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SPACE SHUTTLE
ON-ORBIT FLIGHT CONTROL
SOFTWARE REQUIREMENTS
(Preliminary Version)

December 1975

Recommended for Inclusion in
Space Shuttle Orbiter
Orbital Flight Test
Level C
Functional Subsystem
Software Requirements Document
Guidance, Navigation and Control
Part C
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The Charles Stark Draper Laboratory, Inc.
Cambridge, Massachusetts 02139

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Publication of this report does not constitute approval by NASA of the findings or conclusions contained herein. It is published for the exchange and stimulation of ideas.

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3. Overview

3.1 Relationship to Other GN&C Functions

The GN&C on-orbit flight control function is accomplished in a software module referred to as the Flight Control (FC) or On-Orbit Flight Control (OFC) module. Figure 3.1-1 shows the relationship of the FC module to other GN&C major functions.

3.2 On-Orbit Flight Control Module Overview

Figure 3.2-1 illustrates the interface categories of the FC module, and indicates the general functional relationship of the reconfiguration logic and control law implementation within the FC module.

3.3 Abbreviations

The following specialized acronyms or abbreviations are used in this publication:

cg	center of gravity
DAP	digital autopilot
D&C	Display and Control
FC	Flight Control
GN&C	Guidance, Navigation and Control
GUID	Guidance
MSC	Moding, Sequencing, and Control
NAV	Navigation
OFC	On-Orbit Flight Control
OMS	Orbital Maneuvering System
RCS	Reaction Control System
RHC	Rotational Hand Controller
RM	Redundancy Management
SF	specialist function
SOP	Subsystem Operating Procedure
TBD	to be determined
THC	Translational Hand Controller
TVC	thrust vector control

The tabular parameter descriptions in Section 4 use the following type code:

A(i) - Array (i)
V(i) - Vector (i)
M(i,j) - Matrix (i,j)

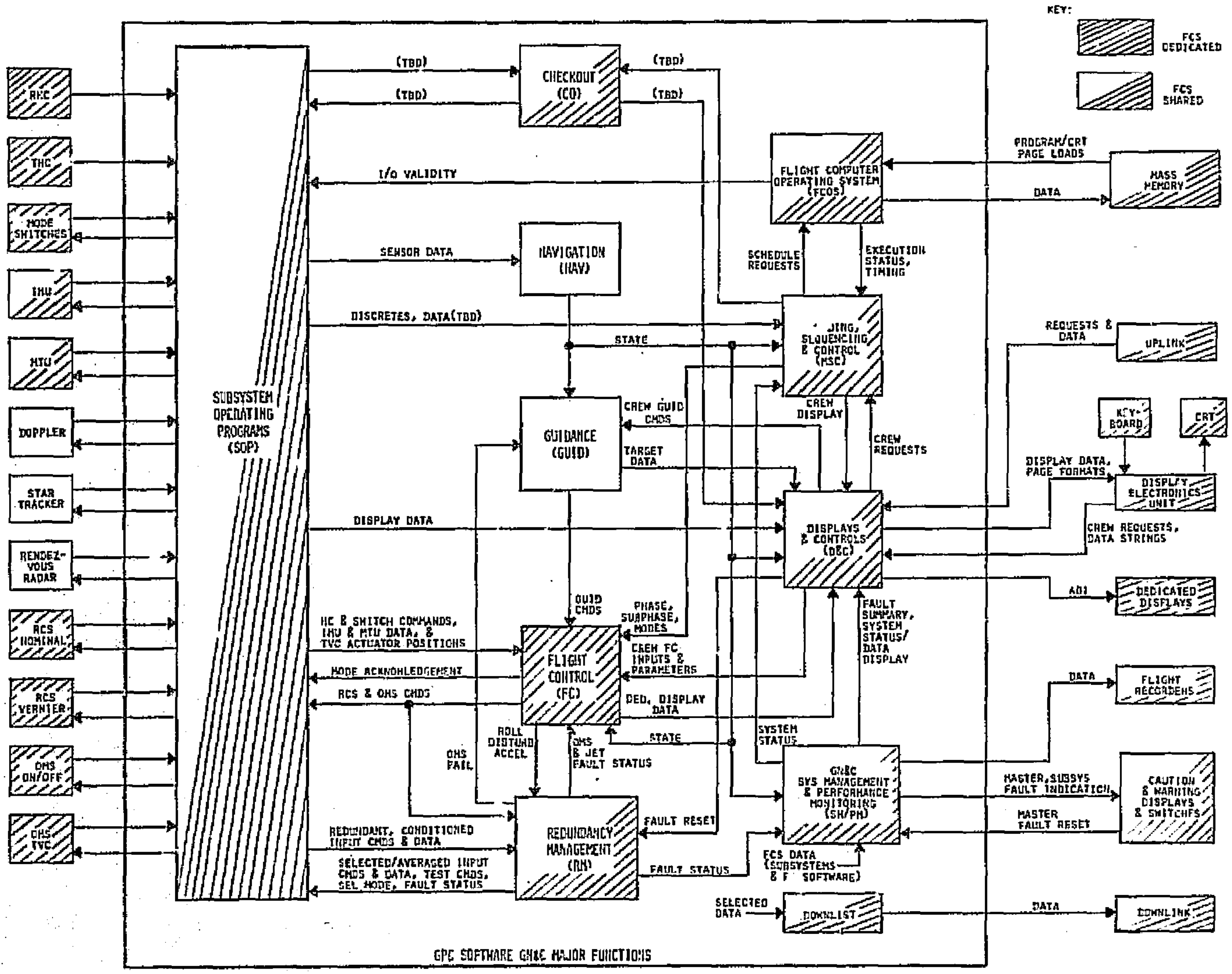

Figure 3.1-1. Relationship of FC module to other GN&C major functions.

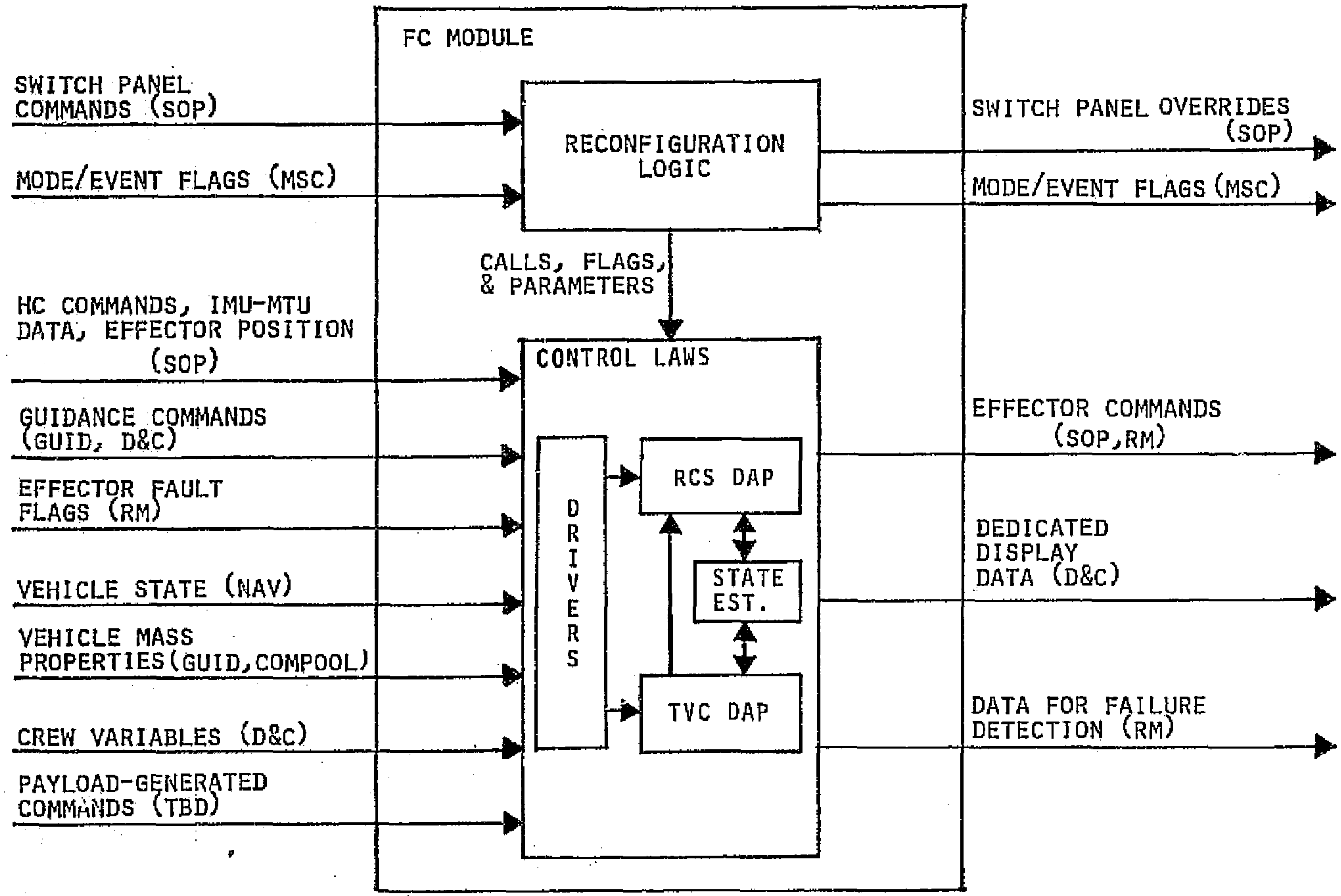

Figure 3.2-1. Relationship of FC module reconfiguration logic and control laws.

S	-	Scalar
B	-	Boolean
I	-	Integer

Example: A(3)I signifies an array of three integers.

4. Functional Requirements

4.1 Interface Requirements

Overall interface requirements for the OFC module are given in Tables 4.1-1 and 4.1-2. This interface specification presupposes the existence of two specialized software modules (possibly located within the SOP group) to interface the OFC module with the rotational hand controller and the switch panel. RHC_READ will convert the controller scalar outputs to integer form (with a range of -1,0,1, where a nonzero value indicates the controller is out of detent and gives the sense of the deflection) and will set a flag when the controller is deflected beyond the soft stop. The routine will incorporate hysteresis to prevent chatter at the switching points. PANEL_SWITCH_INTERP will convert the panel switch settings to a form directly useable by the OFC module. In particular, the module will provide the following:

Discretes	Integers	Scalars
High/low rotation acceleration	Manual rotation submode	Attitude deadband
High/low translation acceleration	Manual translation submode	Manual rotation discrete rate
Nominal/vernier RCS jets		Manual rotation pulse size
		Manual translation pulse size
		Off-axis rate thresholds for compensation

Some of the scalars may be selected from a pad-loaded pool using DAP load A/B switches, and others may be selected by dedicated switches such as pure/cross-coupled, high/low deadband, etc. PANEL_SWITCH_INTERP will also accept override inputs from the OFC module when certain RCS parameters must be forced, as during RCS assistance of TVC, and will be responsible for illuminating the switch annunciators to acknowledge a selection or call attention to an override condition.

TABLE 4.1-1 INPUT PARAMETERS FOR THE OFC MODULE

NAME	DESCRIPTION	SOURCE	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)	UPDATE RATE REQ'D (HZ)
Panel Switch - Derived Commands							
DEADBAND	Attitude deadband	PANEL_SWITCH_INTERP	A(3) S	TBD	deg	25	TBD
DISC_RATE	Derived body angular rate during deflection of rotational hand controller in manual discrete rotation submode	PANEL_SWITCH_INTERP	A(3) S	TBD	deg/s	25	TBD
NOM_VERNIER_SW	RCS nominal/vernier jet select (1=nominal; 0=vernier)	PANEL_SWITCH_INTERP	B	0,1	none	25	TBD
OFF_AXIS_COMP_THRE-SHOLD	Threshold for off-axis compensation firings	PANEL_SWITCH_INTERP	A(6) S	TBD	f/s,deg/s	25	TBD
ROT_HI_LO_SW	Rotational acceleration level select (1=high; 0=low)	PANEL_SWITCH_INTERP	A(3) B	0,1	none	25	TBD
ROT_OPTION	Manual rotation submode select (1=accel; 2=pulse; 3=discrete)	PANEL_SWITCH_INTERP	A(3) I	1,2,3	none	25	TBD
ROT_PULSE_SIZE	Desired body angular rate change per deflection of rotational hand controller in manual pulse rotation submode	PANEL_SWITCH_INTERP	A(3) S	TBD	deg/s	25	TBD
TRANS_HI_LO_SW	Translational acceleration level select (1=high; 0=low)	PANEL_SWITCH_INTERP	A(3) B	0,1	none	25	TBD
TRANS_OPTION	Manual translation submode select (1=accel; 2=pulse)	PANEL_SWITCH_INTERP	A(3) I	1,2	none	25	TBD
TRANS_PULSE_SIZE	Desired velocity change per deflection of translational hand controller in manual pulse translation submode	PANEL_SWITCH_INTERP	A(3) S	TBD	f/s	25	TBD
Mode/Event Flags							

TABLE 4.1-1 INPUT PARAMETERS FOR THE OFC MODULE

NAME	DESCRIPTION	SOURCE	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)	UPDATE RATE REQ'D (HZ)
RCS_ROTATION	RCS rotation mode enable (1=enable)	MSC	B	0,1	none	25	TBD
RCS_AUTO_MANUAL	RCS auto/manual select (1=auto; 0=manual)	MSC	B	0,1	none	25	TBD
ATT_MNVR	Auto RCS rotation mode select (1=maneuver; 0=hold)	MSC	B	0,1	none	25	TBD
TWO_AXIS	Two axis maneuver enable (1=enable)	MSC	B	0,1	none	5/6	TBD
THREE_AXIS	Three axis maneuver enable (1=enable)	MSC	B	0,1	none	5/6	TBD
OMS_PRETHRUST	OMS prethrust maneuver enable (1=enable)	MSC	B	0,1	none	5/6	TBD
LCL_VERT_ATT	Local vertical maneuver enable (1=enable)	MSC	B	0,1	none	5/6	TBD
PAYLD_SUP_CMDS	Payload supplied commands maneuver enable (1=enable)	MSC	B	0,1	none	5/6	TBD
TRACKING	Tracking maneuver enable (1=enable)	MSC	B	0,1	none	5/6	TBD
BBQ	Barbecue maneuver enable (1=enable)	MSC	B	0,1	none	5/6	TBD
RCS_TRANSLATION	RCS translation mode enable (1=enable)	MSC	B	0,1	none	25	TBD
OMS_ARM_REQ	OMS engines arming request (1=request)	MSC	A(2)B	0,1	none	25	TBD
OMS_ON_REQ	OMS engines turn-on request (1=request)	MSC	A(2)B	0,1	none	25	25
TVC_AUTO_MANUAL	TVC auto/manual select (1=auto; 0=manual)	MSC	B	0,1	none	25	TBD

TABLE 4.1-1 INPUT PARAMETERS FOR THE OFC MODULE

NAME	DESCRIPTION	SOURCE	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)	UPDATE RATE REQ'T (HZ)
OFC_RESTART	OFC module initialization flag (1=init)	MSC	B	0,1	none	25	TBD
CLOSED_OPEN_LOOP_TRIM	OMS gimbal trim value select (1=closed loop: use value remaining from previous OMS burn; 0=open loop: use value computed from expected cg location)	MSC	B	0,1	none	1/maneuver	no requirement
HC Commands							
RHC	Rotational hand controller deflection	SOP	A(3)S	TBD	deg	25	TBD
THC	Translational hand controller command	SOP	A(3)I	-1, 0, 1	none	25	TBD
RHC_STATE	Rotational hand controller command	RHC_READ	A(3)I	-1,0,1	none	25	TBD
SOFT_STOP	Flag indicating rotational hand controller is deflected beyond soft stop	RHC_READ	A(3)B	0,1	none	25	TBD
Guidance Commands							
GA_COMMANDED	Commanded terminal IMU gimbal angles	GUID or D&C	A(3)S	-180 < x <= 180	deg	1/maneuver	no requirement
OMEGA_C	Commanded vehicle angular rate is stable member axes	GUID	V(3)S	TBD	deg/s	25	25
POINTING_VECTOR_CMD	Unit vector specifying commanded pointing direction, including initial OMS thrust direction in stable member axes	GUID or D&C	V(3)S	-1 to +1	none	5/6	no requirement

TABLE 4.1-1 INPUT PARAMETERS FOR THE OFC MODULE

NAME	DESCRIPTION	SOURCE	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)	UPDATE RATE REQ'D (HZ)
BODY_POINTING_VECTOR	Unit vector, in body axes, to be aligned with POINTING_VECTOR_CMD or with respect to local vertical	GUID or DEC	V(3)S	-1 to +1	none	5/6	no requirement
DELTA_V_CMD	Commanded translational velocity change	GUID or DEC	V(3)S	TBD	f/s	25	no requirement
Payload-Generated and Tracking Commands							
TBD							
IMU_MTU Data							
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	25	25
DELTA_V	IMU accelerometer data; vehicle velocity change since previous sampling	SOP	V(3)S	TBD	f/s	25	TBD
TNOW	IMU data time tag	SOP	S	TBD	s	5/6	25
Vehicle State							
POSITION	Vehicle position in stable member axes, referred to geocenter	NAV	V(3)S	TBD	f	5/6	TBD
VELOCITY	Vehicle velocity in stable member axes, referred to geocenter	NAV	V(3)S	TBD	f/s	5/6	TBD
Vehicle Mass Properties							

TABLE 4.1-1 INPUT PARAMETERS FOR THE OFC MODULE

NAME	DESCRIPTION	SOURCE	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)	UPDATE RATE REQ'D (HZ)
VEHICLE_CG	Vehicle center of gravity	SF	V(3) S	TBD	f	1/maneuver	no requirement
VEHICLE_INVERSE_IN-ERTIA	Inverse of vehicle inertia	SF	M(3,3) S	TBD	1/((slug)-(f)(f))	1/maneuver	no requirement
Effector Fault Flags							
JFAIL	RCS jet failure (1=fail)	RM	A(44) B	0, 1	none	25	25
OMS_FAIL_DETECT	OMS failure detected (1=detected)	RM	B	0, 1	none	25	25
JFAIL_CHANGE	Flag indicating change in JFAIL (1=changed)	RM	B	0, 1	none	25	25
OMS_FAIL_DETECT	OMS failure detected (1=detected)	RM	B	0, 1	none	25	25
OMS1_FAIL	OMS1 failure identified (1=identified)	RM	B	0, 1	none	25	2
OMS2_FAIL	OMS2 failure identified (1=identified)	RM	B	0, 1	none	25	25
Effector Position							
OMS1_PITCH_YAW	OMS1 engine pitch and yaw	SOP	A(2) S	TBD	deg	25	25
OMS2_PITCH_YAW	OMS2 engine pitch and yaw	SOP	A(2) S	TBD	deg	25	25
Crew Variables							
MAXDESIR_BODYRATE	Desired magnitude of body angular rate in automatic attitude maneuvers	DEC	S	0 to 5	deg/s	5/6	no requirement

TABLE 4.1-1 INPUT PARAMETERS FOR THE OFC MODULE

NAME	DESCRIPTION	SOURCE	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)	UPDATE RATE REQ'D (HZ)
BARBECUE_RATE	Desired barbecue-mode angular rate	D&C	S	TBD	deg/s	1/maneuver	no requirement
LO_PITCH_TAIL_NOSE	Tail or nose jet select for low-level pitch rotation (1=tail; 0=nose)	D&C	B	0,1	none	25	no requirement
LO_YAW_TAIL_NOSE	Tail or nose jet select for low-level yaw rotation (1=tail; 0=nose)	D&C	B	0,1	none	25	no requirement
OMS_SELECT	To burn/not to burn status of OMS engines (1=to burn; 0=not to burn)	D&C	A(2)B	0,1	none	1/maneuver	no requirement

TABLE 4.1-2 OUTPUT PARAMETERS FOR THE OFC MODULE

NAME	DESCRIPTION	DESTINATION	TYPE	RANGE	UNIT	UPDATE RATE (HZ)	SAMPLE RATE REQ'D (HZ)
Effector Commands							
JONLST	RCS jet on commands (1=on)	SOP,RM	A(44)B	0,1	none	25	25
OMS1_ON_CMD	OMS1 engine on command (1=on)	SOP,RM	B	0,1	none	25	25
OMS2_ON_CMD	OMS2 engine on command (1=on)	SOP,RM	B	0,1	none	25	25
OMS1_PITCH_YAW_CMD	OMS1 engine pitch and yaw commands	SOP,RM	A(2)S	TBD	deg	25	25
OMS2_PITCH_YAW_CMD	OMS2 engine pitch and yaw commands	SOP,RM	A(2)S	TBD	deg	25	25
Dedicated Display Data							
AUTO_GA_DESIRED	Desired IMU gimbal angles computed by automatic driver	D&C	A(3)S	-180 < x <= 180	deg	5/6	TBD
GA_DESIRED	Desired IMU gimbal angles	D&C	A(3)S	-180 < x <= 180	deg	25	TBD
GA_MANEUVER_TERMIN-AL	Desired terminal IMU gimbal angles	D&C	A(3)S	-180 < x <= 180	deg	1/maneuver	TBD
MANEUVER_COMPLETE	Flag signifying completion of maneuver	D&C	B	0,1	none	5/6	TBD
RATE_EST	Body angular rate estimate	D&C	V(3)S	TBD	deg/s	25	TBD
RATE_ERROR	Body angular rate error	D&C	V(3)S	TBD	deg/s	25	TBD
Data for Failure Detection							
DISTURB_ACCEL_EST (roll component)	Body angular disturbance acceleration estimate	RM	V(3)S	TBD	deg/((s)(-s))	25	25

TABLE 4.1-2 OUTPUT PARAMETERS FOR THE OFC MODULE

NAME	DESCRIPTION	DESTINATION	TYPE	RANGE	UNIT	UPDATE RATE (HZ)	SAMPLE RATE REQ'D (HZ)
Panel Switch Overrides							
NOM_VERNIER_SW	RCS nominal/vernier jet select (1=nominal; 0=vernier)	PANEL_SWITCH_INTERP	L	0,1	none	25	TBD
ROT_HI_LO_SW	Rotational acceleration level select (1=high; 0=low)	PANEL_SWITCH_INTERP	A(3)B	0,1	none	25	TBD
TRANS_HI_LO_SW	Translational acceleration level select (1=high; 0=low)	PANEL_SWITCH_INTERP	A(3)B	0,1	none	25	TBD
ROT_OPTION	Manual rotation submode select (1=accel; 2=pulse; 3=discrete)	PANEL_SWITCH_INTERP	A(3)I	1,2,3	none	25	TBD
Mode/Event Flags							
OFC_RESTART	OFC module initialization flag (1=init)	HSC	B	0,1	none	25	TBD

Also assumed in this definition is the existence of a specialist function (SF), which will enable the alteration of values in memory. The SF would operate through the displays and controls (D&C) software but on a nondedicated basis, enabling access to any region of memory.

4.2 Detailed Functional Requirements

This section describes the functional requirements of the OFC module in two subsections, reconfiguration module and control law module.

4.2.1 Reconfiguration Module

4.2.1.1. Function

Figure 4.2.1.1-1 illustrates the major reconfiguration functions of OFC_RECON and their general relationship to the configuration-controlling inputs of the OFC module. The decision is first made as to whether TVC or RCS operations are needed. The required TVC or RCS driver modules are set up and executed, and the required component modules of the TVC and/or RCS DAP are likewise set up and executed. Setting up includes initializing, and specifying configuration-dependent parameters such as rates and gains, in response to a commanded mode or configuration change. Equally important to effecting such a change are the cleanup activities, which include forcing DAP outputs to zero or to nominal values when the particular DAP has been deactivated, and making last calls to certain DAP modules for the same purpose. Execution includes selecting and sequencing the control law modules as dictated by the moding inputs. Not shown in the diagram are the more routine executive duties of OFC_RECON, such as clocking the "slow" (5/6 Hz) driver modules, and calling the State Estimator modules every OFC minor cycle.

For clarity in presentation, the remainder of this section, which describes the OFC_RECON execution-sequencing function, distinguishes among three types of variables. First, there are the controlling inputs, generated both externally to OFC and within the control laws, in meaningful logical combinations. Second, there are the resulting "outputs" of OFC_RECON, consisting of sequenced calls to selected control law function modules. Third, there are the OFC modes, which are the definitions by which the OFC_RECON functions and their purposes are made more easily understood.

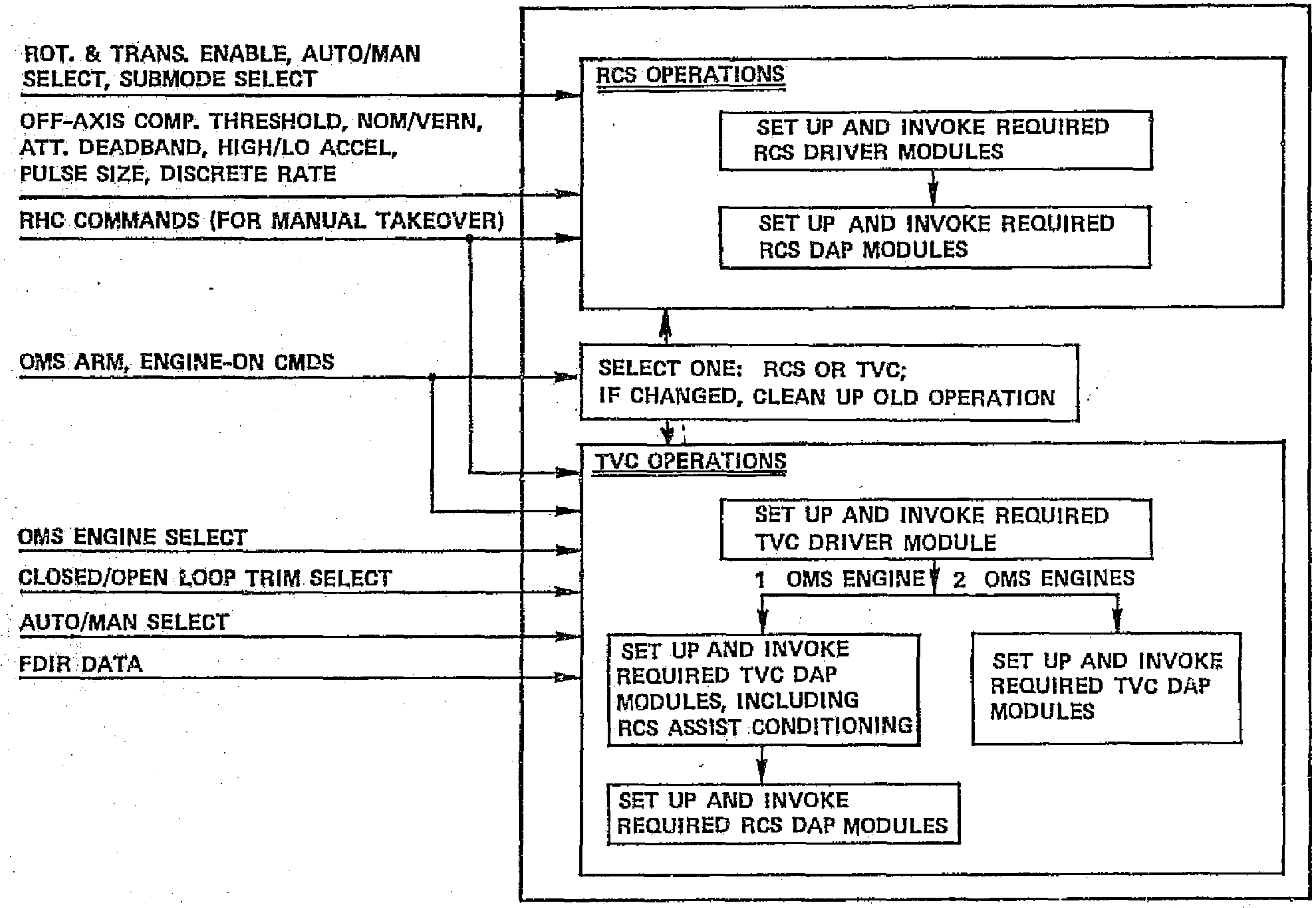

Figure 4.2.1.1-1. OFC reconfiguration module major functions.

Table 4.2.1.1-1 relates the first two variable types, in conjunction with the control law module block diagram, Figure 4.2.2-1. The "switches" in this diagram control data flow among the function modules, and their positions define which modules are needed and, to an extent, their sequencing requirements. (If, with a given switch configuration, module A's outputs are not received anywhere, then module A is not needed. Also, if module B drives only module A, it too is not needed. Generally, if B drives A and both are needed, B should precede A; however, exceptions to this can be found as "one cycle delays" in Figure 4.2.2-1.) Logical combinations of controlling inputs required for each switch position are given in the referenced table.

The first and third variable types are related in Table 4.2.1.1-2, which defines an OFC mode-submode-condition combination for each significant combination of inputs.

With the OFC modes defined, the OFC_RECON actions for these modes are described in two ways. First, Table 4.2.1.1-3 relates the OFC modes to the requisite function modules by specifying a set of switch positions (referring again to Figure 4.2.2-1) for each modal subdivision. Second, the diagrams of Figure 4.2.1.1-2 present an OFC mode-by-mode specification of the required sequences in which the control law function modules must be invoked. The requirements are read vertically from the top of the diagram. Requirements for sequential execution are indicated with solid line arrows running down from "earlier" modules to "later" modules. For those cases in which two or more modules are at a given level there is no execution sequencing requirement among these modules.

