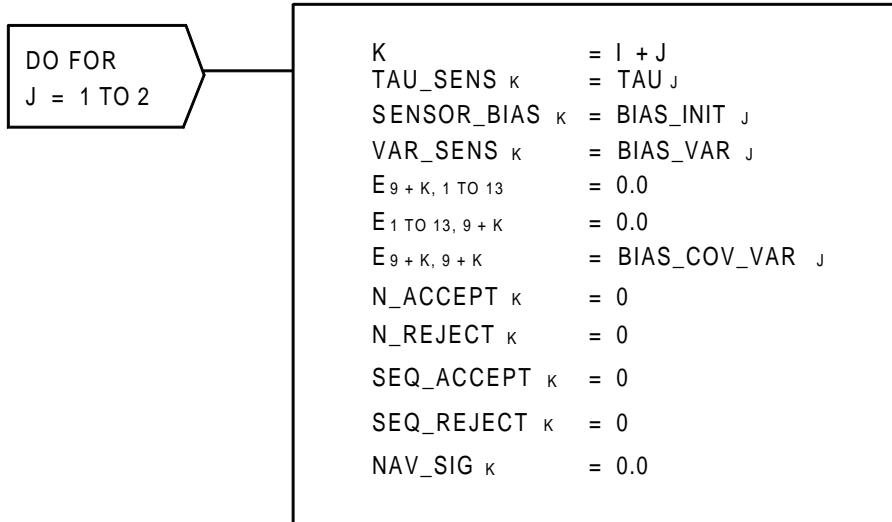
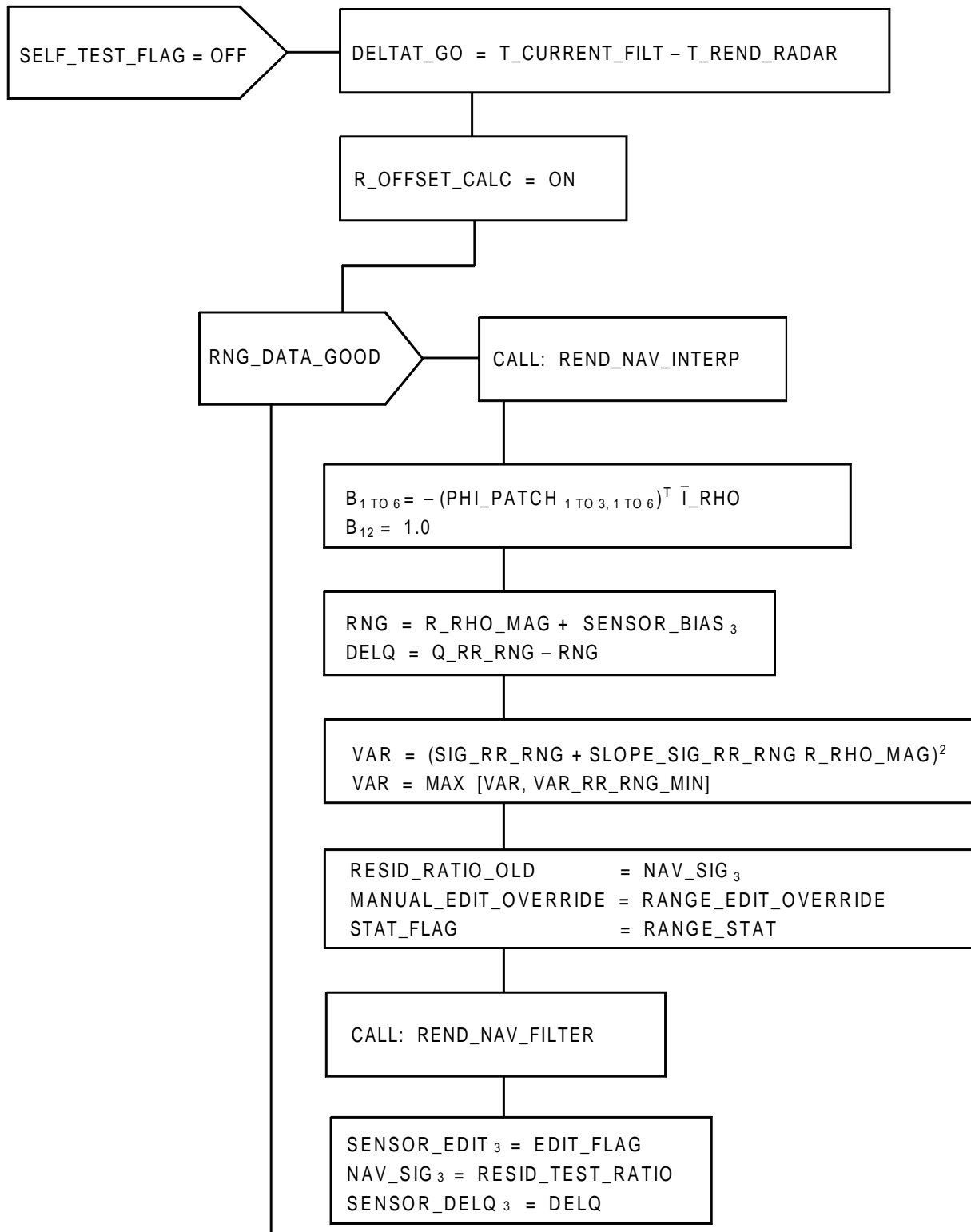


FIGURE 5.2-38. SETUP



(CONT'D)

FIGURE 5.2-39.(1) RRDOT\_NAV (Sheet 1 of 3)



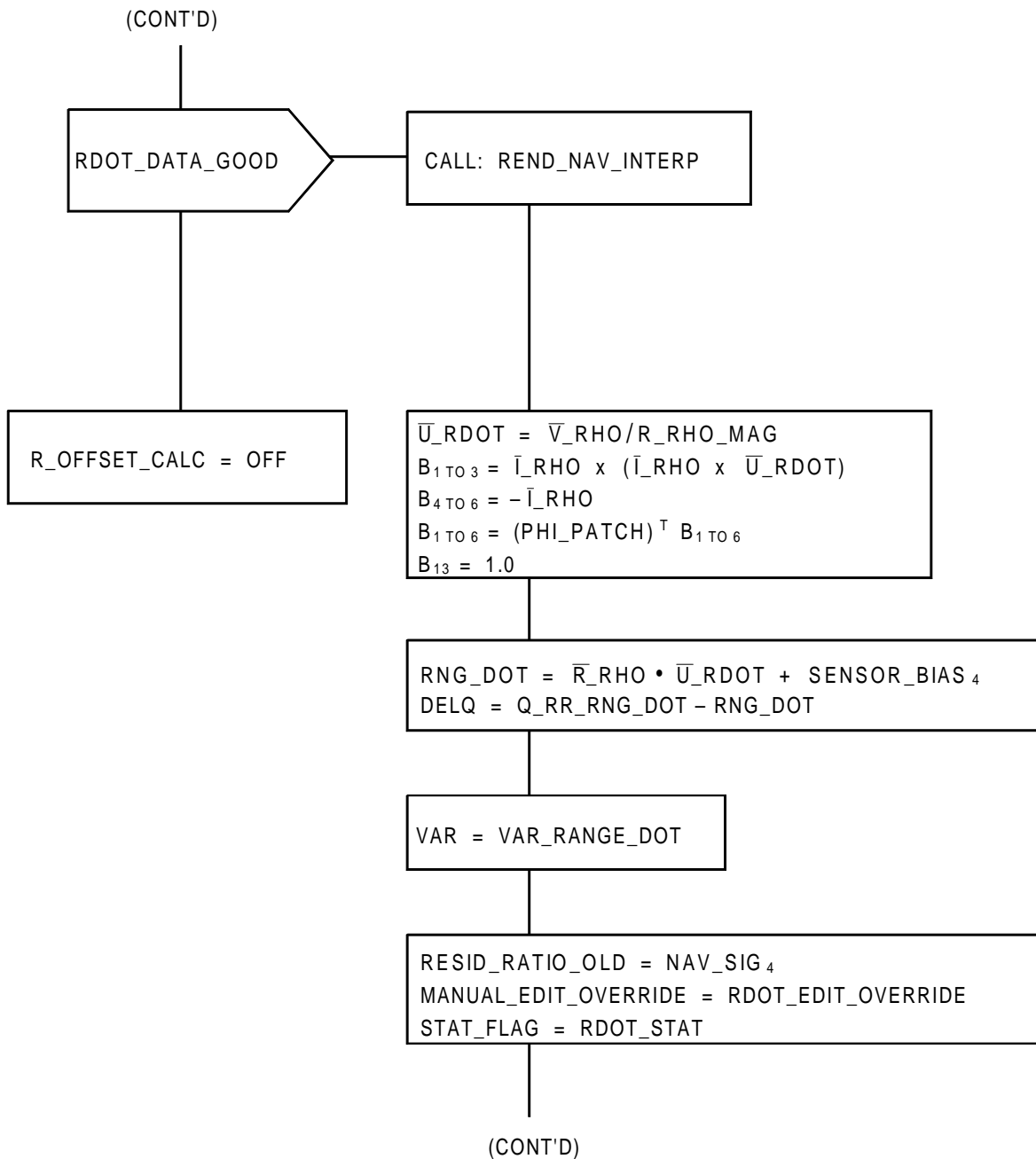


FIGURE 5.2-39.(2) RRDOT\_NAV (Sheet 2 of 3)

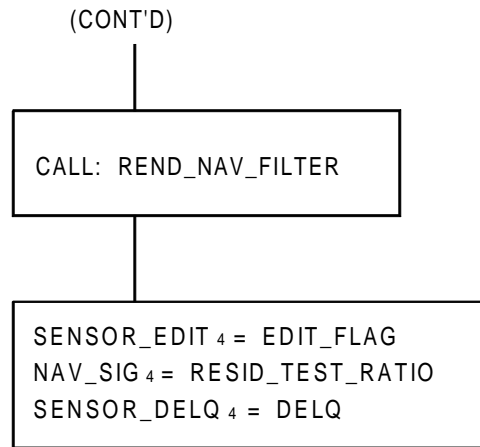


FIGURE 5.2-39.(3) RRDOT\_NAV (Sheet 3 of 3)

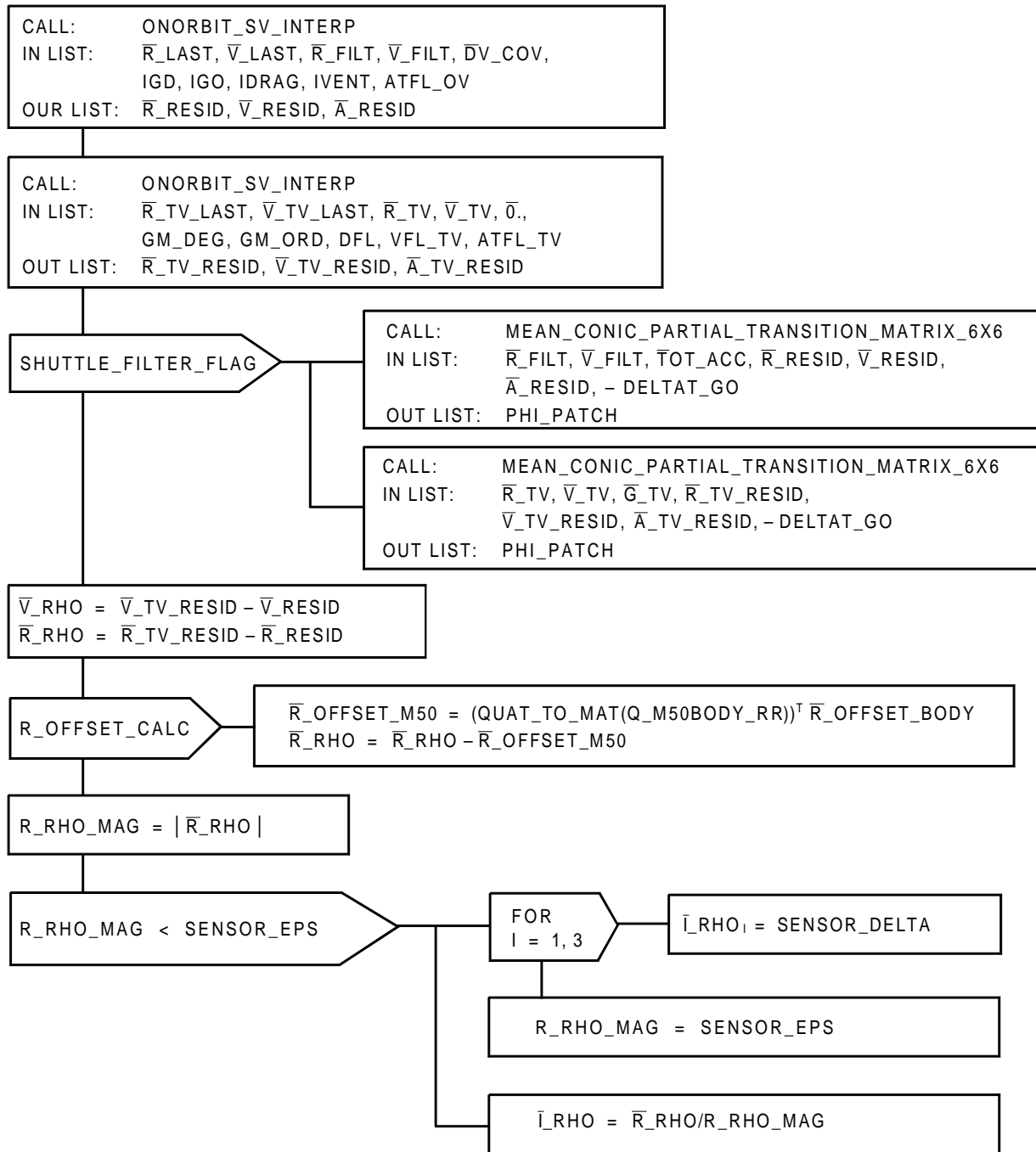


FIGURE 5.2-40. REVD\_NAV\_INTERP

IN LIST:  $\bar{R}_{ONE}$ ,  $\bar{V}_{ONE}$ ,  $\bar{R}_{TWO}$ ,  $\bar{V}_{TWO}$ ,  $\bar{V}_{IMU\_DIF}$ ,  
 IGD, IGO, IDM, IVM, IATM  
 OUT LIST:  $\bar{R}_{RESID}$ ,  $\bar{V}_{RESID}$ ,  $\bar{A}_{RESID}$

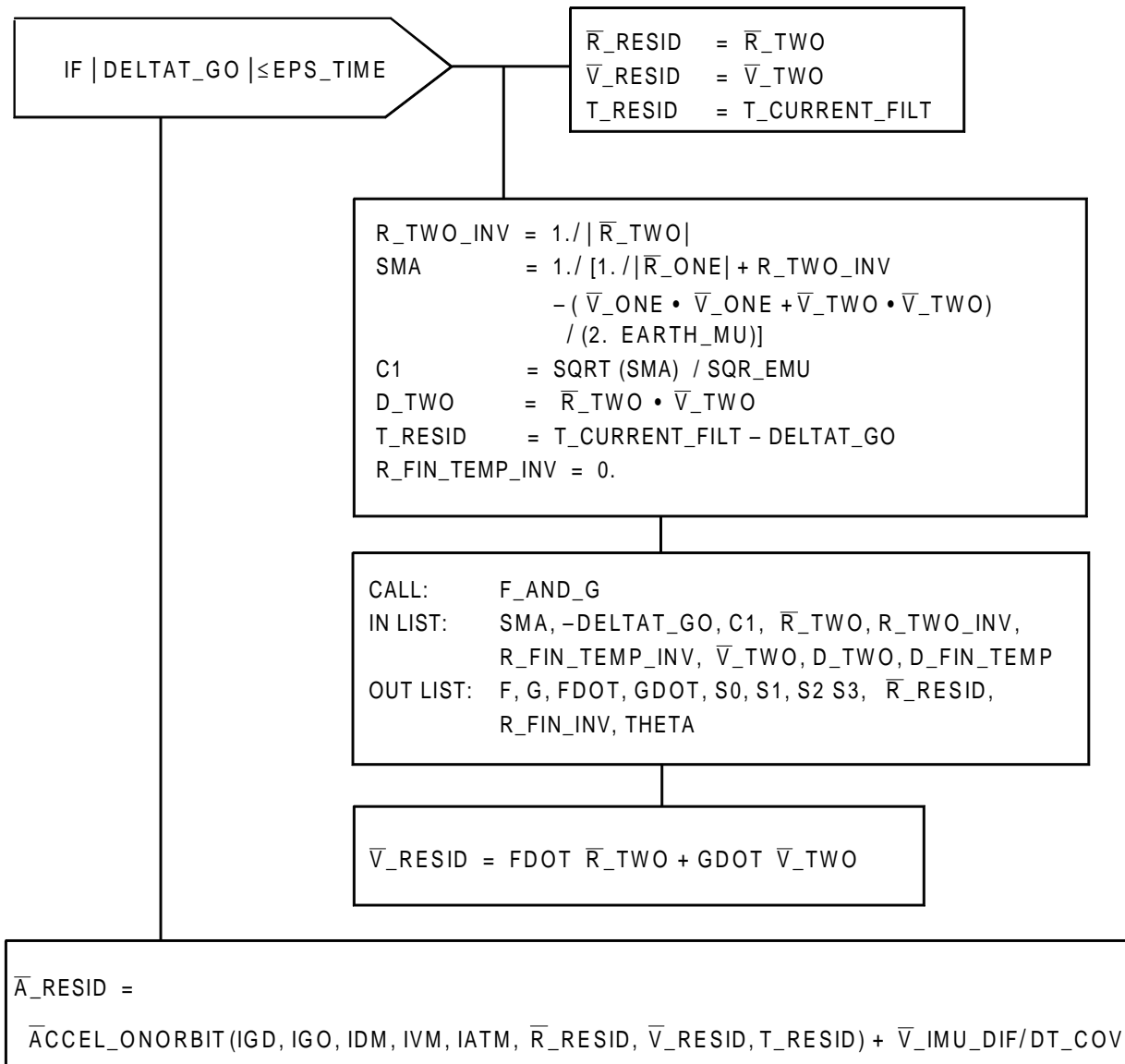


FIGURE 5.2-41. ONORBIT\_SV\_INTERP

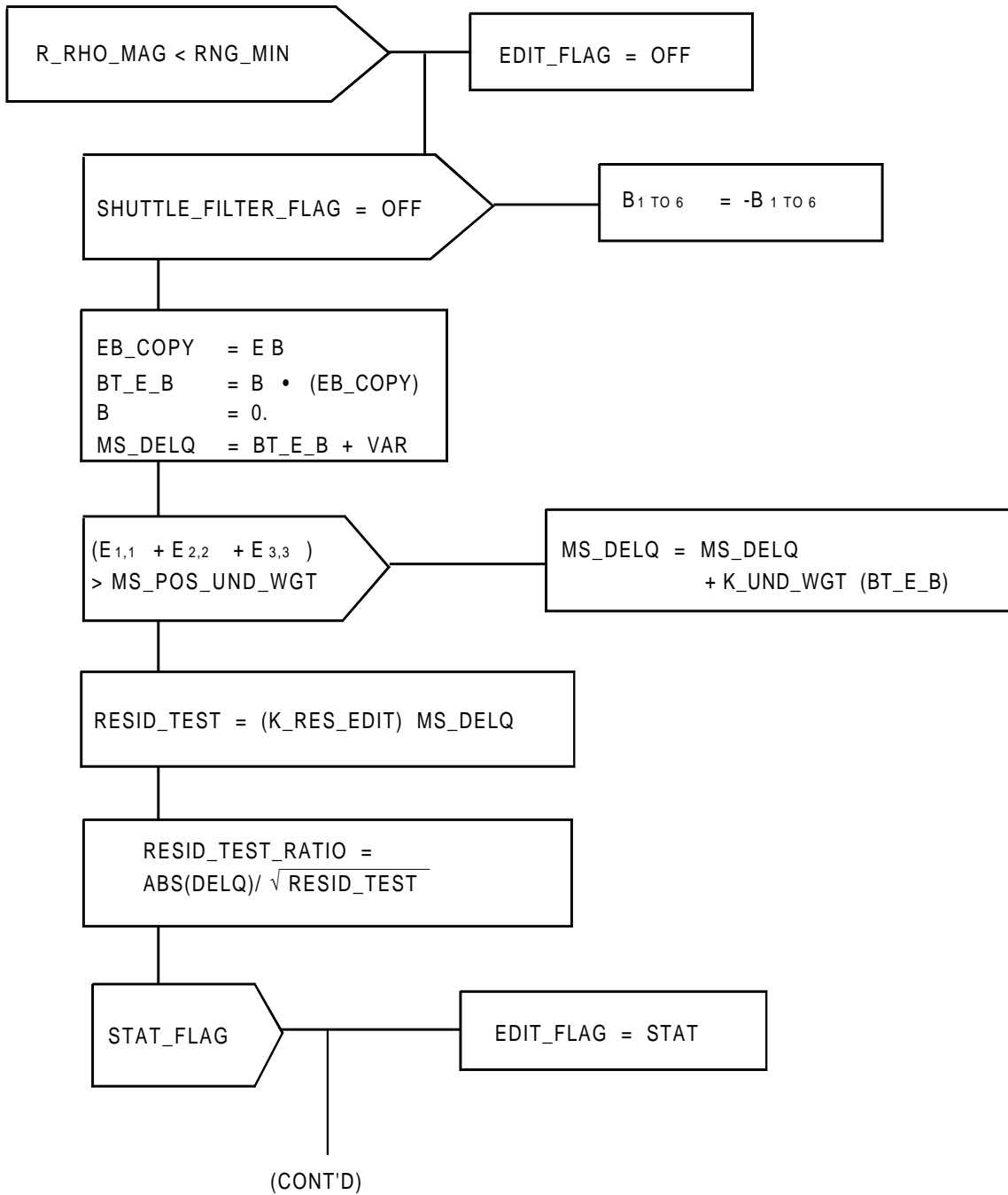


FIGURE 5.2-42.(1) REND\_NAV\_FILTER (Sheet 1 of 2)

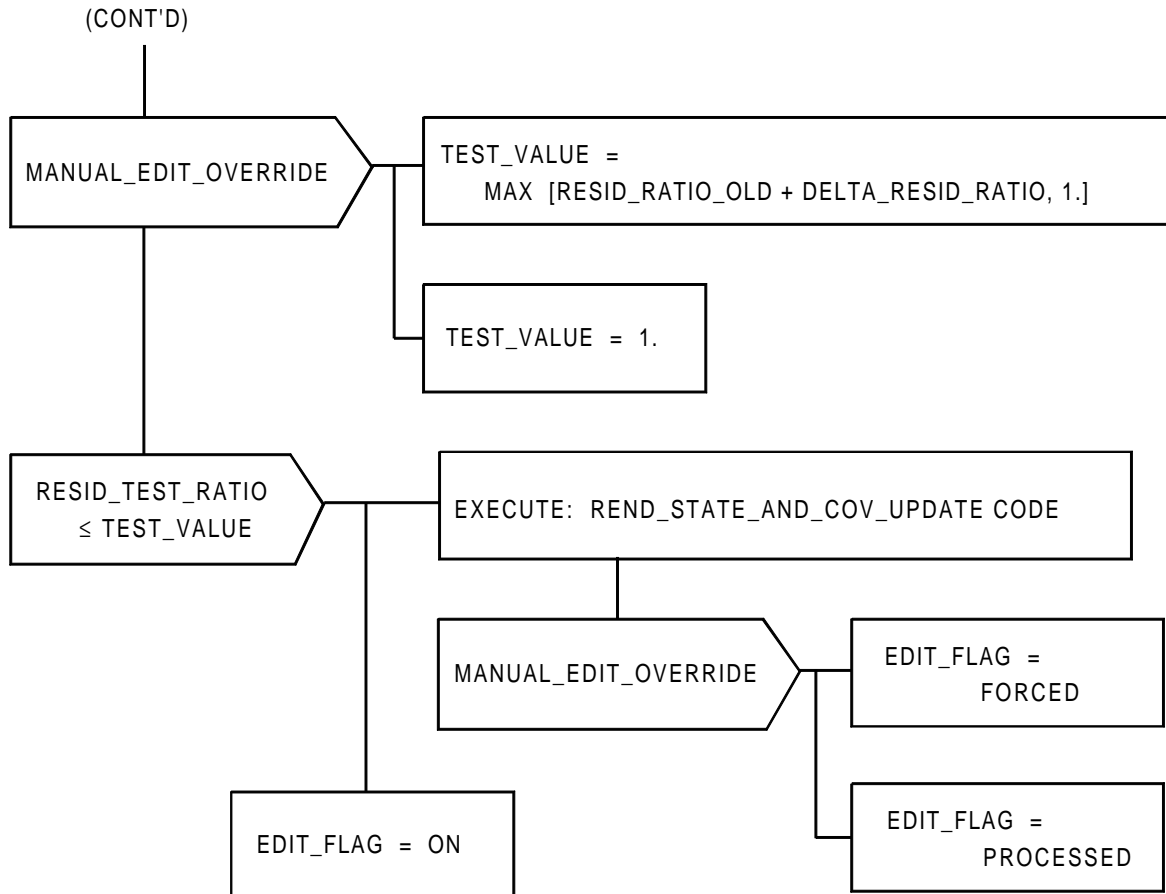


FIGURE 5.2-42.(2) RENDE\_NAV\_FILTER (Sheet 2 of 2)

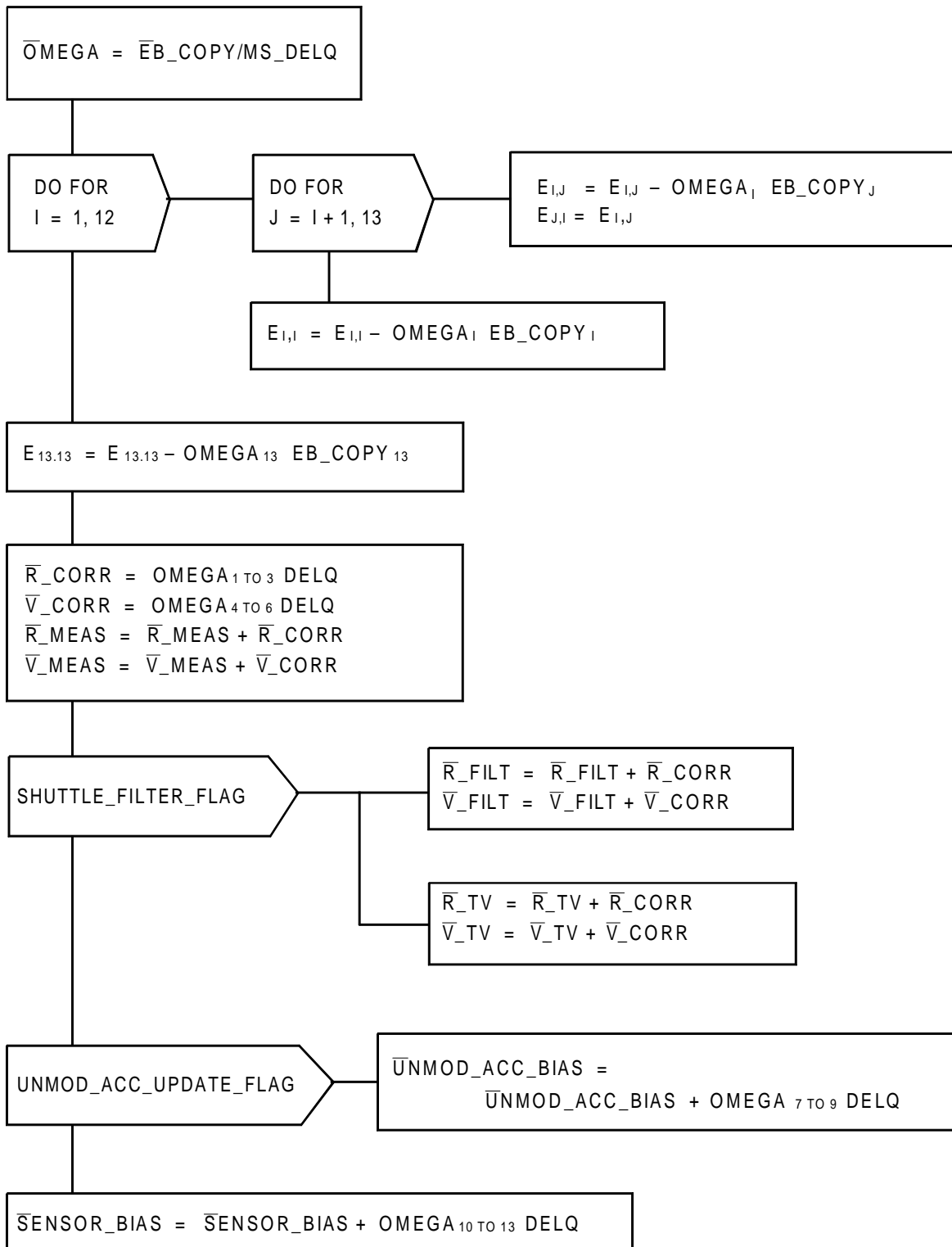


FIGURE 5.2-43. REND\_STATE\_AND\_COV\_UPDATE Code

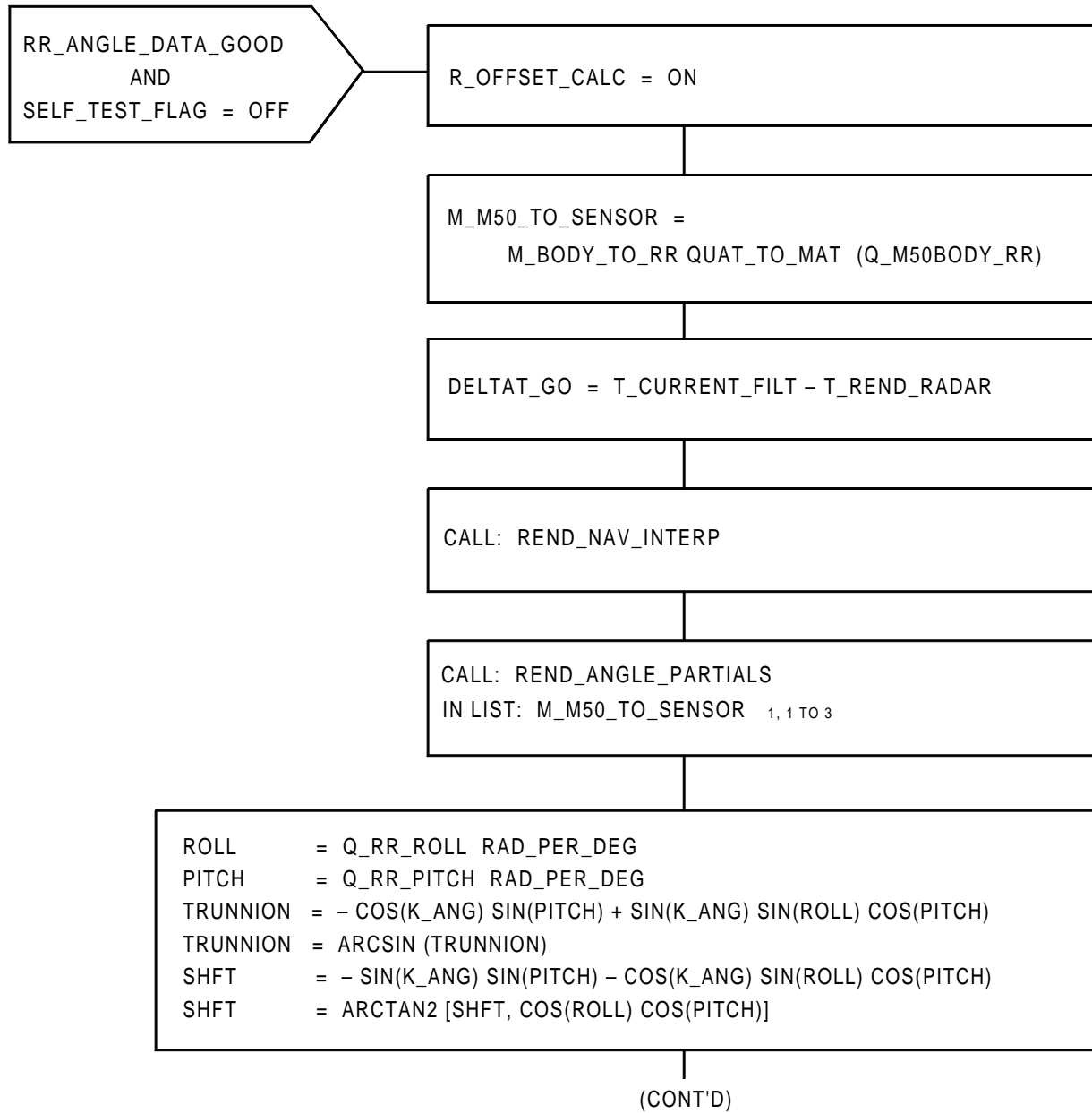


FIGURE 5.2-44.(1) RR\_ANGLE\_NAV (Sheet 1 of 3)