For example, in diagram/mode I.A.1., module 1.4 (AUTO_TVC) must be executed before module 4.4 in a given OFC minor cycle; similarly, module 4.6 must be executed prior to module 4.4. There is no requirement as to the execution sequence of 1.4 with respect to 4.6 (or 3.1). (Later developments may indicate that transport delays might be alleviated by executing one or the other of these first, but this document does not deal with such considerations at present.) Both modules 4.11 and 4.10 must be executed before 4.12 on a given FC cycle.

Table 4.2.1.1-1. Relationship between OFC RECON outputs and moding inputs (page 1 of 2).

OFC RECON OUTPUT (Refer to Fig. 4.2.2-1) SWITCH	POSITION	MODING INPUT COMBINATION (See Note 1)
S1 (Note 2)	A	RCS_TRANSLATION·NOM_VERNIER_SW·[$\overline{\text{RCS\_AUTO\_MANUAL}}$ + $\overline{\text{DETENT}}$]·TRANS_OPTION = 1(ACCEL)
	B	RCS_TRANSLATION·NOM_VERNIER_SW·[$\overline{\text{RCS\_AUTO\_MANUAL}}$ + $\overline{\text{DETENT}}$]·TRANS_OPTION = 2(PULSE)
	C	RCS_TRANSLATION·NOM_VERNIER_SW·RCS_AUTO_MANUAL·DETENT
	D	$\overline{\text{RCS\_TRANSLATION}}$ + $\overline{\text{NOM\_VERNIER\_SW}}$
S2	A	RCS_ROTATION·TWO_AXIS
	B	RCS_ROTATION·THREE_AXIS
	C	RCS_ROTATION·OMS_PRETHRUST
	D	RCS_ROTATION·BBQ
	E	[$\overline{\text{TWO\_AXIS + THREE\_AXIS + OMS\_PRETHRUST + BBQ}}$] + $\overline{\text{RCS\_ROTATION}}$
S3	A	TWO_AXIS·RCS_ROTATION
	B	THREE_AXIS·RCS_ROTATION
	C	OMS_PRETHRUST·RCS_ROTATION
	D	BBQ·RCS_ROTATION
	E	LCL_VERT_ATT·RCS_ROTATION
	F	PAYLD_SUP_CMDS·RCS_ROTATION
	G	TRACKING·RCS_ROTATION
	H	$\overline{\text{RCS\_ROTATION}}$ + [$\overline{\text{TWO\_AXIS + THREE\_AXIS + OMS\_PRETHRUST + BBQ + LCL\_VERT\_ATT + PAYLD\_SUP\_CMDS + TRACKING}}$]
S4 (Note 2)	A	RCS_ROTATION·RCS_AUTO_MANUAL·DETENT·ATT_MNVR
	B	RCS_ROTATION·RCS_AUTO_MANUAL·DETENT·$\overline{\text{ATT\_MNVR}}$
	C	RCS_ROTATION·[$\overline{\text{RCS\_AUTO\_MANUAL}}$ + $\overline{\text{DETENT}}$]·ROT_OPTION =3(DISC)·$\overline{\text{SOFT\_STOP}}$
	D	$\overline{\text{RCS\_ROTATION}}$ + [$\overline{\text{RCS\_AUTO\_MANUAL}}$ + $\overline{\text{DETENT}}$]·[ROT_ OPTION≠3(DISC) + SOFT_STOP]
S5	A	$\overline{\text{RCS\_ASSIST\_P\_Y}}$
	B	RCS_ASSIST_P_Y
S6	A	$\overline{\text{RCS\_ASSIST\_ROLL}}$
	B	RCS_ASSIST_ROLL

Table 4.2.1.1-1. Relationship between OFC RECON outputs and moding inputs (page 2 of 2).

OFC_RECON OUTPUT (Refer to Fig. 4.2.2-1) SWITCH	POSITION	MODING INPUT COMBINATION (See Note 1)
S7 (Note 2)	A	RCS_ASSIST_ROLL + [RCS_ROTATION·RCS_AUTO_MANUAL·DETENT] + [RCS_ROTATION·[$\overline{\text{RCS\_AUTO\_MANUAL}}$ + $\overline{\text{DETENT}}$]·$\overline{\text{SOFTSTOP}}$·ROT_OPTION=3(DISC)]
	B	$\overline{\text{RCS\_ASSIST\_ROLL}}$·RCS_ROTATION·[$\overline{\text{RCS\_AUTO\_MANUAL}}$ + $\overline{\text{DETENT}}$]·[SOFT_STOP + ROT_OPTION=1(ACCEL)]
	C	$\overline{\text{RCS\_ASSIST\_ROLL}}$·RCS_ROTATION·[$\overline{\text{RCS\_AUTO\_MANUAL}}$ + $\overline{\text{DETENT}}$]·$\overline{\text{SOFT\_STOP}}$·ROT_OPTION=2(PULSE)
	D	$\overline{\text{RCS\_ROTATION}}$·$\overline{\text{RCS\_ASSIST\_ROLL}}$
S8	A	RCS_ROTATION + [RCS_TRANSLATION·NOM_VERNIER_SW] + RCS_ASSIST_ROLL
	B	$\overline{\text{RCS\_ROTATION}}$ · [$\overline{\text{RCS\_TRANSLATION}}$ + $\overline{\text{NOM\_VERNIER\_SW}}$]·$\overline{\text{RCS\_ASSIST\_ROLL}}$
S9	A	RCS_ASSIST_ROLL
	B	$\overline{\text{RCS\_ASSIST\_ROLL}}$
S10	A	RCS_ASSIST_P_Y
	B	$\overline{\text{RCS\_ASSIST\_P\_Y}}$
S11	A	$\overline{\text{TVC\_AUTO\_MANUAL}}$
	B	TVC_AUTO_MANUAL·$\overline{\text{RCS\_ASSIST\_P\_Y}}$
	C	TVC_AUTO_MANUAL·RCS_ASSIST_P_Y
S12 (Note 3)	A (Note 2)	[OMS_FAIL_DETECT·TVC] + [OMS_PRETHRUST·$\overline{\text{CLOSED\_OPEN\_LOOP\_TRIM}}$·ONE_ENGINE]
	B	[$\overline{\text{OMS\_PRETHRUST}}$·$\overline{\text{OMS\_FAIL\_DETECT}}$] + [OMS_PRETHRUST·CLOSED_OPEN_LOOP_TRIM]
	C	OMS_SELECT$_1$·OMS_SELECT$_2$·OMS_PRETHRUST·$\overline{\text{CLOSED\_OPEN\_LOOP\_TRIM}}$
S13 (Note 2)	A	$\overline{\text{OMS\_FAIL\_DETECT}}$·TVC
	B	[OMS_FAIL_DETECT·TVC] + [OMS_PRETHRUST·FIRST PASS·RCS]
S14 (Note 4)	A	$\overline{\text{LATCH\_ASSIST\_PITCH\_YAW}}$·FAIL_ID·TVC
	B	LATCH_ASSIST_PITCH_YAW + $\overline{\text{FAIL\_ID}}$ + $\overline{\text{TVC}}$
S15	A	TVC + OMS_PRETHRUST
	B	$\overline{\text{TVC}}$·$\overline{\text{OMS\_PRETHRUST}}$

Notes:

1. Logical symbols used: $+$ = or, $\oplus$ = exclusive or, $\cdot$ = and, $\overline{x}$ = not x.

2. The following mode abbreviations are used:

   $$\text{TVC} = [\text{OMS\_ARM\_REQ}_1 \cdot \text{OMS\_ON\_REQ}_1 \cdot \overline{\text{OMS1\_FAIL}}] + [\text{OMS\_ARM\_REQ}_2 \cdot \text{OMS\_ON\_REQ}_2 \cdot \overline{\text{OMS2\_FAIL}}]$$

   FAIL_ID = OMS1_FAIL + OMS2_FAIL

   $\text{ONE\_ENGINE} = \text{OMS\_SELECT}_1 \oplus \text{OMS\_SELECT}_2$

   RCS_ASSIST_ROLL = TVC·[FAIL_ID + ONE_ENGINE]

   RCS_ASSIST_P_Y = RCS_ASSIST_ROLL·ASSIST_PITCH_YAW (See Note 4)

   DETENT = value of RHC_STATE is 0.

3. The associated modules are executed only once during the OMS_PRETHRUST initialization pass or during the first pass after FAIL_ID.

4. OFC_RECON logic permits cycling between execution of RCS_ ASSIST_PITCH_YAW and TVC_LAW_PITCH_YAW and back to RCS_ ASSIST_PITCH_YAW once (both modules may not be executed in the same pass); once this cycling has occurred, OFC_ RECON logic is "latched" to invoke RCS_ASSIST_PITCH_YAW for the duration of the OMS burn.

   This is mechanized in OFC_RECON as follows: ASSIST_PITCH_YAW is set to 1 if less than TBD time has elapsed since FAIL_ID, and afterwards is controlled by the module PITCH_YAW_ASSIST_ COMPUTATION; however, if ASSIST_PITCH_YAW makes the successive transitions 1→0, 0→1, LATCH_ASSIST_PITCH_YAW is set to 1 and holds ASSIST_PITCH_YAW = 1 for the remainder of the TVC mode.

In general, the sequential execution requirements are determined by the data flow requirements between OFC modules. Occasionally, however, an OFC module must provide OFC_FLCON with information to decide which modules to invoke or to determine parameter settings for subsequently invoked OFC modules. Also, in the case where an automatic driver is required to generate display data, but an attitude hold or manual driver is actually to control the RCS DAP, then the "controlling" driver must be called after the display-generating driver to overwrite the relevant RCS DAP commands. Such exceptional relationships are indicated in the diagrams with dashed lines rather than solid lines.

The diagrams are preceded by an outline listing the OFC modes in the order of the diagrams. The module numbering corresponds to that of the subsections of Section 4.2.2.

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Table 4.2.1.1-2. Relationships between moding inputs and OFC modes.

MODING INPUT COMBINATION (SEE NOTE 1)	OFC MODE, SUBMODE & CONDITION (SEE NOTE 2)				
[OMS_ARM_REQ$_1$ • OMS_ON_REQ$_1$ • $\overline{\text{OMS1\_FAIL}}$]+ [OMS_ARM_REQ$_2$ • OMS_ON_REQ$_2$ • $\overline{\text{OMS2\_FAIL}}$]	TVC				
TVC_AUTO_MANUAL/ $\overline{\text{TVC\_AUTO\_MANUAL}}$		AUTO/ MANUAL			
OMS_ARM_REQ$_1$ • OMS_ON_REQ$_1$ • OMS_ARM_REQ$_2$ • OMS_ON_REQ$_2$ • $\overline{\text{OMS\_FAIL\_DETECT}}$		(SEE NOTE 3)	NOMINAL 2-ENGINE BURN, NO FAILURE		
OMS_FAIL_DETECT • $\overline{\text{OMS1\_FAIL}}$ • $\overline{\text{OMS2\_FAIL}}$			FAILURE DETECTION WITHOUT IDENTIFICATION		
[OMS1_FAIL + OMS2_FAIL + [OMS_SELECT$_1$ ⊕ OMS_SELECT$_2$]] • $\overline{\text{RCS\_ASSIST\_P\_Y}}$ (SEE NOTE 4)			RCS ASSIST ROLL ONLY		
RCS_ASSIST_P_Y (SEE NOTE 4)			RCS ASSIST ROLL AND PITCH_YAW		
[<TBD TIME SINCE RCS_ASSIST_ROLL] + LATCH_ASSIST_PITCH_YAW (SEE NOTE 4)				UNCONDITIONAL	
[>TBD TIME SINCE RCS_ASSIST_ROLL] • $\overline{\text{LATCH\_ASSIST\_PITCH\_YAW}}$ (SEE NOTE 4)				CONDITIONAL	
[$\overline{\text{OMS\_ARM\_REQ}_1}$ + $\overline{\text{OMS\_ON\_REQ}_1}$ + OMS1_FAIL] • [$\overline{\text{OMS\_ARM\_REQ}_2}$ + $\overline{\text{OMS\_ON\_REQ}_2}$ + OMS2_FAIL]	RCS				
RCS_ROTATION		ROTATION			
RCS_AUTO_MANUAL • [RHC_STATE = 0]			AUTO		
$\overline{\text{ATT\_MNVR}}$				ATTITUDE HOLD	
ATT_MNVR				ATTITUDE MANEUVER	
TWO_AXIS					TWO AXIS
THREE_AXIS					THREE AXIS
BBQ					BARBEQUE
LCL_VERT_ATT					LOCAL VERTICAL
PAYLD_SUP_CMDS					PAYLOAD
TRACKING					TRACKING
					OMS/PRETHRUST

ATT_MNVR				ATTITUDE MANEUVER				
TWO_AXIS					TWO AXIS			
THREE_AXIS					THREE AXIS			
BBQ					BARBEQUE			
LCL_VERT_ATT					LOCAL VERTICAL			
PAYLD_SUP_CMDS					PAYLOAD			
TRACKING					TRACKING			
OMS_PRETHRUST					OMS PRETHRUST MANEUVER AND OMS ENGINE TRIM			
CLOSED_OPEN_LOOP_TRIM						CLOSED-LOOP TRIM		
$\overline{\mathrm{CLOSED\_OPEN\_LOOP\_TRIM}}$						OPEN-LOOP TRIM		
$[\overline{\mathrm{OMS\_SELECT}_1 \oplus \mathrm{OMS\_SELECT}_2}]$							2 ENG.	
$\mathrm{OMS\_SELECT}_1 \oplus \mathrm{OMS\_SELECT}_2$							1 ENG.	
$\overline{\mathrm{RCS\_AUTO\_MANUAL}} + [\mathrm{RHC\_STATE} \neq 0]$			MANUAL					
$[\mathrm{ROT\_OPTION}_{\mathrm{AXIS}} = 1] + \mathrm{SOFT\_STOP}_{\mathrm{AXIS}}$				ACCELERATION				SEE NOTE 5
$[\mathrm{ROT\_OPTION}_{\mathrm{AXIS}} = 2] \cdot \overline{\mathrm{SOFT\_STOP}_{\mathrm{AXIS}}}$				PULSE				
$[\mathrm{ROT\_OPTION}_{\mathrm{AXIS}} = 3] \cdot \overline{\mathrm{SOFT\_STOP}_{\mathrm{AXIS}}}$				DISCRETE				
$\mathrm{RCS\_TRANSLATION} \cdot \mathrm{NOM\_VERNIER\_SW}$		TRANSLATION						
$\mathrm{RCS\_AUTO\_MANUAL} \cdot [\mathrm{RHC\_STATE} = 0]$			AUTO					
$\overline{\mathrm{RCS\_AUTO\_MANUAL}} + [\mathrm{RHC\_STATE} \neq 0]$			MANUAL					
$\mathrm{TRANS\_OPTION}_{\mathrm{AXIS}} = 1$				ACCELERATION				(SEE NOTE 5)
$\mathrm{TRANS\_OPTION}_{\mathrm{AXIS}} = 2$				PULSE				

NOTES:

1. LOGICAL SYMBOLS USED: $+$ = OR, $\oplus$ = EXCLUSIVE OR, $\cdot$ = AND, $\overline{X}$ = NOT X.
2. ALL MODES IN A GIVEN CONTIGUOUS VERTICAL STACK ARE MUTUALLY EXCLUSIVE EXCEPT RCS ROTATION/TRANSLATION.
3. ALTHOUGH MUTUALLY EXCLUSIVE, AUTO/MANUAL TVC ARE TREATED TOGETHER TO AVOID REPETITION.
4. THIS CONDITION IS EXPLAINED IN TABLE 4.2.1 1-1.
5. MANUAL RCS SUBMODES MAY BE MIXED AMONG THE 3 AXES.

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Table 4.2.1.1-3. Relationship between OFC modes and OFC_RECON outputs.

OFC MODE, SUBMODE & CONDITION			S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
			OFC_RECON OUTPUT (REFER TO FIG. 4.2.2-1) SWITCHES AND POSITIONS (NUMBERS IN PARENTHESES REFER TO NOTES)														
TVC	AUTO	2 ENGINES, NO FAILURE	D	(1)	H	D	A	A	D	B	B	B	B	B	A	B	A
TVC	AUTO	FAIL DETECT, NO ID					A	A	D	B	B	B	B	A	B	B	
TVC	AUTO	RCS ASSIST ROLL ONLY					A	B	A	A	A	B	B	A	B	A	
TVC	AUTO	RCS ASSIST ROLL AND PITCH-YAW: CONDITIONAL					B	B	A	A	A	A	C	A	B	A	
TVC	AUTO	RCS ASSIST ROLL AND PITCH-YAW: UNCONDITIONAL					B	B	A	A	A	A	C	A	B	B	
TVC	MANUAL	2 ENGINES, NO FAILURE					A	A	D	B	B	B	A	B	A	B	
TVC	MANUAL	FAIL DETECT, NO ID					A	A	D	B	B	B	A	A	B	B	
TVC	MANUAL	RCS ASSIST ROLL ONLY					A	B	A	A	A	B	A	A	B	A	
TVC	MANUAL	RCS ASSIST ROLL AND PITCH-YAW: CONDITIONAL					B	B			A	A	A	A	B	A	
TVC	MANUAL	RCS ASSIST ROLL AND PITCH-YAW: UNCONDITIONAL	D	(1)	H	D	B	B			A	A	A	A	B	B	A
RCS	ROTATION	AUTO: ATT. HOLD	(3)	(4)	(4)	B	A	A			(1)	(1)	(1)	(1)	(1)		B
RCS	ROTATION	AUTO: ATTITUDE MANEUVER: TWO AXIS		A	A	A											
RCS	ROTATION	AUTO: ATTITUDE MANEUVER: THREE AXIS		B	B												
RCS	ROTATION	AUTO: ATTITUDE MANEUVER: BARBEQUE		D	D												
RCS	ROTATION	AUTO: ATTITUDE MANEUVER: LOCAL VERTICAL		E	E												
RCS	ROTATION	AUTO: ATTITUDE MANEUVER: PAYLOAD		E	F												
RCS	ROTATION	AUTO: ATTITUDE MANEUVER: TRACKING		E	G								(1)	(1)		B
RCS	ROTATION	AUTO: ATTITUDE MANEUVER: OMS PRETHRUST: INITIALIZATION PASS: OPEN-LOOP TRIM: 2 ENGINES		C	C									C	B		A
RCS	ROTATION	AUTO: ATTITUDE MANEUVER: OMS PRETHRUST: INITIALIZATION PASS: OPEN-LOOP TRIM: 1 ENGINE		C	C									A	C		[illegible]
RCS	ROTATION	AUTO: ATTITUDE MANEUVER: OMS PRETHRUST: INITIALIZATION PASS: CLOSED-LOOP TRIM		C	C									B	B		A
RCS	ROTATION	AUTO: ATTITUDE MANEUVER: OMS PRETHRUST: LATER PASSES	(3)	C	C	A			A					(1)	(1)		B
RCS	ROTATION	MANUAL: ACCELERATION	(2)	(4)	(4)	D			B								
RCS	ROTATION	MANUAL: PULSE	(2)			D			C								
RCS	ROTATION	MANUAL: DISCRETE	(2)			C			A								
RCS	TRANSLATION	AUTO	C			(2)			A								
RCS	TRANSLATION	MANUAL: ACCELERATION	A			(3)			(4)								
RCS	TRANSLATION	MANUAL: PULSE	B	(4)	(4)	(3)	A	A	(4)	A	(1)	(1)	(1)	(1)	(1)	B	B

NOTES: 1. NOT APPLICABLE
2. A OR B
3. C OR D
4. ALL POSITIONS COMPATIBLE

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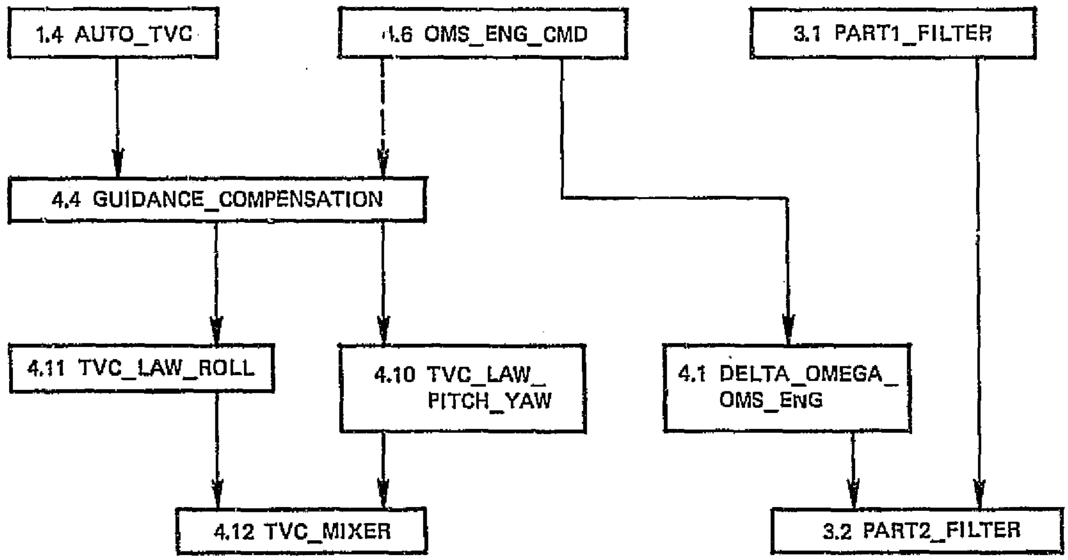
OFC MODES AND SUBMODES

I. TVC	A. AUTO	1. Nominal 2-Engine, No Failure 2. Failure Detection, No Failure Id'n a. First Pass b. Subsequent Pass 3. RCS Assist - Roll Only 4. RCS Assist - Roll and P/Y a. Not Latched and Time > TBD b. Latched or Time < TBD
	B. MANL	1.-4. (Same as above)
II. RCS ROTATION	A. AUTO	1. Two Axis Att Mnvr 2. Three Axis Att Mnvr 3. Barbeque 4. Attitude Local Vertical 5. Payload Attitude 6. Misc Tracking (1.–6.: a. Maneuver; b. Attitude Hold) 7. OMS Prethrust a. First Pass 1) Open Loop Trim a) 2-Engine (1) Maneuver (2) Attitude Hold b) 1-Engine (1) Maneuver (2) Attitude Hold 2) Closed Loop Trim a) Maneuver b) Attitude Hold b. Subsequent Pass 1) Maneuver 2) Attitude Hold
	B. MANL	1. Two Axis a. No Att Hold (= Free Drift) 1) Accel (all axes) 2) Pulse (all axes) 3) Mixed Accel and Pulse b. Att Hold (Disc, all axes) c. Mixed Modes, axis by axis 2.-7. (Same as above)
III. RCS TRANSLATION	A. AUTO	
	B. MANL	1. Accel, Accel 2. Pulse, Pulse 3. Accel, Pulse 4. Pulse, Accel

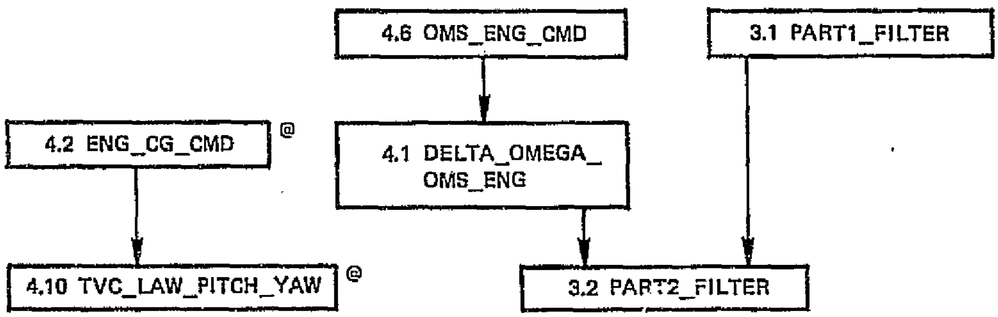
Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 1 of 21).

I.A.1

OMS TVC AUTO NOMINAL 2-ENGINE



I.A.2 FAILURE DETECTION



@Executed first pass Fail Detection only

Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 2 of 21).

I.A.3

TVC AUTO

RCS ASSIST_ROLL ONLY

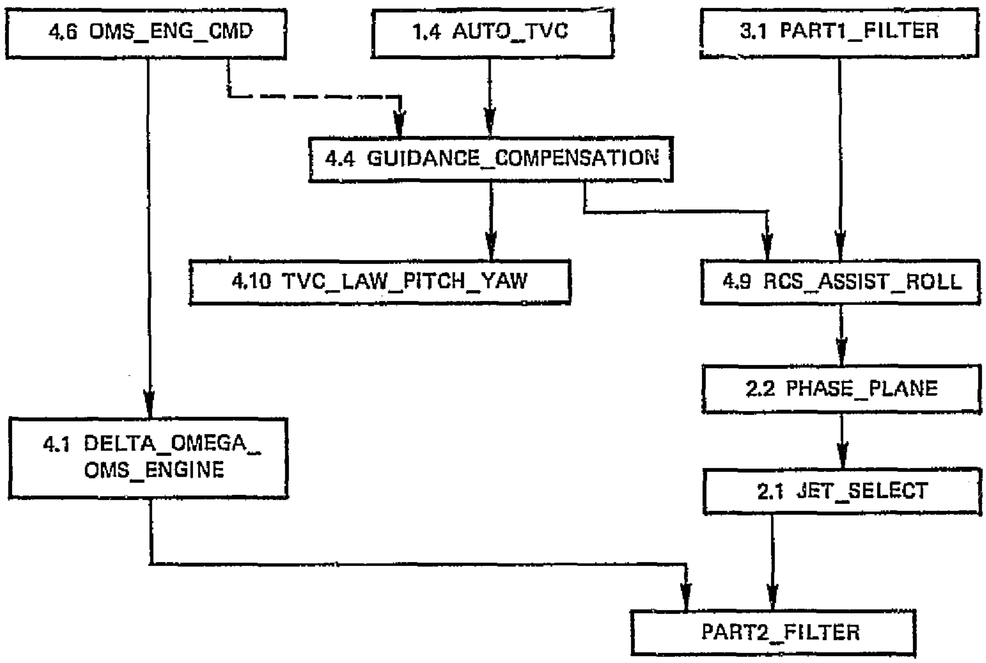


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 3 of 21).

I,A,4,a

TVC AUTO

RCS ASSIST (FAILURE ID'N)

- ROLL ASSIST & P/Y ASSIST (UNLATCHED, ASSIST_TIMER > TBD)

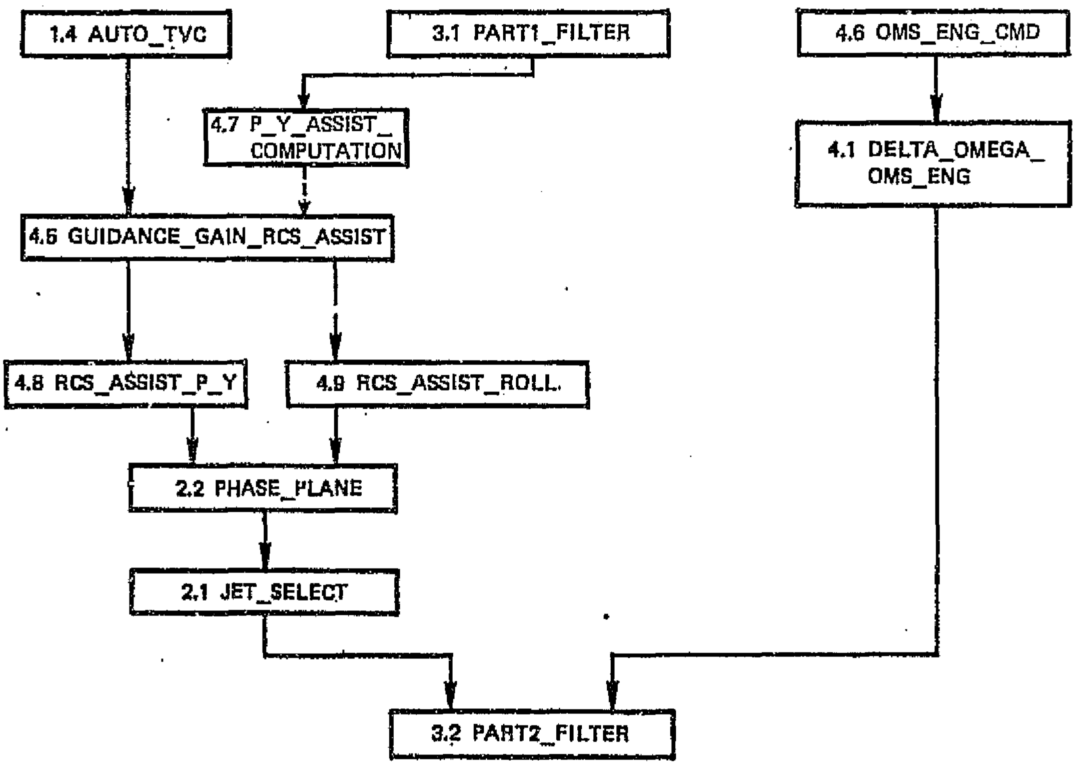


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 4 of 21).