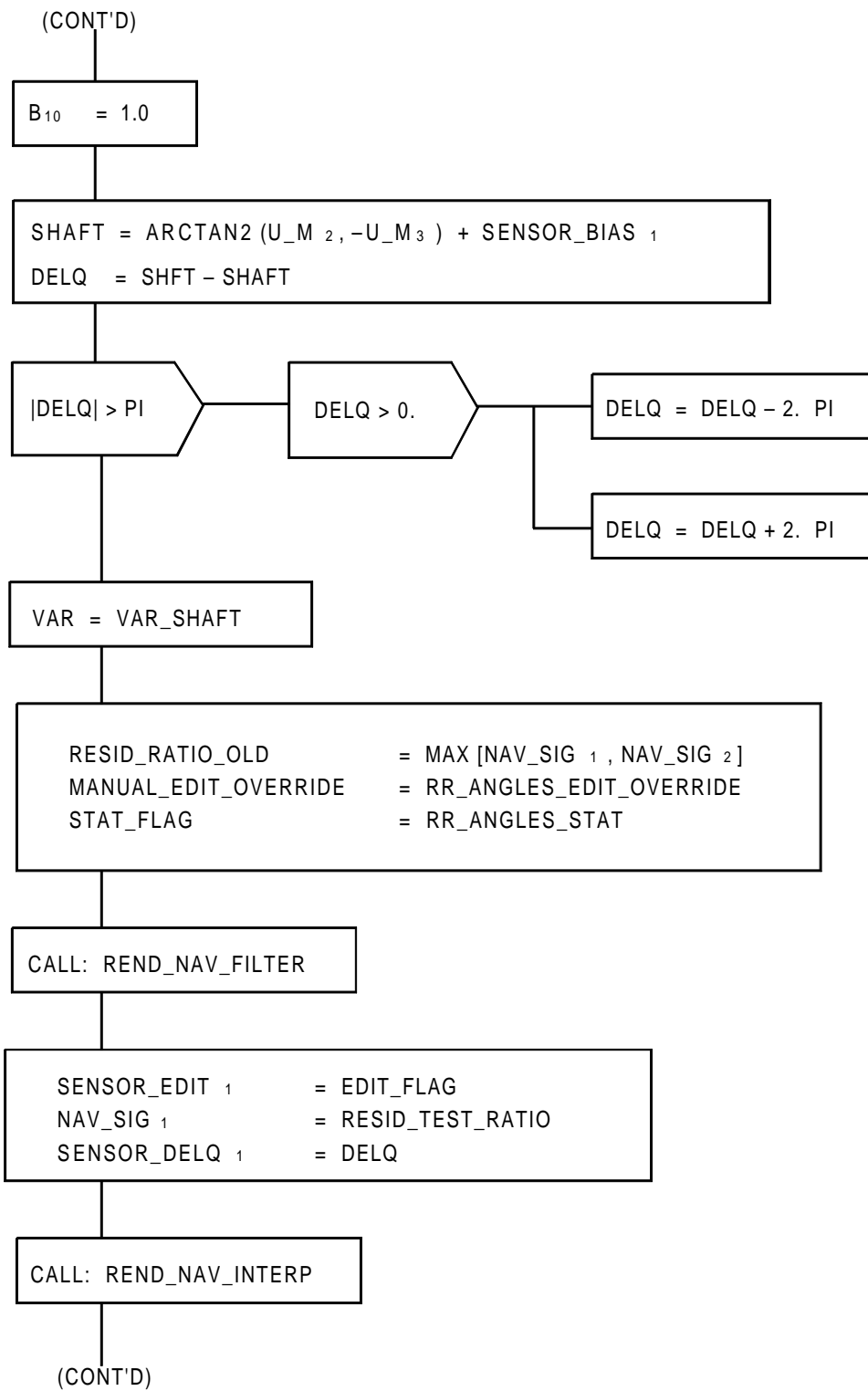


FIGURE 5.2-44.(2) RR\_ANGLE\_NAV (Sheet 2 of 3)

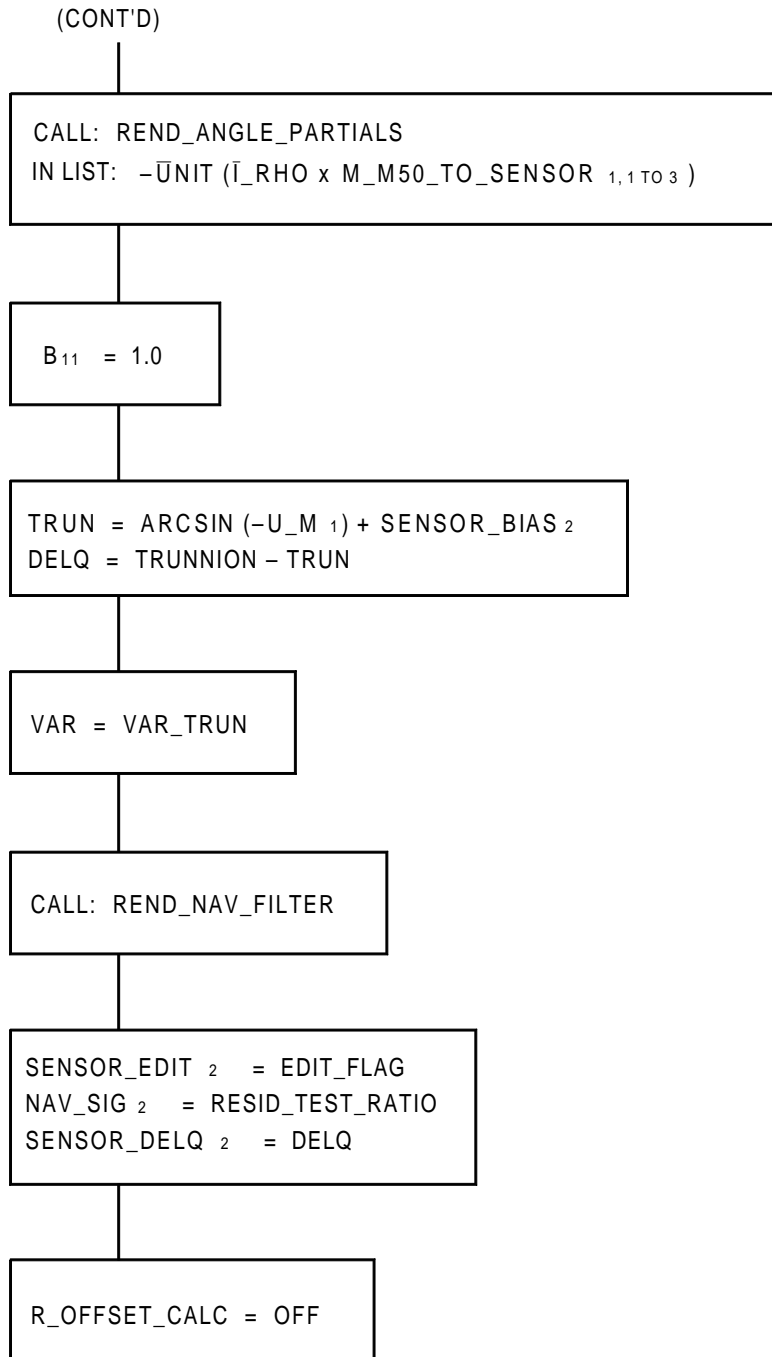


FIGURE 5.2-44.(3) RR\_ANGLE\_NAV (Sheet 3 of 3)

IN LIST:  $\bar{I}_N$

$$\bar{RHO\_PLANE} = \bar{R\_RHO} - (\bar{R\_RHO} \cdot \bar{I}_N) \bar{I}_N$$

$$B_{1\ TO\ 6} = (PHI\_PATCH_{1\ TO\ 3, 1\ TO\ 6})^T [UNIT(\bar{RHO\_PLANE} \times \bar{I}_N) / |\bar{RHO\_PLANE}|]$$

$$\bar{U}_M = M\_M50\_TO\_SENSOR \bar{I}_RHO$$

FIGURE 5.2-45. REND\_ANGLE\_PARTIALS

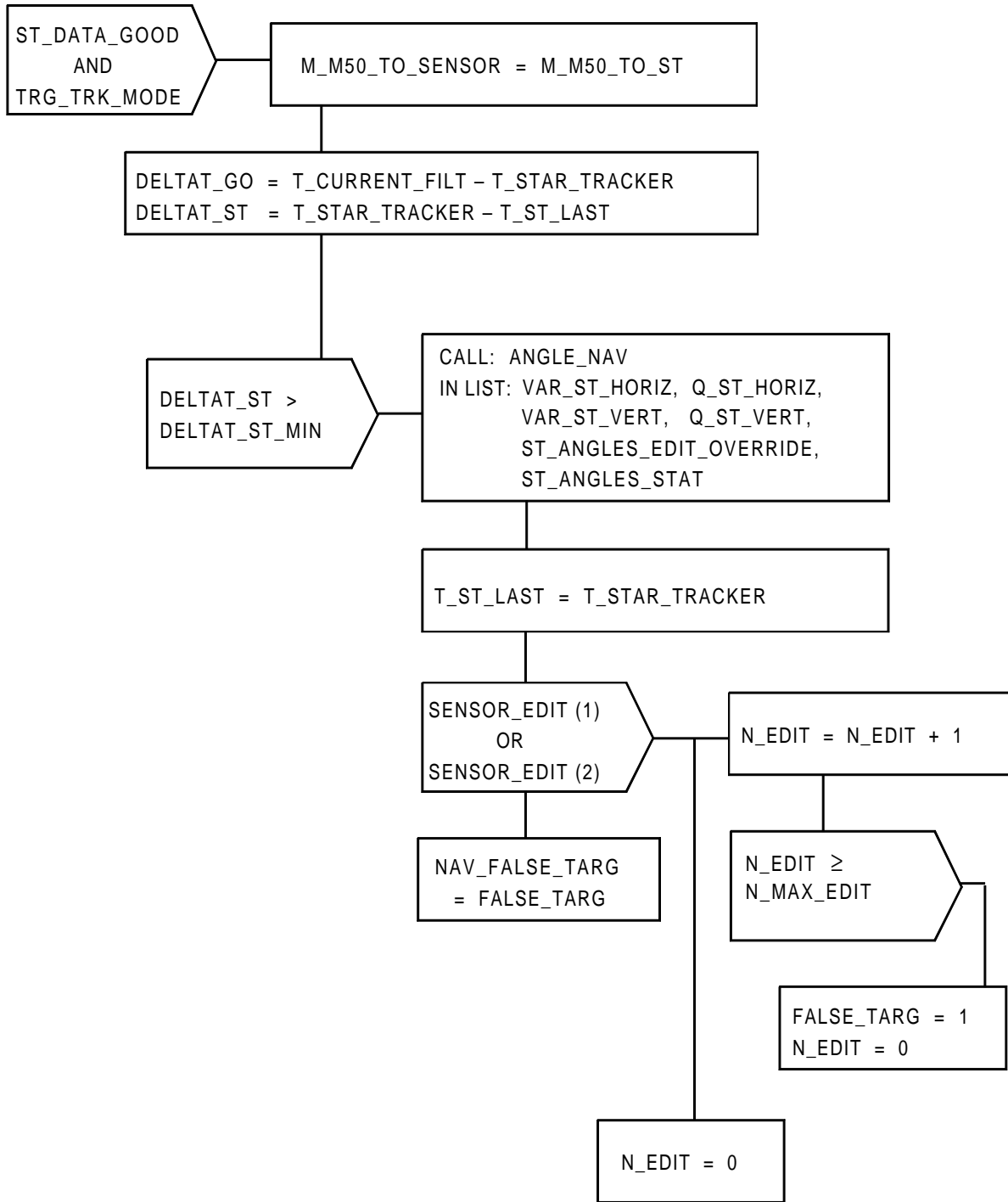


FIGURE 5.2-46. STAR\_TRACKER\_NAV

IN LIST: VAR\_HORIZ, Q\_HORIZ, VAR\_VERT, Q\_VERT, ANGLES\_MANUAL\_EDIT\_OVERRIDE,  
ANGLES\_STAT\_FLAG

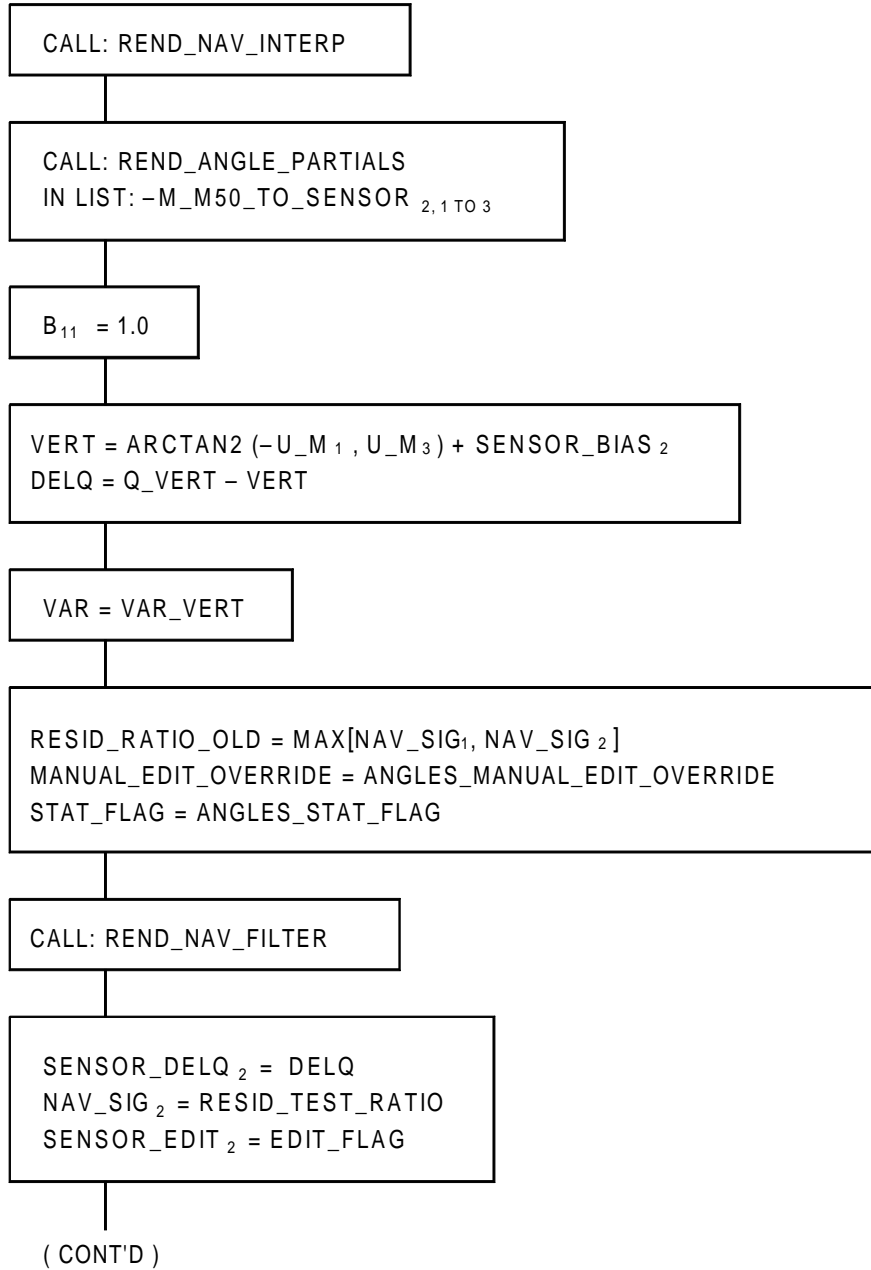


FIGURE 5.2-47.(1) ANGLE\_NAV (Sheet 1 of 2)

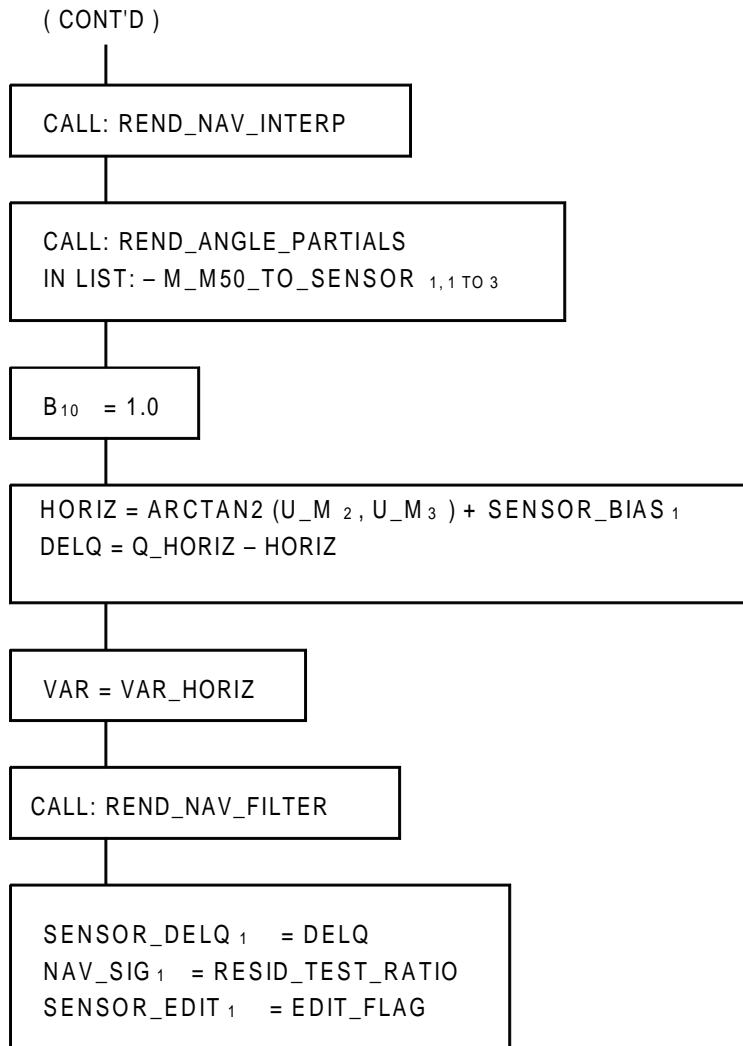


FIGURE 5.2-47.(2) ANGLE\_NAV (Sheet 2 of 2 )

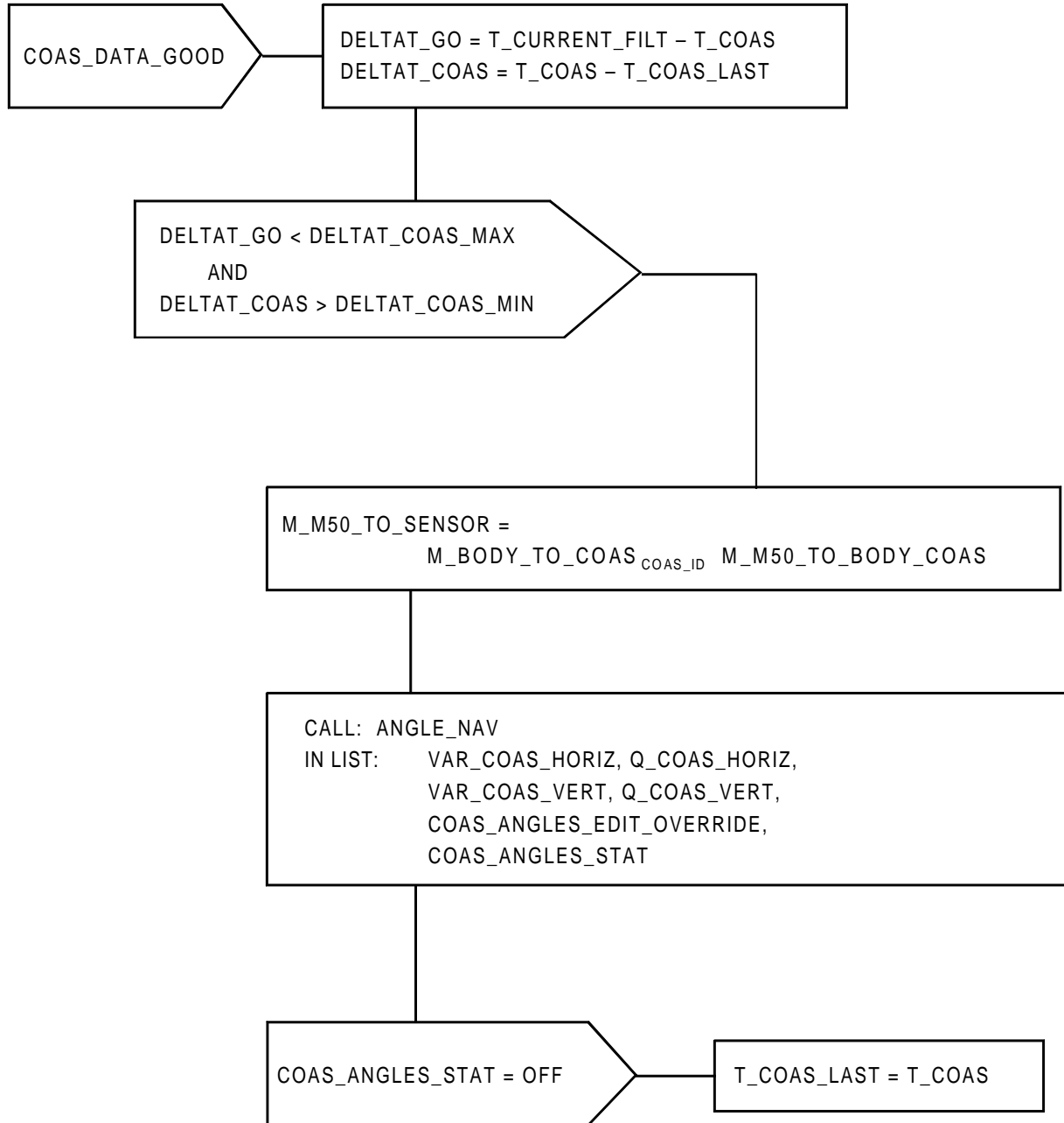


FIGURE 5.2-48. COAS\_NAV

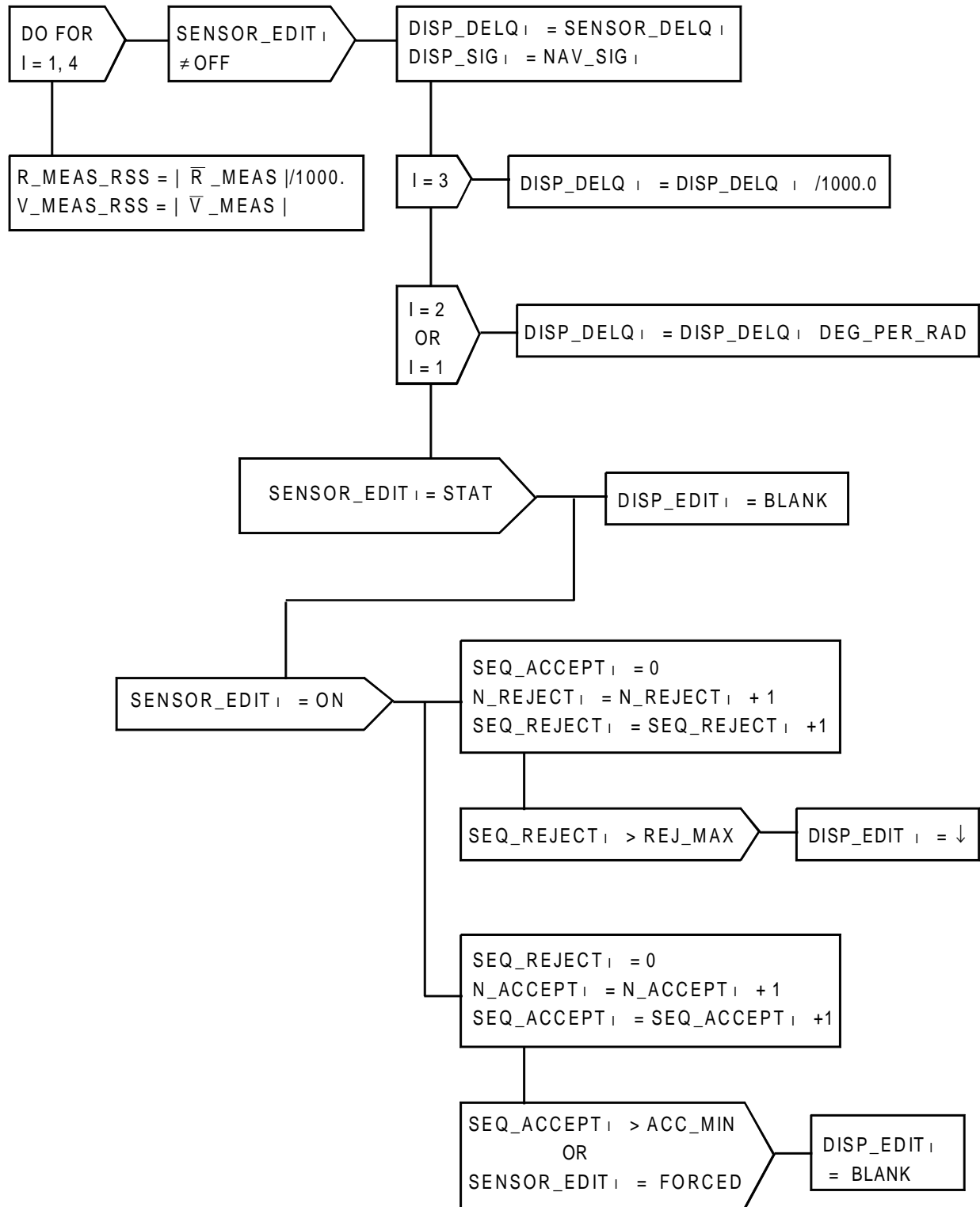


FIGURE 5.2-49. MEAS\_PROCESSING\_STATISTICS\_REND



### **5.3 GENERAL REQUIREMENT FUNCTIONS FLOW CHARTS, VARIABLE NAMES, AND DESCRIPTIONS**

The supplemental material provided in this section includes definitions and explanations of the various coordinate systems used in the navigation requirements, and the transformation and general operations function flow charts (Figures 5.3–1 through 5.3–24). The variable list for the flow charts is provided in Table 5.3–1.

Important coordinate systems are defined in the following figures:

1. Aries Mean of 1950, Cartesian
2. Earth–Fixed Greenwich True of Date
3. Aries True of Date, Cartesian
4. Geodetic Parameters (Basic Definitions)
5. Runway Coordinate System
6. Topodetic Coordinate System
7. MSBLS Radar Coordinate System
8. Body Coordinate System (Structural)
9. Stable Member (IMU)
10. NWU Geographic Coordinate System
11. Body Axis
12. UVW Coordinate System

These flow charts represent the general requirements functions and are composed of the following modules:

13. EARTH\_FIXED\_TO\_M50\_COORD Function
14. EF\_TO\_TOPDET Function
15. EF\_TO\_RUNWAY Function
16. EF\_TO\_SCANNER Function
17. EF\_TO\_GEODETTIC
18. GEODETTIC\_TO\_EF Function
19. UVW\_TO\_M50 Function
20. SBODY\_TO\_M50

21. QUAT\_TO\_MAT Function
22. ONORBIT\_PREDICT
23. RK\_GILL
24. PINES\_METHOD

#### VARIABLES LIST DEFINITIONS

##### Code used for available data type

- F: floating point quantity; an n-dimensional floating point vector will be denoted F(n); similarly, an n x m floating point matrix will be denoted by F(n,m)
- I: integer quantity; I(n) will denote an n-dimensional integer vector
- B: bit, i.e., data having only values of 0 or 1
- C: character; C(n) will denote an n-dimensional character string

##### Code used for variable precision

- D: double precision
- S: single precision; integer quantities are assumed single precision unless otherwise specified

##### Variable location

- COMPOOL: Variable value located in common storage, accessible by all functions
- LOCAL: Variable is used by one function only, and usable to other functions through call argument only

##### Variable initialization category

- blank: display is vacant
- C: constant (unchanging)
- DD: design dependent
- HC: hard coded
- K-load: a former I-load that has become hard coded
- MD: mission dependent (I-load)

##### Variable initial value

Initial operation sequence computer inputs

Variable uplink and downlist status

UPLINK: variable is an uplink item

DOWNLIST: variable is a downlist item

Units definitions

deg: angular measurement, degrees

ft: feet

lb: pounds

n.d. (or –): nondimensional

rad: radian

sec: time measurement, seconds

slugs: mass measurement, slugs

vary: units have different values which depend on variable use

Table 5.3-1. Variable List-General Requirements Functions

Variable Name (M/S ID)	Precision and Type	Com- pool or local	Initial- ization Category	Initial Value	Uplink / Down list	Units	Description
A	SF (3,3)	local	—	—	—	—	Temporary matrix used in QUAT_TO_MAT
AA(1) (V96U9057C)	DF	local	K-load	+5.0 E-01	—	ND	Array of coefficients required by the RK_GILL integrator
AA(2) (V96U9058C)	DF	local	K-load	+2.92893218813 E-01	—	ND	Array of coefficients required by the RK_GILL integrator
AA(3) (V96U9059C)	DF	local	K-load	+1.70710678119 E+00	—	ND	Array of coefficients required by the RK_GILL integrator
AA(4) (V96U9060C)	DF	local	K-load	+1.66666666667 E-01	—	ND	Array of coefficients required by the RK_GILL integrator
ALT	DF	local	—	—	—	ft	Current orbiter altitude above reference ellipsoid
A_O	DF	local	—	—	—	—	One minus eccentricity squared of Earth (ellipsoid), 1.0-FLATCON, initialized only
ATM (V94J3999C)	I	local	—	—	—	—	Flag indicating if current or prestored configuration constants are to be used in drag computations within ACCEL_ONORBIT
ATMP (V94J3999C)	I	com- pool	—	—	down list	—	Flag indicating vehicle attitude mode to be used for prediction
AZ	SF	local	—	—	—	rad	Bearing from true north (EF_TO_ RUNWAY, EF_TO_SCANNER)
BB(1) (V96U9080C)	DF	local	K-load	+0.00 E+00	—	ND	Array of coefficients used by the RK_GILL integrator
BB(2) (V96U9081C)	DF	local	K-load	+1.00 E+00	—	ND	Array of coefficients used by the RK_GILL integrator
BB(3) (V96U9082C)	DF	local	K-load	+1.00 E+00	—	ND	Array of coefficients used by the RK_GILL integrator
BB(4) (V96U9083C)	DF	local	K-load	+2.00 E+00	—	ND	Array of coefficients used by the RK_GILL integrator

Table 5.3-1. Variable List-General Requirements Functions

Variable Name (M/S ID)	Precision and Type	Com- pool or local	Initial- ization Category	Initial Value	Uplink / Down list	Units	Description
CAZ	SF	local	—	—	—	—	Cosine of AZ
CC(1) (V96U9090C)	DF	local	K-load	+1.00 E+00	—	ND	Array of coefficients used by the RK_GILL integrator
CC(2) (V96U9091C)	DF	local	K-load	+5.85786437627 E-01	—	ND	Array of coefficients used by the RK_GILL integrator
CC(3) (V96U9092C)	DF	local	K-load	+3.41421356237 E+00	—	ND	Array of coefficients used by the RK_GILL integrator
CC(4) (V96U9093C)	DF	LO- CAL	K-LOAD	+0.00 E+00	—	ND	Array of coefficients used by the RK_GILL integrator
CLAT	SF	local	—	—	—	—	Cosine of LAT_GEOD (EF_TO_TOPDET)
CLON	SF	local	—	—	—	—	Cosine of LON (EF_TO_TOPDET)
COS_P	SF	local	—	—	—	—	Cosine of geocentric latitude to Shuttle
C1	DF	local	—	—	—	—	Auxiliary variable used in F and G series computations and in Pines method.
C2	DF	local	—	—	—	—	Auxiliary variable used in F and G series computations and in Pines method.
C3	DF	local	—	—	—	—	Auxiliary variable used in F and G series computations and in Pines method.
C4	DF	local	—	—	—	—	Auxiliary variable used in Pines variation of parameters method
C5	DF	local	—	—	—	—	Auxiliary variable used in Pines variation of parameters method
D_AUX	DF	local	—	—	—	ft <sup>2</sup> / sec	Dot product of velocity vector and perturbing acceleration, used in Pines method
D_TAU	DF	local	—	—	—	ft <sup>2</sup> / sec <sup>2</sup>	Variable used in Pines method.
DD	DF	local	—	—	—	ft <sup>2</sup> / sec	Temporary variable used in Pines method

Table 5.3-1. Variable List-General Requirements Functions

Variable Name (M/S ID)	Precision and Type	Com- pool or local	Initial- ization Category	Initial Value	Uplink / Down list	Units	Description
DD(1) (V96U9103C)	DF	local	K-load	+0.00 E+00	—	ND	Array of coefficients used by the RK_GILL integrator
DD(2) (V96U9104C)	DF	local	K-load	+1.21320343556 E-01	—	ND	Array of coefficients used by the RK_GILL integrator
DD(3) (V96U9105C)	DF	local	K-load	-4.12132034356 E+00	—	ND	Array of coefficients used by the RK_GILL integrator
DD(4) (V96U9106C)	DF	local	K-load	+0.00 E+00	—	ND	Array of coefficients used by the RK_GILL integrator
DEL	SF	local	—	—	—	ft	Radius correction factor at geocentric radius of Earth
DEL_LAT	SF	local	—	—	—	rad	Correction angle from geocentric latitude of radius vector to Shuttle to geodetic subvehicle latitude
DELTAT	DF	local	—	—	—	sec	Time interval between two positions in a conic (F and G series)
DERIV	DF(7)	local	—	—	—	ft/sec, ft/sec <sup>2</sup> , ND	Temporary storage for derivatives output from Pines method
D_FIN_TEMP	DF	com- pool	HC	0.	—	ft <sup>2</sup> /sec	Temporary storage for D_FIN (Pines method)
D_IN	DF	local	—	—	—	ft <sup>2</sup> /sec	Dot product of position and velocity used in Pines method in call to F and G series
$\bar{D}$ _SAVE (V95A0804- 6C)	DF(3)	com- pool	—	—	—	ft/sec <sup>2</sup>	Drag acceleration saved for ORB_TGTING
DMP (V94X3969X)	B	com- pool	—	—	—	—	Flag indicating if model for acceleration due to drag is to be used for prediction
DT_MAX (V96U9227C)	I	local	HC	1200	—	sec	Maximum integration step size used for prediction
DT_STEP	DF	local	—	—	—	sec	Integration step size for prediction or propagation
DUM	DF	local	—	—	—	—	Dummy variable (GEODETIC_TO_EF)

Table 5.3-1. Variable List-General Requirements Functions

Variable Name (M/S ID)	Precision and Type	Com- pool or local	Initial- ization Category	Initial Value	Uplink / Down list	Units	Description
DUM1	DF	local	—	—	—	ft	Dummy variable (GEODETIC_TO_EF)
EARTH_MU (V97U4378C)	DF	com- pool	C	14.0764487566 E15	—	ft <sup>3</sup> / sec <sup>2</sup>	Gravitational constant of the Earth
EARTH_ RADIUS_ EQUATOR	DF	com- pool	C	—	—	ft	Earth's equatorial radius
EARTH_RATE	DF	com- pool	C	—	—	rad/sec	Earth's rotation rate
ELLIPT	DF	com- pool	C	—	—	—	Earth's ellipticity constant
F	DF	local	—	—	—	—	Closed form version of the F time series
FDOT	DF	local	—	—	—	sec <sup>-1</sup>	Closed form version of the time derivative of F series
FD_TAU	DF	local	—	—	—	—	Variable used in Pines method
FLATCON (V96U9216C)	DF	local	—	—	—	—	Expression involving ellipticity of reference ellipsoid, initialized only
F_TAU	DF	local	—	—	—	—	Auxiliary variable used in Pines method
G	DF	local	—	—	—	sec	Closed form version of the G time series
$\bar{G}$ _CENTRAL	DF(3)	com- pool	—	—	—	ft/sec <sup>2</sup>	Gravitational acceleration due to Earth as a point mass
GDOT	DF	local	—	—	—	—	Closed form version of the time derivative of the G series
GD_TAU	DF	local	—	—	—	—	Auxiliary variable used in Pines method
GMDP (V94J3975C)	I	com- pool	—	—	—	—	Flag indicating degree of gravitational potential model used for prediction
GMOP (V94J3963C)	I	com- pool	—	—	—	—	Flag indicating order of gravitational potential model used for prediction

Table 5.3-1. Variable List-General Requirements Functions

Variable Name (M/S ID)	Precision and Type	Com- pool or local	Initial- ization Category	Initial Value	Uplink / Down list	Units	Description
G_TAU	DF	local	—	—	—	—	Perturbation derivative of GDOT in Pines method
I	I	local	—	—	—	—	Counter
LAM	SF	local	—	—	—	rad	Earth's rotation angle from epoch
LAT_GEOD	SF	local	—	—	—	rad	Geodetic latitude of $\bar{R}_{EF}$
LON	SF	local	—	—	—	rad	Longitude of $\bar{R}_{EF}$
M	SF (3,3)	local	—	—	—	—	General transformation matrix
MAT	SF (3,3)	local	—	—	—	—	Transformation matrix (SBODY_TO_M50)
MATRIX	SF (3,3)	local	—	—	—	—	Temporary matrix
M_M50TOEF_ AT_EPOCH (V97U5738C- 46C)	DF (3,3)	com- pool	—	Identity Matrix	—	—	Transformation matrix from M50 to Earth-fixed at T_EPOCH
N_STEPS	I	local	—	—	—	—	Number of integration steps in prediction or propagation interval
P	DF	local	—	—	—	—	Variable used in the RK_GILL integrator
$\bar{P}$	DF(3)	local	—	—	—	ft/sec <sup>2</sup>	Variable used in Pines method as perturbing acceleration
PHI	SF	local	—	—	—	rad	Geocentric latitude of position vector to Shuttle
PRED_ENA_ FLAG (V90X4266X)	B	com- pool	—	—	—	—	Signal set by Nav Sequencer to terminate current use of predictor when events to leave OPS 2 or OPS 8 are initiated
PRED_ORB_ AREA (V93U6955C)	SF	com- pool	—	—	down list	ft <sup>2</sup>	Orbiter cross-sectional area
PRED_ORB_ CD (V93U6954C)	SF	com- pool	—	—	down list	—	Orbiter coefficient of drag



Table 5.3-1. Variable List-General Requirements Functions

Variable Name (M/S ID)	Precision and Type	Com- pool or local	Initial- ization Category	Initial Value	Uplink / Down list	Units	Description							
PRED_ORB_MASS (V93U6953C)	SF	com- pool	—	—	down list	slugs	Orbiter mass							
PRED_STEP (V90W3964C)	SF	com- pool	—	—	down list	sec	Input integration step size for prediction							
PRED_TIME_TOL	SF	local	HC	$10^{-8}$	—	sec	Time tolerance for predictor							
P1 P2 P3 P4 P5 P6	} SF	local	—	—	—	—	Temporary variables							
Q								SF(4)	local	—	—	—	Input quaternion to QUAT_TO_MAT	
Q								DF(7)	local	—	0.	—	—	Local array used in RK_GILL integration
Q_FIFTY_BODY								SF(4)	local	—	—	—	—	Quaternion representing current orbiter attitude
R								DF	local	—	—	—	ft	Radius vector to Shuttle in Greenwich true-of-date system
$\bar{R}$								DF(3)	local	—	—	—	ft	Shuttle position vector
RAD_P	DF	local	—	—	—	ft	Geocentric radius of Earth at geocentric latitude of Shuttle							
$\bar{R}_{EF}$	DF(3)	local	—	—	—	ft	Position vector of Shuttle in Earth-fixed coordinates							
$\bar{R}_{EF\_EQUAT}$	DF	local	—	—	—	ft	Position of vehicle position vector in the equatorial plane							
R_FIN_INV	DF	local	—	—	—	ft <sup>-1</sup>	Reciprocal of the magnitude of $\bar{R}_{FIN}$							
R_FIN_TEMP_INV	DF	local	—	—	—	ft <sup>-1</sup>	Dummy variable used in the call to F_AND_G							
$\bar{R}_{IN}$	DF(3)	local	—	—	—	ft	Position vector at the beginning of a time interval in M50. Used in F and G series and in SUPER_G							

Table 5.3-1. Variable List-General Requirements Functions

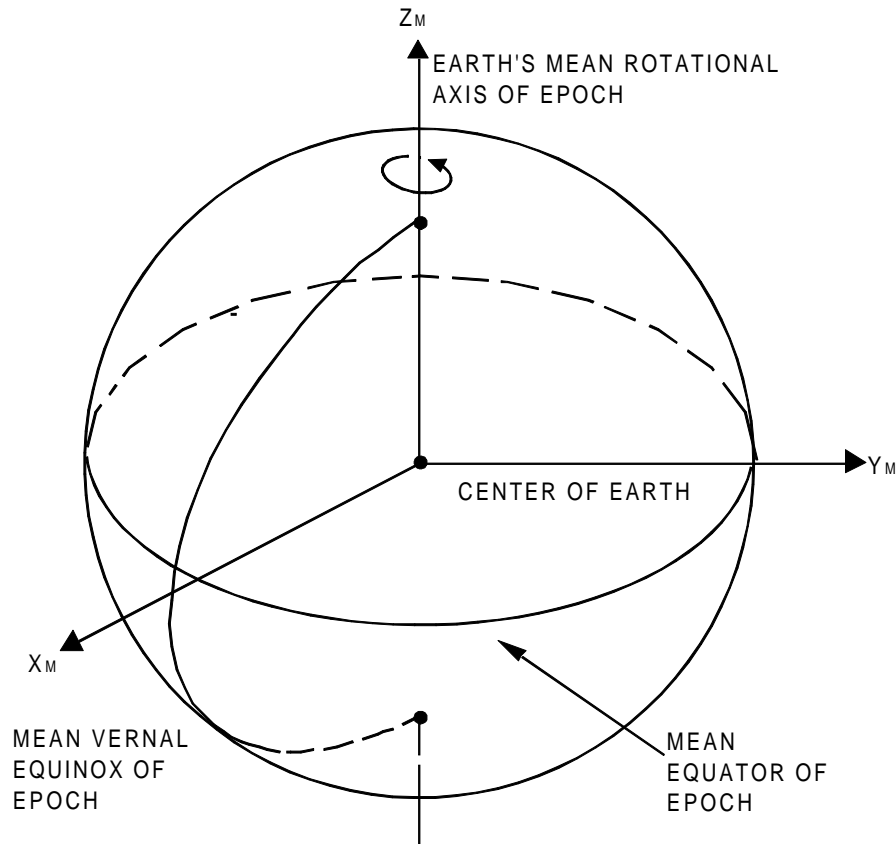
Variable Name (M/S ID)	Precision and Type	Com- pool or local	Initial- ization Category	Initial Value	Uplink / Down list	Units	Description
R_IN_AUX	DF	local	—	—	—	ft <sup>-1</sup>	Reciprocal of the magnitude of the position vector
R_IN_INV	DF	local	—	—	—	ft <sup>-1</sup>	Reciprocal of the magnitude of R_IN
R_IN_TAU	DF	local	—	—	—	—	Auxiliary variable used in the Pines method
R̄_PRED_FINAL (V95H0811C-3C)	DF(3)	com- pool	—	—	down list	ft	Orbiter or target position vector at T_PRED_FINAL
R̄_PRED_INIT (V94H4002C-4C)	DF(3)	com- pool	—	—	down list	ft	Orbiter or target position vector at T_PRED_INIT
R_XY	DF	local	—	—	—	ft <sup>2</sup>	Projection squared of radius vector in X-Y plane of Greenwich true-of-date system
SAZ	SF	local	—	—	—	—	Sine of AZ
SIN_P	SF	local	—	—	—	—	Sine of geocentric latitude to Shuttle
SLAT	SF	local	—	—	—	—	Sine of geocentric latitude
SLON	SF	local	—	—	—	—	Sine of longitude
SMA	DF	com- pool	—	—	—	ft	Semimajor axis of conic
SQR_EMU (V90U1241C)	DF	com- pool	—	—	—	ft <sup>3/2</sup> sec	Square root of the Earth's gravitational constant
S0 S1 S2 S3	} DF	local	—	—	—	—	Auxiliary variables used in F and G series and Pines computations, S1 and S2 also used as auxiliary variables in mean conic partials transition matrix computation
						vary	
						vary	
						vary	
S4 S5 S6	} DF	local	—	—	—	vary	Auxiliary variables used in Pines method
T_ACCEL	DF	local	—	—	—	sec	Time of acceleration function evaluation in Pines method

Table 5.3-1. Variable List-General Requirements Functions

Variable Name (M/S ID)	Precision and Type	Com- pool or local	Initial- ization Category	Initial Value	Uplink / Down list	Units	Description
T_CUR	DF	local	—	—	—	sec	Current integration time within the predictor or propagator
TEMP	DF	local	—	—	—	—	Temporary variable
T_EPOCH (V97W5528C)	DF	com- pool	—	0	—	sec	Time of M_M50TOEF_AT_EPOCH
THETA	DF	local	—	—	—	rad	Difference of eccentric anomaly
TIME	DF	local	—	—	—	sec	General time variable
TIME_DEL	DF	local	—	—	—	sec	Difference between initial and final predictor times
T_IN	DF	local	—	—	—	sec	Initial time input for state propagation
T_PRED_ FINAL (V94W3979C)	DF	com- pool	—	—	down list	sec	Final time input for onorbit prediction
T_PRED_INIT (V94W3970C)	DF	com- pool	—	—	down list	sec	Initial time input for onorbit prediction
T_STOR	DF	local	—	—	—	sec	Initial time of each Runge-Kutta integration step
$\bar{U}, \bar{Z}, \bar{W}$	DF(3)	local	—	—	—	—	Columns of the UVW_TO_M50 temporary matrix
$\bar{V}$	DF(3)	local	—	—	—	ft/sec	Shuttle velocity vector (local)
VM	B	local	—	—	—	—	Flag used in $\bar{ACCEL\_ONORBIT}$ to indicate if Vent/RCS model is to be used
VMP (V94X3971X)	B	com- pool	—	—	—	—	Flag indicating whether venting accelerations are to be modeled for prediction
$\bar{V}$ _PRED_ FINAL (V95L0814C-6C)	DF(3)	com- pool	—	—	down list	ft/sec	Orbiter or target velocity vector at T_PRED_FINAL

Table 5.3-1. Variable List-General Requirements Functions

Variable Name (M/S ID)	Precision and Type	Com- pool or local	Initial- ization Category	Initial Value	Uplink / Down list	Units	Description
$\bar{V}$ _PRED_INIT (V94L4006C -8C)	DF(3)	com- pool	—	—	down list	ft/sec	Orbiter or target velocity vector at T_PRED_INIT
X	DF(6)	local	—	—		ft,ft,ft, ft/sec,ft/ sec,ft/ sec	Temporary array for Shuttle or target state vector used in Pines method
XN	DF(7)	local	—	—		ft,ft,ft, ft/sec,ft/ sec,ft/ sec,sec	Array of integrated initial conditions for onorbit prediction and propagation



NAME: ARIES MEAN-OF-1950, CARTESIAN, COORDINATE SYSTEM

ORIGIN: THE CENTER OF THE EARTH

ORIENTATION: THE EPOCH IS THE BEGINNING OF BESSELIAN YEAR 1950 OR JULIAN EPHEMERIS DATE 2433282.423357.

THE  $X_M - Y_M$  PLANE IS THE MEAN EARTH'S EQUATOR OF EPOCH.

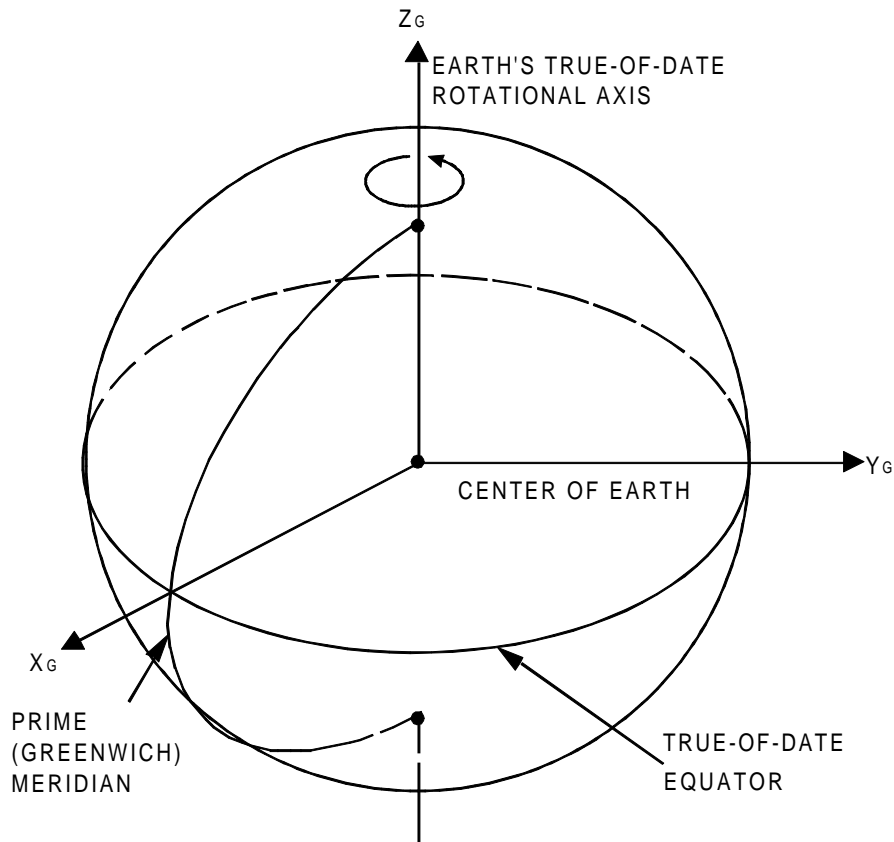
THE  $X_M$  AXIS IS DIRECTED TOWARD THE MEAN VERNAL EQUINOX OF EPOCH.

THE  $Z_M$  AXIS IS DIRECTED ALONG THE EARTH'S MEAN ROTATIONAL AXIS OF EPOCH AND IS POSITIVE NORTH.

THE  $Y_M$  AXIS COMPLETES A RIGHT-HANDED SYSTEM.

CHARACTERISTICS: INERTIAL, RIGHT-HANDED CARTESIAN SYSTEM.

FIGURE 5.3-1. Aries Mean-of-1950, Cartesian



NAME: EARTH-FIXED (GREENWICH TRUE OF DATE) COORDINATE SYSTEM

ORIGIN: THE CENTER OF THE EARTH

ORIENTATION: THE  $X_G - Y_G$  PLANE IS THE EARTH'S TRUE-OF-DATE EQUATOR.

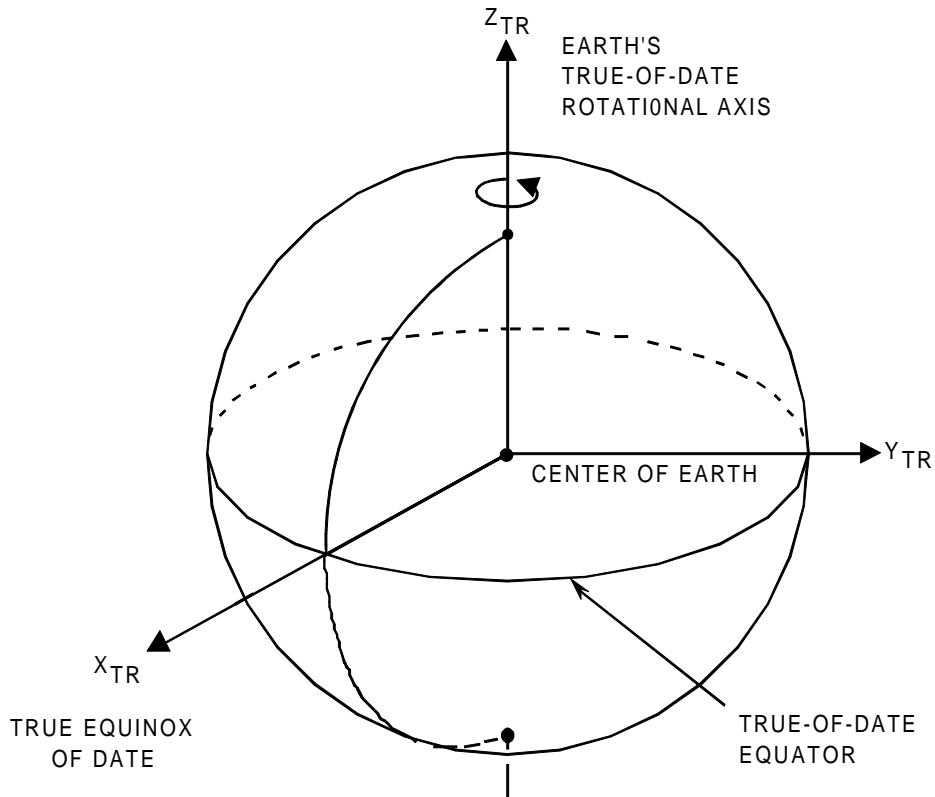
THE  $Z_G$  AXIS IS DIRECTED ALONG THE EARTH'S TRUE-OF-DATE ROTATIONAL AXIS AND IS POSITIVE NORTH.

THE  $+X_G$  AXIS IS DIRECTED TOWARD THE PRIME MERIDIAN.

THE  $Y_G$  AXIS COMPLETES A RIGHT-HANDED SYSTEM.

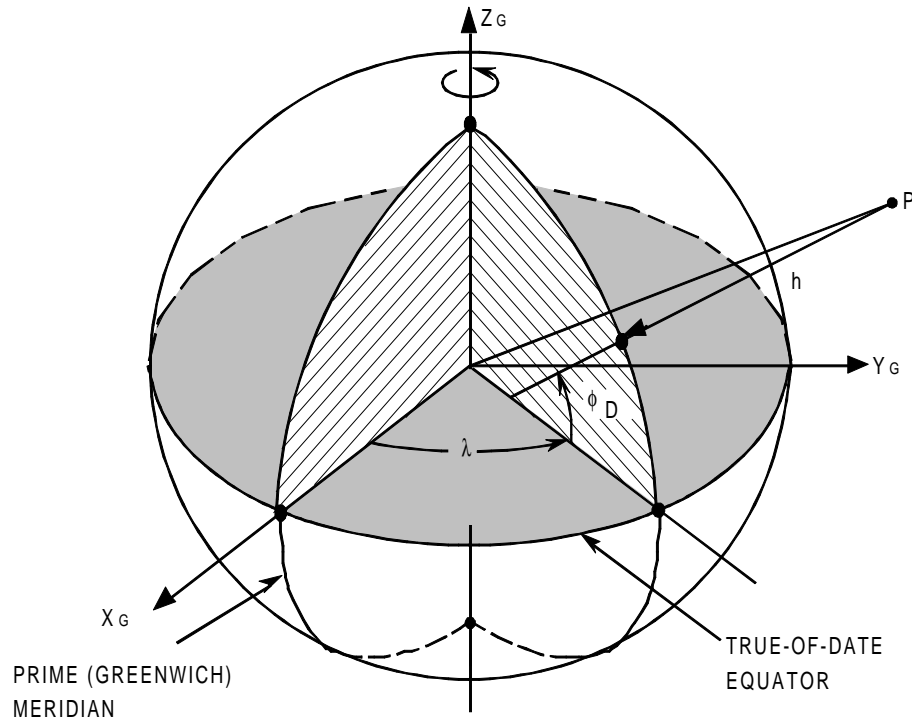
CHARACTERISTICS: ROTATING, RIGHT-HANDED CARTESIAN. VELOCITY VECTORS EXPRESSED IN THIS SYSTEM ARE RELATIVE TO A ROTATING REFERENCE FRAME FIXED TO THE EARTH, WHOSE ROTATION RATES ARE EXPRESSED RELATIVE TO THE ARIES MEAN OF 1950 SYSTEM.