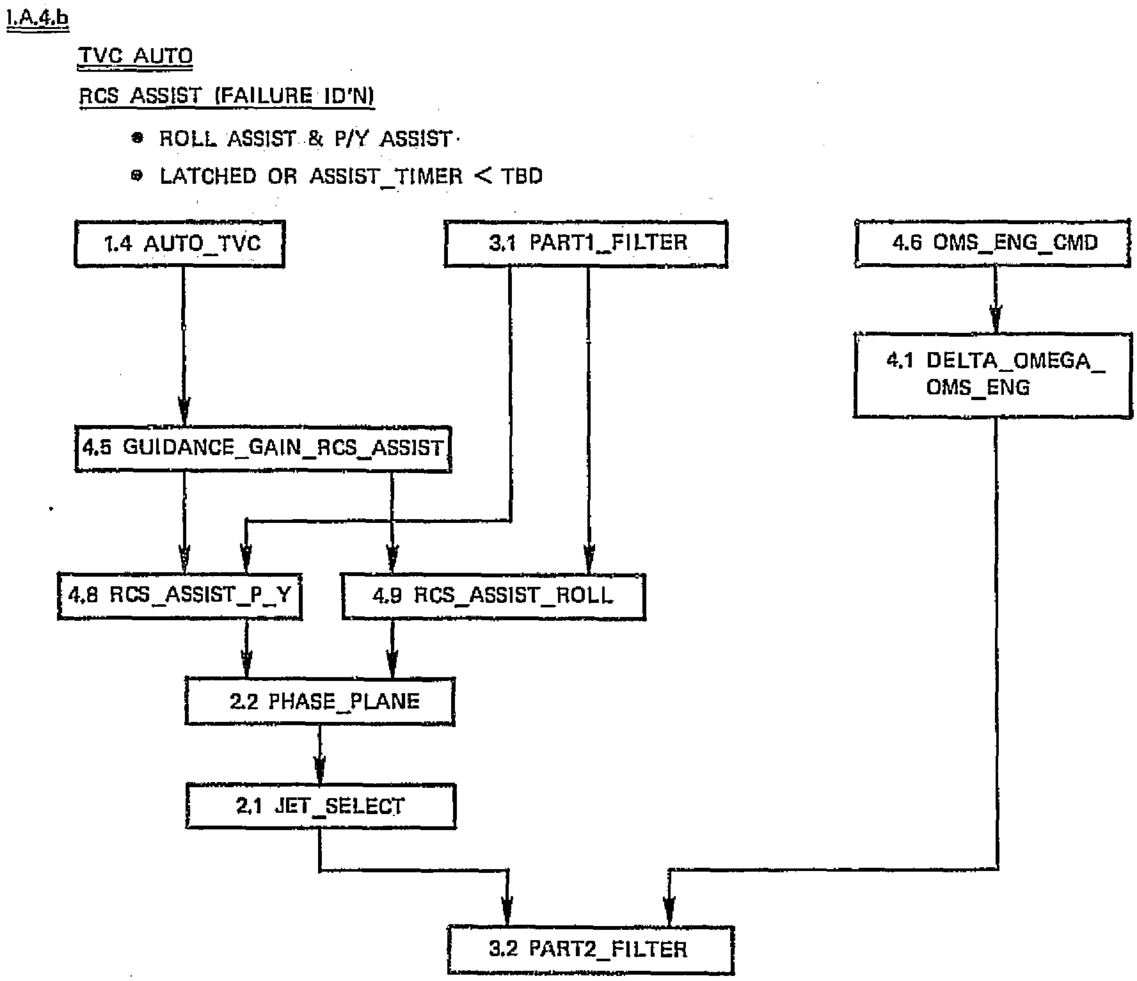
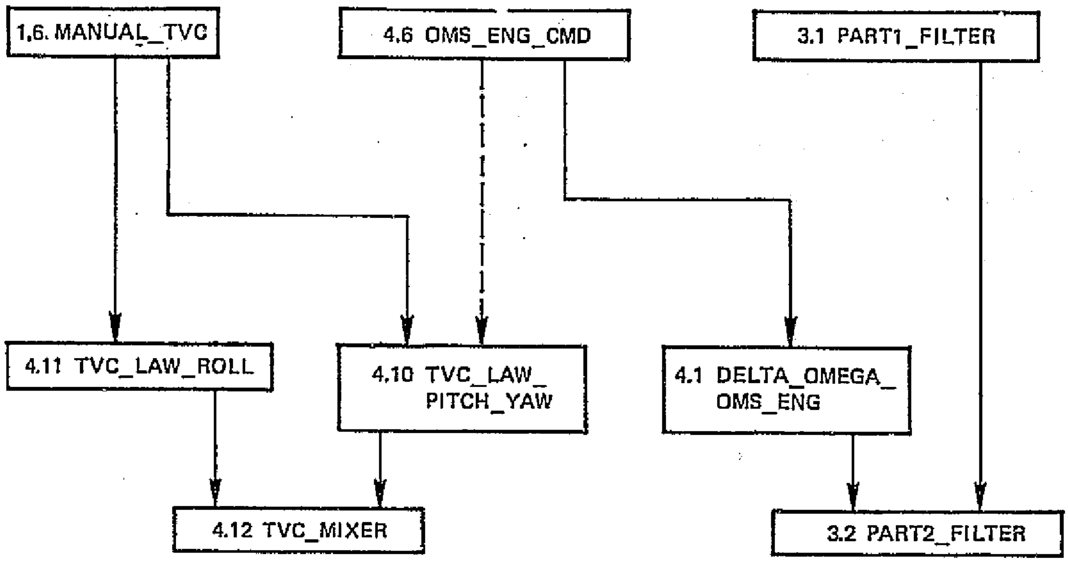


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 5 of 21).

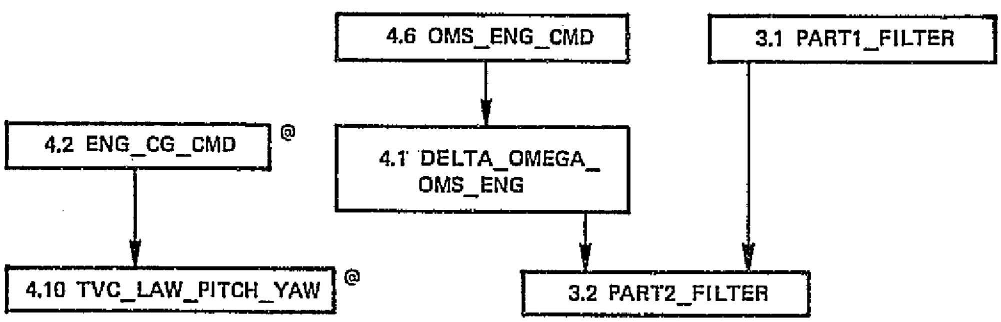
I.B.1

OMS TVC MANUAL NOMINAL 2-ENGINE



I.B.2

FAILURE DETECTION



@Executed first pass Fail Detection only

Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 6 of 21).

I.B.3

TVC MANUAL.

RCS ASSIST ROLL ONLY

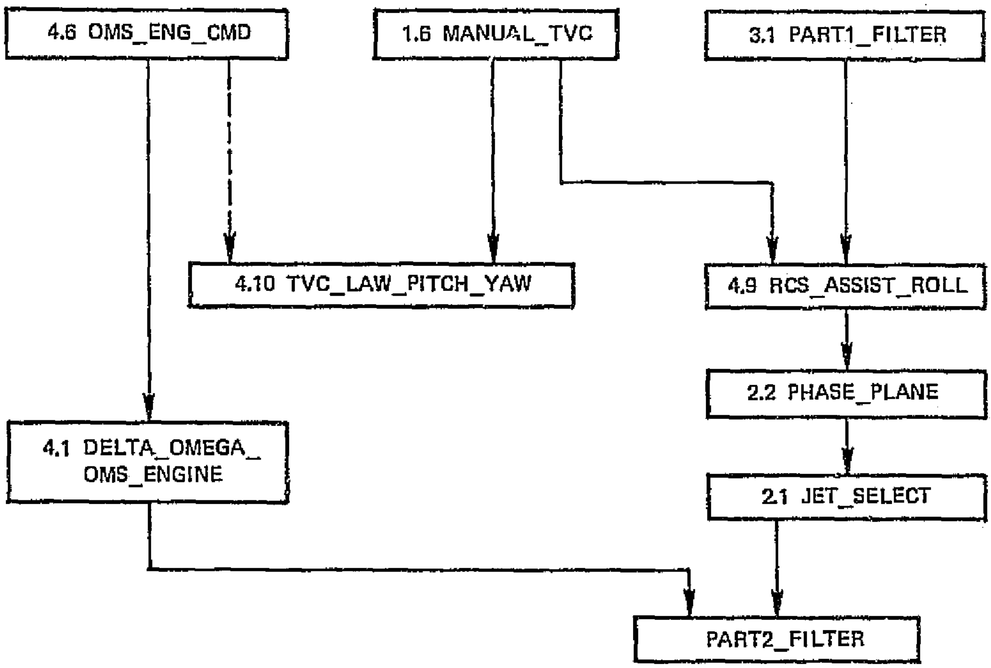


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 7 of 21).

TVC MANUAL

RCS ASSIST (FAILURE ID'N)

- ROLL ASSIST & P/Y ASSIST (UNLATCHED, ASSIST_TIMER > TBD)

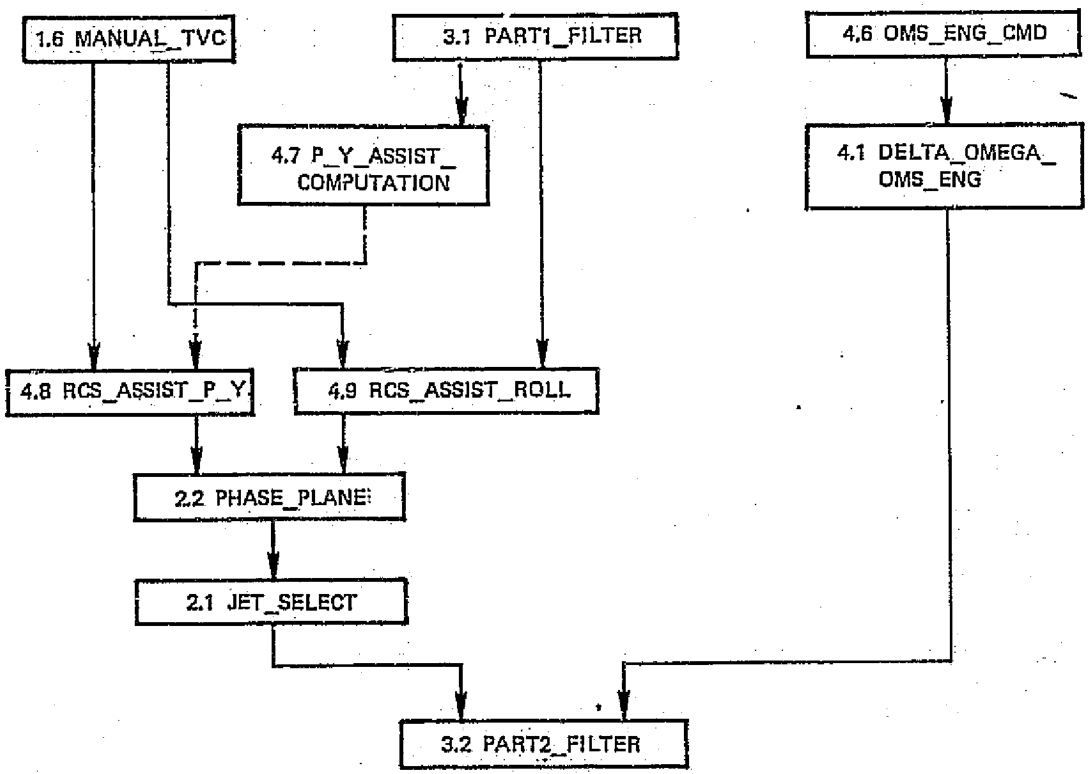


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 8 of 21).

I.B.4.b

TVC MANUAL

RCS ASSIST (FAILURE ID'N)

- ROLL ASSIST & P/Y ASSIST
- LATCHED OR ASSIST_TIMER < TBD

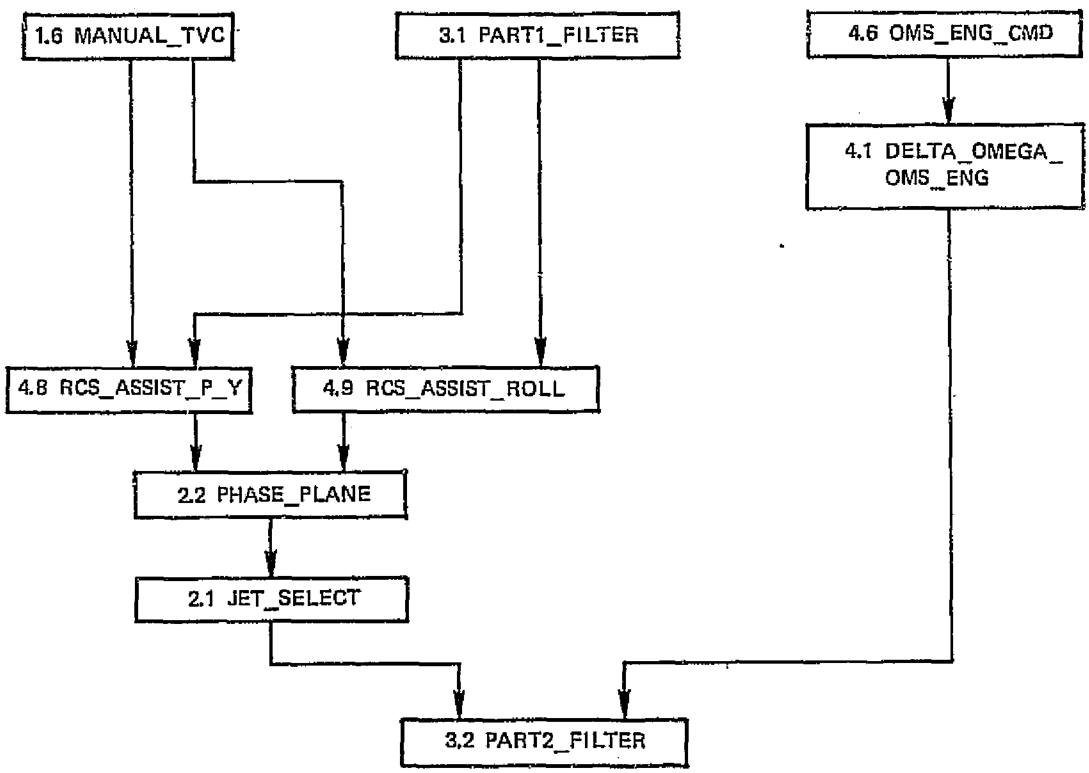


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 9 of 21).

II.A.1 through II.A.6, case a

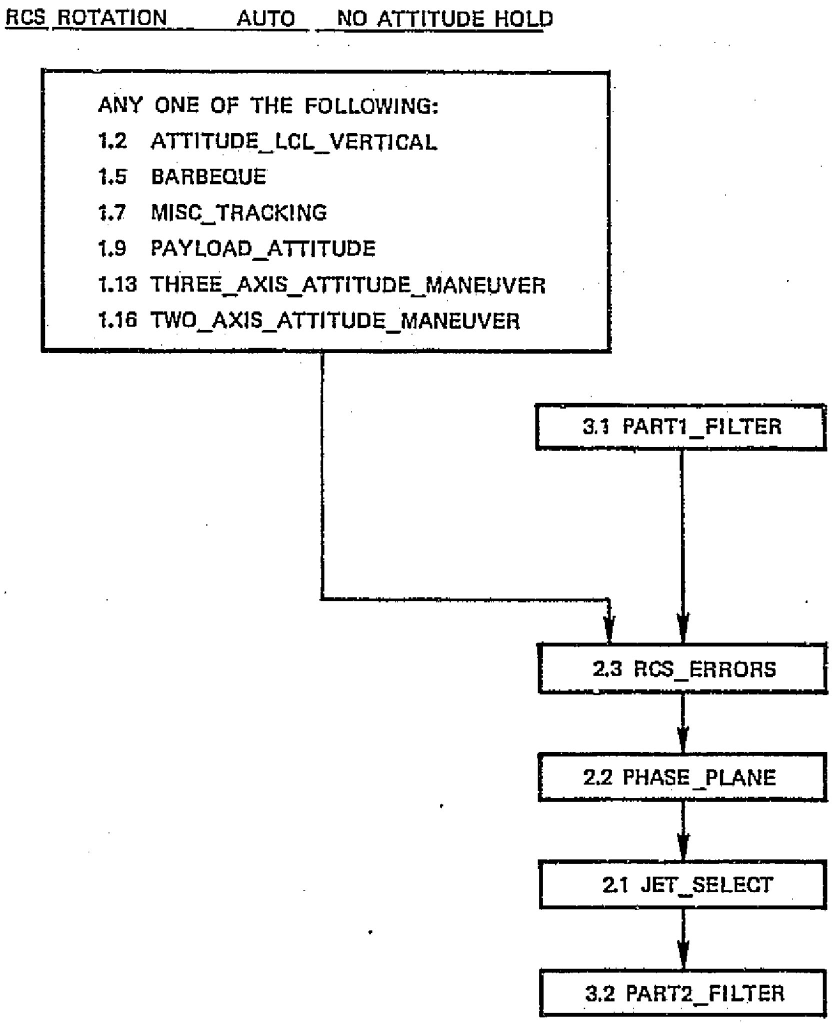


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 10 of 21).

II.A.1 through II.A.6, case b

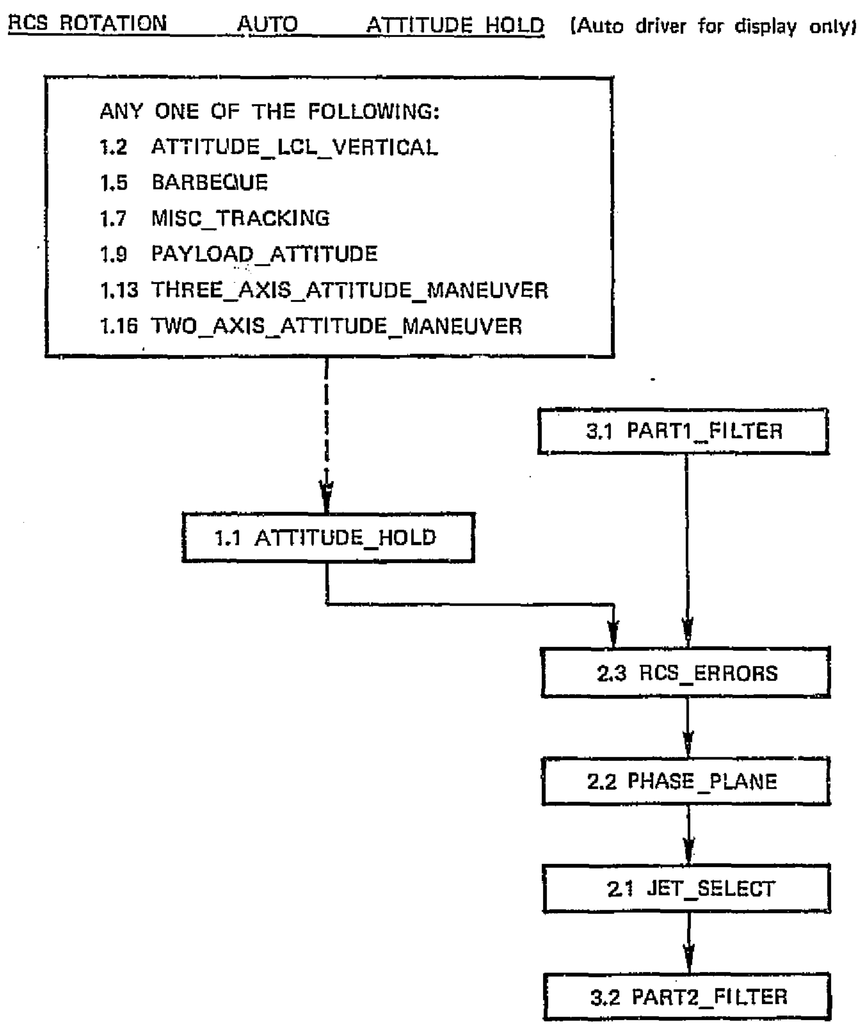


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 11 of 21).

II.A.7.a.1.a.1 OMS_P_T; FIRST_PASS; OPEN LOOP TRIM; NO ATT HOLD; TWO ENGINES

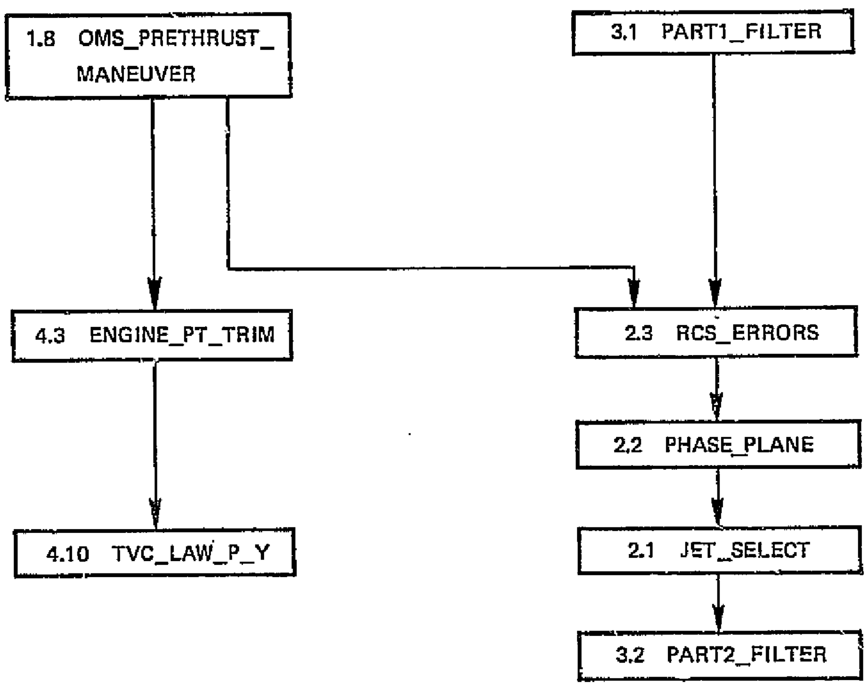


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 12 of 21).

II.A.7.a.1.a.2 OMS_P_T; FIRST_PASS; OPEN LOOP TRIM; ATT HOLD; TWO ENGINES (OMS_PRETHRUST_MANEUVER FOR DISPLAY AND OMS ENGINE TRIM ONLY)

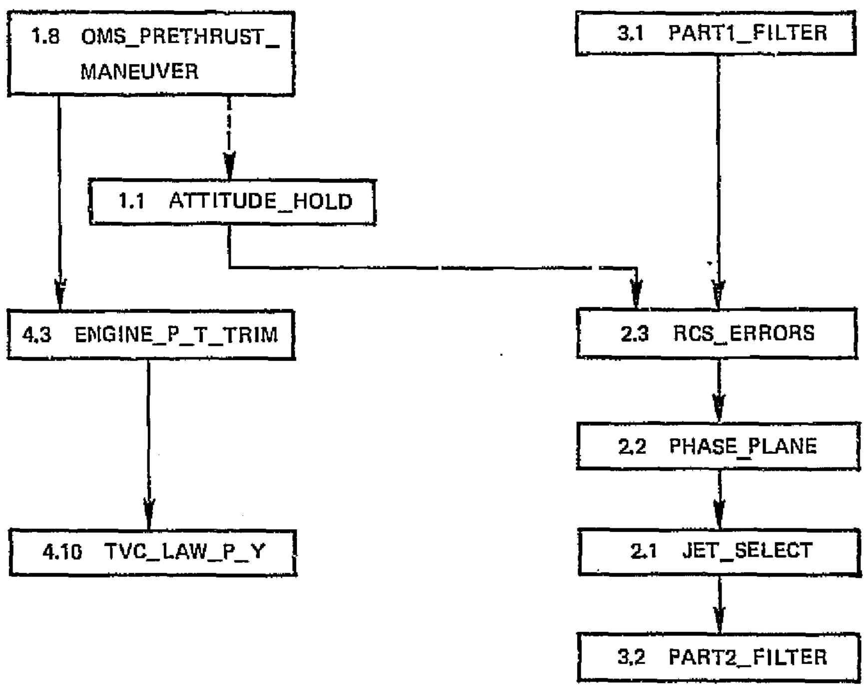


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 13 of 21).

II.A.7.a.1.b.1 OMS_P_T; FIRST_PASS; OPEN LOOP TRIM; NO ATT HOLD; ONE ENGINE

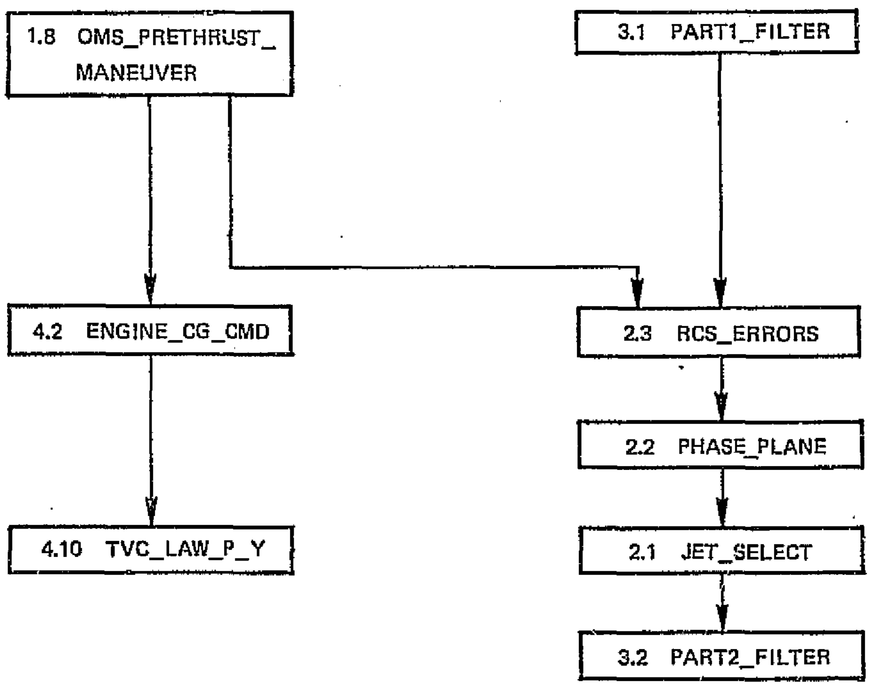


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 14 of 21).

II.A.7.a.1.b.2 OMS_P_T; FIRST PASS; OPEN LOOP TRIM; ATT HOLD; ONE ENGINE (OMS_PRETHRUST_MANEUVER FOR DISPLAY AND OMS ENGINE TRIM ONLY)

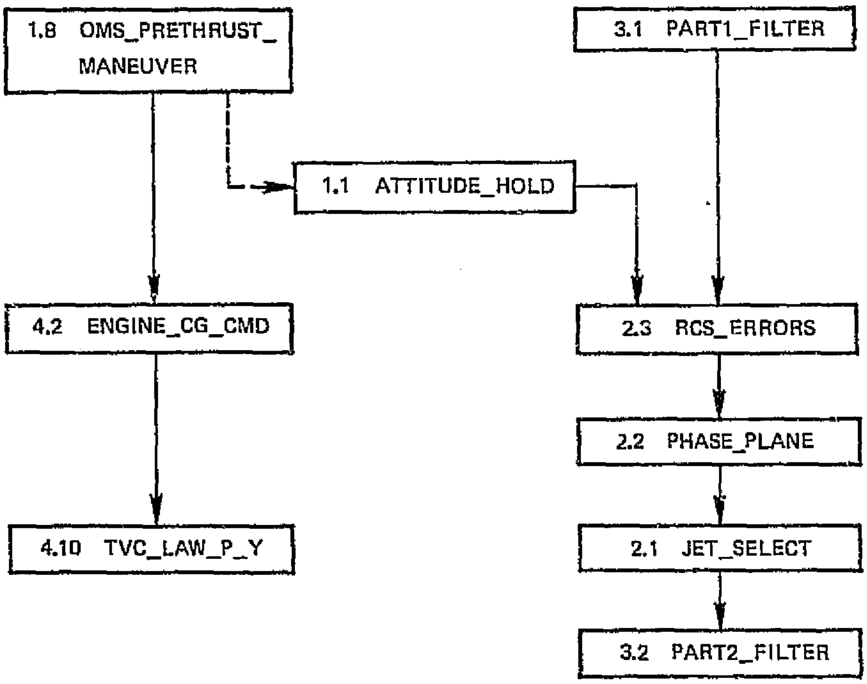


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 15 of 21).