FIGURE 5.3-2. Earth-Fixed Greenwich True-of-Date



- NAME: ARIES TRUE OF DATE, CARTESIAN, COORDINATE SYSTEM.
- ORIGIN: THE CENTER OF THE EARTH.
- ORIENTATION: THE EPOCH IS THE CURRENT TIME OF INTEREST.
- THE  $X_{TR} - Y_{TR}$  PLANE IS THE EARTH'S TRUE EQUATOR OF EPOCH.
- THE  $X_{TR}$  AXIS IS DIRECTED TOWARD THE TRUE VERNAL EQUINOX OF EPOCH.
- THE  $Z_{TR}$  AXIS IS DIRECTED ALONG THE EARTH'S TRUE ROTATIONAL AXIS OF EPOCH AND IS POSITIVE NORTH.
- THE  $Y_{TR}$  AXIS COMPLETES THE RIGHT-HANDED SYSTEM.
- CHARACTERISTICS: QUASI-INERTIAL RIGHT-HANDED CARTESIAN

FIGURE 5.3-3. Aries True-of-Date, Cartesian



NAME: GEODETIC PARAMETERS

ORIGIN: THIS SYSTEM CONSISTS OF A SET OF PARAMETERS RATHER THAN A COORDINATE SYSTEM; THEREFORE, NO ORIGIN IS SPECIFIED.

ORIENTATION: THIS SYSTEM OF PARAMETERS IS BASED ON AN ELLIPSOIDAL MODEL OF THE EARTH (E.G., THE FISCHER ELLIPSE OF 1960). FOR ANY POINT OF INTEREST WE DEFINE A LINE KNOWN AS THE GEODETIC LOCAL VERTICAL WHICH IS PERPENDICULAR TO THE ELLIPSOID AND WHICH CONTAINS THE POINT OF INTEREST.

$h$ , GEODETIC ALTITUDE, IS THE DISTANCE FROM THE POINT OF INTEREST TO THE REFERENCE ELLIPSOID, MEASURED ALONG THE GEODETIC LOCAL VERTICAL, AND IS POSITIVE FOR POINTS OUTSIDE THE ELLIPSOID.

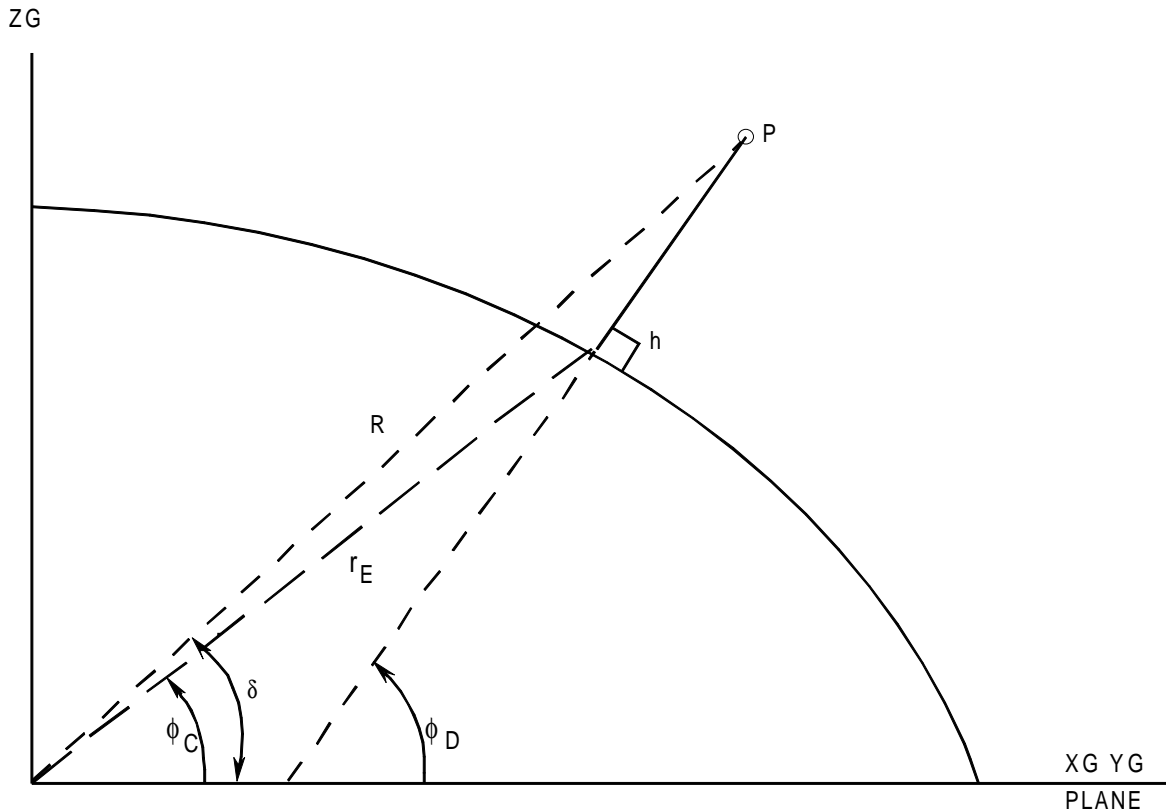
$\lambda$  IS THE LONGITUDE MEASURED IN THE PLANE OF THE EARTH'S TRUE EQUATOR FROM THE PRIME (GREENWICH) MERIDIAN TO THE LOCAL MERIDIAN, MEASURED POSITIVE EASTWARD.

$\phi_D$  IS THE GEODETIC LATITUDE, MEASURED IN THE PLANE OF THE LOCAL MERIDIAN FROM THE EARTH'S TRUE EQUATOR TO THE GEODETIC LOCAL VERTICAL, MEASURED POSITIVE NORTH FROM THE EQUATOR.

CHARACTERISTICS: ROTATING POLAR COORDINATE PARAMETERS. ONLY POSITION VECTORS ARE EXPRESSED IN THIS COORDINATE SYSTEM. VELOCITY VECTORS SHOULD BE EXPRESSED IN THE ARIES MEAN OF 1950 OR THE ARIES TRUE-OF-DATE POLAR FOR INERTIAL OR QUASI-INERTIAL REPRESENTATIONS, RESPECTIVELY.

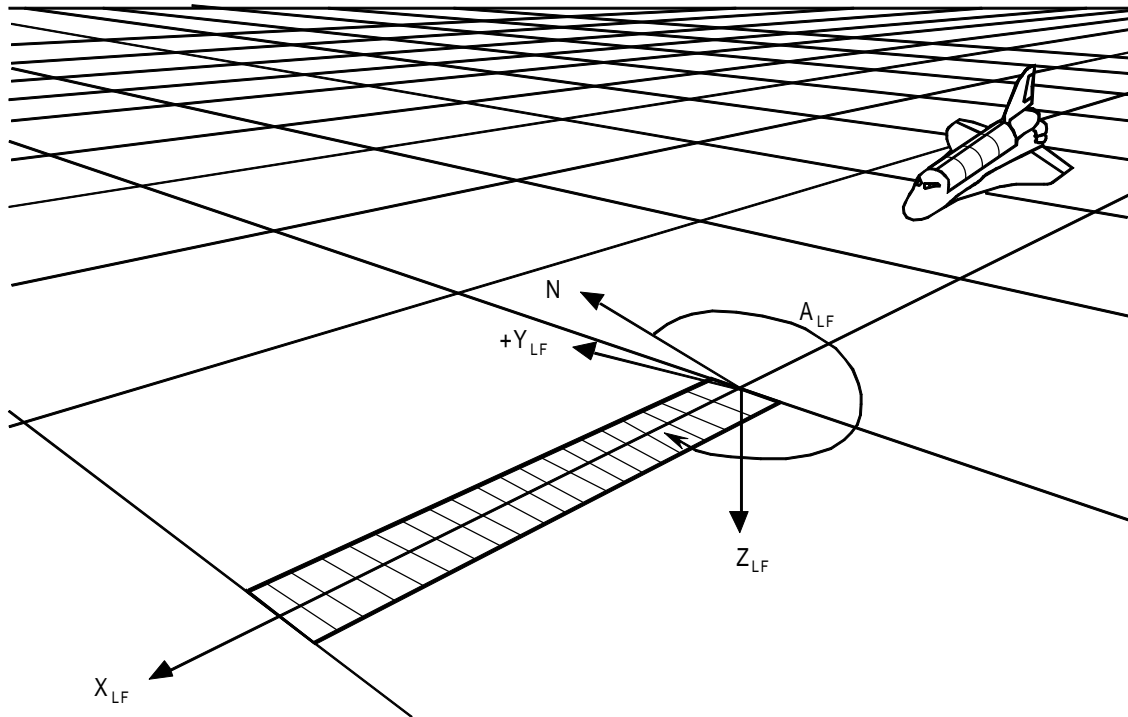
FIGURE 5.3-4.(1) Geodetic Parameters (Detailed Explanation) (Sheet 1 of 2)





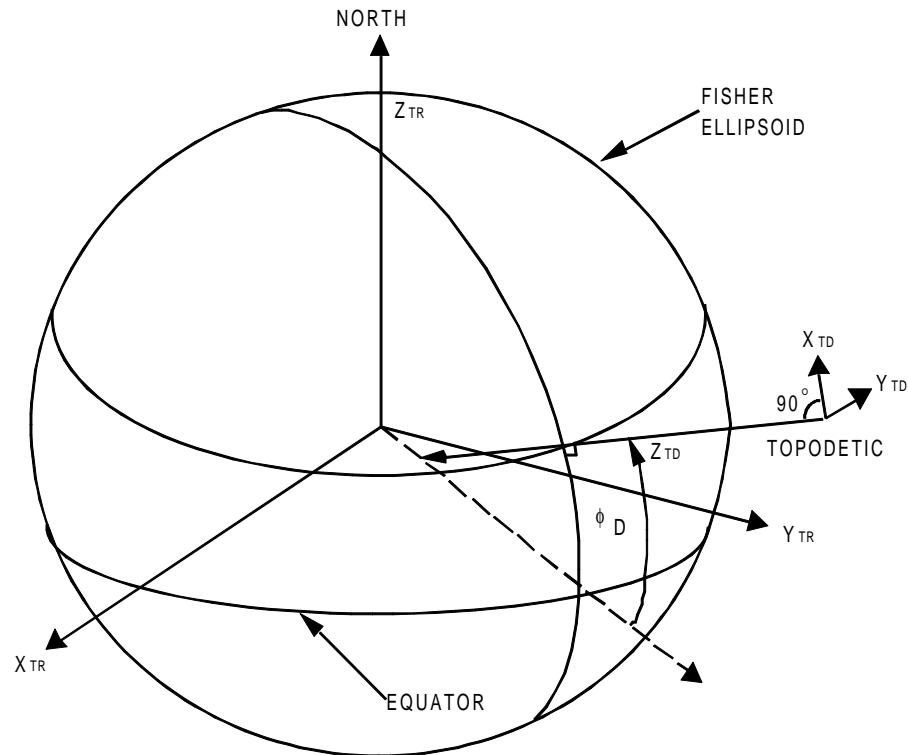
- NAME: GEODETIC PARAMETERS
- DEFINITIONS:
- $h$  IS THE ALTITUDE OF POINT P, MEASURED PERPENDICULAR FROM THE SURFACE OF THE REFERENCED ELLIPSOID.
  - $\phi_D$  IS THE GEODETIC LATITUDE OF POINT P.
  - $\phi_C$  IS THE GEOCENTRIC LATITUDE OF POINT P.
  - $\delta$  IS THE ANGLE BETWEEN RADIUS VECTOR AND EQUATORIAL PLANE (DECLINATION).
  - $\lambda$  IS THE LONGITUDE OF POINT P. ANGLE (+ EAST) BETWEEN PLANE OF THE FIGURE AND THE PLANE FORMED BY THE GREENWICH MERIDIAN.

FIGURE 5.3-4.(2) Geodetic Parameters (Detailed Explanation) (Sheet 2 of 2)



- NAME: RUNWAY COORDINATE SYSTEM
- ORIGIN: RUNWAY CENTER AT APPROACH THRESHOLD
- ORIENTATION AND DEFINITIONS:
- $Z_{LF}$  AXIS IS NORMAL TO THE ELLIPSOID MODEL THROUGH THE RUNWAY CENTERLINE AT THE APPROACH THRESHOLD AND POSITIVE TOWARD THE CENTER OF THE EARTH.
  - $X_{LF}$  AXIS IS PERPENDICULAR TO THE  $Z_{LF}$  AXIS AND LIES IN A PLANE CONTAINING THE  $Z_{LF}$  AXIS AND THE RUNWAY CENTERLINE (POSITIVE IN THE DIRECTION OF LANDING).
  - $Y_{LF}$  AXIS COMPLETES THE RIGHT-HANDED SYSTEM.
  - $A_{LF}$  IS THE RUNWAY AZIMUTH MEASURED IN THE  $X_{LF} Y_{LF}$  PLANE FROM TRUE NORTH TO THE  $+X_{LF}$  AXIS (POSITIVE CLOCKWISE).
- CHARACTERISTICS: ROTATING, EARTH-REFERENCED

FIGURE 5.3-5. Runway Coordinate System



NAME: TOPODETTIC COORDINATE SYSTEM

ORIGIN: ORBITER CENTER OF MASS\*

ORIENTATION:  $Z_{TD}$  IS NORMAL TO A GEODETTIC LOCAL TANGENT PLANE AND IS POSITIVE TOWARD THE EARTH'S CENTER.

$X_{TD}$  IS PERPENDICULAR TO  $Z_{TD}$  AXIS AND IS POSITIVE NORTHWARD ALONG THE MERIDIAN PLANE CONTAINING THE ORBITER.

$Y_{TD}$  COMPLETES THE RIGHT-HANDED ORTHOGONAL SYSTEM

CHARACTERISTICS: ROTATING, RIGHT-HANDED CARTESIAN SYSTEM. VELOCITY VECTORS ARE EXPRESSIBLE IN THIS SYSTEM FOR THE ORBITER, GIVEN RELATIVE VELOCITY  $\bar{V}_{TD}$  IN THIS SYSTEM.

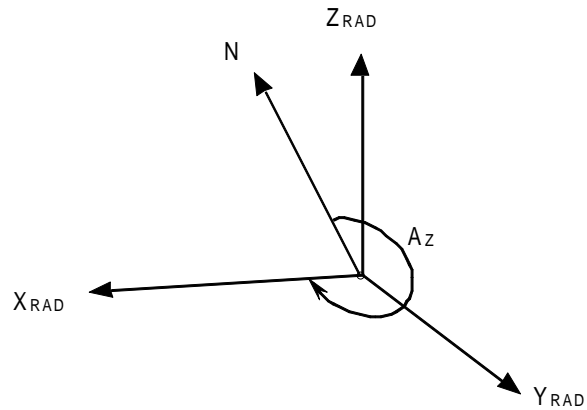
$$\gamma_{TD} = \sin^{-1} \left( \frac{\dot{Z}_{TD}}{V_{TD}} \right)$$

$$\psi_{TD} = \tan^{-1} \left( \frac{\dot{Y}_{TD}}{\dot{X}_{TD}} \right)$$

$\phi_D$  = GEODETTIC LATITUDE

\*A SIMILAR SYSTEM MAY BE DEFINED FOR ANY POINT OF INTEREST

FIGURE 5.3-6. Topodetic Coordinate System



NAME: MSBLS RADAR COORDINATE SYSTEM

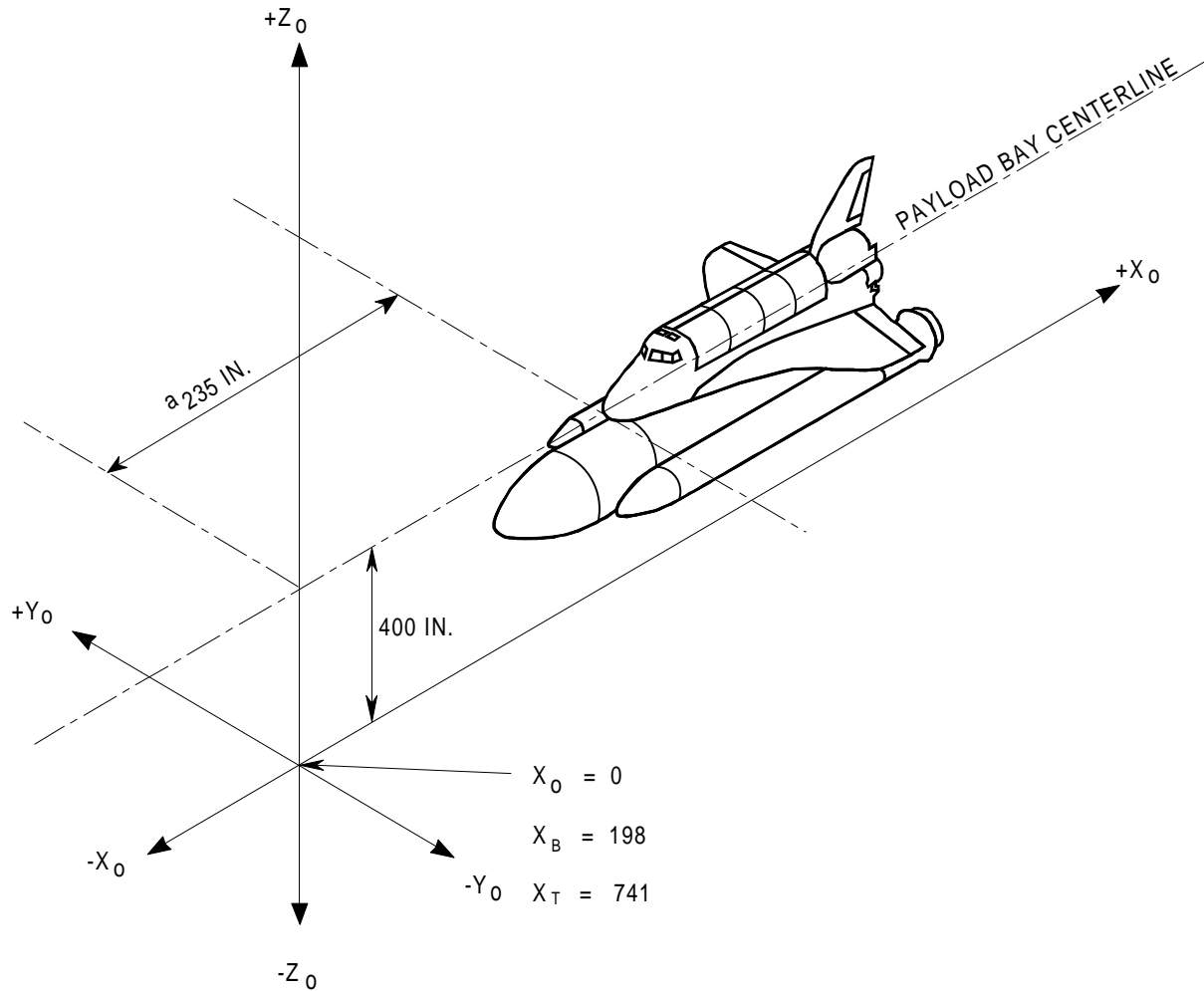
ORIGIN: MSBLS RADAR POSITION

ORIENTATION AND DEFINITIONS:  $Z_{RAD}$  IS NORMAL TO THE ELLIPSOIDAL MODEL, POSITIVE AWAY FROM THE CENTER OF THE EARTH.

$X_{RAD}$  IS IN THE LOCAL HORIZONTAL PLANE OF THE RADAR IN THE BORESIGHT DIRECTION OF THE RADAR ANTENNA. THE ANGLE  $Az$  IS MEASURED POSITIVELY CLOCKWISE FROM TRUE NORTH TO  $X_{RAD}$ .

CHARACTERISTICS: ROTATING, EARTH-REFERENCED.

FIGURE 5.3-7. MSBLS Radar Coordinate System



NAME: BODY COORDINATE SYSTEM (STRUCTURAL)

ORIGIN: IN THE ORBITER PLANE OF SYMMETRY, 400 INCHES BELOW THE CENTERLINE OF THE PAYLOAD BAY AND AT ORBITER X-STATION = 0

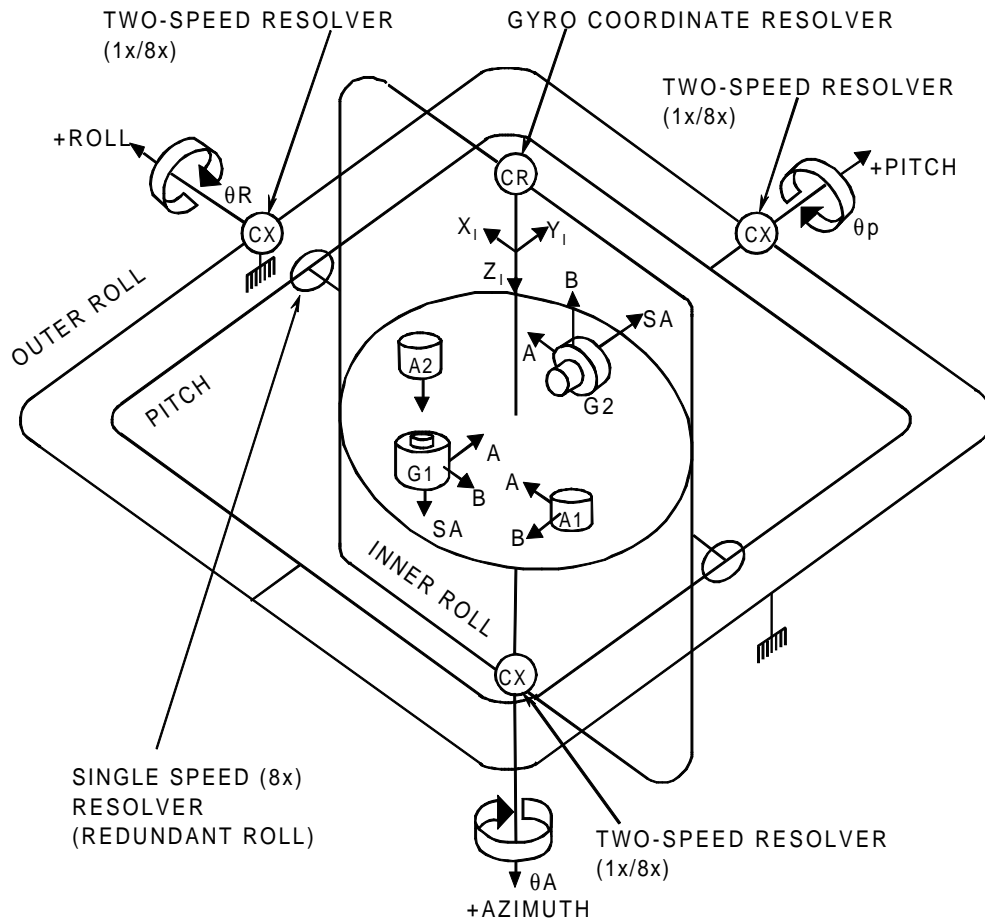
ORIENTATION: THE  $X_0$  AXIS IS IN THE VEHICLE PLANE OF SYMMETRY, PARALLEL TO AND 400 INCHES BELOW THE PAYLOAD BAY CENTERLINE. POSITIVE SENSE IS FROM THE NOSE OF THE VEHICLE TOWARD THE TAIL.

THE  $Z_0$  AXIS IS IN THE VEHICLE PLANE OF SYMMETRY, PERPENDICULAR TO THE  $X_0$  AXIS AND POSITIVE UPWARD IN LANDING ATTITUDE.

THE  $Y_0$  AXIS COMPLETES A RIGHT-HANDED SYSTEM.

CHARACTERISTICS: ROTATING, RIGHT-HANDED CARTESIAN

FIGURE 5.3-8. Body Coordinate System (Structural)



NAME: STABLE MEMBER (IMU)

ORIGIN: THE INTERSECTION OF THE INNERMOST GIMBAL AXIS AND THE MEASUREMENT PLANE OF THE XY TWO-AXIS ACCELEROMETER.

ORIENTATION: THE ZI AXIS IS COINCIDENT WITH THE INNERMOST GIMBAL AXIS.

THE XI AXIS IS DETERMINED BY THE PROJECTION OF THE X ACCELEROMETER INPUT AXIS (IA) ONTO A PLANE ORTHOGONAL TO Z<sub>i</sub>. Y<sub>i</sub> COMPLETES A RIGHT-HANDED TRIAD.

IN A PERFECT IMU, WITH ALL MISALIGNMENTS ZERO, THESE RELATIONSHIPS HOLD:

THE X ACCELEROMETER AND X GYRO IA'S ARE PARALLEL TO THE X<sub>i</sub> AXIS.

THE Y ACCELEROMETER AND Y GYRO IA'S ARE PARALLEL TO THE Y<sub>i</sub> AXIS.

THE Z ACCELEROMETER AND Z GYRO IA'S ARE PARALLEL TO THE Z<sub>i</sub> AXIS.

FIGURE 5.3-9.(1) Stable Member (IMU) (Sheet 1 of 2)

CHARACTERISTICS:

NONROTATING, RIGHT-HANDED, CARTESIAN SYSTEM.

THE REFERENCE ALIGNMENT FOR THE GIMBAL CASE IS DEFINED WITH THE FOUR GIMBAL ANGLES AT ZERO AND WITH THE VEHICLE IN A HORIZONTAL POSITION. IN A PERFECT IMU, WITH ALL MISALIGNMENTS ZERO AND WITH ALL GIMBAL ANGLES AT ZERO, THE FOLLOWING RELATIONSHIPS HOLD.

$X_{NB}$ ,  $Y_{NB}$ ,  $Z_{NB}$  ARE CARTESIAN COMPONENTS OF THE NAVIGATION BASE COORDINATE SYSTEM.

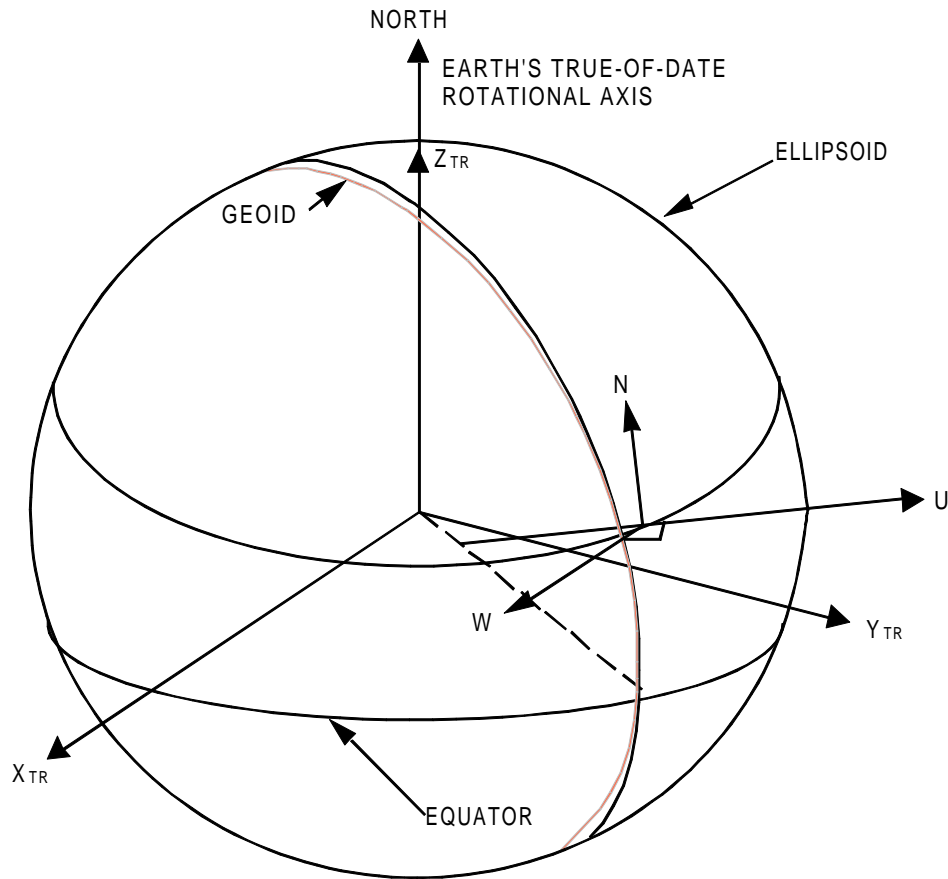
THE OUTER ROLL AXIS AND THE  $X_I$  AXIS WILL BE PARALLEL TO  $X_{NB}$ . POSITIVE  $X_I$  WILL BE IN THE FORWARD DIRECTION. POSITIVE ROLL GIMBAL ANGLES WILL BE IN THE SENSE OF A RIGHT-HANDED ROTATION OF THE GIMBAL CASE RELATIVE TO THE PLATFORM ABOUT THE PLUS OUTER ROLL AXIS.

THE PITCH AXIS AND  $Y_I$  WILL BE PARALLEL TO  $Y_{NB}$ . POSITIVE  $Y_I$  WILL BE TO THE RIGHT OF AN OBSERVER LOOKING FORWARD IN THE VEHICLE. POSITIVE PITCH GIMBAL ANGLES WILL BE IN THE SENSE OF A RIGHT-HANDED ROTATION OF THE GIMBAL CASE RELATIVE TO THE PLATFORM ABOUT THE PLUS PITCH AXIS.

THE INNER ROLL AXIS WILL BE PARALLEL TO THE OUTER ROLL AXIS, WITH THE SENSE OF ROTATION THE SAME AS FOR THE OUTER ROLL AXIS.

THE AZIMUTH AXIS AND  $Z_I$  WILL BE PARALLEL TO  $Z_{NB}$ . POSITIVE  $Z_I$  WILL BE DOWN, RELATIVE TO AN OBSERVER STANDING IN THE VEHICLE. POSITIVE AZIMUTH GIMBAL ANGLES WILL BE IN THE SENSE OF A RIGHT-HANDED ROTATION OF THE GIMBAL CASE RELATIVE TO THE PLATFORM ABOUT THE PLUS AZIMUTH AXIS.

FIGURE 5.3-9(2) Stable Member (IMU) (Sheet 2 of 2)



NAME: NWU GEOGRAPHIC COORDINATE SYSTEM

ORIGIN: POINT OF INTEREST

ORIENTATION: U IS POSITIVE UP ALONG THE EARTH'S ASTRONOMIC  
OR PLUMB-BOB VERTICAL

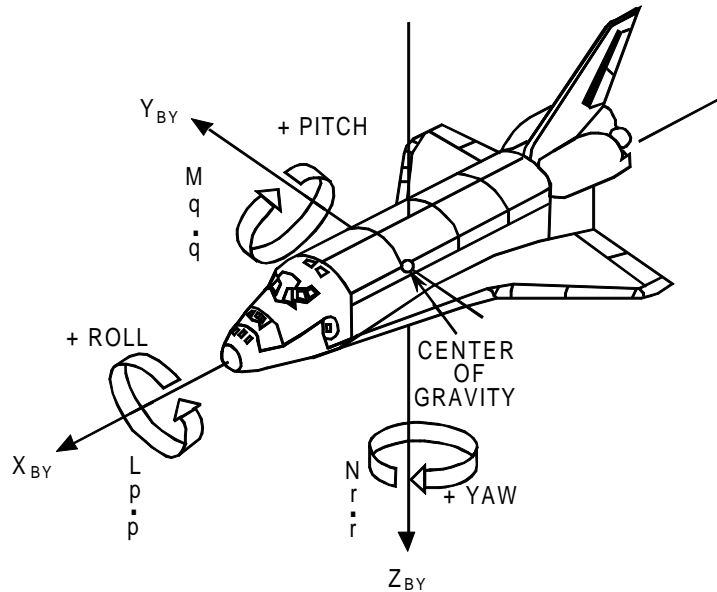
W IS POSITIVE ALONG THE CROSS PRODUCT OF U  
AND THE EARTH'S SPIN AXIS

N COMPLETES THE RIGHT-HANDED ORTHOGONAL  
SYSTEM ( $N = W \times U$ )

CHARACTERISTICS: ROTATING, RIGHT-HANDED, EARTH-REFERENCED  
COORDINATE SYSTEM

FIGURE 5.3-10. NWU Geographic Coordinate System





NAME: BODY AXIS COORDINATE SYSTEM.

ORIGIN: CENTER OF MASS.

ORIENTATION:  $X_{BY}$  AXIS IS PARALLEL TO THE ORBITER STRUCTURAL BODY  $X_O$  AXIS, POSITIVE TOWARD THE NOSE.

$Z_{BY}$  AXIS IS PARALLEL TO THE ORBITER PLANE OF SYMMETRY AND IS PERPENDICULAR TO  $X_{BY}$ , POSITIVE DOWN WITH RESPECT TO THE ORBITER FUSELAGE.

$Y_{BY}$  AXIS COMPLETES THE RIGHT-HANDED ORTHOGONAL SYSTEM.

CHARACTERISTICS: ROTATING, RIGHT-HANDED, CARTESIAN SYSTEM.

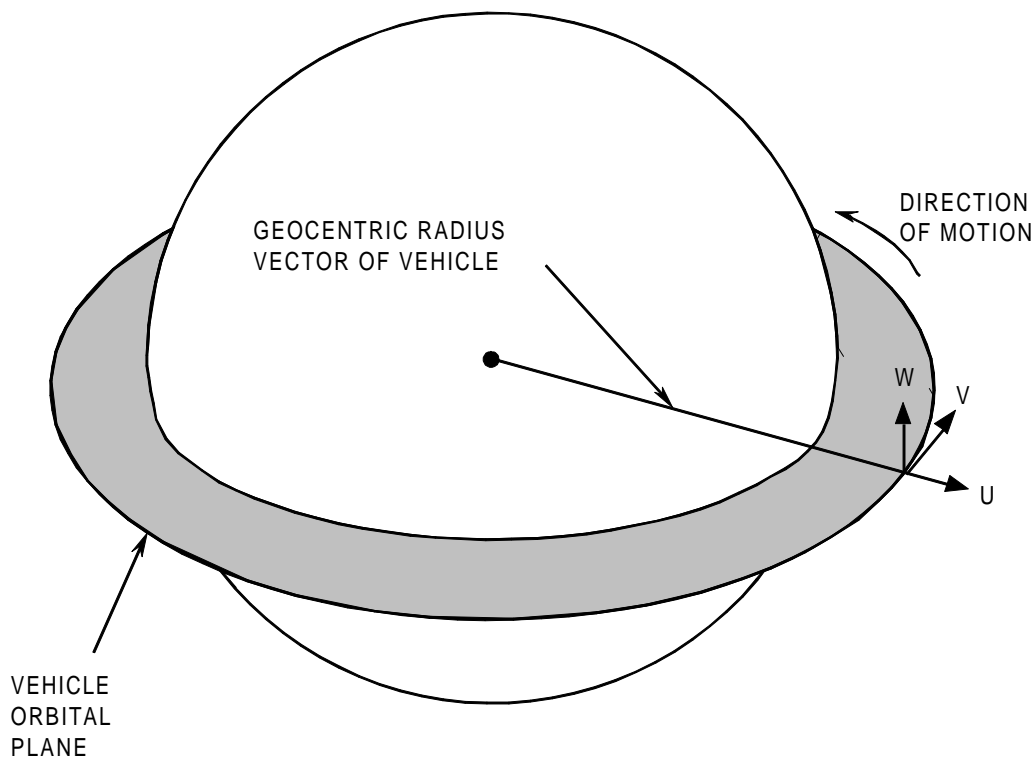
L, M, N: MOMENTS ABOUT  $X_{BY}$ ,  $Y_{BY}$ , AND  $Z_{BY}$  AXES, RESPECTIVELY.

p, q, r: BODY RATES ABOUT  $X_{BY}$ ,  $Y_{BY}$ , AND  $Z_{BY}$  AXES, RESPECTIVELY.

$\dot{p}$ ,  $\dot{q}$ ,  $\dot{r}$ : ANGULAR BODY ACCELERATION ABOUT  $X_{BY}$ ,  $Y_{BY}$ , AND  $Z_{BY}$  AXES, RESPECTIVELY.

THE EULER SEQUENCE THAT IS COMMONLY ASSOCIATED WITH THIS SYSTEM IS A YAW, PITCH, ROLL SEQUENCE, WHERE  $\psi$  = 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 5.3-11. Body Axis



NAME: UVW COORDINATE SYSTEM

ORIGIN: POINT OF INTEREST

ORIENTATION: THE U-V PLANE IS THE INSTANTANEOUS ORBIT PLANE AT EPOCH.

THE U AXIS LIES ALONG THE GEOCENTRIC RADIUS VECTOR TO THE VEHICLE AND IS POSITIVE RADIALLY OUTWARD.

THE W AXIS LIES ALONG THE INSTANTANEOUS ORBITAL ANGULAR MOMENTUM VECTOR AT EPOCH AND IS POSITIVE IN THE DIRECTION OF THE ANGULAR MOMENTUM VECTOR.

THE V AXIS COMPLETES A RIGHT-HANDED SYSTEM ( $V = W \times U$ ).

CHARACTERISTICS: QUASI-INERTIAL, RIGHT-HANDED CARTESIAN COORDINATE SYSTEM. THIS SYSTEM IS QUASI-INERTIAL IN THE SENSE THAT IT IS TREATED AS AN INERTIAL COORDINATE SYSTEM, BUT IT IS REDEFINED AT EACH POINT OF INTEREST.

FIGURE 5.3-12. UVW Coordinate System

$$\text{EARTH\_FIXED\_TO\_M50\_COORD (TIME)} = \text{M\_M50TOEF\_AT\_EPOCH}^T (\text{M})$$

WHERE:

M\_M50TOEF\_AT\_EPOCH IS THE TRANSFORMATION FROM MEAN OF 1950 TO EARTH-FIXED COORDINATES AT TIME = T\_EPOCH. THIS MATRIX, T\_EPOCH, AND EARTH\_RATE INITIAL VALUES ARE DISCUSSED IN SECTION 4.10.2.

M IS COMPUTED WITHIN THE FUNCTION (EARTH\_FIXED\_TO\_M50\_COORD) AS

$$\text{LAM} = \text{EARTH\_RATE (TIME - T\_EPOCH)}$$

$$\text{M} = \begin{pmatrix} \text{COS (LAM)} & -\text{SIN (LAM)} & 0 \\ \text{SIN (LAM)} & \text{COS (LAM)} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

FIGURE 5.3-13. EARTH\_FIXED\_TO\_M50\_COORD FUNCTION

$$\text{EF\_TO\_TOPDET (LAT\_GEOD, LON) = M}$$

WHERE

M IS CALCULATED WITHIN THE FUNCTION AS

CLON = COS (LON), SLON = SIN (LON)

CLAT = COS (LAT\\_GEOD), SLAT = SIN (LAT\\_GEOD)

$$M = \begin{pmatrix} -\text{SLAT CLON} & -\text{SLAT SLON} & \text{CLAT} \\ -\text{SLON} & \text{CLON} & 0 \\ -\text{CLAT CLON} & -\text{CLAT SLON} & -\text{SLAT} \end{pmatrix}$$

FIGURE 5.3-14. EF\_TO\_TOPDET FUNCTION

$$\text{EF\_TO\_RUNWAY (LAT\_GEOD, LON, AZ) = (M) EF\_TO\_TOPDET (LAT\_GEOD, LON)}$$

WHERE

M IS CALCULATED WITHIN THE FUNCTION AS

CAZ = COS (AZ), SAZ = SIN (AZ)

$$M = \begin{pmatrix} \text{CAZ} & \text{SAZ} & 0 \\ -\text{SAZ} & \text{CAZ} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

FIGURE 5.3-15. EF\_TO\_RUNWAY FUNCTION

$$\text{EF\_TO\_SCANNER (LAT\_GEOD, LON, AZ)} = (M) \text{EF\_TO\_RUNWAY (LAT\_GEOD, LON, AZ)}$$

WHERE  
M IS CALCULATED WITHIN THE FUNCTION AS

$$M = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{pmatrix}$$

FIGURE 5.3-16. EF\_TO\_SCANNER FUNCTION

IN LIST:  $\bar{R}_{EF}$   
OUT LIST: LAT\_GEOD, LON, ALT

$$\begin{aligned} \text{FLATCON} &= 1.0 - (1.0 - \text{ELLIPT})^2 \\ \text{A}_O &= 1.0 - \text{FLATCON} \\ \text{R}_{XY} &= \text{R}_{EF1}^2 + \text{R}_{EF2}^2 \\ \text{R} &= (\text{R}_{XY} + \text{R}_{EF3}^2)^{1/2} \\ \text{SIN}_P &= \text{R}_{EF3} / \text{R} \\ \text{COS}_P &= (\text{R}_{XY})^{1/2} / \text{R} \\ \\ \text{RAD}_P &= \frac{\text{EARTH\_RADIUS\_EQUATOR}}{(1.0 + \text{FLATCON} \text{ SIN}_P^2 / \text{A}_O)^{1/2}} \\ \\ \text{DEL} &= (\text{FLATCON} \text{ SIN}_P \text{ COS}_P) / (1.0 - \text{FLATCON} \text{ COS}_P^2) \\ \text{DEL\_LAT} &= \text{RAD}_P \text{ DEL} / \text{R} \\ \text{PHI} &= \text{ARCTAN} (\text{SIN}_P / \text{COS}_P) \\ \text{LAT\_GEOD} &= \text{PHI} + \text{DEL\_LAT} \\ \text{LON} &= \text{ARCTAN2} (\text{R}_{EF2}, \text{R}_{EF1}) \\ \text{ALT} &= (\text{R} - \text{RAD}_P) (1.0 - 0.50 \text{ DEL} \text{ DEL\_LAT}) \end{aligned}$$

FIGURE 5.3-17. EF\_TO\_GEODETTIC

$$\text{GEODETTIC\_TO\_EF (LAT\_GEOD, LON, ALT) = } \bar{R}\_EF$$

WHERE

$\bar{R}\_EF$  IS CALCULATED WITHIN THE FUNCTION AS

CLAT = COS (LAT\\_GEOD), SLAT = SIN (LAT\\_GEOD)

DUM = (1 - ELLIPT)<sup>2</sup>

DUM1 = EARTH\\_RADIUS\\_EQUATOR /  $\sqrt{\text{CLAT}^2 + \text{SLAT}^2 \text{ DUM}}$

R\\_EF\\_EQUAT = (DUM1 + ALT) CLAT

$\bar{R}\_EF = (\text{R\_EF\_EQUAT} \text{ COS (LON), R\_EF\_EQUAT SIN (LON),}$   
 $(\text{DUM DUM1} + \text{ALT})\text{SLAT})$

FIGURE 5.3-18. GEODETTIC\\_TO\\_EF\\_FUNCTION



$$\begin{aligned} &\text{IN LIST: } \bar{R}, \bar{V} \\ &\bar{U} = \bar{R} / |\bar{R}| \\ &\bar{W} = (\bar{R} \times \bar{V}) / |\bar{R} \times \bar{V}| \\ &\bar{Z} = (\bar{W} \times \bar{U}) \\ &\quad \text{UVW\_TO\_M50}_{1\text{ TO }3,1} = \bar{U} \\ &\quad \text{UVW\_TO\_M50}_{1\text{ TO }3,2} = \bar{Z} \\ &\quad \text{UVW\_TO\_M50}_{1\text{ TO }3,3} = \bar{W} \end{aligned}$$

FIGURE 5.3-19. UVW\_TO\_M50 FUNCTION

IN LIST: Q\_FIFTY\_BODY  
OUT LIST: MAT

MATRIX = QUAT_TO_MAT (Q_FIFTY_BODY)	
MAT <sub>1,1</sub>	= - MATRIX <sub>1,1</sub>
MAT <sub>1,2</sub>	= MATRIX <sub>2,1</sub>
MAT <sub>1,3</sub>	= - MATRIX <sub>3,1</sub>
MAT <sub>2,1</sub>	= - MATRIX <sub>1,2</sub>
MAT <sub>2,2</sub>	= MATRIX <sub>2,2</sub>
MAT <sub>2,3</sub>	= - MATRIX <sub>3,2</sub>
MAT <sub>3,1</sub>	= - MATRIX <sub>1,3</sub>
MAT <sub>3,2</sub>	= MATRIX <sub>2,3</sub>
MAT <sub>3,3</sub>	= - MATRIX <sub>3,3</sub>

FIGURE 5.3-20. SBODY\_TO\_M50

$$\text{QUAT\_TO\_MAT}(Q) = A$$

WHERE A IS CALCULATED WITHIN THE FUNCTION AS

$$\begin{aligned} P2 &= Q_2 + Q_2 \\ P3 &= Q_3 + Q_3 \\ P4 &= Q_4 + Q_4 \\ P5 &= P2 Q_2 \\ P6 &= P4 Q_4 \\ \text{TEMP} &= 1.0 - P3 Q_3 \\ A_{1,1} &= \text{TEMP} - P6 \\ A_{2,2} &= 1.0 - P5 - P6 \\ A_{3,3} &= \text{TEMP} - P5 \\ P5 &= P2 Q_3 \\ P6 &= P4 Q_1 \\ A_{1,2} &= P5 - P6 \\ A_{2,1} &= P5 + P6 \\ P5 &= P2 Q_4 \\ P6 &= P3 Q_1 \\ A_{1,3} &= P5 + P6 \\ A_{3,1} &= P5 - P6 \\ P5 &= P3 Q_4 \\ P6 &= P2 Q_1 \\ A_{2,3} &= P5 - P6 \\ A_{3,2} &= P5 + P6 \end{aligned}$$

FIGURE 5.3-21. QUAT\_TO\_MAT FUNCTION

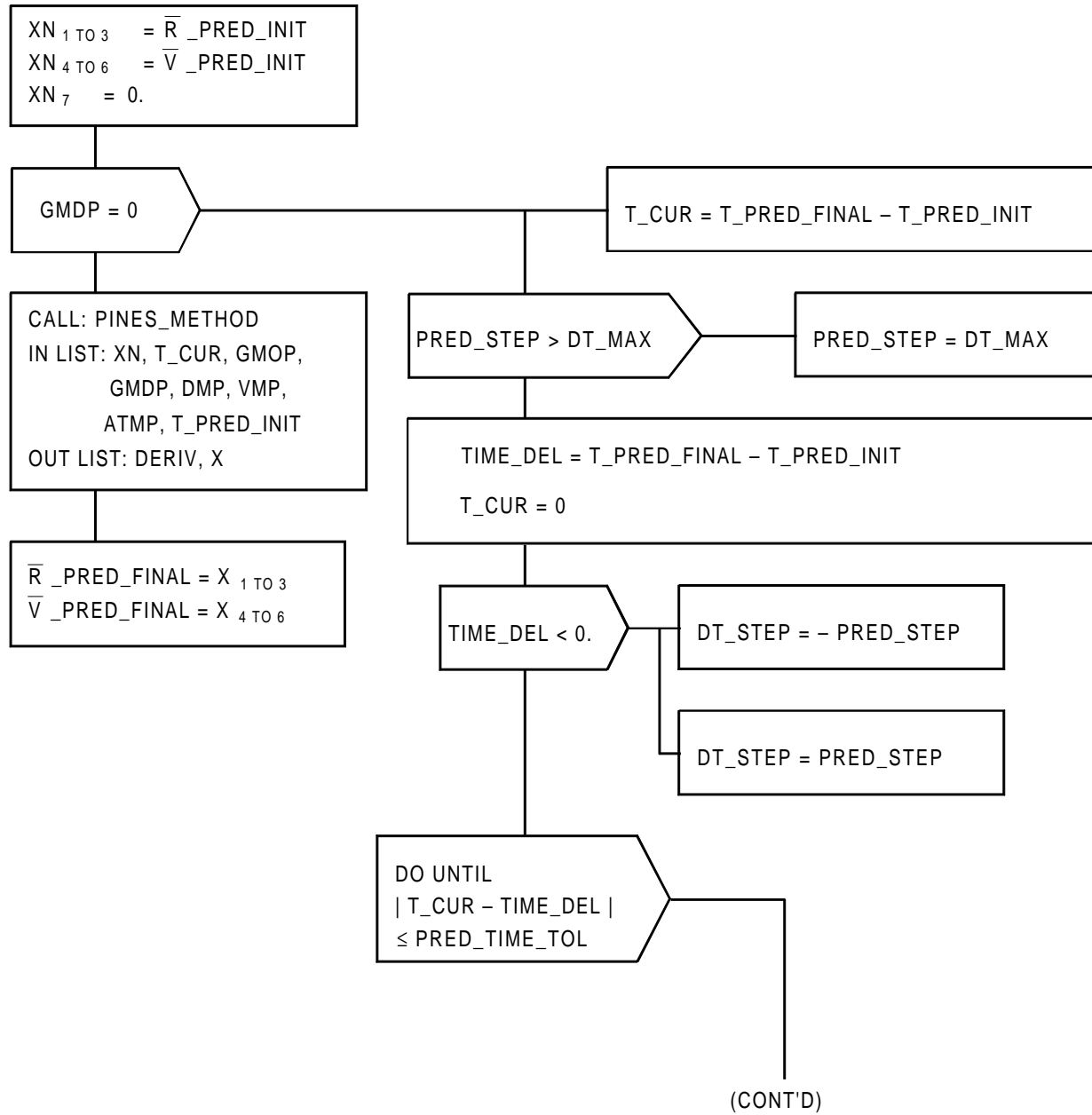


FIGURE 5.3-22.(1) ONORBIT\_PREDICT (Sheet 1 of 2)

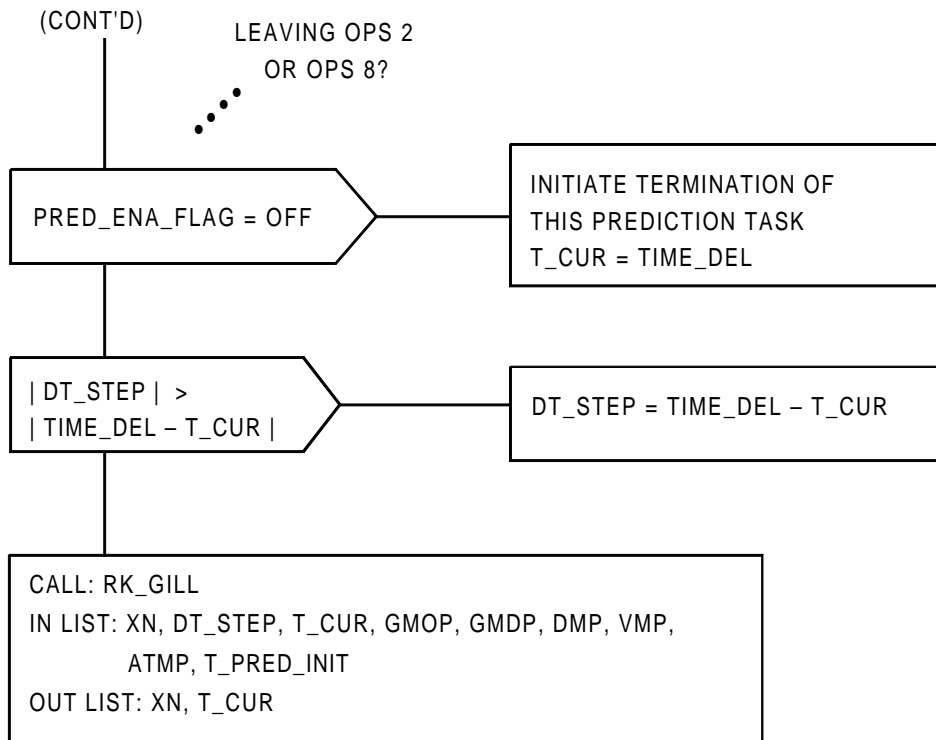


FIGURE 5.3-22.(2) ONORBIT\_PREDICT (Sheet 2 of 2)

IN LIST: XN, DT\_STEP, T\_CUR, GMO, GMD, DM, VM, ATM, T\_IN  
OUT LIST: XN, T\_CUR

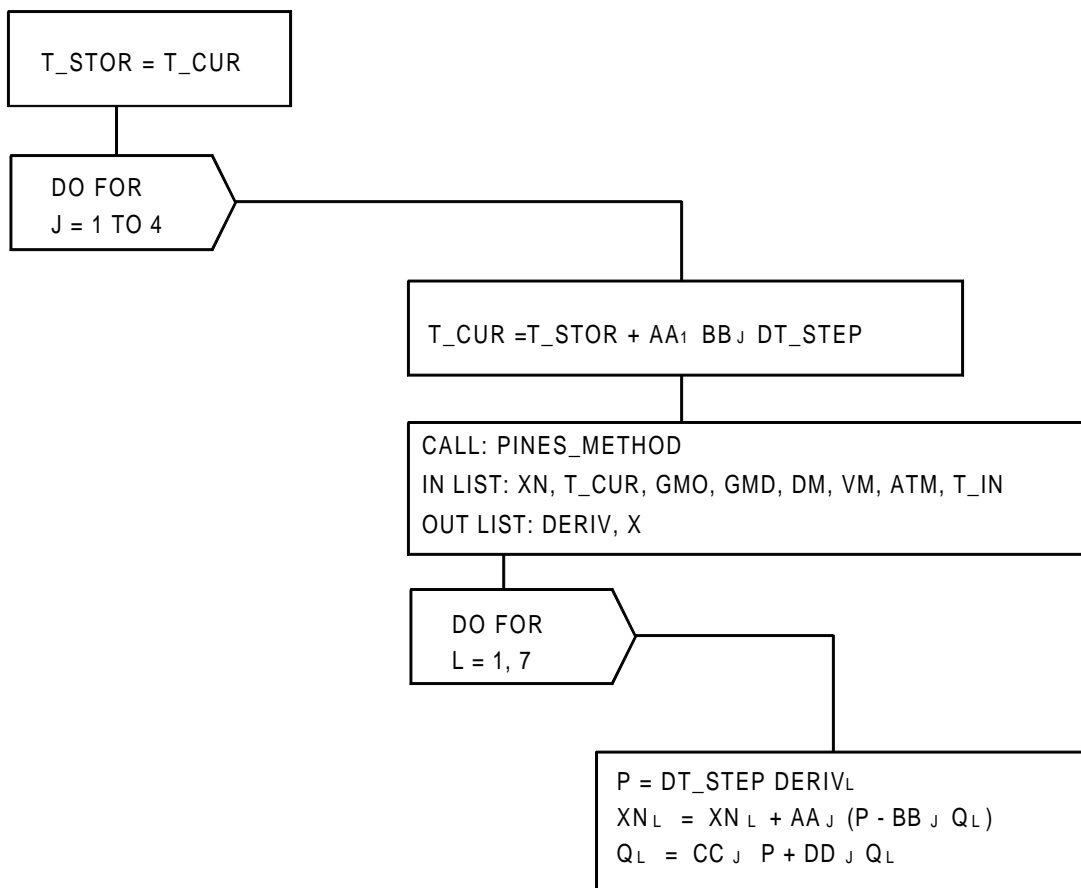


FIGURE 5.3-23. RK\_GILL

IN LIST: XN, T\_CUR, GMO, GMD, DM, VM, ATM, T\_IN  
OUT LIST: DERIV, X

$R\_IN = |XN_{1\ TO\ 3}|$   
 $R\_IN\_INV = 1./R\_IN$   
 $SMA = 1./[2.R\_IN\_INV - (XN_{4\ TO\ 6} \cdot XN_{4\ TO\ 6}) / EARTH\_MU]$   
 $C1 = SQRT(SMA) / SQR\_EMU$   
 $DELTAT = T\_CUR - XN_7$   
 $D\_IN = XN_{1\ TO\ 3} \cdot XN_{4\ TO\ 6}$   
 $R\_FIN\_TEMP\_INV = 0.$

CALL: F\_AND\_G  
 IN LIST: SMA, DELTAT, C1, XN\_{1\ TO\ 3}, R\_IN\_INV,  
           R\_FIN\_TEMP\_INV, XN\_{4\ TO\ 6}, D\_IN, D\_FIN\_TEMP  
 OUT LIST: F, G, FDOT, GDOT, S0, S1, S2, S3, X\_{1\ TO\ 3}, R\_FIN\_INV, THETA

$X_{4\ TO\ 6} = FDOT \cdot XN_{1\ TO\ 3} + GDOT \cdot XN_{4\ TO\ 6}$

$T\_ACCEL = T\_IN + T\_CUR$   
 $\bar{P} = \bar{ACCEL\_ONORBIT}(GMD, GMO, DM, VM, ATM, X_{1\ TO\ 3}, X_{4\ TO\ 6}, T\_ACCEL)$   
 $\bar{P} = \bar{P} - \bar{G\_CENTRAL}$   
 $D\_TAU = X_{1\ TO\ 3} \cdot \bar{P}$   
 $D\_AUX = X_{4\ TO\ 6} \cdot \bar{P}$

(CONT'D)

FIGURE 5.3-24.(1) PINES\_METHOD (Sheet 1 of 2)

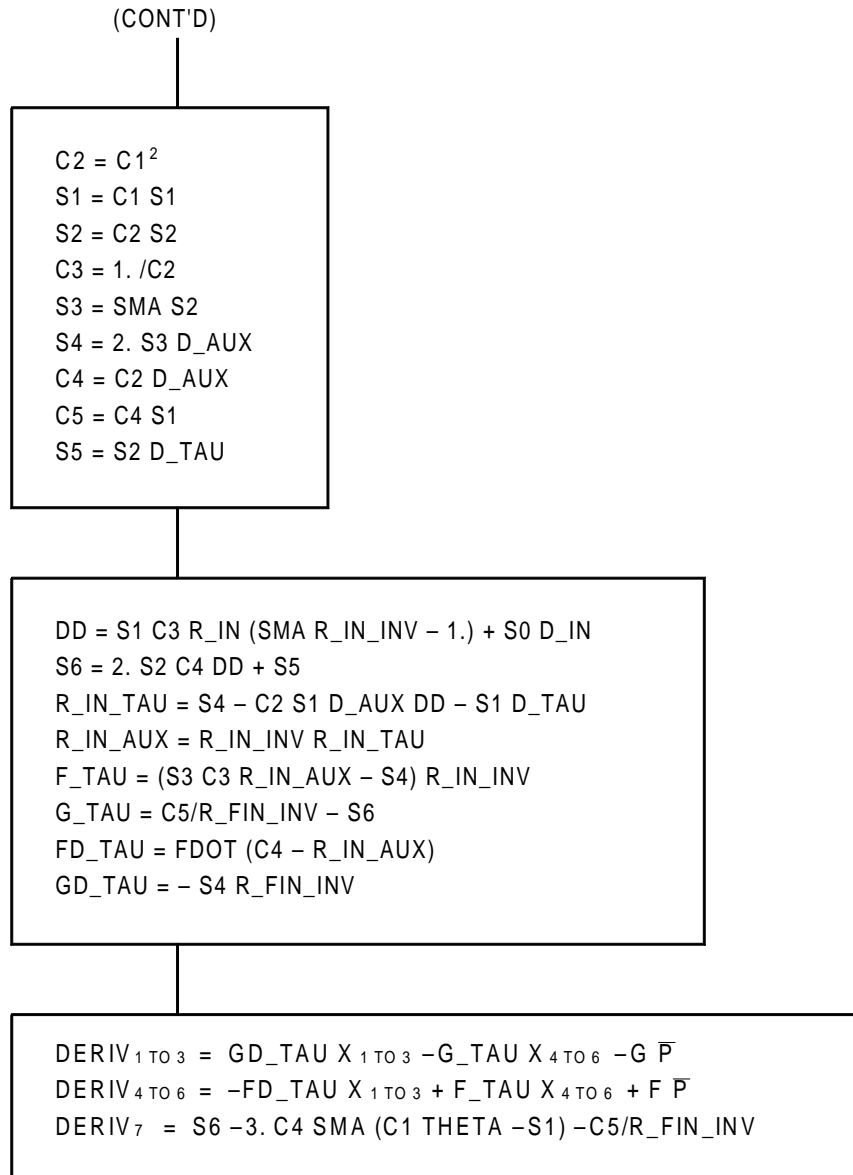


FIGURE 5.3-24.(2) PINES\_METHOD (Sheet 2 of 2)



## 5.4 USER PARAMETER FLOW CHARTS, VARIABLE NAMES AND DESCRIPTIONS

This section provides supplemental material for area navigation in the form of functional flow charts (Figures 5.4-1 through 5.4-4). Table 5.4-1 provides the variable list that supports this material. The list of variable definitions will aid in using Table 5.4-1.