II.A.7.a.2.a OMS_P_T; FIRST_PASS; CLOSED LOOP TRIM; NO ATT HOLD

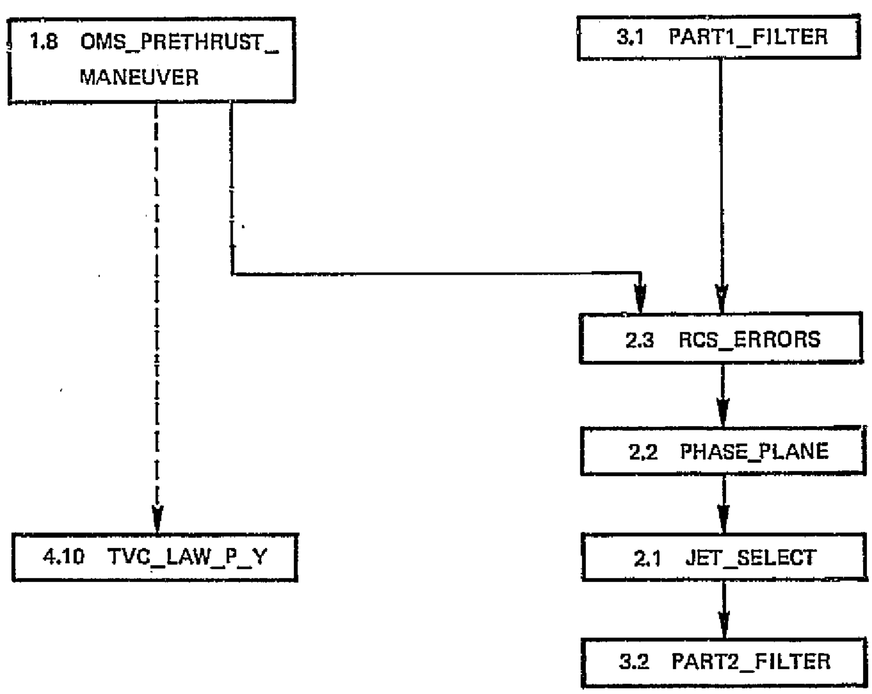


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 16 of 21).

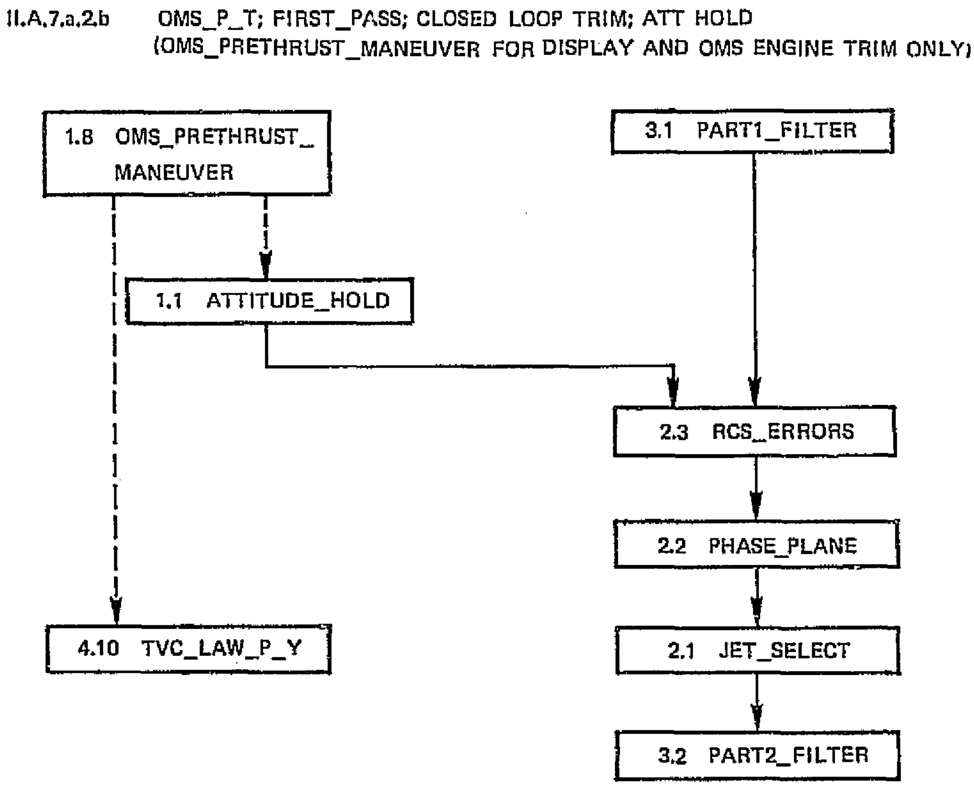


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 17 of 21).

II.A.7.b.1 OMS_P_T; > FIRST_PASS; NO ATT HOLD

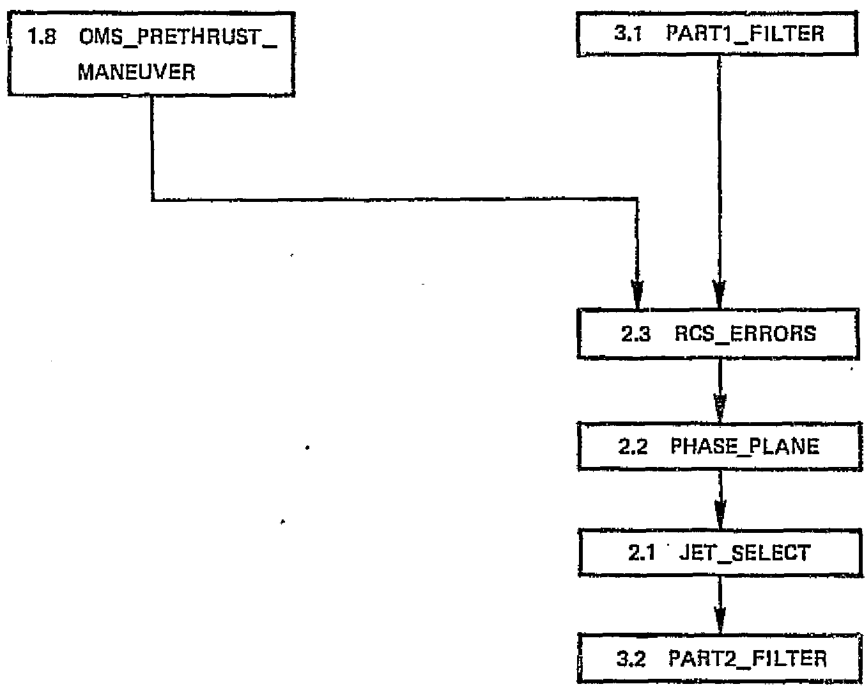


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 18 of 21).

II.A.7.b.2 OMS_P_T; > FIRST_PASS; ATT HOLD (OMS_PRETHRUST_MANEUVER FOR DISPLAY ONLY)

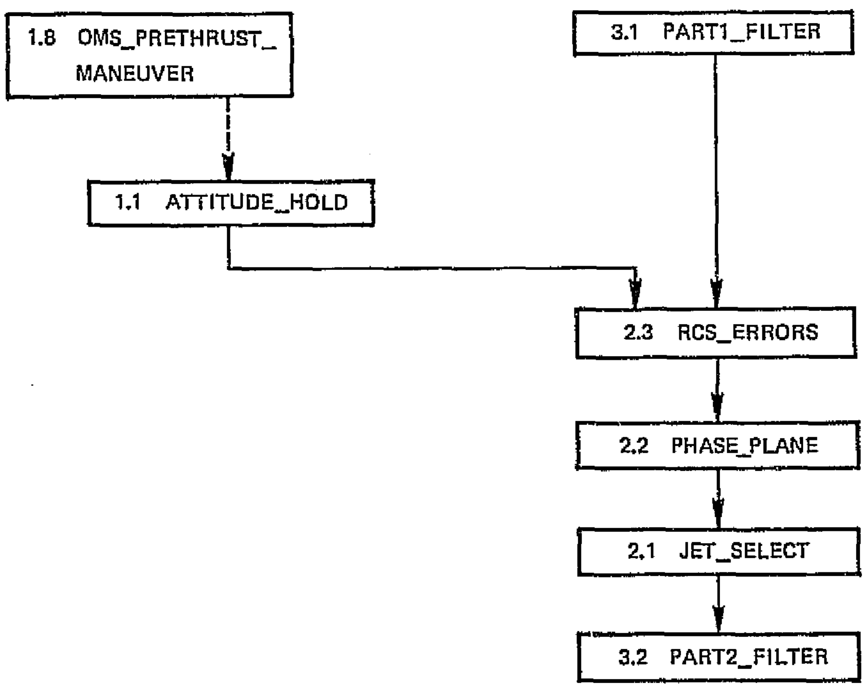


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 19 of 21).

II.B
RCS_ROTATION:MANUAL (OPTIONAL AUTO DRIVER FOR DISPLAY ONLY)

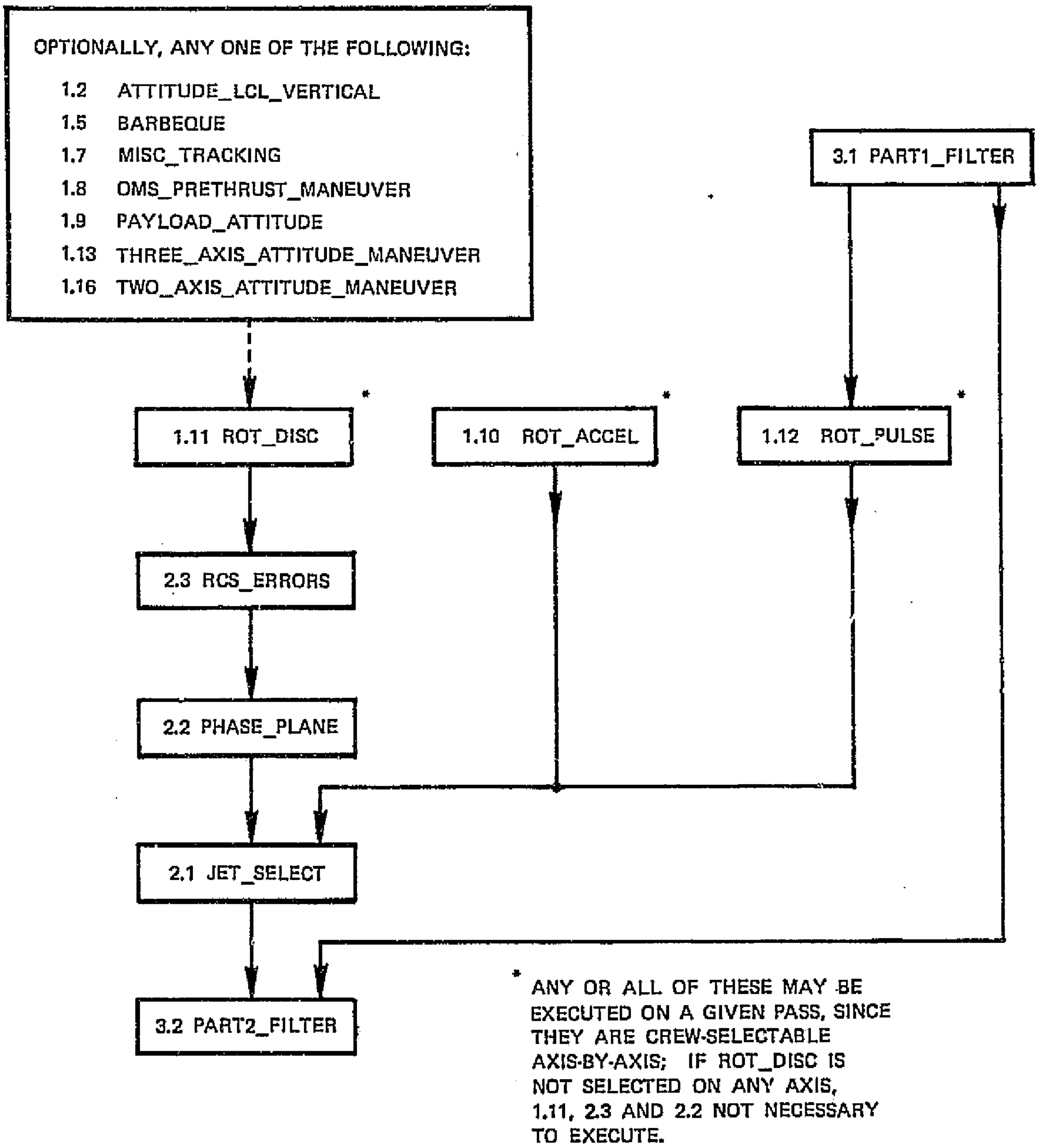
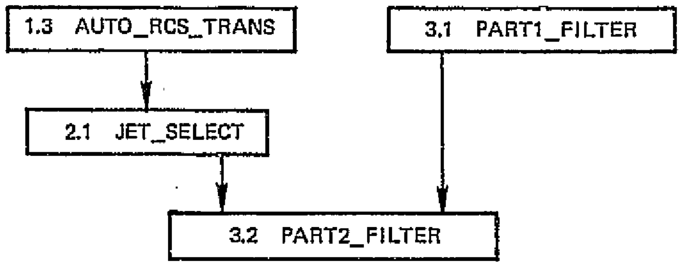
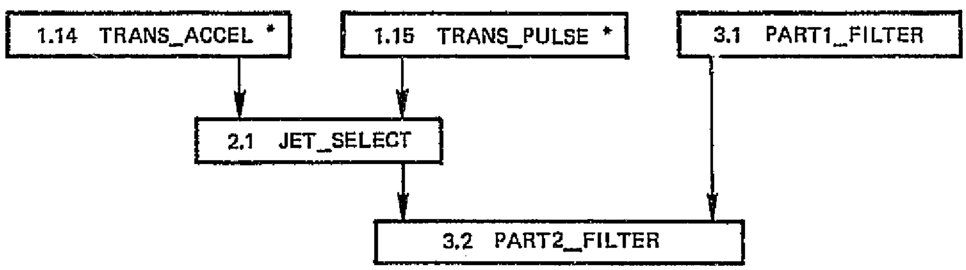


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 20 of 21).

III.A. RCS TRANSLATION_AUTO



III.B. RCS TRANSLATION_MANUAL



* EITHER OR BOTH OF THESE MODULES MAY BE EXECUTED IN A GIVEN CYCLE, BECAUSE THEY ARE SELECTABLE AXIS-BY-AXIS BY THE FLIGHT CREW.

Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 21 of 21).

4.2.1.2 Processing Rate

OFC_RECON is processed at 25 Hz.

4.2.1.3 Interface Requirements

The interface requirements of OFC_RECON are given in Table 4.2.1.3-1.

4.2.1.4 Control Law Function Module Initialization

Table 4.2.1.4-1 lists the conditions for initializing the control law modules. The modes, submodes and conditions are the same as those of Table 4.2.1.1-2 with the following exceptions:

1) First pass/restart is any entry into OFC_RECON with the OFC_RESTART flag set.

2) TVC fail-detect is the presence of OMS_FAIL_DETECT during TVC mode, regardless of whether an identification (OMS1_FAIL or OMS2_FAIL) is present.

The behavior of the individual control law function modules upon initialization is described in subsections 4.2.2.1 through 4.2.2.4.

TABLE 4.2.1.3-1 OFC_RECON INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
RCS_ROTATION	RCS rotation mode enable (1=enable)	MSC	B	0,1	none	25
RCS_AUTO_MANUAL	RCS auto/manual select (1=auto; 0=manual)	MSC	B	0,1	none	25
ATT_MNVR	Auto RCS rotation mode select (1=maneuver: two axis, three axis, OMS prethrust, local vertical, payload, tracking or barbeque; 0=hold)	MSC	B	0,1	none	25
TWO_AXIS	Two axis maneuver enable (1=enable)	MSC	B	0,1	none	5/6
THREE_AXIS	Three axis maneuver enable (1=enable)	MSC	B	0,1	none	5/6
OMS_PRETHRUST	OMS prethrust maneuver enable (1=enable)	MSC	B	0,1	none	5/6
LCL_VERT_ATT	Local maneuver enable (1=enable)	MSC	B	0,1	none	5/6
PAYLD_SUP_CMDS	Payload supplied commands maneuvers enable (1=enable)	MSC	B	0,1	none	5/6
TRACKING	Tracking maneuver enable (1=enable)	MSC	B	0,1	none	5/6
BBQ	Barbecue maneuver enable (1=enable)	MSC	B	0,1	none	5/6
RCS_TRANSLATION	RCS translation mode enable (1=enable)	MSC	B	0,1	none	25
OMS_ARM_REQ	OMS engines arming request (1=request)	MSC	A(2)B	0,1	none	25
OMS_ON_REQ	OMS engines turn-on request (1=request)	MSC	A(2)B	0,1	none	25

TABLE 4.2.1.3-1 OFC_RECON INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
TVC_AUTO_MANUAL	TVC auto/manual select (1=auto; 0=manual)	MSC	B	0,1	none	25
CLOSED_OPEN_LOOP_TRIM	OMS gimbal trim value select (1=closed loop: use value remaining from previous OMS burn; 0=open loop: use value computed from expected cg location)	MSC	B	0,1	none	1/maneuver
OFC_RESTART	OFC module initialization flag (1=init)	MSC, OFC_RECON	B	0,1	none	25
OMS_SELECT	To burn/not to burn status of OMS engines (1=to burn ; 0=not to burn)	D&C	A(2)B	0,1	none	1/maneuver
OMS_FAIL_DETECT	OMS failure detected (1=detected)	RM	B	0,1	none	25
OMS1_FAIL	OMS1 failure identified (1=identified)	RM	B	0,1	none	25
OMS2_FAIL	OMS2 failure identified (1=identified)	RM	B	0,1	none	25
ROT_OPTION	Manual rotation submode select (1=accel; 2=pulse; 3=discrete)	PANEL_SWITCH_INTERP, OFC_RECON	A(3)I	1,2,3	none	25
TRANS_OPTION	Manual translation submode select (1=accel; 2=pulse)	PANEL_SWITCH_INTERP	A(3)I	1,2	none	25
NOM_VERNIER_SW	RCS nominal/vernier jet select (1=nominal; 0=vernier)	PANEL_SWITCH_INTERP, OFC_RECON	A(3)B	0,1	none	25
RHC_STATE	Rotational hand controller command	RHC_READ	A(3)I	-1,0,1	none	25
SOFT_STOP	Flag indicating rotational hand controller is deflected beyond soft stop (1=beyond softstop)	RHC_READ	A(3)B	0,1	none	25
OMS1_ON_CMD	OMS1 engine on command (1=on)	OMS_ENG_CMD	B	0,1	none	25

TABLE 4.2.1.3-1 OFC_RECON INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
CMS2_ON_CMD	OMS2 engine on command (1=on)	OMS_ENG_CMD	B	0,1	none	25
ASSIST_PITCH_YAW	Flag requesting RCS assistance of TVC for pitch and yaw control (1=request)	PITCH_YAW_ASSIST, COMPUTATION, OFC_RECON	B	0,1	none	25
AXIS	Body axis for this execution	OFC_RECON	I	1,2,3	none	25/axis
BYPASS	Non-execution command, by axis (1=do not execute)	OFC_RECON	A(3)B	0,1	none	25
INIT_OMS_PRETHRUST_-MANEUVER	Module initialization flag (1=init)	OFC_RECON	B	0,1	none	25
Outputs						
INIT_AUTO_RCS_TRANS	Module initialization flag (1=initialization)	AUTO_RCS_TRANS	B	0,1	none	25
INIT_TWO_AXIS_ATTIT-UDE_MANEUVER	Module initialization flag (1=initialization)	TWO_AXIS_ATTITUDE_MA-NEUVER	B	0,1	none	5/6
INIT_THREE_AXIS_ATT-ITUDE_MNVR	Module initialization flag (1=initialization)	THREE_AXIS_ATTITUDE_-MANEUVER	B	0,1	none	5/6
INIT_OMS_PRETHRUST_-MANEUVER	Module initialization flag (1=initialization)	OMS_PRETHRUST_MANEUV-ER, OFC_RECON	B	0,1	none	5/6
INIT_ROT_PULSE	Module initialization flag (1=initialization)	ROT_PULSE	A(3)B	0,1	none	25
INIT_TRANS_PULSE	Module initialization flag (1=initialization)	TRANS_PULSE	A(3)B	0,1	none	25
INIT_ROT_DISC	Module initialization flag (1=initialization)	ROT_DISC	B	0,1	none	25
INIT_ATTITUDE_LCL_V-ERTICAL	Module initialization flag (1=initialization)	ATTITUDE_LCL_VERTICAL	B	0,1	none	5/6

TABLE 4.2.1.3-1 OFC_RECON INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
INIT_BARBEQUE	Module initialization flag (1=initialization)	BARBEQUE	B	0,1	none	5/6
INIT_ATTITUDE_HOLD	Module initialization flag (1=initialization)	ATTITUDE_HOLD	B	0,1	none	25
INIT_MANUAL_TVC	Module initialization flag (1=initialization)	MANUAL_TVC	B	0,1	none	25
INIT_RCS_ERRORS	Module initialization flag (1=initialization)	RCS_ERRORS	B	0,1	none	25
INIT_PHASE_PLANE	Module initialization flag (1=initialization)	PHASE_PLANE	B	0,1	none	25
INIT_JET_SELECT	Module initialization flag (1=initialization)	JET_SELECT	B	0,1	none	25
INIT_PART1_FILTER	Module initialization flag (1=initialization)	PART1_FILTER	B	0,1	none	25
INIT_GUIDANCE_COMPE-NSATION	Module initialization flag (1=initialization)	GUIDANCE_COMPENSATION	B	0,1	none	25
INIT_OMS_ENG_CMD	Module initialization flag (1=initialization)	OMS_ENG_CMD	B	0,1	none	25
INIT_PITCH_YAW_ASSI-ST_COMPUTATN	Module initialization flag (1=initialization)	PITCH_YAW_ASSIST_COM-PUTATION	B	0,1	none	25
INIT_RCS_ASSIST_ROLL	Module initialization flag (1=initialization)	RCS_ASSIST_ROLL	B	0,1	none	25
INIT_RCS_ASSIST_PIT-CH_YAW	Module initialization flag (1=initialization)	RCS_ASSIST_PITCH_YAW	B	0,1	none	25
INIT_TVC_LAW_ROLL	Module initialization flag (1=initialization)	TVC_LAW_ROLL	B	0,1	none	25

TABLE 4.2.1.3-1 OFC_RECON INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
INIT_TVC_LAW_PITCH_-YAW	Module initialization flag (0=no init; 1 =closed loop init using trim value remaining from previous OMS burn; 2=open loop init using trim value computed from expected cg location)	TVC_LAW_PITCH_YAW	I	0,1,2	none	25
OFC_RESTART	OFC module initialization flag (1=init)	MSC, OFC_RECON	B	0,1	none	25
ROT_OPTION	Manual rotation submode select (1=accel; 2=pulse; 3=discrete)	PANEL_SWITCH_INTERP, OFC_RECON	A(3)I	1,2,3	none	25
ROT_HI_LO_SW	Rotational acceleration level select (1=high; 0=low)	PANEL_SWITCH_INTERP, JET_SELECT	A(3)B	0,1	none	1/maneuver
TRANS_HI_LO_SW	Translational acceleration level select (1=high; 0=low)	PANEL_SWITCH_INTERP, JET_SELECT	A(3)B	0,1	none	1/maneuver
NOM_VERNIER_SW	RCS nominal/vernier jet select (1=nominal; 0=vernier	PANEL_SWITCH_INTERP, JET_SELECT, OFC_RECON	B	0,1	none	25
OMS1_PITCH_YAW_CMD	OMS1 engine pitch and yaw commands	SOP, RM	A(2)S	TBD	deg	1/maneuver
OMS2_PITCH_YAW_CMD	OMS2 engine pitch and yaw commands	SOP, RM	A(2)S	TBD	deg	1/maneuver
AXIS	Body axis for this execution	ROT_ACCEL, ROT_PULSE, TRANS_ACCEL, TRANS_PULSE, OFC_RECON	I	1,2,3	none	25/axis
BYPASS	Non-execution command, by axis (1=do not execute)	ROT_DISC, PHASE_PLANE, OFC_RECON	A(3)B	0,1	none	25
ROT_JET_CMD	Rotation command	JET_SELECT, PHASE_PLANE	A(3)I	-1,0,1	none	25
TRANS_JET_CMD	Translation command	JET_SELECT	A(3)I	-1,0,1	none	25

TABLE 4.2.1.3-1 OFC_RECON INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
ATTITUDE_GAIN1	Filter 1 gain for attitude term	PART1_FILTER	S	TBD	none	1/maneuver
ATTITUDE_GAIN2	Filter 2 gain for attitude term	PART1_FILTER	S	TBD	none	1/maneuver
RATE_GAIN1	Filter 1 gain for rate term	PART1_FILTER	S	TBD	none	1/maneuver
RATE_GAIN2	Filter 2 gain for rate term	PART1_FILTER	S	TBD	none	1/maneuver
ACCEL_GAIN	Filter 2 gain for acceleration term	PART1_FILTER	S	TBD	none	1/maneuver
TVC_LAW_P_Y_GAIN_FL-AG	Flag indicating number of OMS engines to burn (1 = 1 engine; 2 = 2 engines)	TVC_LAW_PITCH_YAW	I	1,2	none	25
GUID_COMP_GAIN	TVC compensation gains	GUIDANCE_COMPENSATION	A(3)S	TBD	none	25
ASSIST_PITCH_YAW	Flag requesting RCS assistance of TVC for pitch and yaw control (1=request)	OFC_RECON	B	0,1	none	25

Table 4.2.1.4-1. Control law function module initialization conditions.

INITIALIZATION FLAG	SET FLAG ON ENTRY INTO SPECIFIED MODE, SUBMODE, CONDITION
INIT_AUTO_RCS_TRANS	RCS translation auto
INIT_TWO_AXIS_ATTITUDE_MANEUVER	RCS two-axis*
INIT_THREE_AXIS_ATTITUDE_MNVR	RCS three-axis*
INIT_OMS_PRETHRUST_MANEUVER	RCS OMS-prethrust*
INIT_ROT_PULSE	RCS rotation manual pulse (by axis)
INIT_TRANS_PULSE	RCS translation manual pulse (by axis)
INIT_ROT_DISC	RCS rotation manual discrete (each axis)
INIT_ATTITUDE_LCL_VERTICAL	RCS local-vertical*
INIT_BARBEQUE	RCS barbeque*
INIT_ATTITUDE_HOLD	RCS rotation auto attitude-hold
INIT_MANUAL_TVC	TVC manual
INIT_RCS_ERRORS	First pass/restart
INIT_PHASE_PLANE	RCS or TVC
INIT_JET_SELECT	RCS or TVC
INIT_PART1_FILTER	First pass/restart
INIT_GUIDANCE_COMPENSATION	TVC auto
INIT_OMS_ENG_CMD	First pass/restart
INIT_PITCH_YAW_ASSIST_COMPUTATN	TVC
INIT_RCS_ASSIST_ROLL	TVC
INIT_RCS_ASSIST_PITCH_YAW	TVC RCS-assist-roll-pitch-yaw
INIT_TVC_LAW_ROLL	TVC
INIT_TVC_LAW_PITCH_YAW	RCS OMS-prethrust* closed-loop-trim (flag=1)
	RCS OMS-prethrust* open-loop-trim or TVC fail-detect (flag=2)

*These drivers may be called for display purposes without the necessity of performing the maneuver by enabling the rotation, automatic and attitude-maneuver submodes. Calling OMS_PRETHRUST_MANEUVER will cause OMS engine trimming in addition to generating display outputs.

4.2.2 Control Law Module

Figure 4.2.2-1 is the major block diagram of the On-Orbit FC control law module. This module contains 33 function modules which execute the control laws. On any given pass, the configuration of the control law module, i.e., the effective interconnection of the function modules, is determined by inputs from the supervisory module OFC_RECON and from external sources including RM, MSC, D&C, RHC_READ and PANEL_SWITCH_INTERP.

Configuration control is implemented in four ways:

1) By executing the particular function modules necessary to perform a given task in the sequence required. This function is performed by OFC_RECON and indicated in Figure 4.2.2-1 by switches S1 through S15, whose logic is described in Section 4.2.1.1.

2) By passing initialization flags to the function modules which in turn initialize pass-to-pass storage elements such as filters, counters and integrators. All initialization flags are generated by OFC_RECON.

3) By passing parameters defining quantitative behavior of certain function modules. These parameters include gains, magnitudes, thresholds and deadbands, and are supplied by OFC_RECON and external sources.

4) By directly "forcing" certain variables. OFC_RECON does this when making major mode changes.

The control law function modules are grouped into four categories: Drivers, RCS DAP, TVC DAP, and State Estimator. The general sequence of processing is:

1) State Estimator, part 1
2) Driver(s)
3) DAP(s)
4) State Estimator, part 2

The State Estimator combines IMU attitude measurement data with extrapolations based on effector commands, to form a filtered estimate of the vehicle angular state. To reduce transport lag, the process is divided into two parts. Part 1 performs only those portions of the estimation function which are necessary to develop the effector commands.