These flow charts represent the user parameters and are composed of the following modules.

1. ONORBIT\_REND\_UPP\_SEQ
2. ONORBIT\_REND\_USER\_PARAM\_STATE\_PROP
3. AVERAGE\_G\_INTEGRATOR
4. ONORBIT\_USER\_PARAMETER\_CALCULATIONS

### VARIABLES LIST DEFINITIONS

#### Code used for variable data type

- F: floating point quantity; an n-dimensional floating point vector will be denoted F(n); similarly, and n x m floating point matrix will be denoted by F(n,m)
- I: integer quantity; I(n) will denote an n-dimensional integer vector
- B: bit; i.e., data having only values of 0 or 1
- C: character; C(n) will denote an n-dimensional character string

#### Code used for variable precision

- D: double precision
- S: single precision; integer quantities are assumed single precision unless otherwise stated

#### Variable location

- COMPOOL: Variable value located in common storage, accessible by all functions
- LOCAL: Variable is used by one function only, and usable to other functions through call argument only

#### Variable initialization category

- blank: display is vacant
- C: constant (unchanging)
- DD: design dependent
- HC: hard coded

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K-load: a former I-load that has become hard coded

MD: mission dependent (I-load)

Variable initial value

Initial operation sequence computer inputs

Variable uplink and downlist status

UPLINK: variable is an uplink item

DOWNLIST: variable is a downlist item

Units definitions

deg: angular measurement, degrees

ft: feet

lb: pounds

n.d.: nondimensional

rad: radian

sec: time measurement, seconds

slugs: mass measurement, slugs

vary: units have different values which depend on variable use

Table 5.4-1. Variables List-User Parameter Functions

Variable Name (M/S ID)	Precision and Type	Com- pool or local	Initial- ization Category	Initial Value	Uplink/ Down- list	Units	Description
$\bar{A}C$	SF (3)	local	—	—	—	ft/sec <sup>2</sup>	Sensed acceleration (local variable used in AVERAGE_G_INTEGRATOR).
$\bar{A}_{SENSED}$ (V95A0902C-4C)	SF (3)	com- pool	—	—	downlist	ft/sec <sup>2</sup>	Ratio of difference of selected accelerometer readings to difference of their time tags.
ATFL_OV	I	com- pool	HC	0	—	—	Attitude flag for Orbiter and for UPP.
DA_ THRESHOLD_ IMU	SF	local	—	—	—	ft/sec <sup>2</sup>	Threshold value for IMU acceleration in UPP.
$\bar{D}EL\_R\_TARG$ (V95H0855C-7C)	DF (3)	com- pool	—	—	downlist	ft	M50 vector from Shuttle to target.
$\bar{D}EL\_V\_TARG$ (V95L0858C-60C)	DF (3)	com- pool	—	—	downlist	ft/sec	M50 delta velocity vector between Shuttle and target.
DFL_AVG	B	local	HC	0	—	—	Drag flag used in average-G integration.
DOING_ REND_NAV (V90X4765X)	B	com- pool	—	—	downlist	—	Flag indicating whether rendezvous navigation is active (ON) or onorbit navigation is active (OFF).
DTIME	SF	local	—	—	—	sec	Step size for state vector advancement (local variable used in AVERAGE_G_INTEGRATOR).
DT_IMU	SF	local	—	—	—	sec	State vector average-G integration time step.
EARTH_RATE	DF	com- pool	C	—	—	rad/sec	Rotation rate of Earth in radians per second.
EVENT_60H (V90X8644X)	B	com- pool	—	OFF	—	—	Transition from OPS 8 to OPS 3.
EVENT_E1 (V90X8164X)	B	com- pool	—	OFF	—	—	Transition to MM201 from MM301 event flag.
EVENT_60 (V90X8189X)	B	com- pool	—	OFF	—	—	Transition to MM201 from MM106 event flag.
EVENT_60A (V90X8160X)	B	com- pool	—	OFF	—	—	Transition to MM201 from OPS 8 event flag.

Table 5.4-1. Variables List-User Parameter Functions

Variable Name (M/S ID)	Precision and Type	Com- pool or local	Initial- ization Category	Initial Value	Uplink/ Down- list	Units	Description
EVENT_60B (V90X8645X)	B	com- pool	—	OFF	—	—	Transition to OPS 8 from MM201.
EVENT_83 (V90X8655X)	B	com- pool	—	OFF	—	—	Transition from MM201 to OPS 00.
EVENT_84 (V90X8148X)	B	com- pool	—	OFF	—	—	Transition to MM201 from OPS 00 event.
EVENT_85 (V90X8180X)	B	com- pool	—	OFF	—	—	Transition from MM201 to MM301.
FILT_UPDATE (V90X0224X)	B	com- pool	—	OFF	downlist	—	Flag indicating the availability of a filter updated state.
$\bar{G}$ (V95A0905C) (V95A0906C) (V95A0907C)	SF (3)	com- pool	—	—	—	ft/sec <sup>2</sup>	Noncentral body gravitational acceleration for ORB GUID
$\bar{G}_-$ NONCENTRAL	SF(3)	local	—	—	—	ft/sec <sup>2</sup>	Noncentral body gravitational acceleration
GM_DEG_LOW (V96U9118C)	SI	com- pool	K-load	+2	—	—	Prestored value of potential model degree indicator.
GM_ORD_ LOW (V96U9120C)	SI	com- pool	K-load	+0	—	—	Prestored value of potential model order indicator.
GO	SF	local	C	—	—	ft/sec <sup>2</sup> / g	Earth gravity acceleration constant.
$\bar{G}R$	DF (3)	local	—	—	—	ft/sec <sup>2</sup>	Gravitational acceleration (local variable used in AVERAGE_G_ INTEGRATOR).
$\bar{G}R1$	DF (3)	local	—	—	—	ft/sec <sup>2</sup>	Gravitational acceleration (local variable used in AVERAGE_G_ INTEGRATOR).
IMU_NAV_ ACCEL_ THRESH (V93A6710C)	I	com- pool	MD	—	—	g	IMU navigation acceleration threshold value in g's
M50_TO_EF	DF (3,3)	local	—	—	—	—	Mean of 1950 to Earth-fixed Greenwich coordinate transformation matrix.
OPS_2_OR_8_ INITIALIZE_ COMPLETE (V90X1242X)	B	com- pool	—	—	—	—	Signal to MSC indicating that initialization of user parameter state propagation is complete.

Table 5.4-1. Variables List-User Parameter Functions

Variable Name (M/S ID)	Precision and Type	Com- pool or local	Initial- ization Category	Initial Value	Uplink/ Down- list	Units	Description
PWRD_FLT_ NAV (V93X5408X)	B	com- pool	—	—	downlist	—	Flag indicating use of powered flight propagation (ON) or coasting flight propagation (OFF).
$\bar{R}_{AV}$	DF (3)	local	—	—	—	ft	Position vector (local variable used in AVERAGE_G_INTEGRATOR).
$\bar{R}_{AVGG}$ (V95H0185C -7C)	DF (3)	com- pool	—	—	downlist	ft	Current orbiter position vector updated by user parameter propagator.
$\bar{R}_{EF}$ (V95H0155C -7C)	DF (3)	com- pool	—	—	—	ft	Orbiter position vector in Earth-fixed coordinates.
$\bar{R}_{RESET}$ (V90H0235C -7C)	DF (3)	com- pool	—	—	—	ft	Copy of filter updated orbiter position vector for user parameter propagator reset.
$\bar{R}_{TARGET}$ (V95H0862C -4C)	DF (3)	com- pool	—	—	downlist	ft	Position vector of the target vehicle updated by the user parameter propagator.
$\bar{R}_{TV\_RESET}$ (V90H1383C -5C)	DF (3)	com- pool	—	—	—	ft	Copy of filter updated target position vector for user parameter propagator reset.
T_IMU (V95W0901C)	DF	com- pool	—	—	downlist	sec	Current time tag snapped from the IMU SOP (IMU SOP name T_IMUS M/SID V95W0002C).
T_RESET (V90W0534C)	DF	com- pool	—	—	—	sec	Copy of time tag of filter update of state vectors for user parameter propagator reset.
T_SEC_GMT (V95W3890C)	DF	com- pool	—	—	—	sec	Time in seconds since Greenwich midnight of the reference day.
T_STATE (V95W0200C)	DF	com- pool	—	—	downlist	sec	Time tag for current user parameter state vector.
UPP_USE_IMU _DATA (V95X0889X)	B	com- pool	IV	OFF	downlist	—	Flag indicating IMU data are to be used in integration (ON) in UPP.
$\bar{V}_{AV}$	DF (3)	local	—	—	—	ft/sec	Velocity vector (local variable used in AVERAGE_G_INTEGRATOR).
$\bar{V}_{AVGG}$ (V95L0190C -2C)	SF (3)	com- pool	—	—	downlist	ft/sec	Velocity vector of orbiter updated by the user parameter propagator.

Table 5.4-1. Variables List-User Parameter Functions

Variable Name (M/S ID)	Precision and Type	Com- pool or local	Initial- ization Category	Initial Value	Uplink/ Down- list	Units	Description
$\bar{V}$ _AVGG_DP (V95L0142C- 4C)	DF (3)	com- pool	—	—	—	ft/sec	Double precision velocity vector of the user parameter propagator
$\bar{V}$ _EF	SF (3)	local	—	—	—	ft/sec	Orbiter velocity vector in Earth- fixed coordinates.
VFLTV_PRED	B	com- pool	HC	0	—	—	Venting flag for target vehicle prediction and for UPP state prop.
$\bar{V}$ _IMU_SNAP (V95L0898C- 900C)	DF (3)	com- pool	—	—	downlist	ft/sec	Current snapped accumulated IMU velocity obtained from the IMU SOP (IMU SOP name SEL_V_M50_CG MSID V90L2607C-09C).
$\bar{V}$ _IMU_OLD (V95L0210C- 2C)	DF (3)	com- pool	—	—	—	ft/sec	Previous accumulated IMU velocity.
$\bar{V}$ _IMU_ RESET (V90L0247C- 9C)	DF (3)	com- pool	—	—	downlist	ft/sec	Copy of IMU accumulated sensed velocity for user parameter propagator reset.
$\bar{V}$ _RESET (V90L0239C- 41C)	DF (3)	com- pool	—	—	—	ft/sec	Copy of filter updated orbiter velocity vector for user parameter propagator reset.
$\bar{V}$ _RHO_EF (V95L3884C- 6C)	DF (3)	com- pool	—	—	—	ft/sec	Earth-fixed velocity vector for Shuttle.
$\bar{V}$ _TARGET (V95L0867C- 9C)	DF (3)	com- pool	—	—	downlist	ft/sec	Velocity vector of target vehicle updated by the user parameter propagator.
$\bar{V}$ _TV_RESET (V90L1380C- 2C)	DF (3)	com- pool	—	—	—	ft/sec	Copy of filter updated target velocity vector for user parameter propagator reset.

(TRANS TO MM201 FROM OPS-1, OPS-3, OR OPS-8),  
(TRANS TO OPS-8 FROM MM201),  
OR (OPS-2 FROM OPS-00)

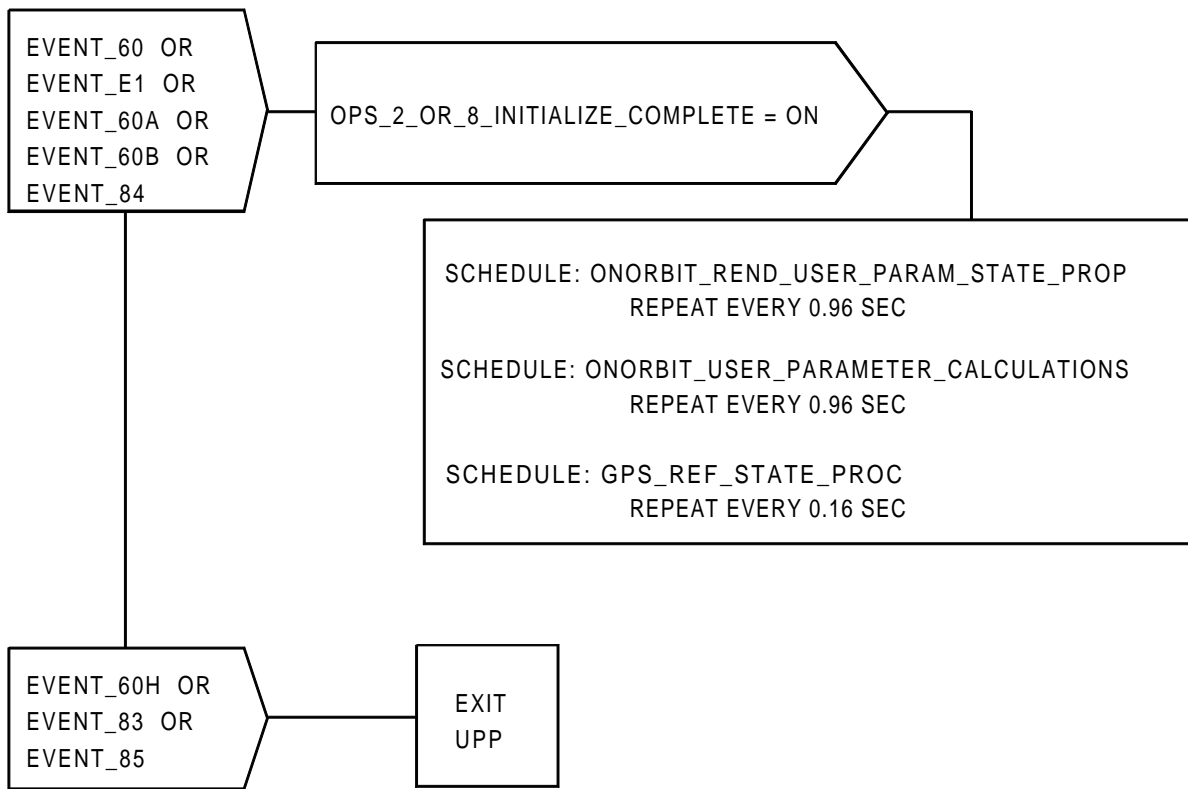


FIGURE 5.4-1. ONORBIT\_REND\_UPP\_SEQ

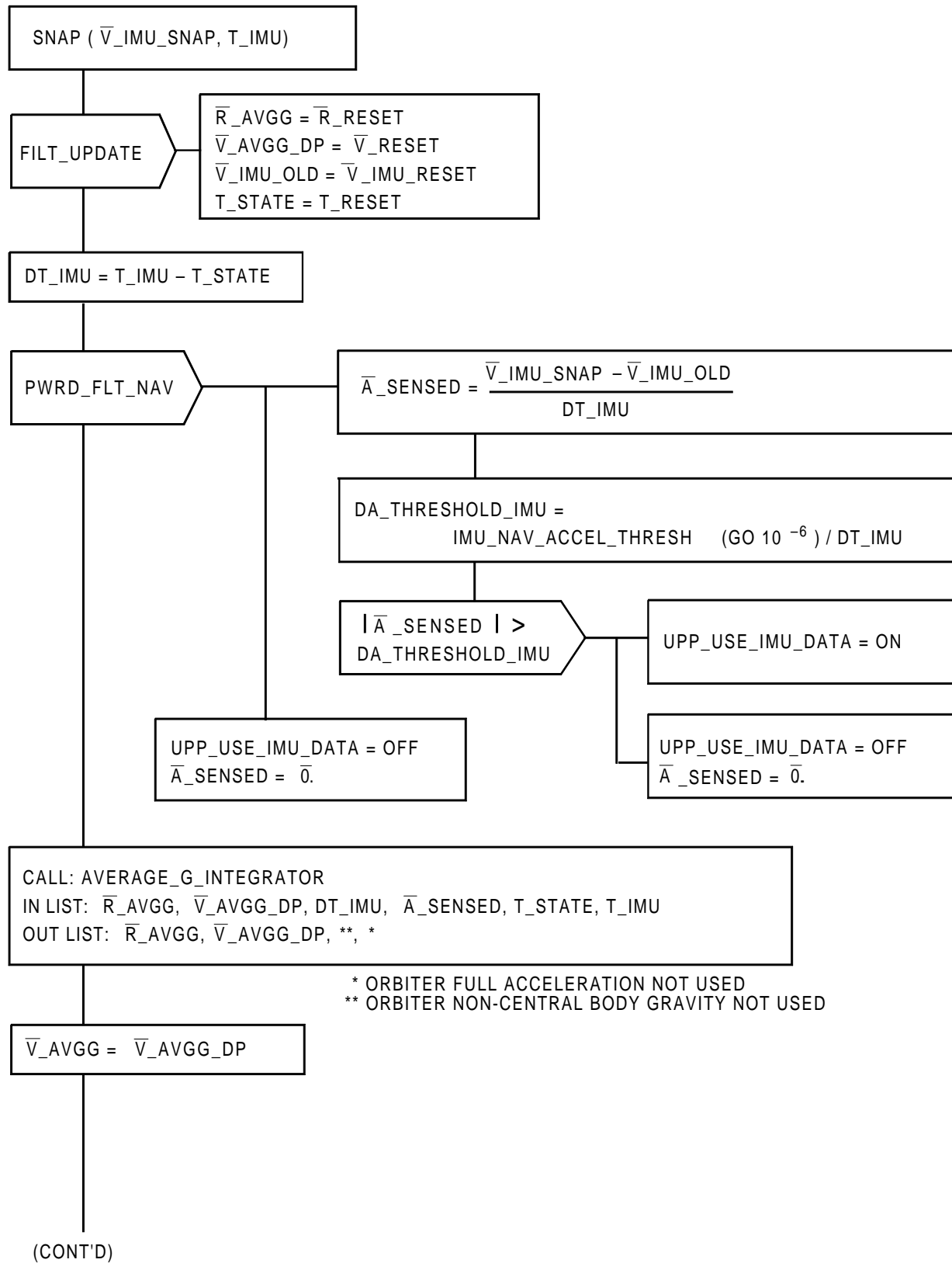
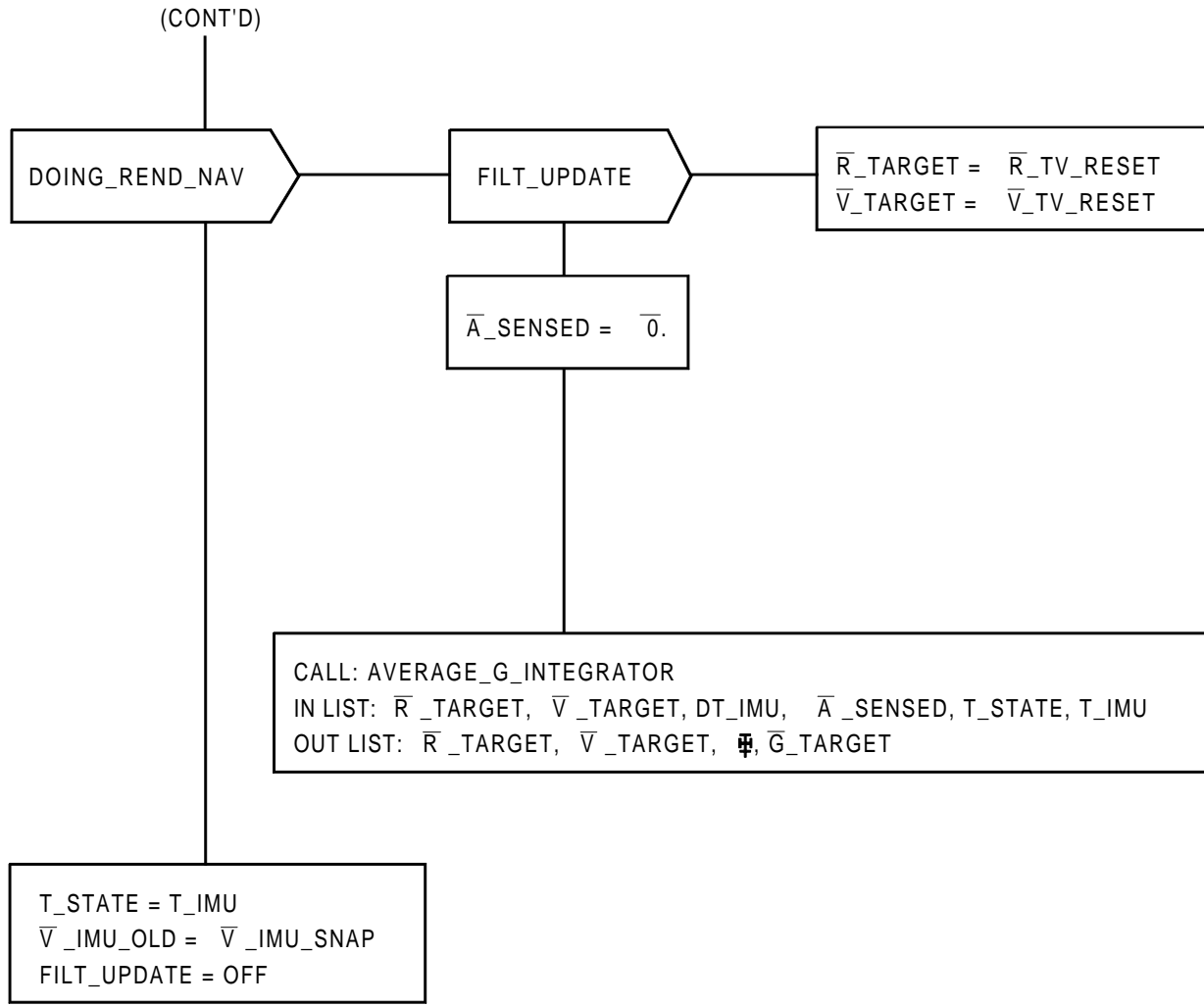


FIGURE 5.4-2.(1) ONORBIT\_REND\_USER\_PARAM\_STATE\_PROP (Sheet 1 of 2)





⊘ TARGET NONCENTRAL GRAVITY ACCELERATION NOT USED

FIGURE 5.4-2.(2) ONORBIT\_REND\_USER\_PARAM\_STATE\_PROP (Sheet 2 of 2)

IN LIST:  $\bar{R}_{AV}$ ,  $\bar{V}_{AV}$ , DTIME,  $\bar{A}C$ , T\_STATE, T\_IMU  
OUT LIST:  $\bar{R}_{AV}$ ,  $\bar{V}_{AV}$ ,  $\bar{G}_{NONCENTRAL}$ ,  $\bar{G}R1$

$$\begin{aligned}\bar{G}R &= \bar{A}CCEL\_ONORBIT (GM\_DEG\_LOW, GM\_ORD\_LOW, DFL\_AVG, VFLTV\_PRED, ATFL\_OV, \\ &\quad \bar{R}_{AV}, \bar{V}_{AV}, T\_STATE) \\ \bar{R}_{AV} &= \bar{R}_{AV} + DTIME [\bar{V}_{AV} + 0.5 DTIME (\bar{A}C + \bar{G}R)] \\ \bar{G}R1 &= \bar{A}CCEL\_ONORBIT (GM\_DEG\_LOW, GM\_ORD\_LOW, DFL\_AVG, VFLTV\_PRED, ATFL\_OV, \\ &\quad \bar{R}_{AV}, \bar{V}_{AV}, T\_IMU) \\ \bar{V}_{AV} &= \bar{V}_{AV} + DTIME [\bar{A}C + 0.5 (\bar{G}R + \bar{G}R1)]\end{aligned}$$

$$\bar{G}_{NONCENTRAL} = \bar{G}R1 - \bar{G}_{CENTRAL}$$

FIGURE 5.4-3. AVERAGE\_G\_INTEGRATOR

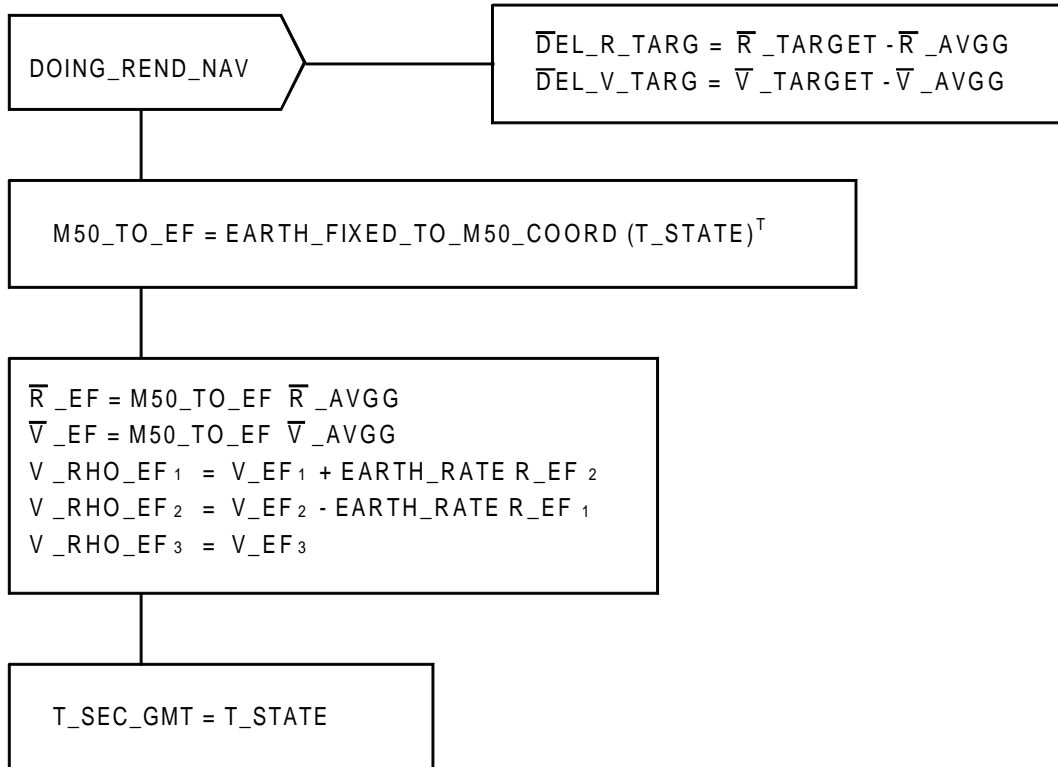


FIGURE 5.4-4. ONORBIT\_USER\_PARAMETER\_CALCULATIONS

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## 5.5 NAVIGATION UPLINK PROCESSING FUNCTIONS: FLOW CHARTS, VARIABLE NAMES AND DESCRIPTIONS

Supplemental material included in this section for navigation uplink processing functions includes functional flow charts (Figures 5.5-1 through 5.5-5); Table 5.5-1, which provides the variable list to support the flow charts; and the list of variable definitions that will aid in interpreting Table 5.5-1.

These flow charts represent navigation uplink processing and are composed of the following modules.

1. ORBIT\_STATE\_VECTOR\_UPLINK
2. RENDEZVOUS\_STATE\_VECTOR\_UPLINK
3. VENT\_RCS\_MODEL\_PARAM\_UPLINK
4. DRAG\_MODEL\_PARAM\_UPLINK
5. COV\_MATRIX\_PARAM\_UPLINK

### VARIABLES LIST DEFINITIONS

#### Code used for variable data type

- F: floating point quantity; an n-dimensional floating point vector will be denoted F(n); similarly, an n x m floating point matrix will be denoted by F(n,m)
- I: integer quantity; I(n) will denote an n-dimensional integer vector
- B: bit; i.e., data having only values of 0 or 1
- C: character; C(n) will denote an n-dimensional character string

#### Code used for variable precision

- D: double precision
- S: single precision; integer quantities are assumed single precision unless otherwise stated.

#### Variable location

- COMPOOL: Variable value located in common storage, accessible by all functions
- LOCAL: Variable is used by one function only, and usable to other functions through call argument only

#### Variable initialization category

- blank: display is vacant
- C: constant (unchanging), Level A
- DD: design dependent

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HC: hard coded

MD: mission dependent (I-Load)

K-load: a former I-load that has become hard coded

Variable initial value

Initial operation sequence computer inputs

Variable uplink and downlist status

UPLINK: variable is an uplink item

DOWNLIST: variable is a downlist item

Units definitions

deg: angular measurement, degrees

ft: feet

lb: pounds

n.d.: nondimensional

rad: radian

sec: time measurement, seconds

slugs: mass measurement, slugs

vary: units have different values which depend on variable use

Table 5.5-1. Variable List - Navigation Uplink Processing Functions

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial- ization Category	Initial Value	Uplink/ Down list	Units	Description
$\bar{C}OV\_COR\_UPDATE$ (V96H1290C-6C)	SF(7)	compool	MD	—	uplink	vary	Vector of correlation coefficients associated with UVW standard deviations ( $\bar{S}IG\_UPDATE$ ) used for orbiter position/velocity covariance initialization (ground update).
DO_OV_UPLINK (V90X4754X)	B	compool	—	OFF	—	—	Flag indicating (ON) that data has been uplinked for orbiter state vector update.
DO_TV_UPLINK (V90X4757X)	B	compool	—	OFF	—	—	Flag indicating (ON) that data has been uplinked for target state vector update.
$\bar{R}\_GND$ (V96H3500C-02C)	DF (3)	compool	—	—	uplink	ft	Uplink orbiter position vector (M50).
$\bar{R}\_TV\_GND$ (V96H1277C-79C)	DF (3)	compool	—	—	uplink	ft	Uplinked target vehicle position vector at T_TV_GND.
$\bar{S}IG\_UPDATE$ (V96H1284C-9C)	SF (6)	compool	MD	—	uplink	ft, ft/sec	Vector of standard deviations for orbiter position/velocity covariance initialization (ground update).
T_GND (V96W3520C)	DF	compool	—	—	uplink	sec	Uplinked time tag of orbiter state vector ( $\bar{R}\_GND$ , $\bar{V}\_GND$ ).
T_TV_GND (V96W1283C)	DF	compool	—	—	uplink	sec	Uplinked target state time tag.
$\bar{V}\_GND$ (V96L3510C-12C)	DF (3)	compool	—	—	uplink	ft/sec	Uplinked orbiter velocity vector.
$\bar{V}\_TV\_GND$ (V96L1280C-82C)	DF (3)	compool	—	—	uplink	ft/sec	Uplinked M1950 target vehicle velocity vector at T_TV_GND.
$\bar{B}UFFER\_B$	SF (3)	local	—	—	—	lb	Buffer area associated with Vent/RCS vector uplink.
$\bar{B}UFFER\_C$	SF (7)	local	—	—	—	—	Buffer area associated with covariance matrix uplink (correlation coefficients).
BUFFER_K	SF	local	—	—	—	—	Buffer location associated with orbiter drag model scale factor.
BUFFER_K_TGT	SF	local	—	—	—	—	Buffer location associated with target drag model scale factor.
$\bar{B}UFFER\_O$	DF (2)	local	—	—	—	sec	Buffer area associated with Vent/RCS ON-OFF times uplink.

Table 5.5-1. Variable List - Navigation Uplink Processing Functions

Variable Name (M/S ID)	Precision and Type	Compool or local	Initial- ization Category	Initial Value	Uplink/ Down list	Units	Description
$\bar{B}$ UFFER_R	DF (3)	local	—	—	—	ft	Buffer area associated with orbiter state position vector uplink.
$\bar{B}$ UFFER_RT	DF (3)	local	—	—	—	ft	Buffer area associated with target vehicle position vector uplink.
BUFFER_S	SF (6)	local	—	—	—	ft, ft/sec	Buffer designations for UVW standard deviations associated with covariance matrix uplink.
BUFFER_T	DF	local	—	—	—	sec	Buffer location associated with orbiter state vector uplink (time tag).
BUFFER_TT	DF	local	—	—	—	sec	Buffer location associated with rendezvous vehicle state vector uplink (time tag).
$\bar{B}$ UFFER_V	SF (3)	local	—	—	—	ft/sec	Buffer area associated with orbiter state vector uplink (velocity).
$\bar{B}$ UFFER_VT	SF (3)	local	—	—	—	ft/sec	Buffer area associated with target vehicle state vector uplink (velocity).
KFACTOR (V96U8173C)	SF	compool	MD	—	uplink	—	Drag model scale factor for orbiter.
OP_CODE (V90U4943C)	SI	compool	—	—	uplink	—	7-BIT string code to define command load uplink type.
TARGET_ KFACTOR (V90U4004C)	SF	compool	—	1.0	uplink	—	Drag model scale factor for target.
TFOFF (V96W8178C)	DF	compool	MD	—	uplink/ down list	sec	Vent/RCS off time.
TFON (V96W8177C)	DF	compool	MD	—	uplink/ down list	sec	Vent/RCS on time.
$\bar{V}$ FORCE (V96U8174C-76C)	SF (3)	compool	MD	—	uplink/ down list	lbs	Vent/RCS body force vector.



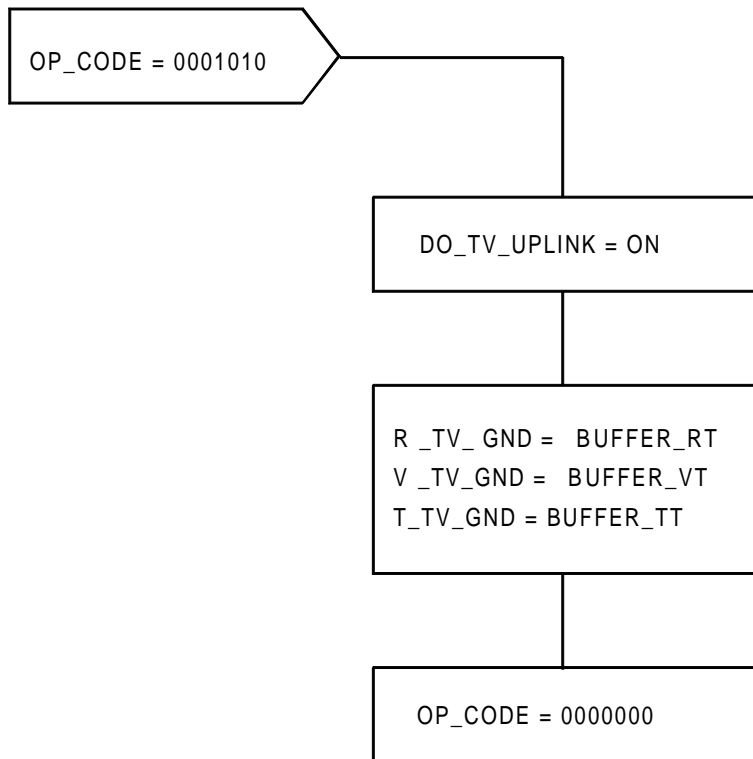


FIGURE 5.5-2. RENDEZVOUS\_STATE\_VECTOR\_UPLINK

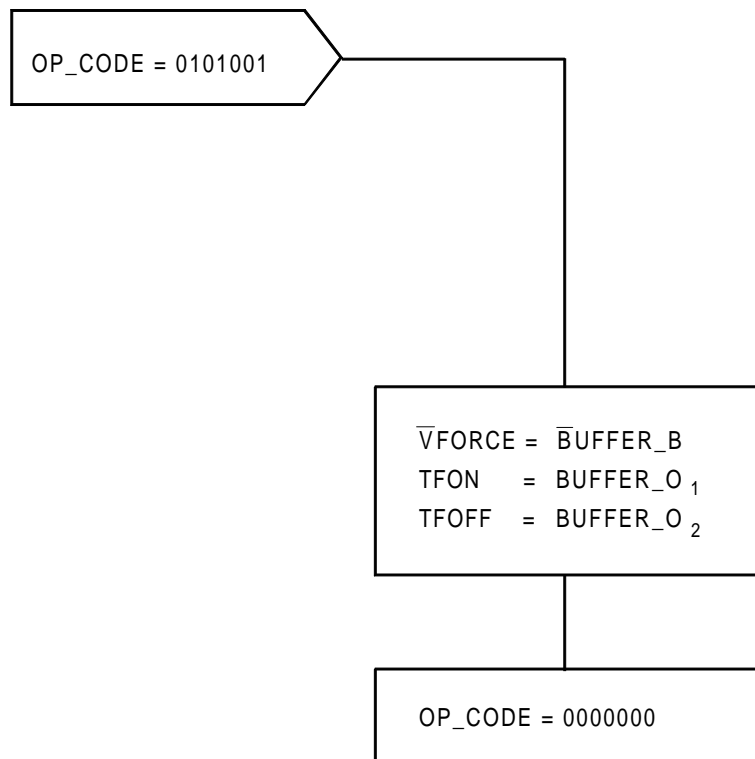


FIGURE 5.5-3. VENT\_RCS\_MODEL\_PARAM\_UPLINK

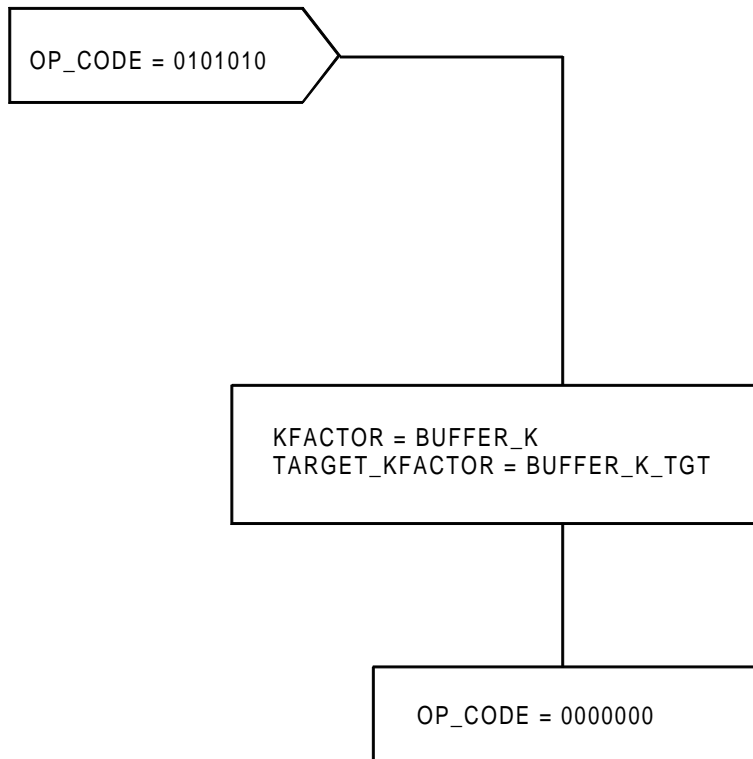


FIGURE 5.5-4. DRAG\_MODEL\_PARAM\_UPLINK

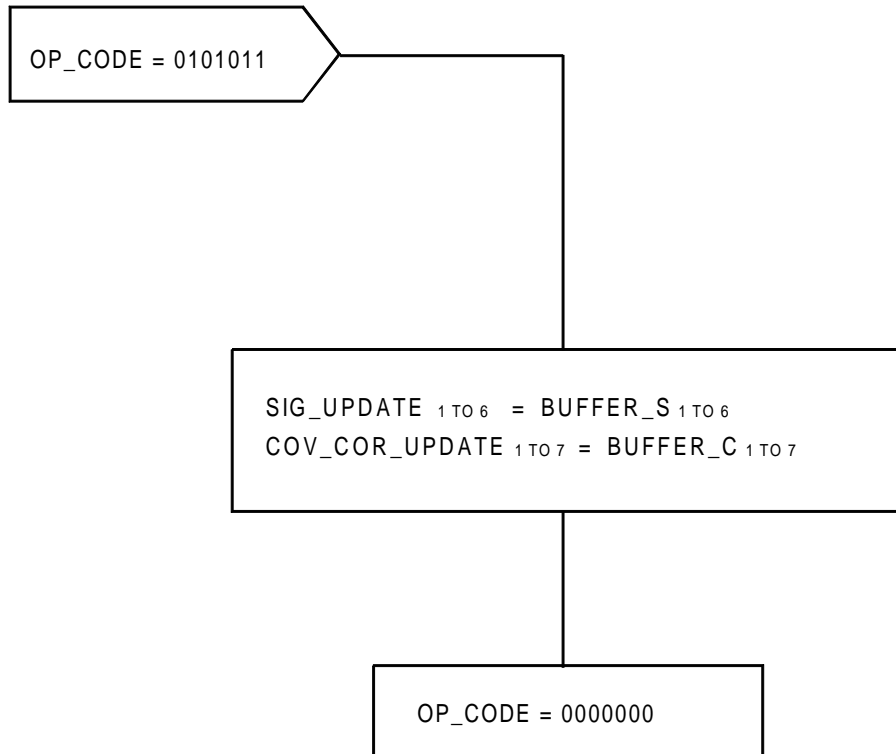


FIGURE 5.5-5. COV\_MATRIX\_PARAM\_UPLINK

RNP\_MATRIX\_TIME\_UPLINK\_PROCESSING

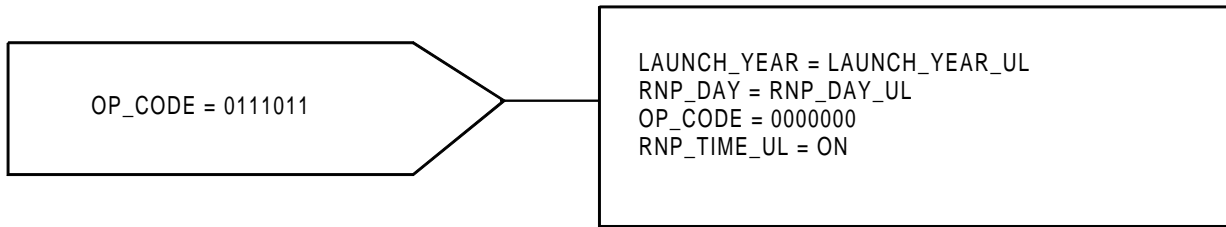


FIGURE 5.5-6. RNP\_MATRIX\_TIME\_UPLINK\_PROCESSING

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## **5.6 INTERFACE DIAGRAMS FOR THE ONORBIT/RENDEZVOUS NAVIGATION SEQUENCER PRINCIPAL FUNCTION, THE ONORBIT/RENDEZVOUS NAVIGATION PRINCIPAL FUNCTION AND THE ONORBIT PRECISION STATE PREDICTION PRINCIPAL FUNCTION**

This section provides supplementary interface information concerning the following principal functions:

- Onorbit/Rendezvous Navigation Sequencer
- Onorbit/Rendezvous Navigation
- Onorbit Precision State Prediction

The intent of this section is to provide block diagrams (Figures 5.6–1 through 5.6–3) for each principal function in order to supply the following information:

- The constituent subfunctions of each principal function
- A calling diagram for each subfunction in each principal function
- The interrelationship of the principal functions

The information contained in this section is intended to be supplementary only.

The flow charts represent the onorbit rendezvous navigation sequencer and are composed of the following modules:

1. The Onorbit/Rendezvous Navigation Sequencer Principal Function
2. Module Interface for Onorbit/Rendezvous Navigation
3. The Onorbit Precision State Prediction Principal Function

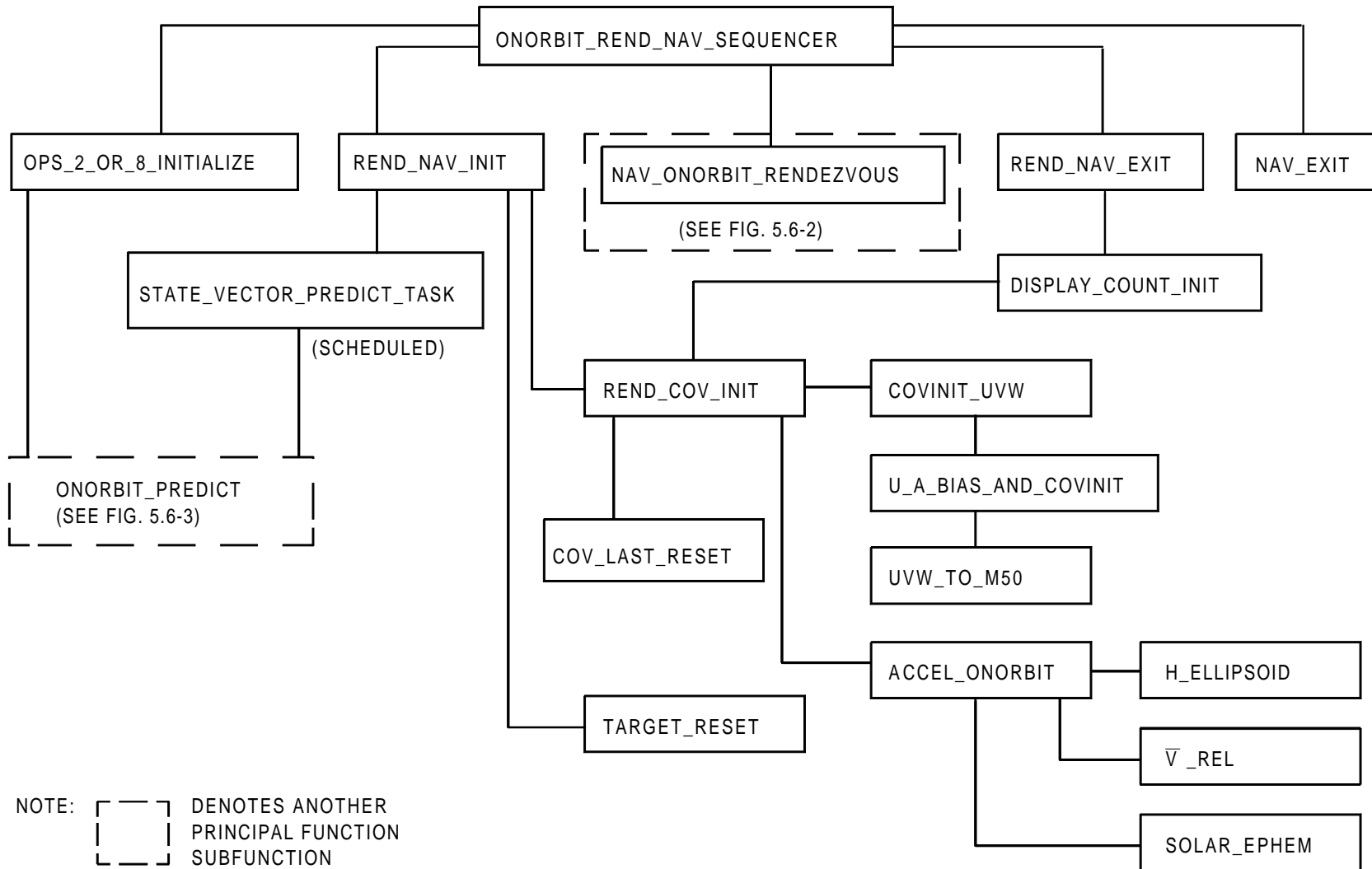


FIGURE 5.6-1. The Onorbit/Rendezvous Navigation Sequencer Principal Function





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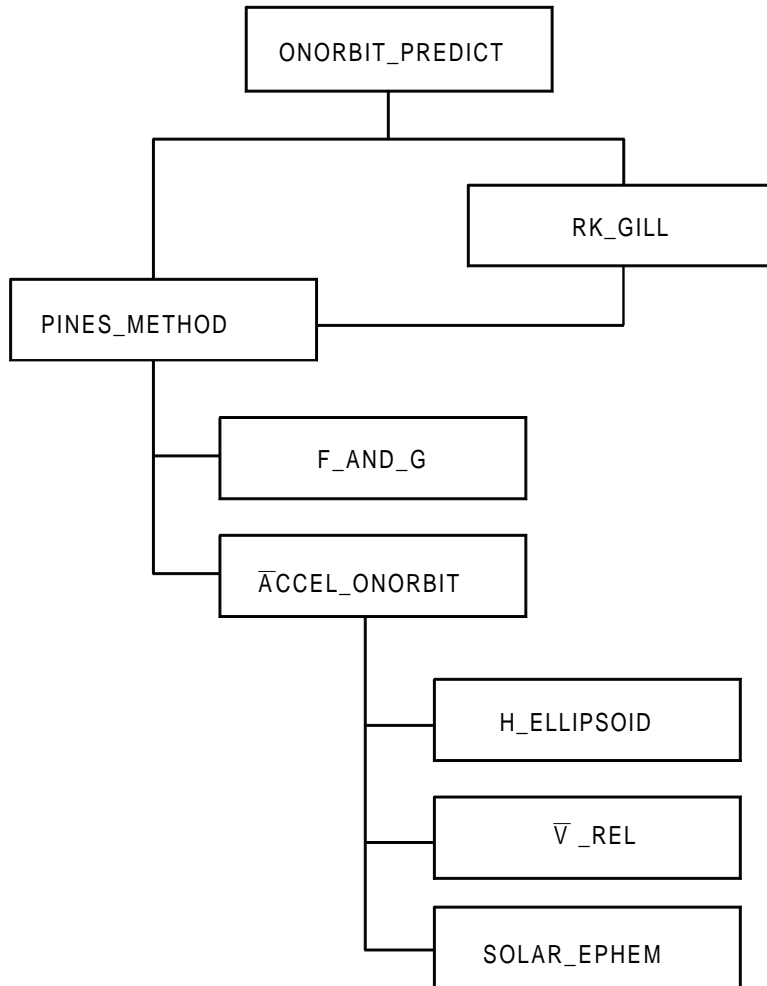


FIGURE 5.6-3. The Onorbit Precision State Prediction Principal Function

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**APPENDIX R CHANGE AUTHORIZATION REFERENCES**

**R.1 CR REFERENCE SUMMARY**

Table R.1-1. lists the paragraphs, tables (T), and figures (F) that have been changed as a result of approved change requests commencing with OI-26 up to the current OI. Changes incorporated prior to OI-26 are listed in the Historical Change Request Summary.

Table R.1-1. CR Reference Summary			
Paragraph	CR No.	OI	CR Title
N/A	92307	29	FSSR Format Change - Documentation Only
N/A	92744B	30	STS 83-0006 Errata Cleanup
N/A	92983	32	Reassign Effectivity of SCRs 92834C & 92931A to OI-32
N/A	93009	32	Reassign Effectivity of SCR 92843B to OI-32
1.2	92025B	26B	Onorbit TACAN Deletion
1.3-1.(T)	92103A	26B	FSSR Parameter Table Upgrade
3.3	91051K	26B	Streamlined Shuttle GPS Capability
	92369B	29	PASS GPS Operational Enhancements
3.3.1	91051K	26B	Streamlined Shuttle GPS Capability
	92025B	26B	Onorbit TACAN Deletion
	92369B	29	PASS GPS Operational Enhancements
3.3.4	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
	92369B	29	PASS GPS Operational Enhancements
3.3.4.1	91051K	26B	Streamlined Shuttle GPS Capability
3.3.4.1.2	92025B	26B	Onorbit TACAN Deletion
3.3.4.2	91051K	26B	Streamlined Shuttle GPS Capability
3.3.4.2.1	91051K	26B	Streamlined Shuttle GPS Capability
3.3.4.2.2	91051K	26B	Streamlined Shuttle GPS Capability
3.3-2.(F)	92025B	26B	Onorbit TACAN Deletion
4.0.(T)	92025B	26B	Onorbit TACAN Deletion
4.1.1	91051K	26B	Streamlined Shuttle GPS Capability
4.1-1.(T)	92329E	29	Onboard Calculation of RNP Matrix
4.1.1.1.	92834C	32	Rendezvous NAV Item Entry Corrections
4.1.1.1.(T)	92834C	32	Rendezvous NAV Item Entry Corrections
4.1.2	91051K	26B	Streamlined Shuttle GPS Capability
	92049C	26B	Corrections to CR 91051K, Streamlined Shuttle GPS Capability
	92069B	26B	Single String GPS Documentation Cleanup

Table R.1-1. CR Reference Summary			
Paragraph	CR No.	OI	CR Title
4.1.2.(T)	92080B	26B	Single-String GPS UPP and SOP Corrections
	92067D	27	Three String GPS Capability
	92208C	28	GPS Issues for Correction on OI-28
	92369B	29	PASS GPS Operational Enhancements
	91051K	26B	Streamlined Shuttle GPS Capability
	92069B	26B	Single-String GPS Documentation Cleanup
	92067D	27	Three String GPS Capability
	92208C	28	GPS Issues for Correction on OI-28
	92369B	29	PASS GPS Operational Enhancements
	91051K	26B	Streamlined Shuttle GPS Capability
	92069B	26B	Single-String GPS Documentation Cleanup
	92067D	27	Three String GPS Capability
	92214A	27	Post-CI Three-String GPS Documentation Cleanup
	92297B	27	Delete Erroneous TLM Destinations for NAV
4.1.2.1	92208C	28	GPS Issues for Correction on OI-28
	92369B	29	PASS GPS Operational Enhancements
4.1.2.1(T)	92834C	32	Rendezvous NAV Item Entry Corrections
4.1.2.1.(T)	91051K	26B	Streamlined Shuttle GPS Capability
4.1.2.2.	91051K	26B	Streamlined Shuttle GPS Capability
4.1.2.2.(T)	92834C	32	Rendezvous NAV Item Entry Corrections
4.1.2.2.1.(T)	92067D	27	Three String GPS Capability
	92834C	32	Rendezvous NAV Item Entry Corrections
4.1.2.2.1.1.(T)	92067D	27	Three String GPS Capability
4.1.2.2.1.3	92067D	27	Three String GPS Capability
4.1.2.2.1.3.(T)	92067D	27	Three String GPS Capability
4.1.3	92067D	27	Three String GPS Capability
	92369B	29	PASS GPS Operational Enhancements
4.1.3-1.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92069B	26B	Single-String GPS Documentation Cleanup
	92067D	27	Three String GPS Capability
	92132C	27	Three String GPS GN&C Corrections
	92354	27	Delete Erroneous TLM Destinations
	92329E	29	Onboard Calculation of RNP Matrix
	92355B	29	GPC Major Mode to MEDS
	92369B	29	PASS GPS Operational Enhancements

Table R.1-1. CR Reference Summary			
Paragraph	CR No.	OI	CR Title
4.1.3-2.(T)	92392C	29	Doc-Only Corrections for OI-29 CRs 92329E, 92364D, and 92369B
	92834C	32	Rendezvous NAV Item Entry Corrections
	93090E	33	Bearing Displays
	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
	92132C	27	Three String GPS GN&C Corrections
	92214A	27	Post-CI Three-String GPS Documentation Cleanup
	92297B	27	Delete Erroneous TLM Destinations for NAV
4.1.3-3.(T)	92369B	29	PASS GPS Operational Enhancements
	92834C	32	Rendezvous NAV Item Entry Corrections
	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
	92292B	28	GPS Related Category Modifications for OI-28
4.1.3-4.(T)	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
	92080B	26B	Single-String GPS UPP and SOP Corrections
4.1.3-5.(T)	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
	92834C	32	Rendezvous NAV Item Entry Corrections
	91051K	26B	Streamlined Shuttle GPS Capability
	92069B	26B	Single-String GPS Documentation Cleanup
	92080B	26B	Single-String GPS UPP and SOP Corrections
4.2	92067D	27	Three String GPS Capability
	93090E	33	Bearing Displays
	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
	92132C	27	Three String GPS GN&C Corrections
	92208C	28	GPS Issues for Correction on OI-28
	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion
	92529B	30	GPS Capability Enhancements For OI-30
4.2.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92025B	26B	Onorbit TACAN Deletion
	92069B	26B	Single-String GPS Documentation Cleanup
	92067D	27	Three String GPS Capability
	92214A	27	Post-CI Three-String GPS Documentation Cleanup
	92208C	28	GPS Issues for Correction on OI-28