These include incorporation of IMU data and development of vehicle angular rate and undesired angular acceleration data. Part 2 of the State Estimator performs the remainder of the estimation function, chiefly the extrapolations, after the DAP(s) have issued the effector commands.

The Drivers convert a variety of input commands and data to forms acceptable by the respective DAPs. Reading from top to bottom in Figure 4.2.2-1, the 16 drivers are divided into the following types:

1) 2 manual RCS translation
2) 1 automatic RCS translation
3) 7 automatic RCS rotation: attitude maneuver
4) 1 automatic RCS rotation: attitude hold
5) 3 manual RCS rotation
6) 1 manual TVC
7) 1 automatic TVC

The RCS translation drivers generate commands for the jet selection module in the RCS DAP. The two manual RCS translation drivers process a single vehicle axis at a time, while the automatic RCS translation driver is a three-axis routine.

Of the RCS rotation drivers, all but two generate commands for the RCS DAP error determination module; the remaining two (ROT_ACCEL_ and ROT_PULSE) drive the jet selection routine directly. The seven attitude maneuver drivers additionally supply display data expressing desired vehicle attitude as IMU gimbal angles, and five of these provide a flag for display indicating completion of a maneuver. It is possible to display the outputs of any of the attitude maneuver drivers while actually controlling RCS rotation with attitude hold or manual RCS rotation drivers. All the automatic RCS rotation drivers operate on three vehicle axes. The manual RCS rotation drivers may be selected axis by axis. Two of these, ROT_ACCEL and ROT_PULSE, are in fact single-axis processors. ROT_DISC is somewhat hybrid, combining single-axis and three-axis attributes. It is basically a three-axis routine, since it must supply a complete set of desired IMU gimbal angle increments to the RCS DAP; however, it is operated such that any one, two or three axes can be processed while components about nonparticipating axes are zeroed. Although this causes spurious error components to be generated (assuming that ROT_ACCEL and/or ROT_PULSE are producing rotations about axes not using ROT_DISC), these components are never acted upon since the phase plane switching logic reads the same variable, BYPASS, that ROT_DISC does in determining which axes to process.

Each of the TVC drivers provides a three-axis body rate command to the TVC DAP.

The RCS DAP consists of jet selection logic preceded by a "front end" for rotation only, which obtains attitude and angular rate errors, and processes these through a phase plane switching logic that drives the vehicle into a limit cycle about the desired attitude and angular rate. No preprocessing is used for the translation commands, which come directly from the drivers to the jet selection logic; two rotation drivers also feed commands directly to the jet selection logic. In addition to producing the primary RCS DAP output—commands to the RCS jets—the jet selection logic also provides translational and rotational velocity change predictions for use respectively by TRANS_PULSE and part 2 of the State Estimator. During TVC operation, the RCS DAP may be called upon to assist the TVC DAP in controlling vehicle attitude. When this happens, error signals from the TVC DAP drive the phase plane switching logic, and thus the selected TVC driver is in control of both DAPs.

The TVC DAP contains all the functions required for on-off and thrust vector control of the OMS engines, and provides extrapolation data to the State Estimator. When only one OMS engine is operating, the TVC DAP needs RCS DAP assistance for roll control, and may need it for pitch and yaw control; the TVC DAP must then additionally supply error data to the RCS DAP and calculate whether or not RCS assistance is needed in pitch and yaw. Because pitch and yaw may be controlled differently from roll, the TVC law function and the RCS assist error-determination function are each split into two modules to prevent execution of unnecessary code.

The starting or trim orientations of the OMS engines are calculated and commanded both before an OMS burn and at the time of an engine failure during a two-engine burn. The one-engine trim value has each engine pointed to thrust through the vehicle cg, and the two-engine value has both engines parallel, with the total thrust through the cg. A third choice of trim exists after an OMS burn has taken place: the trim value stored in the TVC law function, which has had the benefit of thrust misalignment correction, can be used as the starting trim for the next burn.

The control law function modules are described in Sections 4.2.2.1 through 4.2.2.5. Within these sections, the modules are ordered alphanumerically by name. The groupings are as follows:

Section	Subject
4.2.2.1	Driver modules
4.2.2.2	RCS DAP modules
4.2.2.3	State Estimator modules
4.2.2.4	TVC DAP modules
4.2.2.5	Service modules (referred to in Sections 4.2.2.1 through 4.2.2.4)

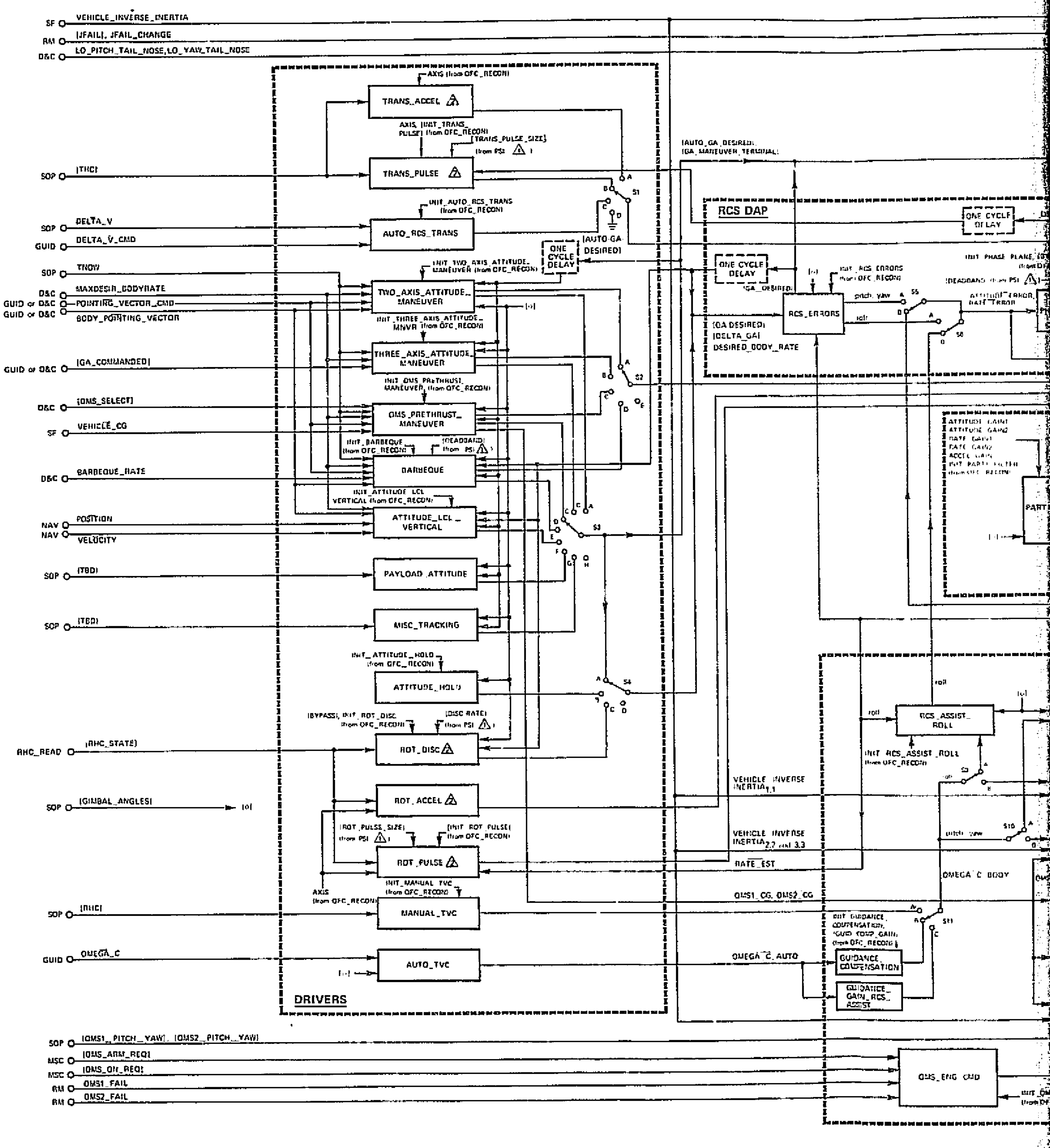
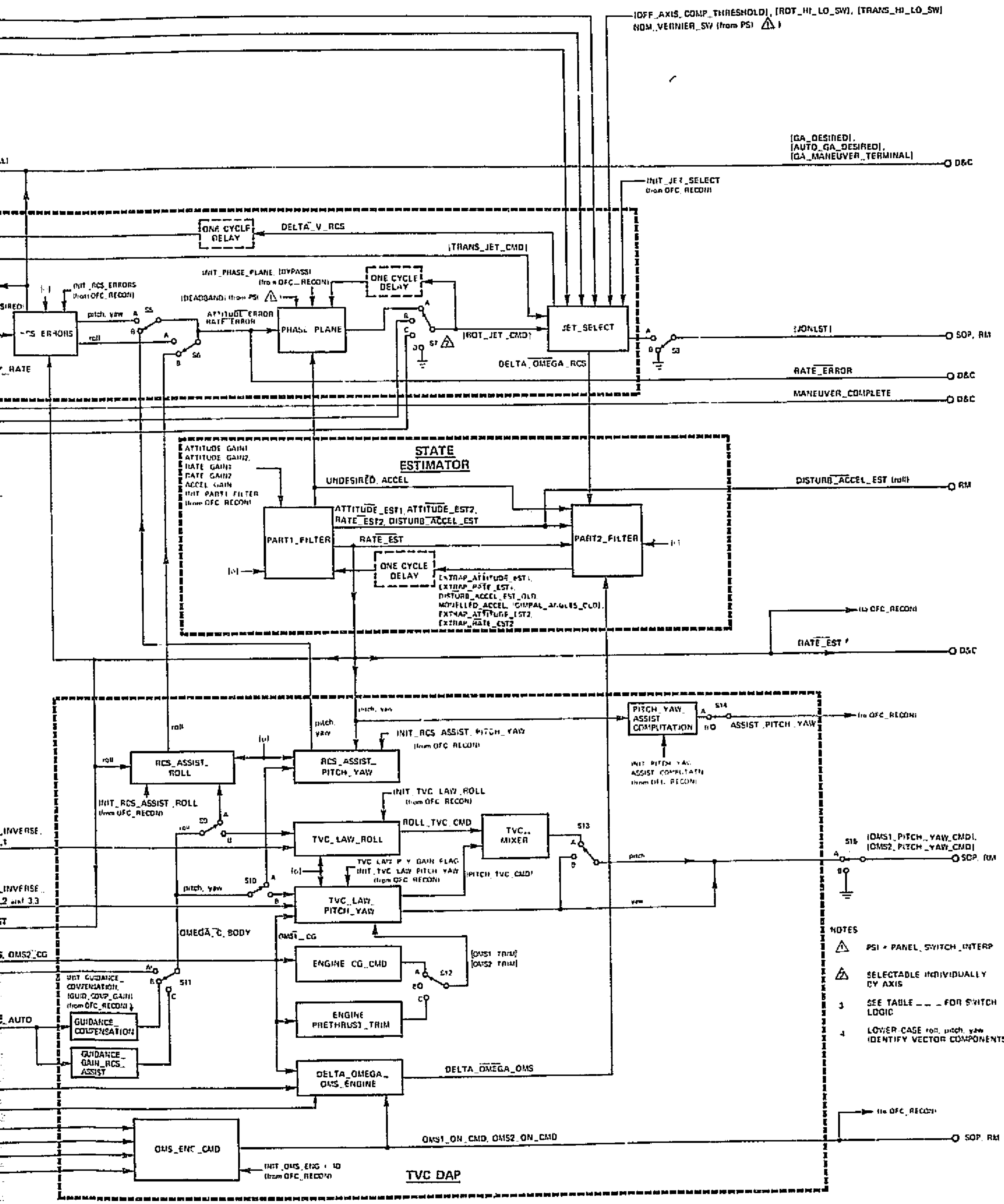


Figure 4.2.2-1. OFC control law module func



OFC control law module functions.

FOLDOUT FRAME 2

4.2.2.1. Drivers

4.2.2.1.1 ATTITUDE_HOLD

A. Function: This module provides inputs to the RCS DAP to effect a three-axis attitude hold. The vehicle is held to the attitude it had at the time of selection of the attitude hold submode, and will return to that attitude if it has a nonzero angular rate when the selection is made.

B. Block Diagram: Figure 4.2.2.1.1-1

C. Processing Rate: TBD

D. Interface Requirements: Table 4.2.2.1.1-1

E. Constants: none

F. Initialization Requirements: Table 4.2.2.1.1-2

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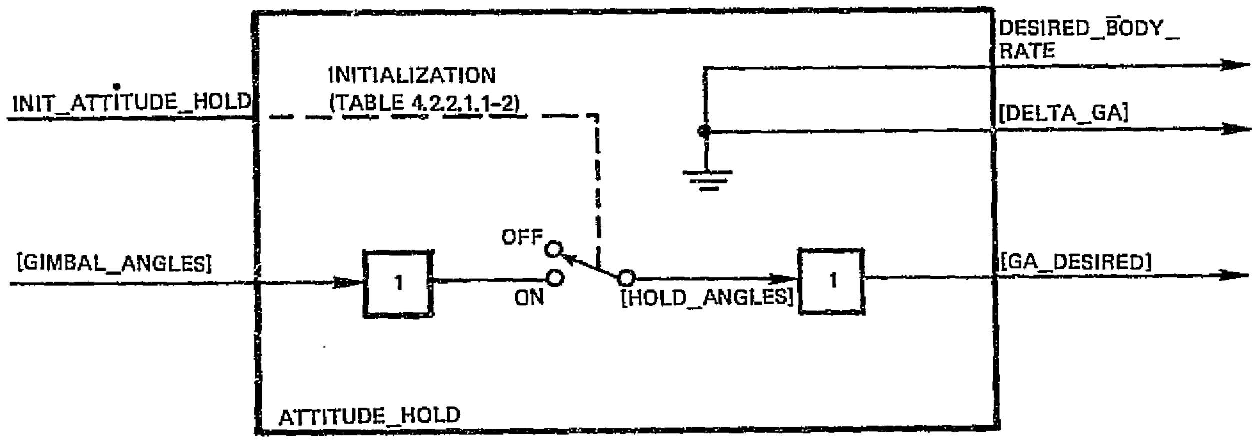


Figure 4.2.2.1.1-1. ATTITUDE_HOLD.

TABLE 4.2.2.2.1.1-1 ATTITUDE_HOLD INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	1/maneuver
INIT_ATTITUDE_HOLD	Module initialization flag	CFC_RECON	B	0,1	none	TBD
Outputs						
DELTA_GA	Desired IMU gimbal angle increments	RCS_ERRORS	A(3)S	TBD	deg	TBD
DESIRED_BODY_RATE	Desired body angular rate	RCS_ERRORS	V(3)S	TBD	deg/s	TBD
GA_DESIRED	Desired IMU gimbal angles	D&C, RCS_ERRORS	A(3)S	-180 < x <= 180	deg	TBD

TABLE 4.2.2.1.1-2 ATTITUDE_HOLD INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_ATTITUDE_HOLD = OFF	INIT_ATTITUDE_HOLD = ON	HOLD_ANGLES	GIMBAL_ANGLES

4.2.2.1.2 ATTITUDE_LCL_VERTICAL

A. Function: This module provides inputs to the RCS DAP to maintain a specified body-axis vector aligned to the local vertical, with zero rotational rate about the specified vector.

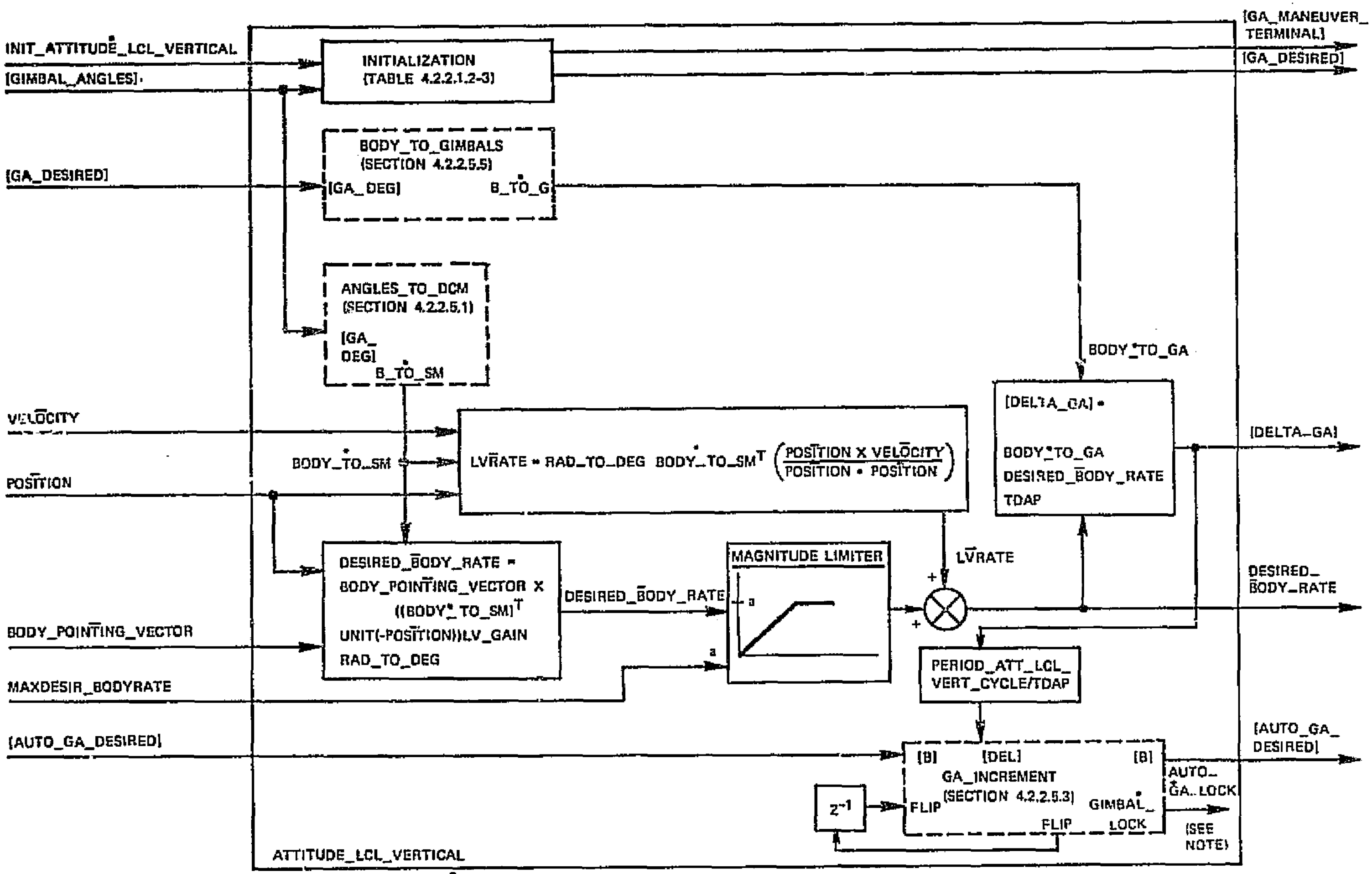
B. Block Diagram: Figure 4.2.2.1.2-1

C. Processing Rate: 5/6 Hz

D. Interface Requirements: Table 4.2.2.1.2-1

E. Constants: Table 4.2.2.1.2-2

F. Initialization Requirements: Table 4.2.2.1.2-3



NOTE: Processing of AUTO_GA_LOCK is TBD.

Figure 4.2.2.1.2-1. ATTITUDE_LCL_VERTICAL.

TABLE 4.2.2.1.2-1 ATTITUDE_LCL_VERTICAL INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
BODY_POINTING_VECTOR	Unit vector, in body axes, to be aligned with respect to local vertical	GUID or D&C	V(3)S	-1 to +1	none	5/6
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	5/6
POSITION	Vehicle position in stable member axes, referred to geocenter	NAV	V(3)S	TBD	f	5/6
VELOCITY	Vehicle velocity in stable member axes, referred to geocenter	NAV	V(3)S	TBD	f/s	5/6
INIT_ATTITUDE_LCL_V-ERTICAL	Module initialization flag	CFC_RECON	B	0,1	none	5/6
GA_DESIRED	Desired IMU gimbal angles	RCS_ERRORS	A(3)S	-180 < x <= 180	deg	5/6
AUTO_GA_DESIRED	Desired IMU gimbal angles	ATTITUDE_LCL_VERTICAL	A(3)S	-180 < x <= 180	deg	5/6
MAXDESIR_BODYRATE	Desired maximum body angular rate	D&C	S	0 to 5	deg/s	5/6
Outputs						
DELTA_GA	Desired IMU gimbal angle increments	RCS_ERRORS	A(3)S	TBD	deg	5/6
DESIRED_BODY_RATE	Desired body angular rate	RCS_ERRORS	V(3)S	TBD	deg/s	5/6
GA_DESIRED	Desired IMU gimbal angles	D&C, RCS_ERRORS	A(3)S	-180 < x <= 180	deg	1/maneuver
AUTO_GA_DESIRED	Desired IMU gimbal angles	D&C, ATTITUDE_LCL_VERTICAL	A(3)S	-180 < x <= 180	deg	5/6
GA_MANEUVER_TERMINAL	Desired terminal gimbal angles	D&C	A(3)S	-180 < x <= 180	deg	1/maneuver

TABLE 4.2.2.1.2-2 ATTITUDE_LCL_VERTICAL CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
TDAP	Period of RCS DAP cycle	S	0.04	s
PERIOD_ATT_LCL_VERT_CYCLE	Period of ATTITUDE_LCL_VERTICAL cycle	S	1.2	s
LV_GAIN	Attitude error gain	S	TBD	(deg/s)/deg
RAD_TO_DEG	Radians to degrees conversion factor	S	180/pi	deg

TABLE 4.2.2.1.2-3 ATTITUDE_LCL_VERTICAL INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_ATTITUDE_LCL_VERTICAL = OFF	INIT_ATTITUDE_LCL_VERTICAL = ON	GA_DESIRED GA_MANEUVER_TERMINAL AUTO_GA_DESIRED	GIMBAL_ANGLES GIMBAL_ANGLES GIMBAL_ANGLES
INIT_ATTITUDE_LCL_VERTICAL = OFF	INIT_ATTITUDE_LCL_VERTICAL = ON	FLIP	TBD

4.2.2.1.3 AUTO_RCS_TRANS

A. Function: This module provides an input to the RCS DAP to achieve commanded translational velocity changes in three axes. The input command is assumed to differ from its value on the previous pass if and only if it is a new increment; any number of such increments can be commanded in a given maneuver. A velocity error deadband is incorporated to prevent severe cycling.

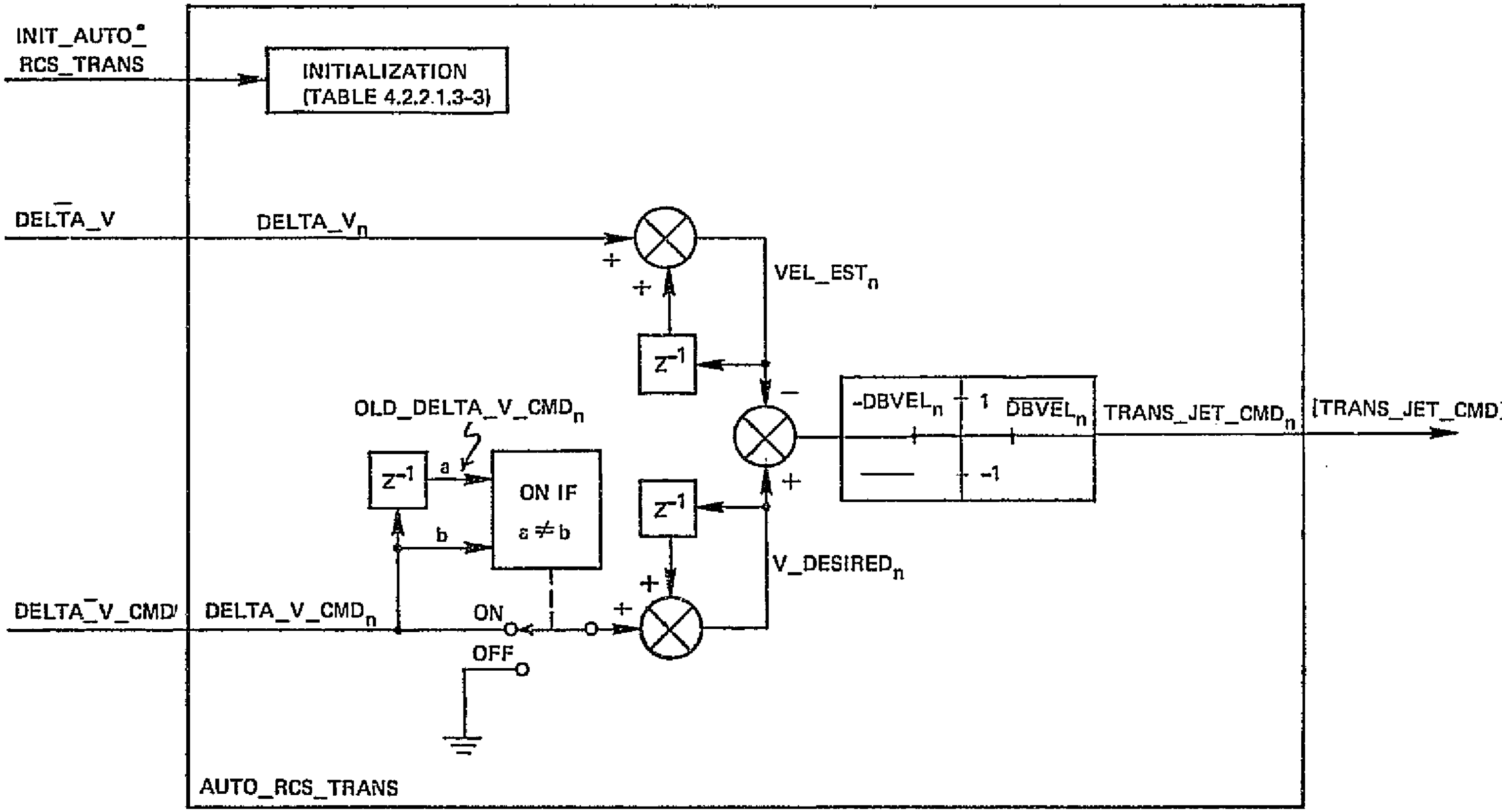
B. Block Diagram: Figure 4.2.2.1.3-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.1.3-1

E. Constants: Table 4.2.2.1.3-2

F. Initialization Requirements: Table 4.2.2.1.3-3



NOTE: Array or vector subscript n should be taken as indicating that the processing shown is for one element, and all three elements are processed.

TABLE 4.2.2.1.3-1 AUTO_RCS_TRANS INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
DELTA_V_CMD	Commanded translational velocity change	GUID or DSC	V(3)S	TBD	f/s	25
DELTA_V	IMU accelerometer data; vehicle velocity change since previous sampling	SOP	V(3)S	TBD	f/s	25
INIT_AUTO_RCS_TRANS	Module initialization flag	CFC_RECON	B	0,1	none	25
Output						
TRANS_JET_CMD	Translation command	JET_SELECT	A(3)I	-1,0,1	none	25

TABLE 4.2.2.1.3-2 AUTO_RCS_TRANS CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
DBVEL	Velocity error deadband, by axis	A(3)S	TBD	f/s

TABLE 4.2.2.1.3-3 AUTO_RCS_TRANS INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_AUTO_RCS_TRANS = OFF	INIT_AUTO_RCS_TRANS = ON	VEL_EST	0
		V_DESIRED	0
		OLD_DELTA_V_CMD	0

4.2.2.1.4 AUTO_TVC

A. Function: This module provides an input to the TVC DAP to achieve a three-axis vehicle angular rate corresponding to a commanded angular rate in inertial coordinates, during a TVC burn.

B. Block Diagram: Figure 4.2.2.1.4-1

C. Processing Rate: 2 Hz (tentative)

D. Interface Requirements: Table 4.2.2.1.4-1

E. Constants: none

F. Initialization Requirements: none

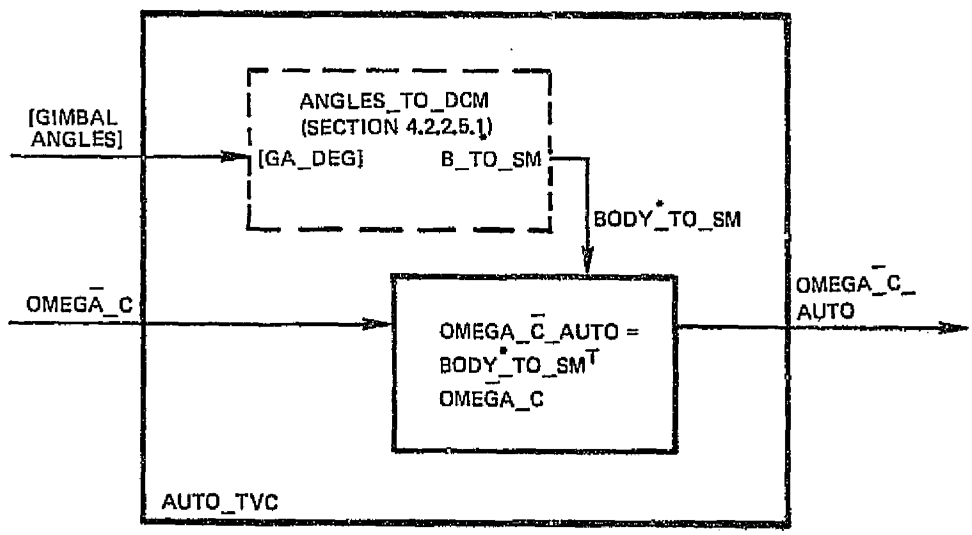


Figure 4.2.2.1.4-1. AUTO_TVC.

TABLE 4.2.2.1.4-1 AUTO_TVC INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
OMEGA_C	Commanded vehicle angular rate in stable member axes	GUID	V(3)S	TBD	deg/s	2
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	$-180 < x < 180$	deg	2
Output						
OMEGA_C_AUTO	Commanded vehicle angular rate in body axes	GUIDANCE_COMPENSATION, GUIDANCE_GAIN_RCS_ASSIST	V(3)S	TBD	deg/s	2

4.2.2.1.5 BARBEQUE

A. Function: This module provides drive signals to the RCS DAP to align a specified body vector to a commanded inertial vector and then rotate the vehicle about the body vector at a predetermined rate. Upon initialization, TWO_AXIS_ATTITUDE_MANEUVER is called to perform the vector alignment maneuver. When the maneuver has proceeded to within a predetermined angular deadband of the terminal attitude, it is abandoned and the rate drive algorithms executed instead. Any maneuver rate components usable by the rate drive are thus preserved. A second initialization is used to implement the changeover.

B. Block Diagram: Figure 4.2.2.1.5-1

C. Processing Rate: 5/6 Hz

D. Interface Requirements: Table 4.2.2.1.5-1

E. Constants: Table 4.2.2.1.5-2

F. Initialization Requirements: Table 4.2.2.1.5-3

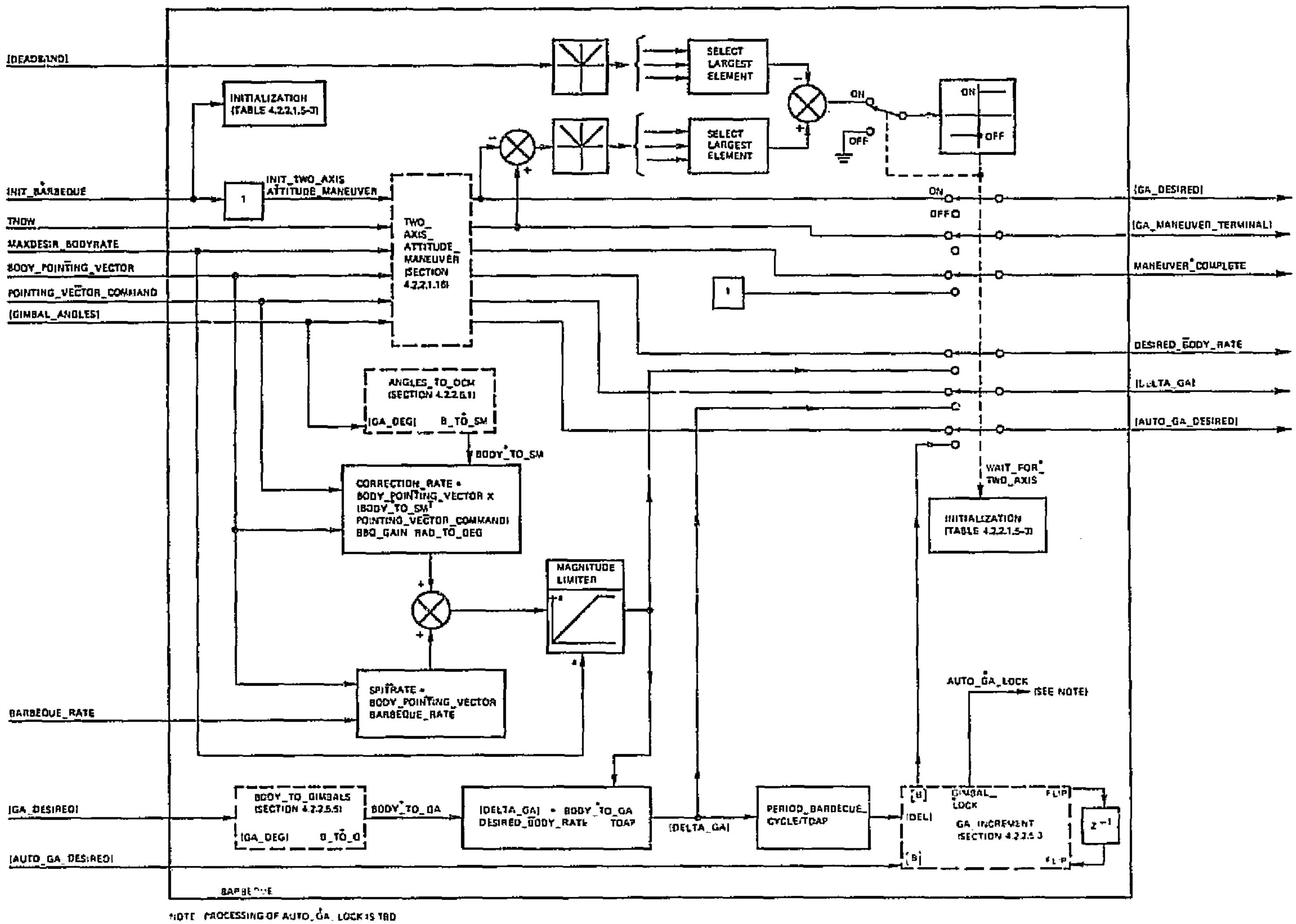


Figure 4.2.2.1.5-1. BARBEQUE.

TABLE 4.2.2.1.5-1 BARBEQUE INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
BODY_POINTING_VECTOR	Unit vector, in body axes, to be aligned with POINTING_VECTOR_CMD	GUID or D&C	V(3)S	-1 to +1	none	5/6
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	5/6
POINTING_VECTOR_CMD	Unit vector specifying commanded pointing direction in stable member axes	GUID or D&C	V(3)S	-1 to +1	none	5/6
BARBEQUE_RATE	Desired barbeque-mode angular rate	D&C	S	TBD	deg/s	1/maneuver
GA_DESIRED	Desired IMU gimbal angles	RCS_ERRORS	A(3)S	-180 < x <= 180	deg	5/6
AUTO_GA_DESIRED	Desired IMU gimbal angles	BARBEQUE	A(3)S	-180 < x <= 180	deg	5/6
MAXDESIR_BODYRATE	Desired maximum body angular rate	D&C	S	0 to 5	deg/s	5/6
TNOW	Current time	SOP	S	TBD	S	5/6
DEADBAND	Attitude deadband	PANEL_SWITCH_INTERP	A(3)S	TBD	deg	5/6
INIT_BARBEQUE	Module initialization flag	OFC_RECON	B	0,1	none	5/6
Outputs						
DELTA_GA	Desired IMU gimbal angle increments	RCS_ERRORS	A(3)S	TBD	deg	5/6
DESIRED_BODY_RATE	Desired body angular rate	RCS_ERRORS	V(3)S	TBD	deg/s	5/6
GA_DESIRED	Desired IMU gimbal angles	D&C, RCS_ERRORS	A(3)S	-180 < x <= 180	deg	5/6
AUTO_GA_DESIRED	Desired IMU gimbal angles	D&C, BARBEQUE	A(3)S	-180 < x <= 180	deg	5/6
GA_MANEUVER_TERMINAL	Desired terminal IMU gimbal angles	D&C	A(3)S	-180 < x <= 180	deg	1/maneuver
MANEUVER_COMPLETE	Flag signifying completion of initial maneuver	D&C	B	0,1	none	5/6

TABLE 4.2.2.1.5-2 BARBEQUE CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
TDAP	Period of RCS DAP cycle	S	0.04	s
PERIOD_BARBEQUE_CYCLE	Period of BARBEQUE cycle	S	1.2	s
RAD_TO_DEG	Radians to degrees conversion factor	S	180/pi	none

TABLE 4.2.2.1.5-3 BARBEQUE INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_BARBEQUE = OFF	INIT_BARBEQUE = ON	WAIT_FOR_TWO_AXIS	ON
		FLIP	TBD
WAIT_FOR_TWO_AXIS = ON	WAIT_FOR_TWO_AXIS = OFF	AUTO_GA_DESIRED	GA_MANEUVER_TERMINAL
		GA_DESIRED	GA_MANEUVER_TERMINAL

4.2.2.1.6 MANUAL_TVC

A. Function: This module provides inputs to the TVC DAP to generate a three-axis vehicle angular rate corresponding in sense and, up to a limit and subject to the deadband described below, proportional in magnitude to the RHC deflection, during a TVC burn. A movable deadband is incorporated to suppress manual jitter.

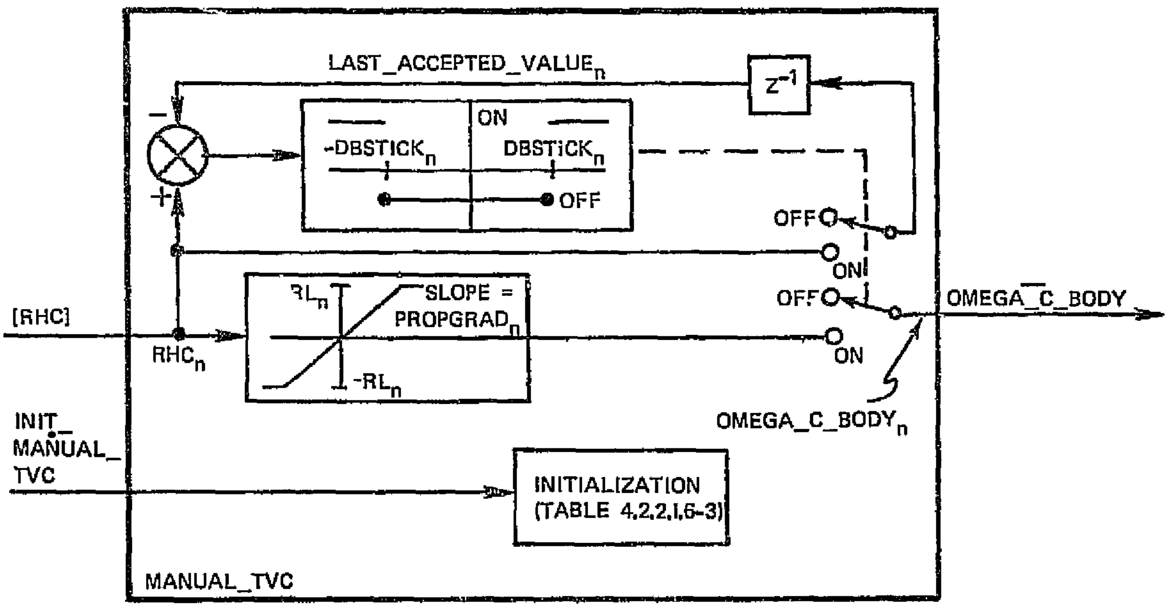
B. Block Diagram: Figure 4.2.2.1.6-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.1.6-1

E. Constants: Table 4.2.2.1.6-2

F. Initialization Requirements: Table 4.2.2.1.6-3



NOTES:
1. ARRAY OR VECTOR SUBSCRIPT n SHOULD BE TAKEN AS INDICATING THAT THE PROCESSING SHOWN IS FOR ONE ELEMENT, AND ALL THREE ELEMENTS ARE PROCESSED.
2. THE EFFECT OF THE PROCESSING SHOWN IS TO PLACE A DEADBAND ABOUT RHC$_n$ CENTERED ON THE VALUE OF RHC$_n$ LAST RESPONDED TO.

Figure 4.2.2.1.6-1. MANUAL_TVC.

TABLE 4.2.2.1.6-1 MANUAL_TVC INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
RHC	Rotational hand controller deflection	SOP	A(3)S	TBD	deg	25
INIT_MANUAL_TVC	Module initialization flag	OFC_RECON	B	0,1	none	25
Output						
OMEGA_C_BODY	Commanded vehicle angular rate in body axes	Roll component: RCS_ASSIST_ROLL, TVC_LAW_ROLL Pitch and yaw components: RCS_ASSIST_PITCH_YAW, TVC_LAW_PITCH_YAW	V(3)S	TBD	deg/s	25

TABLE 4.2.2.1.6-2 MANUAL_TVC CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
PROPGRAD	Gain; commanded body rate divided by RHC deflection	A(3)S	TBD	(deg/s)/deg
DBSTICK	Deadband; required hand controller deflection from last accepted value	A(3)S	TBD	deg
RL	Rate command limit	A(3)S	TBD	deg/s

TABLE 4.2.2.1.6-3 MANUAL_TVC INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_MANUAL_TVC = OFF	INIT_MANUAL_TVC = ON	LAST_ACCEPTED_VALUE	0

4.2.2.1.7 MISC_TRACKING

A. Function: This module provides inputs to the RCS DAP to effect attitude control. The command inputs and the internal functions of the module are TBD.

B. Block Diagram: TBD

C. Processing Rate: TBD

D. Interface Requirements: Table 4.2.2.1.7-1

E. Constants: TBD

F. Initialization Requirements: TBD

TABLE 4.2.2.1.7-1 MISC_TRACKING INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
TBD	TBD	SOP	TBD	TBD	TBD	TBD
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	TBD
AUTO_GA_DESIRED	Desired IMU gimbal angles	MISC_TRACKING	A(3)S	-180 < x <= 180	deg	TBD
Outputs						
DELTA_GA	Desired IMU gimbal angle increments	RCS ERRORS	A(3)S	TBD	deg	TBD
DESIRED_BODY_RATE	Desired body angular rate	RCS_ERRORS	V(3)S	TBD	deg/s	TBD
GA DESIRED	Desired IMU gimbal angles	D&C, RCS_ERRORS	A(3)S	-180 < x <= 180	deg	TBD
AUTO_GA_DESIRED	Desired IMU gimbal angles	D&C, MISC_TRACKING	A(3)S	-180 < x <= 180	deg	TBD
GA_MANEUVER_TERMINAL	Desired terminal IMU gimbal angles	D&C	A(3)S	-180 < x <= 180	deg	TBD

4.2.2.1.8 OMS_PRETHRUST_MANEUVER

A. Function: This module provides the RCS DAP with inputs to align the expected OMS thrust direction with a desired direction expressed as a unit vector in IMU stable member coordinates. It also supplies the TVC DAP with the position of the orbiter center of gravity (cg) relative to each OMS engine. Upon initialization, the module calculates the engine-to-cg vectors and the expected thrust vector for a one- or two-engine burn. The expected thrust vector is supplied as the vehicle-fixed pointing vector to TWO_AXIS_ATTITUDE_MANEUVER.

B. Block Diagram: Figure 4.2.2.1.8-1

C. Processing Rate: 5/6 Hz

D. Interface Requirements: Table 4.2.2.1.8-1

E. Constants: Table 4.2.2.1.8-2

F. Initialization Requirements: Table 4.2.2.1.8-3

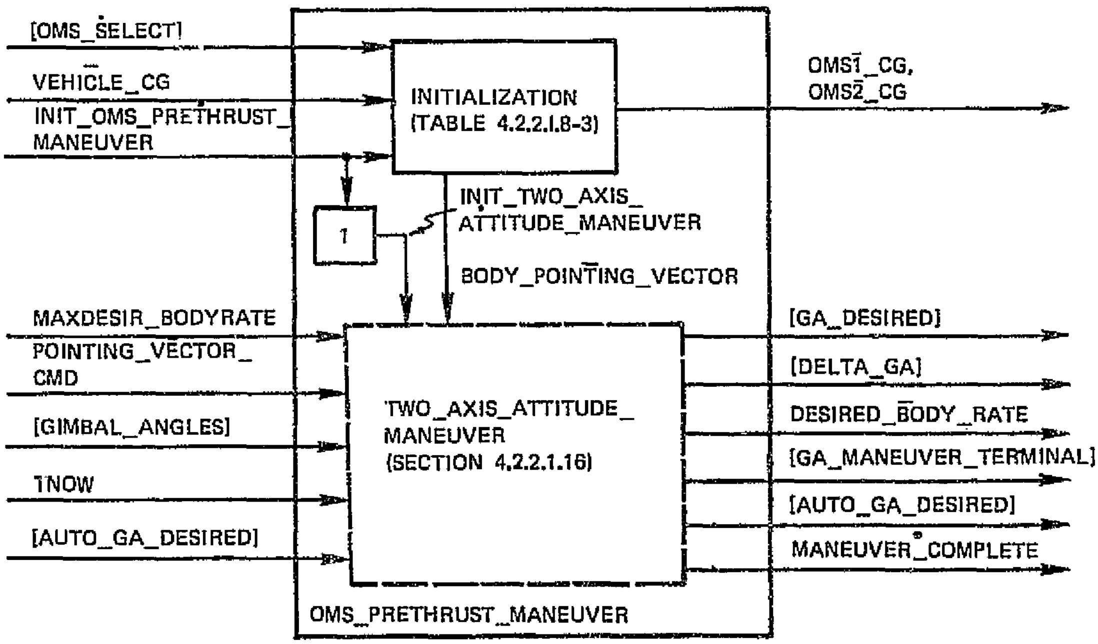


Figure 4.2.2.1.8-1. OMS_PRETHRUST_MANEUVER.

TABLE 4.2.2.1.8-1 OMS_PRETHRUST_MANEUVER INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
OMS_SELECT	To burn/not to burn status of OMS engines (1=to burn; 0=not to burn)	DEC	A(2)B	0,1	none	1/maneuver
POINTING_VECTOR_CMD	Unit vector specifying commanded initial OMS thrust direction in stable member axes	GUID or DEC	V(3)S	-1 to +1	none	1/maneuver
MAXDESIR_BODYRATE	Desired magnitude of body angular rate in automatic attitude maneuvers	DEC	S	0 to 5	deg/s	1/maneuver
TNOW	Current time	SOP	S	TBD	s	5/6
VEHICLE_CG	Vehicle center of gravity, in body axis	SP	V(3)S	TBD	f	1/maneuver
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	1/maneuver
INIT_OMS_PRETHRUST_-MANEUVER	Module initialization flag	CPC_RECON	B	0,1	none	5/6
AUTO_GA_DESIRED	Desired IMU gimbal angles	OMS_PRETHRUST_MANEUV-ER	A(3)S	-180 < x <= 180	deg	5/6
Outputs						
DELTA_GA	Desired IMU gimbal angle increments	RCS_ERRORS	A(3)S	TBD	deg	5/6
DESIRED_BODY_RATE	Desired body angular rate	RCS_ERRORS	V(3)S	TBD	deg/s	1/maneuver
GA_DESIRED	Desired IMU gimbal angles	DEC, RCS_ERRORS	A(3)S	-180 < x <= 180	deg	5/6
AUTO_GA_DESIRED	Desired IMU gimbal angles	DEC, OMS_PRETHRUST_MANEUV-ER	A(3)S	-180 < x <= 180	deg	5/6

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TABLE 4.2.2.1.8-1 OMS_PRETHRUST_MANEUVER INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
OMS1_CG	Vector from OMS1 hinge point to vehicle cg, in body axes	ENGINE_CG_CMD, ENGINE_PRETHRUST_TRIM, DELTA_OMEGA_OMS_ENGINE, TVC_LAW_PITCH_YAW	V(3)S	TBD	f	1/maneuver
OMS2_CG	Vector from OMS2 hinge point to vehicle cg, in body axes	ENGINE_CG_CMD, ENGINE_PRETHRUST_TRIM, DELTA_OMEGA_OMS_ENGINE, TVC_LAW_PITCH_YAW	V(3)S	TBD	f	1/maneuver
GA_MANEUVER_TERMINAL	Desired terminal IMU gimbal angles	DEC	A(3)S	-180 < x <= 180	deg	1/maneuver
MANEUVER_COMPLETE	Flag signifying completion of maneuver	DEC	B	0,1	none	5/6

TABLE 4.2.2.1.8-2 OMS_PRETHRUST_MANEUVER CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
OMS1	Vector in body coordinate system from origin to OMS engine 1 hinge point	A(3)S	TBD	ft
OMS2	Vector in body coordinate system from origin to OMS engine 2 hinge point	A(3)S	TBD	ft

TABLE 4.2.2.1.8-3 OMS_PRETHRUST_MANEUVER INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_OMS_PRETHRUST_MANEUVER = OFF	INIT_OMS_PRETHRUST_MANEUVER = ON	OMS1_CG	VEHICLE_CG - OMS1
		OMS2_CG	VEHICLE_CG - OMS2
		BODY_POINTING_VECTOR	See Note 1

Note 1: $-$unit (OMS1_CG scalar (OMS_SELECT$_1$) + OMS2_CG scalar (OMS_SELECT$_2$))

4.2.2.1.9 PAYLOAD_ATTITUDE

A. Function: This module provides the RCS DAP with inputs to effect attitude control. The command inputs and the internal functions of the module are TBD.

B. Block Diagram: TBD

C. Processing Rate: TBD

D. Interface Requirements: Table 4.2.2.1.9-1

E. Constants: TBD

F. Initialization Requirements: TBD

TABLE 4.2.2.1.9-1 PAYLOAD_ATTITUDE INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
TBD	TBD	SOP	TBD	TBD	TBD	TBD
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	TBD
AUTO_GA_DESIRED	Desired IMU gimbal angles	PAYLOAD_SUPPLIED_CMDS	A(3)S	-180 < x <= 180	deg	TBD
Outputs						
DELTA_GA	Desired IMU gimbal angle increments	RCS_ERRORS	A(3)S	TBD	deg	TBD
DESIRED_BODY_RATE	Desired body angular rate	RCS_ERRORS	V(3)S	TBD	deg/s	TBD
GA_DESIRED	Desired IMU gimbal angles	D&C, RCS_ERRORS	A(3)S	-180 < x <= 180	deg	TBD
AUTO_GA_DESIRED	Desired IMU gimbal angles	D&C, PAYLOAD_SUPPLIED_CMDS	A(3)S	-180 < x <= 180	deg	TBD
GA_MANEUVER_TERMINAL	Desired terminal IMU gimbal angles	D&C	A(3)S	-180 < x <= 180	deg	TBD

4.2.2.1.10 ROT_ACCEL

A. Function: For each vehicle axis that is in the manual acceleration rotation submode, this module provides an input to the RCS DAP to generate a vehicle angular acceleration about that axis while the RHC is out of detent in that axis. The sense of the angular acceleration corresponds to the sense of the RHC deflection. When the RHC is in detent, vehicle rotation about the affected axis is free.

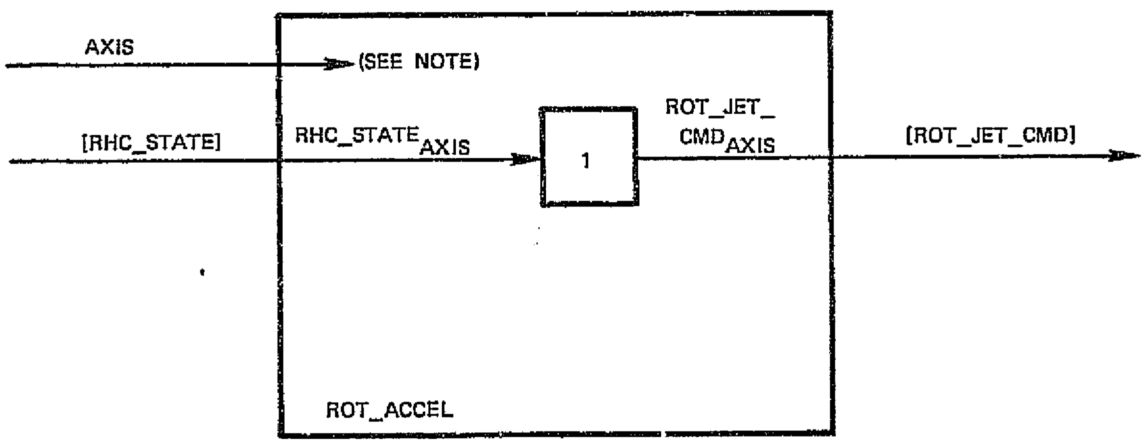
B. Block Diagram: Figure 4.2.2.1.10-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.1.10-1

E. Constants: none

F. Initialization Requirements: none



NOTE: Array cr vector subscript AXIS should be taken as indicating that the processing shown is for that element specified by the present value of AXIS.

Figure 4.2.2.1.10-1. ROT_ACCEL.

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TABLE 4.2.2.1.10-1 ROT_ACCEL INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
RHC_STATE	Rotational hand controller command with sense of deflection	RHC_READ	A(3)I	-1,0,1	none	25/axis
AXIS	Body axis for this execution	OFC_RECON	I	1,2,3	none	25/axis
Outputs						
ROT_JET_CMD	Rotation command	JET_SELECT, PHASE_PLANE	A(3)I	-1,0,1	none	25/axis

4.2.2.1.11 ROT_DISC

A. Function: For each vehicle axis that is in the manual discrete rate rotation submode, this module provides inputs to the RCS DAP to generate a predetermined vehicle angular rate about that axis while the RHC is out of detent in that axis. The sense of the angular rate corresponds to the sense of the RHC deflection. When the RHC is in detent, an attitude hold is performed in the affected axis; the vehicle returns to the attitude it had at the instant the RHC went into detent.

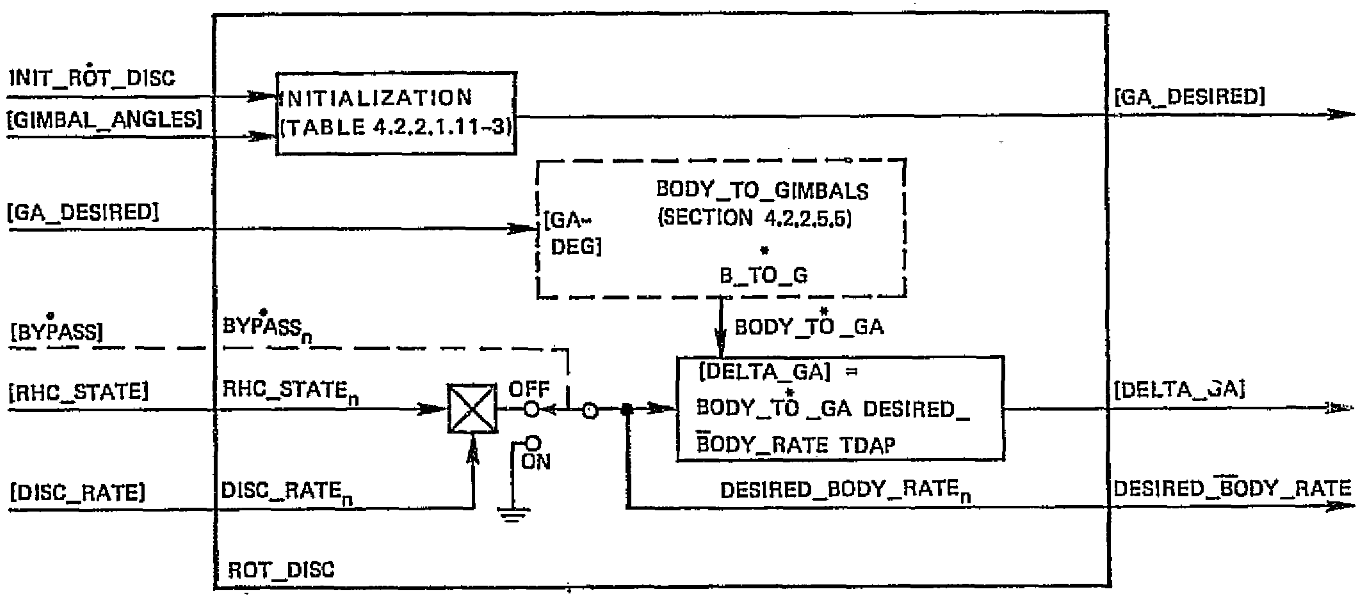
B. Block Diagram: Figure 4.2.2.1.11-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.1.11-1

E. Constants: Table 4.2.2.1.11-2

F. Initialization Requirements: Table 4.2.2.1.11-3



NOTE:

ARRAY OR VECTOR SUBSCRIPT n SHOULD BE TAKEN AS INDICATING THAT THE PROCESSING SHOWN IS FOR ONE ELEMENT, AND ALL THREE ELEMENTS ARE PROCESSED.

Figure 4.2.2.1.11-1. ROT_DISC.