Table R.1-1. CR Reference Summary			
Paragraph	CR No.	OI	CR Title
4.2.1	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion
	92369B	29	PASS GPS Operational Enhancements
	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
	92834C	32	Rendezvous NAV Item Entry Corrections
	91051K	26B	Streamlined Shuttle GPS Capability
	92025B	26B	Onorbit TACAN Deletion
	92067D	27	Three String GPS Capability
	92132C	27	Three String GPS GN&C Corrections
4.2.1.(T)	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion
	92369B	29	PASS GPS Operational Enhancements
	92529B	30	GPS Capability Enhancements For OI-30
	92834C	32	Rendezvous NAV Item Entry Corrections
	91051K	26B	Streamlined Shuttle GPS Capability
	92025B	26B	Onorbit TACAN Deletion
	92069B	26B	Single-String GPS Documentation Cleanup
	92067D	27	Three String GPS Capability
	92132C	27	Three String GPS GN&C Corrections
	92208C	28	GPS Issues for Correction on OI-28
	92281D	28	Post FACI OI-28 GPS Documentation Cleanup
	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion
4.2.1.1	92369B	29	PASS GPS Operational Enhancements
	92834C	32	Rendezvous NAV Item Entry Corrections
	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
	92208C	28	GPS Issues for Correction on OI-28
4.2.1.1-1.(T)	92369B	29	PASS GPS Operational Enhancements
	91051K	26B	Streamlined Shuttle GPS Capability
	92069B	26B	Single-String GPS Documentation Cleanup
	92067D	27	Three String GPS Capability
	92214A	27	Post-CI Three-String GPS Documentation Cleanup
4.2.2	92208C	28	GPS Issues for Correction on OI-28
	92369B	29	PASS GPS Operational Enhancements
	91051K	26B	Streamlined Shuttle GPS Capability



Table R.1-1. CR Reference Summary			
Paragraph	CR No.	OI	CR Title
4.2.2.1	92025B	26B	Onorbit TACAN Deletion
	92067D	27	Three String GPS Capability
	92281D	28	Post FACI OI-28 GPS Documentation Cleanup
	92369B	29	PASS GPS Operational Enhancements
	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
4.2.2.2	92214A	27	Post-CI Three-String GPS Documentation Cleanup
	92281D	28	Post FACI OI-28 GPS Documentation Cleanup
	92369B	29	PASS GPS Operational Enhancements
	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
	92132C	27	Three String GPS GN&C Corrections
4.2.2.3	92214A	27	Post-CI Three-String GPS Documentation Cleanup
	92369B	29	PASS GPS Operational Enhancements
4.2.2.4	91051K	26B	Streamlined Shuttle GPS Capability
4.2.3.1	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
4.2.3.1.(T)	92208C	28	GPS Issues for Correction on OI-28
	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
4.2.3.1.1	92208C	28	GPS Issues for Correction on OI-28
	91051K	26B	Streamlined Shuttle GPS Capability
4.2.3.2.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
4.2.4.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
4.2.4.1.1	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
4.2.4.1.1.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
4.2.4.1.1.(1)(T)	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
4.2.4.1.1.3	92537A	30	Modify Star Tracker SOP to Eliminate Unnecessary I-Load/K-Loads
4.2.5.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
4.2.5.1.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability

Table R.1-1. CR Reference Summary			
Paragraph	CR No.	OI	CR Title
4.2.5.2.(T)	91051K	26B	Streamlined Shuttle GPS Capability
4.2.6.(T)	91051K	26B	Streamlined Shuttle GPS Capability
4.2.7.(T)	91051K	26B	Streamlined Shuttle GPS Capability
4.2.7.1.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
4.2.8	91051K	26B	Streamlined Shuttle GPS Capability
4.2.8.1.(T)	91051K	26B	Streamlined Shuttle GPS Capability
4.2.8.1.1.(T)	91051K	26B	Streamlined Shuttle GPS Capability
4.2.8.1.1.1.(T)	91051K	26B	Streamlined Shuttle GPS Capability
4.2.8.1.2.(T)	92067D	27	Three String GPS Capability
4.2.10.1	92067D	27	Three String GPS Capability
	92132C	27	Three String GPS GN&C Corrections
	92208C	28	GPS Issues for Correction on OI-28
4.2.10.1.(T)	92105B	26B	GPS MSID Documentation Corrections
	92067D	27	Three String GPS Capability
	92132C	27	Three String GPS GN&C Corrections
	92208C	28	GPS Issues for Correction on OI-28
4.2.10.2.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92069B	26B	Single-String GPS Documentation Cleanup
	92067D	27	Three String GPS Capability
4.2.11	91051K	26B	Streamlined Shuttle GPS Capability
	92069B	26B	Single-String GPS Documentation Cleanup
	92067D	27	Three String GPS Capability
	92132C	27	Three String GPS GN&C Corrections
	92369B	29	PASS GPS Operational Enhancements
4.2.11-1.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92025B	26B	Onorbit TACAN Deletion
	92069B	26B	Single-String GPS Documentation Cleanup
	92105B	26B	GPS MSID Documentation Corrections
	92067D	27	Three String GPS Capability
	92132C	27	Three String GPS GN&C Corrections
	92144C	27	Three String GPS Documentation Cleanup
	92214A	27	Post-CI Three-String GPS Documentation Cleanup
	92244A	27	Change V_GPS_SEL to Double Precision
	92297B	27	Delete Erroneous TLM Destinations for NAV
	92354	27	Delete Erroneous TLM Destinations

Table R.1-1. CR Reference Summary			
Paragraph	CR No.	OI	CR Title
4.2.11-2.(T)	92157	28	IDD Clarification to Remove Blanks from FSSR Names
	92237	28	IDD Documentation Cleanup of Uplink Data
	92329E	29	Onboard Calculation of RNP Matrix
	92355B	29	GPC Major Mode to MEDS
	92369B	29	PASS GPS Operational Enhancements
	92392C	29	Doc-Only Corrections for OI-29 CRs 92329E, 92364D, and 92369B
	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
	92834C	32	Rendezvous NAV Item Entry Corrections
	93090E	33	Bearing Displays
	91051K	26B	Streamlined Shuttle GPS Capability
	92025B	26B	Onorbit TACAN Deletion
	92067D	27	Three String GPS Capability
	92132C	27	Three String GPS GN&C Corrections
	92214A	27	Post-CI Three-String GPS Documentation Cleanup
4.2.11-3.(T)	92208C	28	GPS Issues for Correction on OI-28
	92369B	29	PASS GPS Operational Enhancements
	92834C	32	Rendezvous NAV Item Entry Corrections
	91051K	26B	Streamlined Shuttle GPS Capability
	92069B	26B	Single-String GPS Documentation Cleanup
	92098D	26B	Single-String GPS RCVR STATE PROC/Status Display Corrections
	92139	26B	GPS I-Load Categorization Updates
	92067D	27	Three String GPS Capability
	92178C	27	Altitude Threshold & Floor for GPS to Nav Updates
	92329E	29	Onboard Calculation of RNP Matrix
4.2.11-4.(T)	92537A	30	Modify Star Tracker SOP to Eliminate Unnecessary I-Load/K-loads
	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
	91051K	26B	Streamlined Shuttle GPS Capability
	92069B	26B	Single-String GPS Documentation Cleanup
4.2.11-5.(T)	92537A	30	Modify Star Tracker SOP to Eliminate Unnecessary I-Load/K-loads
	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
	92834C	32	Rendezvous NAV Item Entry Corrections
	91051K	26B	Streamlined Shuttle GPS Capability
	92069B	26B	Single-String GPS Documentation Cleanup

Table R.1-1. CR Reference Summary			
Paragraph	CR No.	OI	CR Title
4.3.3-1.(T)	92067D	27	Three String GPS Capability
	92395F	28	Incorporate G on MEDS Displays
	92329E	29	Onboard Calculation of RNP Matrix
	92389C	29	Spiral HAC in TAEM Area Navigation
	92332D	30	Add Theta Limits Bracket to MEDS ADI Displays
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
	92749B	30	Universal Pointing Processor Degrees to Radians Documentation Clean-up
	93090E	33	Bearing Displays
	92329E	29	Onboard Calculation of RNP Matrix
	92392C	29	Doc-Only Corrections for OI-29 CRs 92329E, 92364D, and 92369B
4.3.3-3.(T)	93090E	33	Bearing Displays
	92069B	26B	Single-String GPS Documentation Cleanup
4.3.3-5.(T)	92329E	29	Onboard Calculation of RNP Matrix
	92069B	26B	Single-String GPS Documentation Cleanup
4.4	93090E	33	Bearing Displays
4.4	91051K	26B	Streamlined Shuttle GPS Capability
4.4-1.(T)	91051K	26B	Streamlined Shuttle GPS Capability
4.4.1-1.(T)	92354	27	Delete Erroneous TLM Destinations
	92355B	29	GPC Major Mode to MEDS
4.5	92025B	26B	Onorbit TACAN Deletion
4.5.(T)	92297B	27	Delete Erroneous TLM Destinations for NAV
	92208C	28	GPS Issues for Correction on OI-28
	92748B	30	Make a Double Precision Copy of V_AVGG for REL NAV
	92843B	32	Lambert Guidance Improvement
4.5.1	92208C	28	GPS Issues for Correction on OI-28
	92688B	30	Fix for DR 50120 - Time To Node Oscillation
	92727A	30	Initialization of R_AVGG and V_AVGG
	92748B	30	Make a Double Precision Copy of V_AVGG for REL NAV
4.5.1.(T)	92843B	32	Lambert Guidance Improvement
	92208C	28	GPS Issues for Correction on OI-28
	92688B	30	Fix for DR 50120 - Time To Node Oscillation
	92748B	30	Make a Double Precision Copy of V_AVGG for REL NAV

Table R.1-1. CR Reference Summary			
Paragraph	CR No.	OI	CR Title
4.5.1.1	92843B	32	Lambert Guidance Improvement
	92688B	30	Fix for DR 50120 - Time To Node Oscillation
4.5.1.1.(T)	92748B	30	Make a Double Precision Copy of V_AVGG for REL NAV
4.5.1.1.(1)(T)	92688B	30	Fix for DR 50120 - Time To Node Oscillation
4.5.3-1.(T)	92132C	27	Three String GPS GN&C Corrections
	92329E	29	Onboard Calculation of RNP Matrix
	92392C	29	Doc-Only Corrections for OI-29 CRs 92329E, 92364D, and 92369B
4.5.3-2.(T)	92834C	32	Rendezvous NAV Item Entry Corrections
	93090E	33	Bearing Displays
	92025B	26B	Onorbit TACAN Deletion
	92297B	27	Delete Erroneous TLM Destinations for NAV
	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
	92688B	30	Fix for DR 50120 - Time To Node Oscillation
	92748B	30	Make a Double Precision Copy of V_AVGG for REL NAV
4.5.3-5.(T)	92843B	32	Lambert Guidance Improvement
	91051K	26B	Streamlined Shuttle GPS Capability
	92069B	26B	Single-String GPS Documentation Cleanup
	92395F	28	Incorporate G on MEDS Displays
	92389C	29	Spiral HAC in TAEM Area Navigation
	93090E	33	Bearing Displays
4.7	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
4.9	92025B	26B	Onorbit TACAN Deletion
	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion
4.9.4	92529B	30	GPS Capability Enhancements For OI-30
	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
4.9.4-1.(T)	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
4.9.4-2.(T)	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
4.9.6	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion
	92529B	30	GPS Capability Enhancements For OI-30
4.10	92329E	29	Onboard Calculation of RNP Matrix
4.10.1	92329E	29	Onboard Calculation of RNP Matrix

Table R.1-1. CR Reference Summary				
Paragraph	CR No.	OI	CR Title	
4.10.2	92329E	29	Onboard Calculation of RNP Matrix	
	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion	
	92529B	30	GPS Capability Enhancements For OI-30	
4.10.2.(T)	92329E	29	Onboard Calculation of RNP Matrix	
5.0	92025B	26B	Onorbit TACAN Deletion	
5.1	92545B	30	Convert Target Drag Properties I-Loads to K-Loads	
5.1-1.(T)	92025B	26B	Onorbit TACAN Deletion	
	92067D	27	Three String GPS Capability	
	92208C	28	GPS Issues for Correction on OI-28	
	92329E	29	Onboard Calculation of RNP Matrix	
	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion	
	92529B	30	GPS Capability Enhancements For OI-30	
	92545B	30	Convert Target Drag Properties I-Loads to K-Loads	
	91051K	26B	Streamlined Shuttle GPS Capability	
	92069B	26B	Single-String GPS Documentation Cleanup	
	92080B	26B	Single-String GPS UPP and SOP Corrections	
	92067D	27	Three String GPS Capability	
	92132C	27	Three String GPS GN&C Corrections	
	92214A	27	Post-CI Three-String GPS Documentation Cleanup	
5.1A-1.(T)	92208C	28	GPS Issues for Correction on OI-28	
	92281D	28	Post FACI OI-28 GPS Documentation Cleanup	
	92369B	29	PASS GPS Operational Enhancements	
	91051K	26B	Streamlined Shuttle GPS Capability	
	92025B	26B	Onorbit TACAN Deletion	
	92834C	32	Rendezvous NAV Item Entry Corrections	
	5.2-3.(F)	91051K	26B	Streamlined Shuttle GPS Capability
		92080B	26B	Single-String GPS UPP and SOP Corrections
		92067D	27	Three String GPS Capability
		92369B	29	PASS GPS Operational Enhancements
91051K		26B	Streamlined Shuttle GPS Capability	
5.2-6.(F)	92067D	27	Three String GPS Capability	
	92369B	29	PASS GPS Operational Enhancements	
	92834C	32	Rendezvous NAV Item Entry Corrections	
5.2-7(2).(F)	92834C	32	Rendezvous NAV Item Entry Corrections	
5.2-9.(F)	92067D	27	Three String GPS Capability	

Table R.1-1. CR Reference Summary			
Paragraph	CR No.	OI	CR Title
5.2-14.(F)	91051K	26B	Streamlined Shuttle GPS Capability
	92025B	26B	Onorbit TACAN Deletion
	92067D	27	Three String GPS Capability
	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion
5.2-14(1)(F)	92834C	32	Rendezvous NAV Item Entry Corrections
5.2-14A.(F)	91051K	26B	Streamlined Shuttle GPS Capability
	92025B	26B	Onorbit TACAN Deletion
	92067D	27	Three String GPS Capability
	92132C	27	Three String GPS GN&C Corrections
	92144C	27	Three String Documentation Cleanup
5.2.14A(1)(F)	92834C	32	Rendezvous NAV Item Entry Corrections
5.2.14A(3)(F)	92834C	32	Rendezvous NAV Item Entry Corrections
5.2-15A.(F)	91051K	26B	Streamlined Shuttle GPS Capability
5.2-16.(F)	92067D	27	Three String GPS Capability
	92208C	28	GPS Issues for Correction on OI-28
5.2-18A.(F)	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
	92132C	27	Three String GPS GN&C Corrections
	92208C	28	GPS Issues for Correction on OI-28
5.2-18B.(F)	91051K	26B	Streamlined Shuttle GPS Capability
5.2-26.(1)(F)	92545B	30	Convert Target Drag Properties I-Loads to K-Loads
5.3-1.(T)	92329E	29	Onboard Calculation of RNP Matrix
5.4-1.(T)	92748B	30	Make a Double Precision Copy of V_AVGG for REL NAV
5.4-1.(F)	91051K	26B	Streamlined Shuttle GPS Capability
5.4-2	92208C	28	GPS Issues for Correction on OI-28
5.4-2.(1)(F)	92688B	30	Fix for DR 50120 - Time To Node Oscillation
	92748B	30	Make a Double Precision Copy of V_AVGG for REL NAV
5.4-2.(1)(F)	92843B	32	Lambert Guidance Improvement
5.4-2.(2)(F)	92688B	30	Fix for DR 50120 - Time To Node Oscillation
5.4-3.(F)	92688B	30	Fix for DR 50120 - Time To Node Oscillation
5.5-6.(F)	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion
5.6-1.(F)	91051K	26B	Streamlined Shuttle GPS Capability
	92025B	26B	Onorbit TACAN Deletion

Table R.1-1. CR Reference Summary			
Paragraph	CR No.	OI	CR Title
5.6-2.(F)	91051K	26B	Streamlined Shuttle GPS Capability
	92025B	26B	Onorbit TACAN Deletion
5.6-3.(F)	92025B	26B	Onorbit TACAN Deletion

## R.2 HISTORICAL CHANGE REQUEST SUMMARY

Table R.2-1. is an historical record of approved change requests incorporated since the initial baseline up to OI-25. Change requests commencing with OI-26 are reformatted and listed in the CR Reference Summary.

Table R.2-1. Historical Change Request Summary		
CR No.	OI	CR Title
2599B		Relative Motion Specification (5.9) and Display (6.28) Update
12019		Standardization of FSSR Principal Function I/O Tables
12024B		Navigation Monitor Display (6.11) Update
12164		Vent Timeline Command Load
12214A		ST SOP Interface Table Update
12266A		TACAN SOP and RM
12285		Structural Body to M50 Transforation Changes to Correct Formulation Errors
12286		Changes to Rendezvous Navigation and Star Tracker SOP Interfaces
12326		Changes to Rendezvous Navigaton and On-Orbit UPP Interface With Relative Motion and Rendezvous Targeting
12336		I-Load OFT-1 Baseline, of Mission and LRU Dependent Parameters
12337		I-Load OFT-1 Baseline, of Design Dependent Parameters
12338		I-Load OFT-1 Baseline, of Constants
12339		I-Load OFT-1 Baseline, of Removals
12374		RR SOP Interface Table Update
12411B		OMS Engine FDI Simplification
12419		RR SOP Corrections
12442A		Integrated Entry Navigation, Ascent Navigation, and Orbit Navigation Interface Signal Requirements
12456A		Page Changes for CR 12338
12478		Update to Vehicle Mass Definition Inconsistency
12545		On-Orbit Navigation FSSR



Table R.2-1. Historical Change Request Summary

CR No.	OI	CR Title
12600C		Integrated MSID Assignment for Uplink D&C and GN&C Requirements for OPS 1, 2, 3, 6, and 9
12623		FCS Dedicated Display Changes for OFT-3
12661		Block Update-Level C Navigation FSSR, On-Orbit, November 1977
12676		Non-Issue Errata and Typos to the November 1977 On-Orbit Navigation FSSR
12681		Initialization of Mass (Current Orbiter Mass) in OPS 2
12756		IUS Platform Alignment Support
12765A		RR SOP/Rendezvous Navigation Interface Corrections
12803		Errata and Typos Generated in the FSSR Track Task Input Dated 14 October 1977
12809A		Modification of Universal Pointing (6.27) to be the MM 201 Display
12812A		Relative Navigation Display
12813A		Orbit Targeting
12817		Removal of Angle Measurement Error Compensation Code in Rendezvous Navigation
12818A		Acceleration Models, Constants, and Uplink Revisions for On-Orbit Navigation
12819A		OFT-3 Plus S/W Revisions to On-Orbit/Rendezvous/Navigation Covariance Matrix Propagation and the On-Orbit/Rendezvous Navigation Sequence
12820		Correction to Drag State Noise Formulation in Rendezvous Navigation
12821		Deletion of Adams Moulton Code From the On-Orbit Predictor
12822		Correction of Miscellaneous Error in the Rendezvous Navigation Principal Function
12823		Delete Rendezvous Radar Angle-Rate Processing for Navigation Principal Function
12825B		Delete Occultation Test From Star Tracker SOP for OFT-3
19167B		Relative Navigation Display Interface Correction
19246B		Corrections to Runway Name MSID's and Associated CRT Display Chgs (STS-1)
19361A		Rewrite of the November 1977 Navigation Level C FSSR
19373B		Runway/TACAN/MLS Mini-Table Parameter
19445A		Capability to Change IMU Acceleration Navigation Threshold Level in On-Orbit Operation
19446A		Star Tracker SOP 2 Rendezvous Navigation Interface Corrections (STS-2)
19452B		I-Load Correction Necessary for 3/19 Release

Table R.2-1. Historical Change Request Summary		
CR No.	OI	CR Title
19472A		Addition of IMU Nav Acceleration Threshold Test in the On-Orbit User Parameter Processor (Post STS-1)
19484A		I-Load Data Tape Corections From Community Review
19556A		I-Load Corrections for STS-1
19571A		OPS 2 State Vector Propagation Scrub
19575		Correct Runway Name Parameters for Universal Pointing Display (STS-2)
19655A		Predictor Cycle Overrun Change Request
19700		FSSR Update 4
19785B		Relative Navigation Spec and Display Requirements and Interface Corrections (STS-2)
19810B		STS-2 Nav Downlist Delta
19873A		I-Load Additions for On-Orbit Navigation (STS-2)
19874A		Universal Pointing Changes (STS-2)
19900		FSSR Update 5
29149B		Add Program Interrupt Handling to Level A CPDS
29188C		Time Sync On-Orbit Nav Input
29300A		FSSR Update 6
29408C		Rendezvous Downlist Requirements
29425C		Star Tracker SOP Comfault
29426A		Rel NAV Update
29456		Orbit Targeting I-Load Mod
29458B		Rendezvous Nav False TGT Track
29471B		HFE Overrun Definition
29500		FSSR Update 7
29504B		Orbit Nav Rendezvous Data Snaps
29522B		Changes to On-Orbit Predictor
29589A		Update Site Dependent Parameters
29592		I/L Correction – CR 19873A
29627A		Time Sync of IMU Threshold
29646		Remove Rendezvous U/L From OPS R8 (Ref only)
29657C		STS-1 Cycle 3.1.1 MPAD I/L
29660A		Current Vehicle Mass Update (Ref Only)
29740		Change I/L for NAV Drag Model
29741A		NAV Drag Model Funct of ALT
29772A		Modification of CR 12824

Table R.2-1. Historical Change Request Summary		
CR No.	OI	CR Title
29800		FSSR Update 8
29841		TACAN Bias Deletion
29845		Correct On-Orb/Rend Nav I/L
29858		Orb Nav I/L – Mod CR 19873/19571
29859		Rendezvous NAV I/L Mod CR 19873/19571
29889		Updates for TACAN Stations
29895B		Update GN&C/SM-PL I/F Requirements
29898B		STS-2 D/L Requirements and Loading
29935		NAV D/L Update for OPS 8
29972B		Update STS-2 D/L Loading
39000		FSSR Update No. 9
39006		Correct ORB NAV ORB ID I/F
39032A		I/L Corrections to CR 29858
39050		On-Orbit Nav Release 18 Requirement B/L
39051		Orb Guid R18/R19 Baseline
39052		Star Tracker R18/R19 Baseline (Ref Only)
39076A		I/Load Values TACAN Site Data
39087A		Head Up Display (HUD)
39100		CR Implement Baseline – December 1980
39131B		D/L OPS 8 Predictor Output
39165A		Orb Nav Design I/L Update
39184E		STS-2 Cycle/MPAD I-Loads (Ref Only)
39324		ON-ORB NAV I/Loads (Ref Only)
39365F		UP PROC I/O Cleanup
39400		FSSR Update No. 10/R18, No. 1/R19
39436F		TACAN Table Reorganization & Value Updates (Ref Only)
39463B		Delete I/L SIG_DIAG_UVW_OPS_2 (Ref Only)
39530F		STS-2 Cycle 2 I-Loads (Ref Only)
39563D		RR/COAS SW MODS TO Nav
39595A		CR Implementation Baseline – August 1981
39602B		STS-3 Cycle 2 ORB/END I-Loads (Ref Only)
39618		I-Load KSC Permanent TACAN (Ref Only)
39622		Eliminate EDW Mobile TACAN
39640		FSSR Update No. 11/R18, No. 2/R19
39658E		STS-4 Cycle 1 MPAD (Ref IL) I-LOADS (REF)
39766G		Rendezvous State Vector Management

Table R.2-1. Historical Change Request Summary		
CR No.	OI	CR Title
39784		Change KSC TACAN I-LOADS
39790A		CR Implementating Baseline – November 1981
39812		MSBLS at Northrup Reinstate
39832D		Orbit Targeting Update
39847		STS-4 EOM Landing at EDW (Ref STS-4 Only)
39898B		I-Load Precision Change
39917D		Onorbit CG Offset Correction
39920A		STS-3 CY3 Seasonal Update (Ref Only)
39950		FSSR Update No. 12/R18, No. 3/R19
39980		CR Implementation Baseline – February 1982
39988F		STS-5 Cycle 3 DESC/ENT IL's (Ref Only)
39990E		STS-5 Cycle 3 ASC I-Loads
59005C		CR Implementation Baseline – March 1982 (Ref Only)
59013B		Add DAKAR to Site I-Loads (Ref Only)
59021		DAKAR RW Length for HUD (Ref Only) STS-7
59050		FSSR Update No. 13/R18, No. 4/R19
59084A		Runway Change (STS-4 I-Loads Ref Only)
59100B		Rendezvous D/L Flow Data Rate (Ref Only)
59130A		Update Rendezvous I-Load (Ref Only)
59162		STS-5 CY 4 TAL to DAKAR NAV (Ref Only) STS-6, -7, and -8
59220		CR Implementation Baseline July 1982 (Ref Only)
59270B		STS-7 CY7 NAV/ENT I/L (Ref Only)
59326		Delete Duplicate D/L-RNDZ TGT (Ref Only)
59350		FSSR Update No. 6
59426F		Landing Site Table Mod
59455G		TACAN Orb NAV-date ACG and D/L
59547C		OI2 Reconfig Base Update (IL Ref Only)
59564B		Add MSBLS for DAKAR (TAL) (IL Ref Only)
59571		Add Corrections to Rendez Nav (IL Ref Only)
59605B		On-Orbit Rendezvous NAV DL
59606		Header Format 22 Bandwidth Change
59619		Rendezvous LDR Downlist
59650		CR Implementation Baseline-March 1983
59652B		STS-9 CYCLE 1 NAV/LAND SITE (IL Ref Only)
59709		TACAN Orbit NAV Op Code
59750		FSSR Update 2

Table R.2-1. Historical Change Request Summary		
CR No.	OI	CR Title
59761B		GN&C Downlist Deletions
59818		CR 399170 Cleanup (Ref Only)
59926D		STS-11 Cycle 1 NAV I-Loads (Ref Only)
59939B		Nav Matrix Prop Rate (Ref Only)
59953		I-Load Scrub: RNDZ NAV
59960		I-Load Scrub: Land Site (Information Only)
69034A		Orbit Targeting I-Loads
69055A		Orbit Targeting STS-13 Only IL's
69056		STS-13 Cycle 1 Nav I-Loads (Ref Only)
69057A		On-Orbit Nav Update (IL Ref Only)
69070		FSSR Update 3 (OI2, 3, and 4)
69075		Add TACAN for Zaragoza (I-Load Only)
69097C		TACAN D/L Parent MSID's
69125B		CR Implementation Baseline – September 1983
69139		OPS 2/8 S/V Uplink Processing
69154A		STS-14 Cycle 1 NAV I-Loads (Ref Only)
69166		Add MSBLS at Zaragoza – STS-9 (Ref Only)
69187A		Delete OPS2_FLAG-TACAN ORB NAV
69212		I/L's for the Zaragoza MSBLS (Ref Only)
69240		Star Tracker Angle I-Loads (Ref Only)
69251A		Dakar Survey Update (IL Ref Only)
69267B		Fixed I-Loads Base (IL Ref Only)
69272		Orb TACAN Sites—001 Through 180 (IL Ref Only)
69273		Orb TACAN Sites—181 Through 250 (IL Ref Only)
69274		Rendezvous NAV I-Load Base (Ref Only)
69447B		On-Orbit Guid/UPP Requirements Update
69477		Orbit TACAN 001-180, inc=57 (IL Ref Only)
69478		Orbit TACAN 181-250, inc=57 (IL Ref Only)
69589A		Delete Char Data From D/L
69601		I_RHO Comp in REND NAV INTERP
69772		Doc Global Table U/L Protect
69777		Atmosphere I-Load Update (Ref Only)
69858		O/O TACAN HW TLM Status Bit
69973		PDP Rendezvous Target I-Load (Ref Only)
79109		State Vector Interpolation Doc Change
79425		CR Effectivity Baseline April 1985

Table R.2-1. Historical Change Request Summary		
CR No.	OI	CR Title
79499		FSSR Update 5
79790A		CR Implementation Baseline – November 1985
79801G	20	On–Orbit/Rendezvous NAV D/L Cleanup
79930D		FSSR Update 6
89387D		Time-Homogeneous State Vector Display
89493B		FSSR Errata, STS 83-0006B
89542		K-Load Changes for STS 83-0003B OI-8B
89599C		Cleanup Level-B GN&C Document
89622A		I-Load Changes for STS 83-0003B
89648A		STS 83-0006B PCN-1 Errata
89661		OI-8B K-Load Baseline
89662B		FSSR STS 83-0003B Errata Update
89692B	20	Orbit Targeting Protect and Alarm
89813B	20	IMU BITE Mask via SPEC 21
89866		Single Precision V_AVGG
89947A		STS 83-0005B PCN-2 Errata
89980A		STS 83-0006B PCN-2 Errata
90185A	20	Add CR Field to FSSR I/O Tables
90374C	20	Automated FSSR Constants
90444	21	Intermediate Predicted States Not Available for Downlink
90528A	22	EARTH_POLE Initialization
90606E	23	PFS/BFS ICD Baseline
90690A	24	Deletion of EQTN MSID Column from K–Load FSSR Tables
90705H	25	3 Engines Out Auto Contingency
90781C	24	Define Parametric Data Nomenclature(s)
90790	24	Add Memory Configuration to the FSSR I–Load Tables
90814C	24	Add Description of Database Generated FSSR Parameter Tables
90885D	24	FSSR Documentation Changes, On–Orbit Nav
90890	24	More FSSR-20 Display Documentation Cleanup
90966A	24	Deletion of the Qualifier from the FSSR I–Load Tables
91066D	25	Standardize the FSSR Correlation Tables
92027B	25	TDMS-2 Required FSSR Changes