TABLE 4.2.2.1.11-1 ROT_DISC INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
BYPASS	Zero output command, by axis (1=zero output; 0=RHC-commanded output)	OFC_RECON	A(3)B	0,1	none	25
RHC_STATE	Rotational hand controller command with sense of deflection	RHC_READ	A(3)I	-1,0,1	none	25
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	25
GA_DESIRED	Desired IMU gimbal angles	RCS_ERRORS	A(3)S	-180 < x <= 180	deg	25
DISC_RATE	Desired body angular rate during deflection of rotational hand controller	PANEL_SWITCH_INTERP	A(3)S	TBD	deg/s	25
INIT_ROT_DISC	Module initialization flag	OFC_RECON	B	0,1	none	25
Outputs						
DELTA_GA	Desired IMU gimbal angle increments	RCS_ERRORS	A(3)S	TBD	deg	25
DESIRED_BODY_RATE	Desired body angular rate	RCS_ERRORS	V(3)S	TBD	deg/s	25
GA_DESIRED	Desired IMU gimbal angles	DEC, RCS_ERRORS	A(3)S	-180 < x <= 180	deg	25

TABLE 4.2.2.1.11-2 ROT_DISC CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
TDAP	Period of RCS DAP cycle	S	0.04	s

TABLE 4.2.2.1.11-3 ROT_DISC INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_ROT_DISC = OFF	INIT_ROT_DISC = ON	GA_DESIRED	GIMBAL_ANGLES

4.2.2.1.12 ROT_PULSE

A. Function: For each vehicle axis that is in the manual pulse rotation submode, this module provides an input to the RCS DAP to generate a predetermined vehicle angular rate increment about that axis for each time the RHC is moved out of detent in that axis. The sense of the angular rate increment corresponds to the sense of the RHC deflection. When the RHC is in detent, the achieved rate is maintained about the affected axis. A rate error deadband is incorporated to prevent severe cycling.

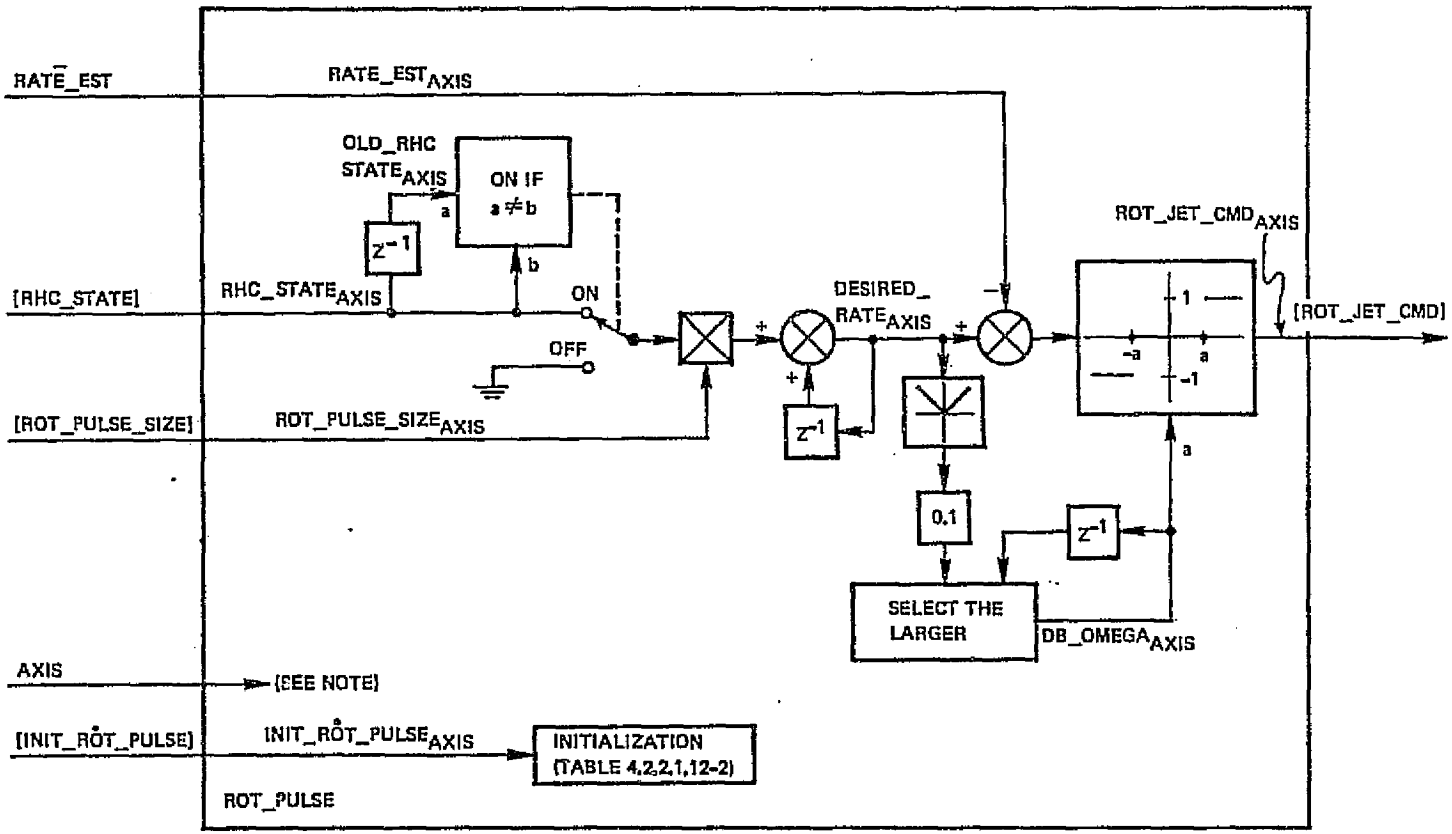
B. Block Diagram: Figure 4.2.2.1.12-1

C. Prccessing Rate: 25 Hz/axis

D. Interface Requirements: Table 4.2.2.1.12-1

E. Constants: none

F. Initialization Requirements: Table 4.2.2.1.12-2



NOTE:

ARRAY OR VECTOR SUBSCRIPT AXIS SHOULD BE TAKEN TO INDICATE THAT THE PROCESSING SHOWN IS FOR THAT ELEMENT SPECIFIED BY THE PRESENT VALUE OF AXIS.

Figure 4.2.2.1.12-1. ROT_PULSE.

TABLE 4.2.2.1.12-1 ROT_PULSE INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
RHC_STATE	Rotational hand controller command with sense of deflection	RHC_READ	A(3)I	-1,0,1	none	25/axis
RATE_EST	Body angular rate estimate	PART1_FILTER	V(3)S	TBD	deg/s	25/axis
INIT_ROT_PULSE	Module initialization flag, by axis	OFC_RECON	A(3)B	0,1	none	25/axis
ROT_PULSE_SIZE	Desired body angular rate change per deflection of rotational hand controller	PANEL_SWITCH_INTERP	A(3)S	TBD	deg/s	25/axis
AXIS	Body axis for this execution	OFC_RECON	I	1,2,3	none	25/axis
Outputs						
ROT_JET_CMD	Rotation command	JET_SELECT, PHASE_PLANE	A(3)I	-1,0,1	none	25/axis

TABLE 4.2.2.1.12-2 ROT_PULSE INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_ROT_PULSE$(AXIS) = OFF	INIT_ROT_PULSE$(AXIS) = ON	DESIRED_RATE$(AXIS)	RATE_EST$(AXIS)
		OLD_RHC_STATE$(AXIS)	RHC_STATE$(AXIS)

4.2.2.1.13 THREE_AXIS_ATTITUDE_MANEUVER

A. Function: This module provides the RCS DAP with inputs to achieve a desired vehicle attitude, expressed as commanded IMU gimbal angles, through a single equivalent rotation. Calculations to determine the maneuver path, rate and duration are made once, upon initialization. Successive executions during the maneuver interval continue to define the maneuver path by updating the desired IMU gimbal angles and the desired angle increments per RCS DAP cycle. At the end of the maneuver interval, the module effects an attitude hold at the commanded IMU gimbal angles.

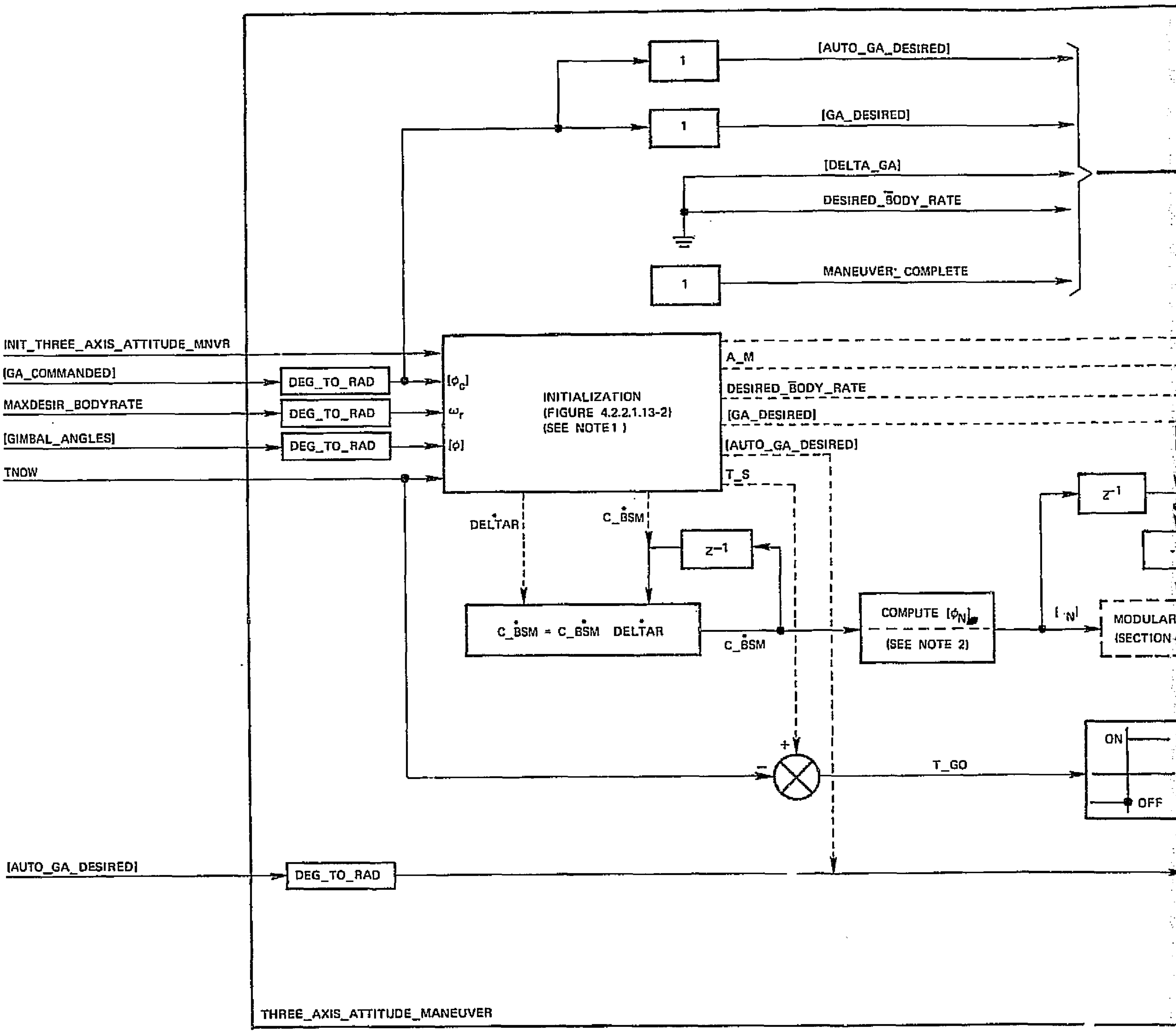
B. Block Diagram: Figure 4.2.2.1.13-1

C. Processing Rate: 5/6 Hz

D. Interface Requirements: Table 4.2.2.1.13-1

E. Constants: Table 4.2.2.1.13-2

F. Initialization Requirements: Figure 4.2.2.1.13-2



NOTE 1: INITIALIZATION is executed only when INIT_THREE_AXIS_ATTITUDE_MNVR is ON.

NOTE

NOTE 2: $\phi_{N,3} = \sin^{-1}(C\_BSM_{2,1})$

$\phi_{N,2} = \sin^{-1}(C\_BSM_{3,1}/\cos(\phi_{N,3}))$

$\phi_{N,1} = \sin^{-1}(\ C\_BSM_{2,3}/\cos(\phi_{N,3}))$

if $C\_BSM_{1,1} < 0.0; \phi_{N,2} = \pi \text{ sign } (\phi_{N,2}) - \phi_{N,2}$

if $C\_BSM_{2,2} < 0.0; \phi_{N,1} = \pi \text{ sign } (\phi_{N,1}) - \phi_{N,1}$

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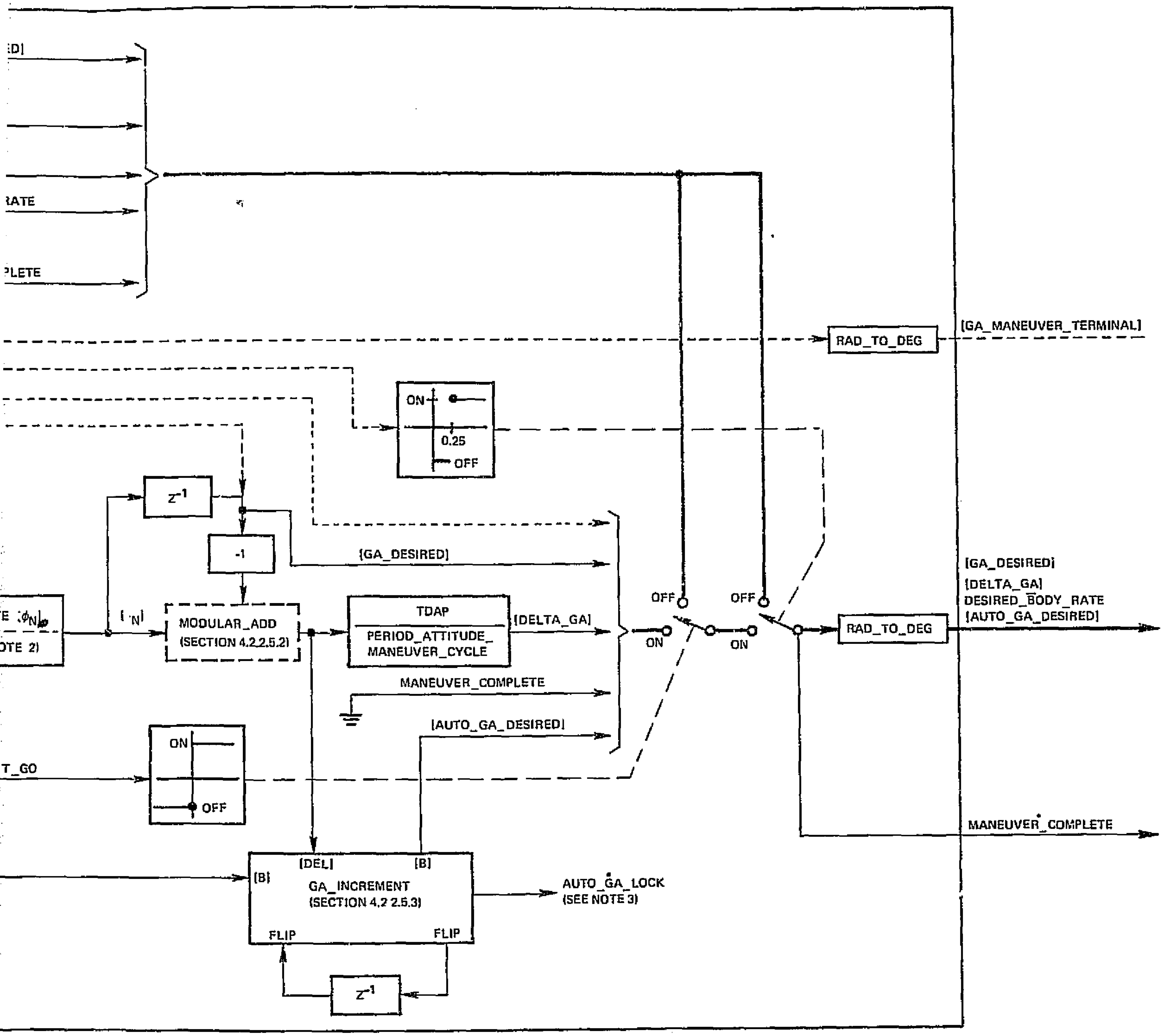
Figure 4.2.2.1.13-1. THREE_AXIS_

FOLDOUT FRAME



NOTE 3: Processing of AUTO_GA_LOCK is TBD.

2.1.13-1. THREE_AXIS_ATTITUDE_MANEUVER

FOLDOUT FRAME 2

TABLE 4.2.2.1.13-1 THREE_AXIS_ATTITUDE_MANEUVER INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
MAXDESIR_BODYRATE	Desired magnitude of body angular rate in automatic attitude maneuvers	D&C	S	0 to 5	deg/s	1/maneuver
GA_COMMANDED	Commanded terminal IMU gimbal angles	GUID or D&C	A(3)S	-180 < x <= 180	deg	1/maneuver
INIT_THREE_AXIS_ATT-ITUDE_MNVR	Module initialization flag	OFC_RECON	B	0,1	none	5/6
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	1/maneuver
AUTO_GA_DESIRED	Desired IMU gimbal angle	THREE_AXIS_ATTITUDE_-MANEUVER	A(3)S	-180 < x <= 180	deg	5/6
TNOW	Current time	SOP	S	TBD	S	5/6
Outputs						
GA_DESIRED	Desired IMU gimbal angles	D&C, RCS_ERRORS	A(3)S	-180 < x <= 180	deg	5/6
DELTA_GA	Desired IMU gimbal angle increments	RCS_ERRORS	A(3)S	TBD	deg	5/6
DESIRED_BODY_RATE	Desired body angular rate	RCS_ERRORS	V(3)S	TBD	deg/s	1/maneuver
AUTO_GA_DESIRED	Desired IMU gimbal angles	D&C, THREE_AXIS_ATTITUDE_-MANEUVER	A(3)S	-180 < x <= 180	deg	5/6
GA_MANEUVER_TERMINAL	Desired terminal IMU gimbal angles	D&C	A(3)S	-180 < x <= 180	deg	1/maneuver
MANEUVER_COMPLETE	Flag signifying completion of maneuver	D&C	B	0,1	none	5/6

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TABLE 4.2.2.1.13-2 THREE_AXIS_ATTITUDE_MANEUVER CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
PERIOD_ATTITUDE_MANEUVER_CY-CLE	Processing period of THREE_AXIS_ATTITUDE_MANEUVER	S	1.2	s
TDAP	Period of FC cycle	S	.04	s
I	Identity matrix	A(3)S	1 0 0 0 1 0 0 0 1	none
RAD_TO_DEG	Radians to degrees conversion factor	S	180/pi	deg/rad
DEG_TO_RAD	Degrees to radians conversion factor	S	pi/180	rad/deg

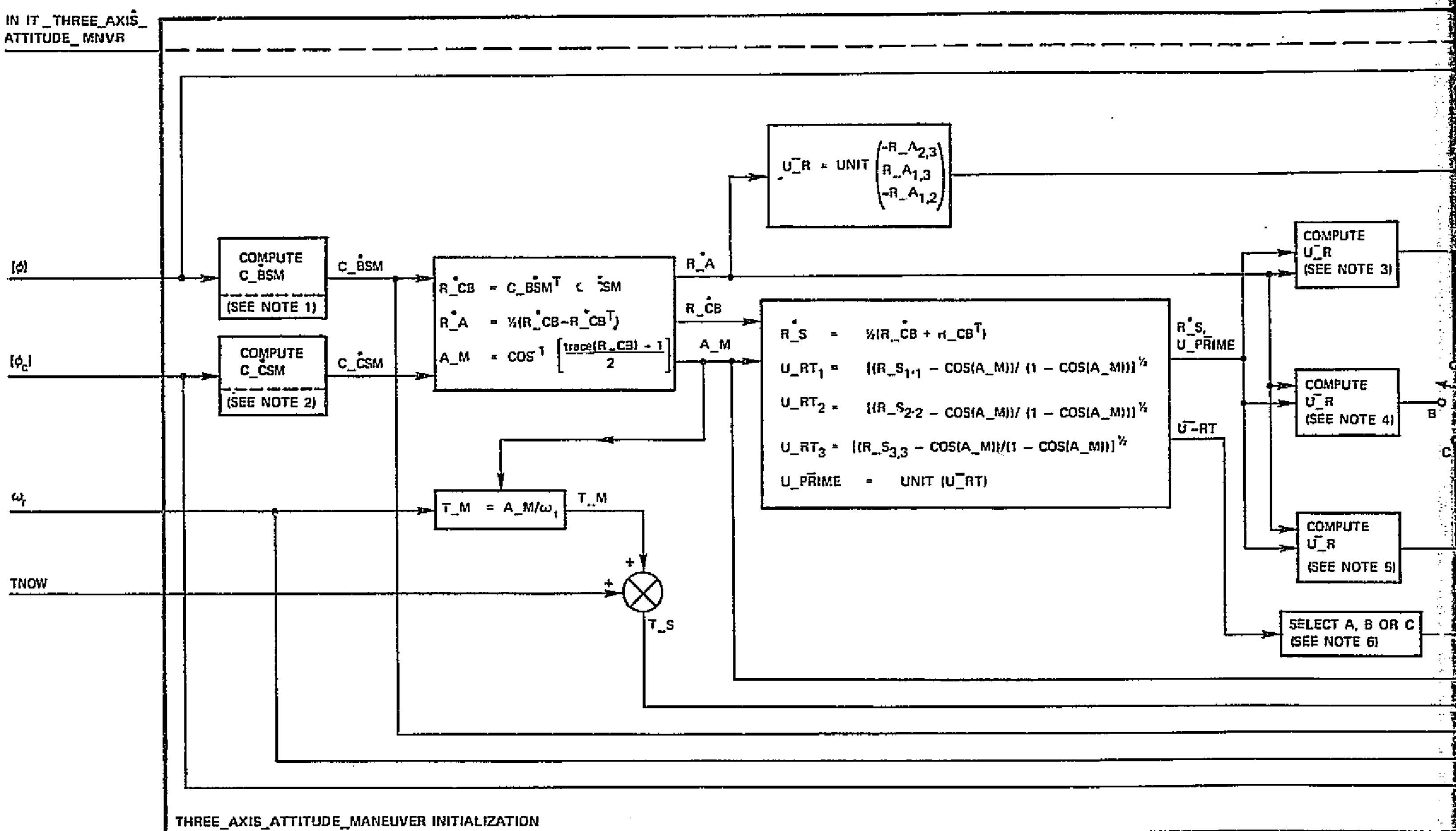

Figure 4.2.2.1.13-2. THREE_AXIS_ATTITUDE_MANEUV
(page 1 of 3).

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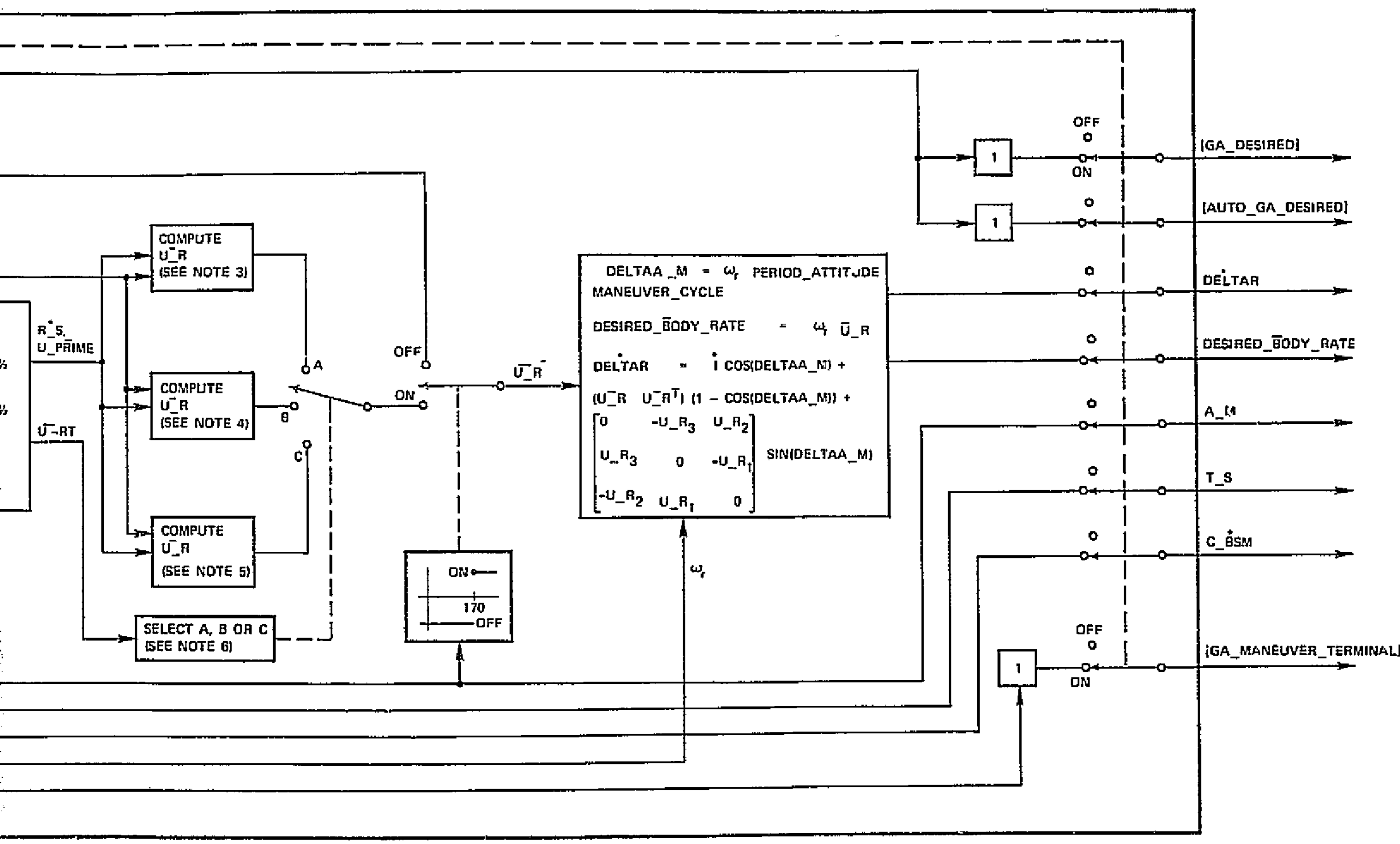


HREE_AXIS_ATTITUDE_MANEUVER initialization
page 1 of 3).

NOTE 1

$$\text{C\_BSM} = \begin{bmatrix} \cos\phi_2 \cos\phi_3 & -\cos\phi_2 \sin\phi_3 \cos\phi_1 + \sin\phi_2 \sin\phi_1 & \cos\phi_2 \sin\phi_3 \sin\phi_1 + \sin\phi_2 \cos\phi_1 \\ \sin\phi_3 & \cos\phi_3 \cos\phi_1 & -\cos\phi_3 \sin\phi_1 \\ -\sin\phi_2 \cos\phi_3 & \sin\phi_2 \sin\phi_3 \cos\phi_1 + \cos\phi_2 \sin\phi_1 & -\sin\phi_2 \sin\phi_3 \sin\phi_1 + \cos\phi_2 \cos\phi_1 \end{bmatrix}$$

NOTE 2

$$\text{C\_CSM} = \begin{bmatrix} \cos\phi_{C2} \cos\phi_{C3} & -\cos\phi_{C2} \sin\phi_{C3} \cos\phi_{C1} + \sin\phi_{C2} \sin\phi_{C1} & \cos\phi_{C2} \sin\phi_{C3} \sin\phi_{C1} + \sin\phi_{C2} \cos\phi_{C1} \\ \sin\phi_{C3} & \cos\phi_{C3} \cos\phi_{C1} & -\cos\phi_{C3} \sin\phi_{C1} \\ -\sin\phi_{C2} \cos\phi_{C3} & \sin\phi_{C2} \sin\phi_{C3} \cos\phi_{C1} + \cos\phi_{C2} \sin\phi_{C1} & -\sin\phi_{C2} \sin\phi_{C3} \sin\phi_{C1} + \cos\phi_{C2} \cos\phi_{C1} \end{bmatrix}$$

NOTE 3

$$\text{U\_R}_1 = \text{U\_PRIME}_1 \ \text{SIGN}(-\text{R\_A}_{2,3})$$

$$\text{U\_R}_2 = \text{U\_PRIME}_2 \ \text{SIGN}(\text{R\_S}_{1,2})$$

$$\text{U\_R}_3 = \text{U\_PRIME}_3 \ \text{SIGN}(\text{R\_S}_{1,3})$$

Figure 4.2.2.1.13-2. THREE_AXIS_ATTITUDE_MANEUVER initialization (page 2 of 3).

NOTE 4

$$U\_R_1 = U\_PRIME_1 \; SIGN(R\_A_{1,3})$$

$$U\_R_2 = U\_PRIME_2 \; SIGN(R\_S_{1,2})$$

$$U\_R_3 = U\_PRIME_3 \; SIGN(R\_S_{2,3})$$

NOTE 5

$$U\_R_1 = U\_PRIME_1 \; SIGN(-R\_A_{1,2})$$

$$U\_R_2 = U\_PRIME_2 \; SIGN(R\_S_{1,3})$$

$$U\_R_3 = U\_PRIME_3 \; SIGN(R\_S_{2,3})$$

NOTE 6

$$A = (U\_RT_1 > U\_RT_2) \cdot (U\_RT_1 > U\_RT_3)$$

$$B = (U\_RT_2 > U\_RT_1) \cdot (U\_RT_2 > U\_RT_3)$$

$$C = \overline{A+B}$$

Figure 4.2.2.1.13-2. THREE_AXIS_ATTITUDE_MANEUVER initialization (page 3 of 3).

4.2.2.1.14 TRANS_ACCEL

A. Function: For each vehicle axis that is in the manual acceleration translation mode, this module provides inputs to the RCS DAP to generate a vehicle translational acceleration along that axis while the THC is out of detent in that axis. The sense of the translational acceleration corresponds to the sense of the THC deflection. When the THC is in detent, vehicle translation along the affected axis is free.

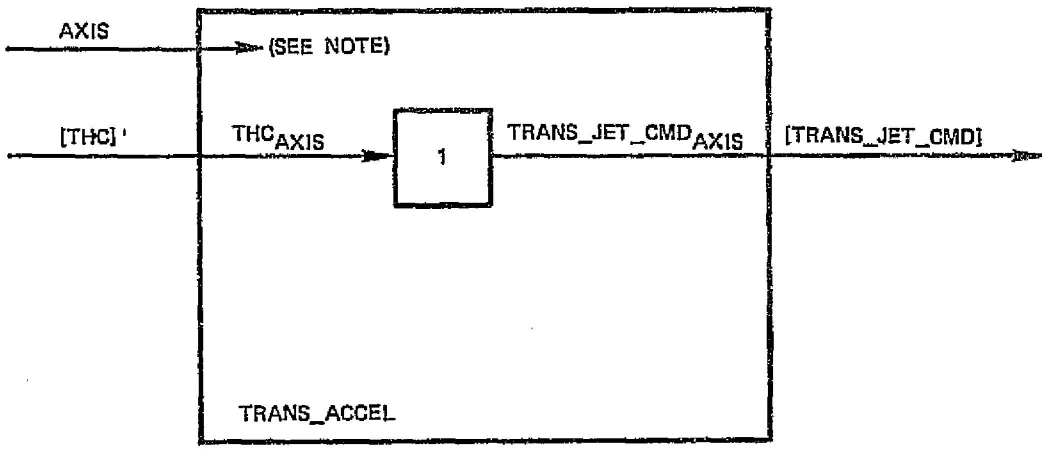
B. Block Diagram: Figure 4.2.2.1.14-1

C. Processing Rate: 25 Hz/axis

D. Interface Requirements: Table 4.2.2.1.14-1

E. Constants: none

F. Initialization Requirements: none



NOTE: Array or vector subscript AXIS should be taken to indicate that the processing shown is for that element specified by the present value of AXIS.

Figure 4.2.2.1.14-1. TRANS_ACCEL.

TABLE 4.2.2.1.14-1 TRANS_ACCEL INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
THC	Translational hand controller command	SOP	A(3)I	-1,0,1	none	25/axis
AXIS	Body axis for this execution	OPC_RECON	I	1,2,3	none	25/axis
Outputs						
TRANS_JET_CMD	Translation command	JET_SELECT	A(3)I	-1,0,1	none	25/axis

4.2.2.1.15 TRANS_PULSE

A. Function: For each vehicle axis that is in the manual pulse translation mode, this module provides inputs to the RCS DAP to generate a predetermined vehicle translational velocity increment along that axis for each time the THC is moved out of detent in that axis. The sense of the translational velocity increment corresponds to the sense of the THC deflection. When the THC is in detent, the achieved velocity along the affected axis is maintained. A velocity error deadband is incorporated to prevent severe cycling.

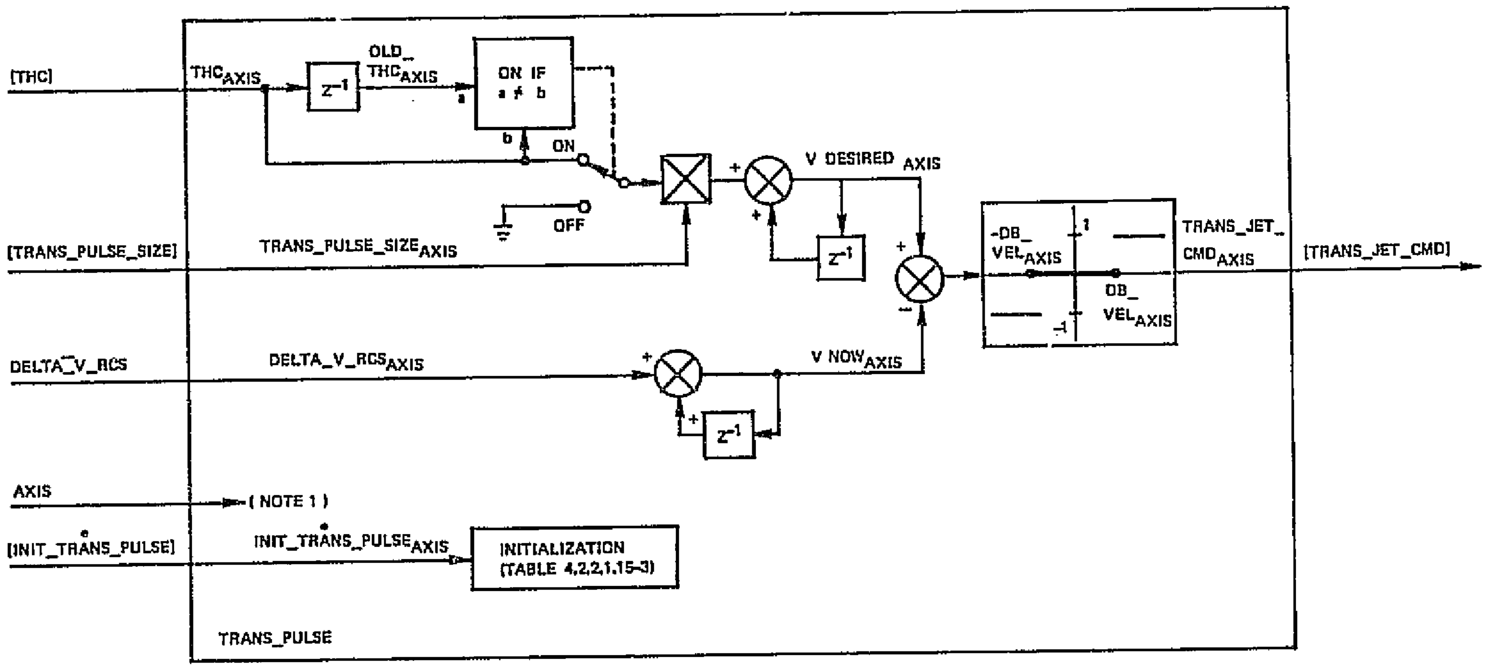
B. Block Diagram: Figure 4.2.2.1.15-1

C. Processing Rate: 25 Hz/axis

D. Interface Requirements: Table 4.2.2.1.15-1

E. Constants: Table 4.2.2.1.15-2

F. Initialization Requirements: Table 4.2.2.1.15-3



NOTE: Array or vector subscript AXIS should be taken to indicate that the processing shown is for that element specified by the present value of AXIS.

Figure 4.2.2.1.15-1. TRANS_PULSE.

TABLE 4.2.2.1.15-1 TRANS_PULSE INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
THC	Translational hand controller command	SOP	A(3)I	-1,0,1	none	25/axis
DELTA_V_RCS	Modelled vehicle velocity increment due to RCS jet firings in the previous cycle	JET_SELECT	V(3)S	TBD	f/s	25/axis
INIT_TRANS_PULSE	Module initialization flag, by axis	OFC_RECON	A(3)B	0,1	none	25/axis
TRANS_PULSE_SIZE	Desired velocity change per deflection of translational hand controller	PANEL_SWITCH_INTERP	A(3)S	TBD	f/s	25/axis
AXIS	Body axis for this execution	OFC_RECON	I	1,2,3	none	25/axis
Outputs						
TRANS_JET_CMD	Translational command	JET_SELECT	A(3)I	-1,0,1	none	25/axis

TABLE 4.2.2.1.15-2 TRANS_PULSE CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
DB_VEL	Velocity error deadband, by axis	A(3) S	TBD	f/s

TABLE 4.2.2.1.15-3 TRANS_PULSE INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_TRANS_PULSE$(AXIS) = OFF	INIT_TRANS_PULSE$(AXIS) = ON	VNOW$(AXIS)	0
		VDESIRED$(AXIS)	0
		OLD_THC$(AXIS)	0

4.2.2.1.16 TWO_AXIS_ATTITUDE_MANEUVER

A. Function: This module provides the RCS DAP with inputs to achieve a desired vehicle pointing direction through a single rotation. The desired direction is expressed as a unit vector in IMU stable member coordinates to which a vehicle-fixed vector is to be aligned. No rotation is made about the vehicle-fixed vector. Upon initialization, the module computes the IMU gimbal angles resulting from the vector alignment, and supplies these as commanded IMU gimbal angles to THREE_AXIS_ATTITUDE_MANEUVER.

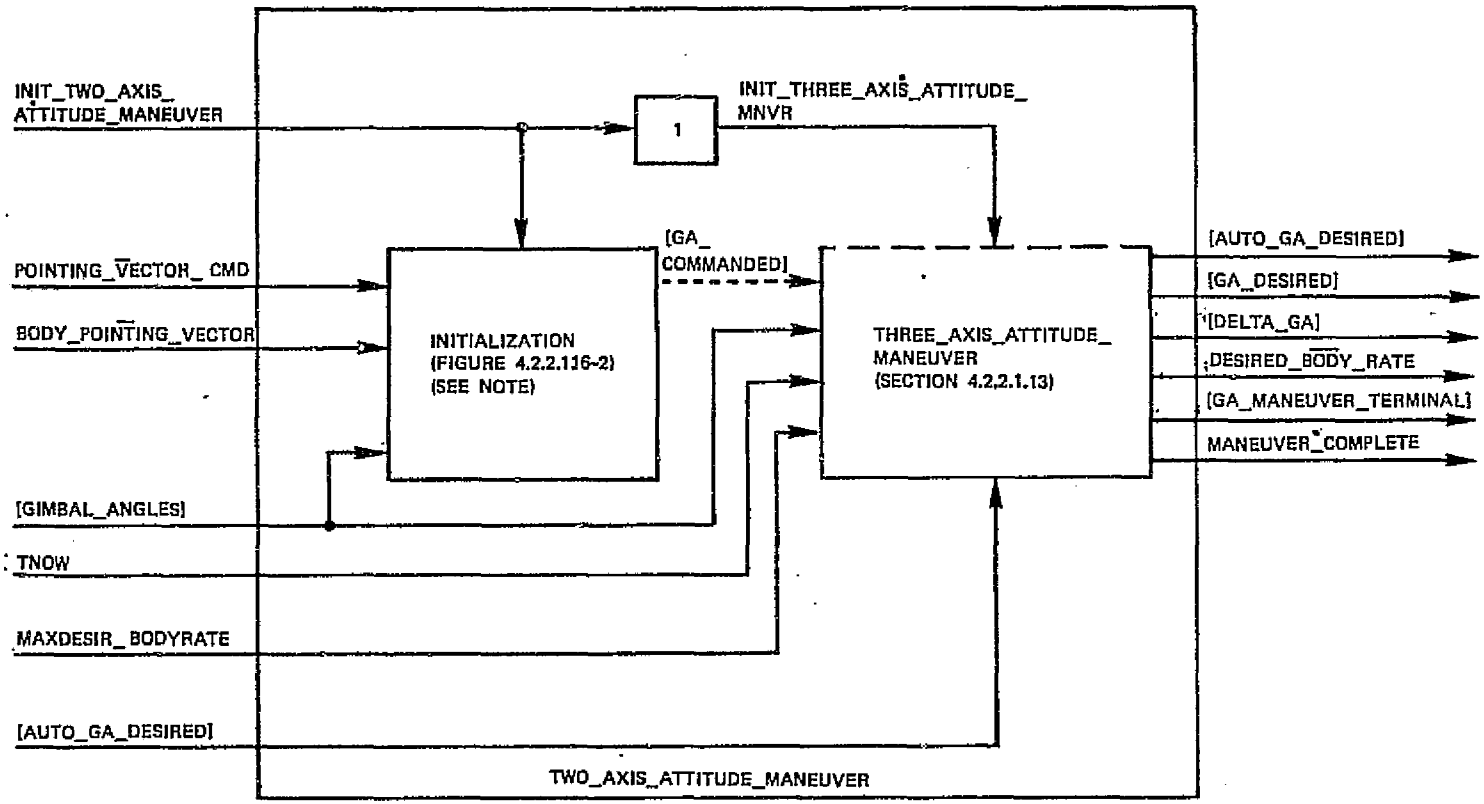
B. Block Diagram: Figure 4.2.2.1.16-1

C. Processing Rate: 5/6 Hz

D. Interface Requirements: Table 4.2.2.1.16-1

E. Constants: Table 4.2.2.1.16-2

F. Initialization Requirements: Figure 4.2.2.1.16-2



NOTE: Initialization is executed only when INIT_TWO_AXIS_ATTITUDE_MANEUVER is on.

Figure 4.2.2.1.16-1. TWO_AXIS_ATTITUDE_MANEUVER.

TABLE 4.2.2.1.16-1 TWO_AXIS_ATTITUDE_MANEUVER INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
BODY_POINTING_VECTOR	Unit vector, in body axes, to be aligned with POINTING_VECTOR_CMD	GUID or DSC	V(3)S	-1 to +1	none	1/maneuver
MAXDESIR_BODYRATE	Desired magnitude of body angular rate in automatic attitude maneuvers	DSC	S	0 to 5	deg/s	1/maneuver
TNOW	Current time	SOP	S	TBD	s	5/6
POINTING_VECTOR_CMD	Unit vector specifying commanded pointing direction in stable member axes	GUID or DSC	V(3)S	-1 to +1	none	1/maneuver
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	1/maneuver
INIT_TWO_AXIS_ATTITUDE_MANEUVER	Module initialization flag	OPC_RECON	B	0,1	none	5/6
AUTO_GA_DESIRED	Desired IMU gimbal angles	TWO_AXIS_ATTITUDE_MANEUVER	A(3)S	-180 < x <= 180	deg	5/6
Outputs						
GA_MANEUVER_TERMINAL	Desired terminal IMU gimbal angles	DSC	A(3)S	-180 < x <= 180	deg	1/maneuver
GA_DESIRED	Desired IMU gimbal angles	DSC, RCS_ERRORS	A(3)S	-180 < x <= 180	deg	5/6
AUTO_GA_DESIRED	Desired IMU gimbal angles	DSC, TWO_AXIS_ATTITUDE_MANEUVER	A(3)S	-180 < x <= 180	deg	5/6
DELTA_GA	Desired IMU gimbal angle increments	RCS_ERRORS	A(3)S	TBD	deg	5/6
DESIRED_BODY_RATE	Desired body angular rate	RCS_ERRORS	V(3)S	TBD	deg/s	1/maneuver
MANEUVER_COMPLETE	Flag signifying completion of maneuver	DSC	B	0,1	none	5/6

TABLE 4.2.2.1.16-2 TWO_AXIS_ATTITUDE_MANEUVER CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
BODY_TO_NB	Vehicle to IMU navigation base transformation matrix	A(3,3) S	See Note 1	none
U_SYM	Unit vector in y direction in stable member coordinates	V(3) S	(0,1,0)	none
U_XL	Unit vector in x direction in navigation base coordinates	V(3) S	(1,0,0)	none
PI	Pi	S	pi	none
RAD_TO_DEG	Radians to degrees conversion factor	S	180/pi	deg/rad
DEG_TO_RAD	Degrees to radians conversion factor	S	pi/180	rad/deg

Note 1:

$$\text{BODY\_TO\_NB} = \begin{bmatrix} \cos(11^\circ) & 0 & \sin(11^\circ) \\ 0 & 1 & 0 \\ -\sin(11^\circ) & 0 & \cos(11^\circ) \end{bmatrix}$$

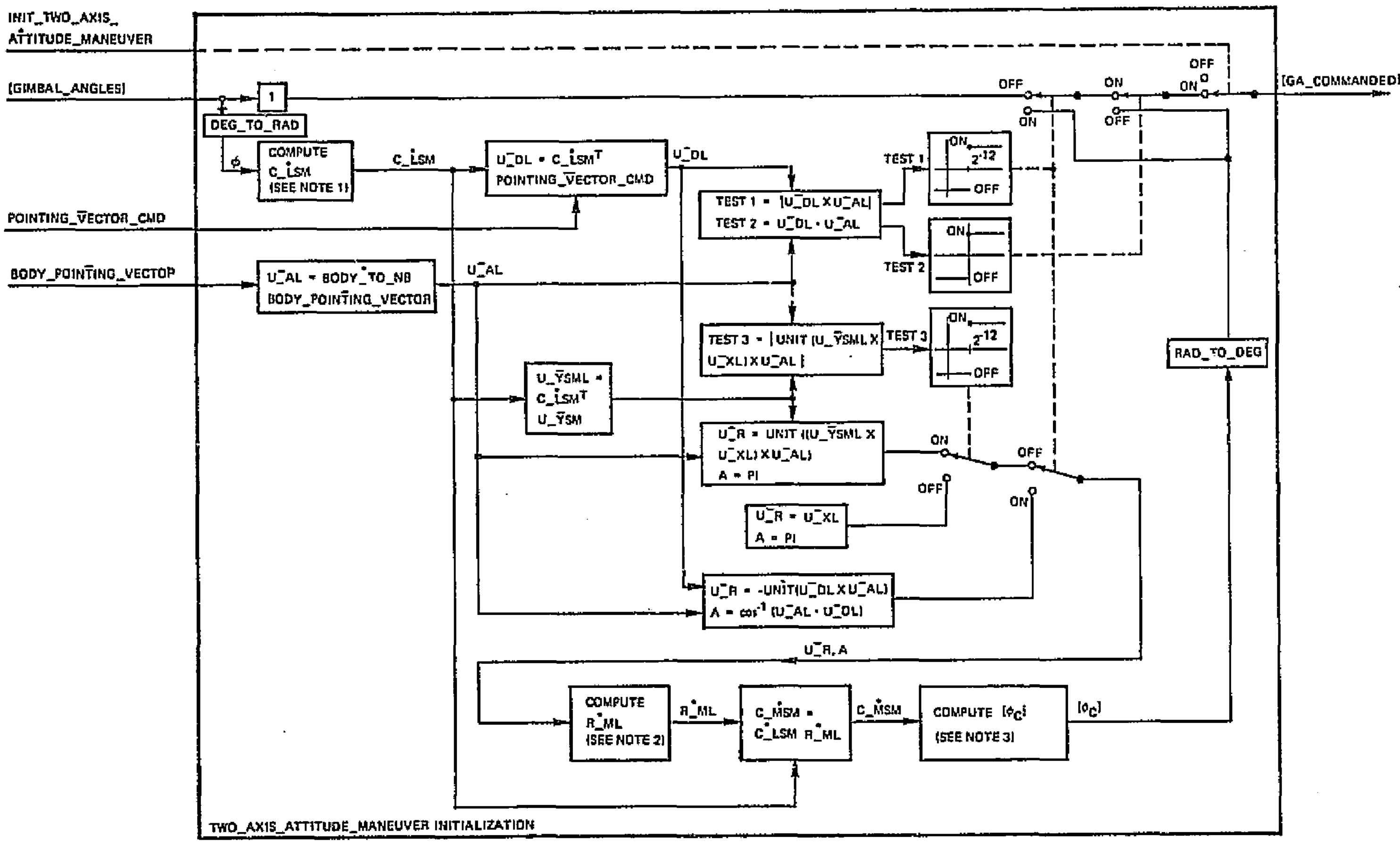


Figure 4.2.2.1.16-2. TWO_AXIS_ATTITUDE_MANEUVER initialization (page 1 of 2).

NOTE 1

$$C\_L\overset{*}{S}M = \begin{bmatrix} \cos\phi_2 \cos\phi_3 & -\cos\phi_2 \sin\phi_3 \cos\phi_1 + \sin\phi_2 \sin\phi_1 & \cos\phi_2 \sin\phi_3 \sin\phi_1 + \sin\phi_2 \cos\phi_1 \\ \sin\phi_3 & \cos\phi_3 \cos\phi_1 & -\cos\phi_3 \sin\phi_1 \\ -\sin\phi_2 \cos\phi_3 & \sin\phi_2 \sin\phi_3 \cos\phi_1 + \cos\phi_2 \sin\phi_1 & -\sin\phi_2 \sin\phi_3 \sin\phi_1 + \cos\phi_2 \cos\phi_1 \end{bmatrix}$$

NOTE 2

$$R\_\overset{*}{M}L = \overset{*}{I} \cos A + (U\_R \ U\_R^T)(1 - \cos A) + \begin{bmatrix} 0 & -U\_R_3 & U\_R_2 \\ U\_R_3 & 0 & -U\_R_1 \\ -U\_R_2 & U\_R_1 & 0 \end{bmatrix} \sin A$$

NOTE 3

$$\phi_{C,3} = \sin^{-1} (C\_MSM_{2,1})$$

$$\phi_{C,2} = \sin^{-1} (C\_MSM_{3,1}/\cos(\phi_{C,3}))$$

$$\phi_{C,1} = \sin^{-1} (-C\_MSM_{2,3}/\cos(\phi_{C,3}))$$

$$\text{if } C\_MSM_{1,1} < 0.0;\ \phi_{C,2} = \pi \sin(\phi_{C,3}) - \phi_{C,2}$$

$$\text{if } C\_MSM_{2,2} < 0.0;\ \phi_{C,1} = \pi \sin(\phi_{C,1}) - \phi_{C,1}$$

Figure 4.2.2.1.16-2. TWO_AXIS_ATTITUDE_MANEUVER initialization (page 2 of 2).

4.2.2.2 RCS DAP

4.2.2.2.1 JET_SELECT

A. Function: This module generates jet firing commands required to implement commanded translations and rotations. It also predicts the resulting velocity and angular rate increments. The module contains separate logic for external selection of either the nominal (main) or vernier jets, and takes into account any jet failures. The nominal-jet logic enables external selection of high or low acceleration levels in translation and rotation (except roll) independently, includes algorithms that fire jets to compensate for off-axis and translation/rotation coupling, and allows external selection of forward or aft jets to effect low-level rotations in pitch and yaw independently. This last option is to permit forward/aft RCS fuel use balancing.

B. Block Diagram: TBD

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.2.1-1

E. Constants: TBD

F. Initialization Requirements: TBD

TABLE 4.2.2.2.1-1 JET_SELECT INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
ROT_JET_CMD	Rotation command	PHASE_PLANE, ROT_ACCEL, ROT_PULSE or OFC_RECON	A(3) I	-1,0,1	none	25
TRANS_JET_CMD	Translation command	AUTO_RCS_TRANS, TRANS_ACCEL, TRANS_PULSE or OFC_RECON	A(3) I	-1,0,1	none	25
JFAIL	RCS jet failure	RM	A(44) B	0,1	none	25
NOM_VERNIER_SW	RCS nominal/vernier jet select	PANEL_SWITCH_INTERP	B	0,1	none	25
ROT_HI_LO_SW	Rotation acceleration level select	PANEL_SWITCH_INTERP	A(3) B	0,1	none	25
JFAIL_CHANGE	Flag signifying change in JFAIL	RM	B	0,1	none	25
TRANS_HI_LO_SW	Translation acceleration level select	RM, PANEL_SWITCH_INTERP	A(3) B	0,1	none	25
LO_PITCH_TAIL_NOSE	Tail or nose jet select for low-level pitch rotation	D&C	B	0,1	none	25
LO_YAW_TAIL_NOSE	Tail or nose jet select for low-level yaw rotation	D&C	B	0,1	none	25
OFF_AXIS_COMP_THRES-HOLD	Threshold for off-axis compensation firings	PANEL_SWITCH_INTERP	A(6) S	TBD	f/s,deg/s	25
INIT_JET_SELECT	Module initialization flag	OFC_RECON	B	0,1	none	25
VEHICLE_INVERSE_INE-RTIA	Inverse of vehicle inertia	SF	M(3,3) S	TBD	1/((slug)(f)-(f))	25
Outputs						
JONLST	RCS jet on command	SOP, RM	A(44) B	0,1	none	25
DELTA_OMEGA_RCS	Modelled body angular rate increment due to RCS jet firings	PART2_FILTER	V(3) S	TBD	deg/s	25
DELTA_V_RCS	Modelled vehicle velocity increment due to RCS jet firings	TRANS_PULSE	V(3) S	TBD	f/s	25

4.2.2.2.2 PHASE_PLANE

A. Function: For each body axis requiring RCS rotation control and not in the manual rotation acceleration or manual rotation pulse submode, this module determines whether an angular rate change is needed and the sign of the desired rate change. The vehicle is driven into and held in a limit cycle about the desired attitude and attitude rate. The parameters of the limit cycle are selected to minimize a weighted combination of response time and RCS fuel use. The attitude deadband is selected externally, and the module takes into account the undesired vehicle angular acceleration—the sum of the disturbance and modelled undesired accelerations.

B. Block Diagram: Figures 4.2.2.2.2-1 through 4.2.2.2.2-8; Tables 4.2.2.2.2-1 and 4.2.2.2.2-2.

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.2.2-3

E. Constants: Table 4.2.2.2.2-4

F. Initialization Requirements: Table 4.2.2.2.2-5

Note: PHASE_PLANE is in the process of redesign as of the publication date of this document.

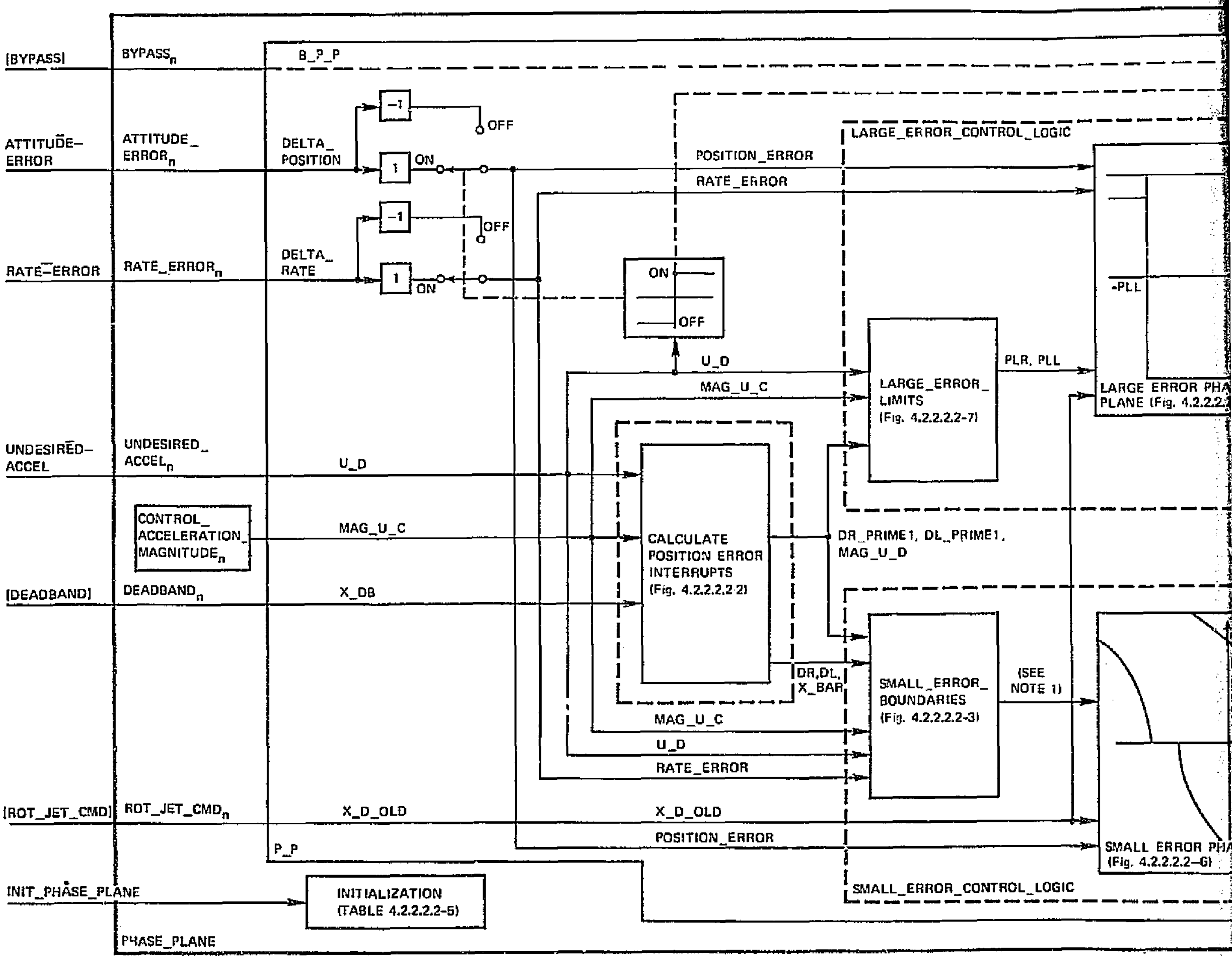


Figure 4.2.2.2.2-1. PHASE_PLANE

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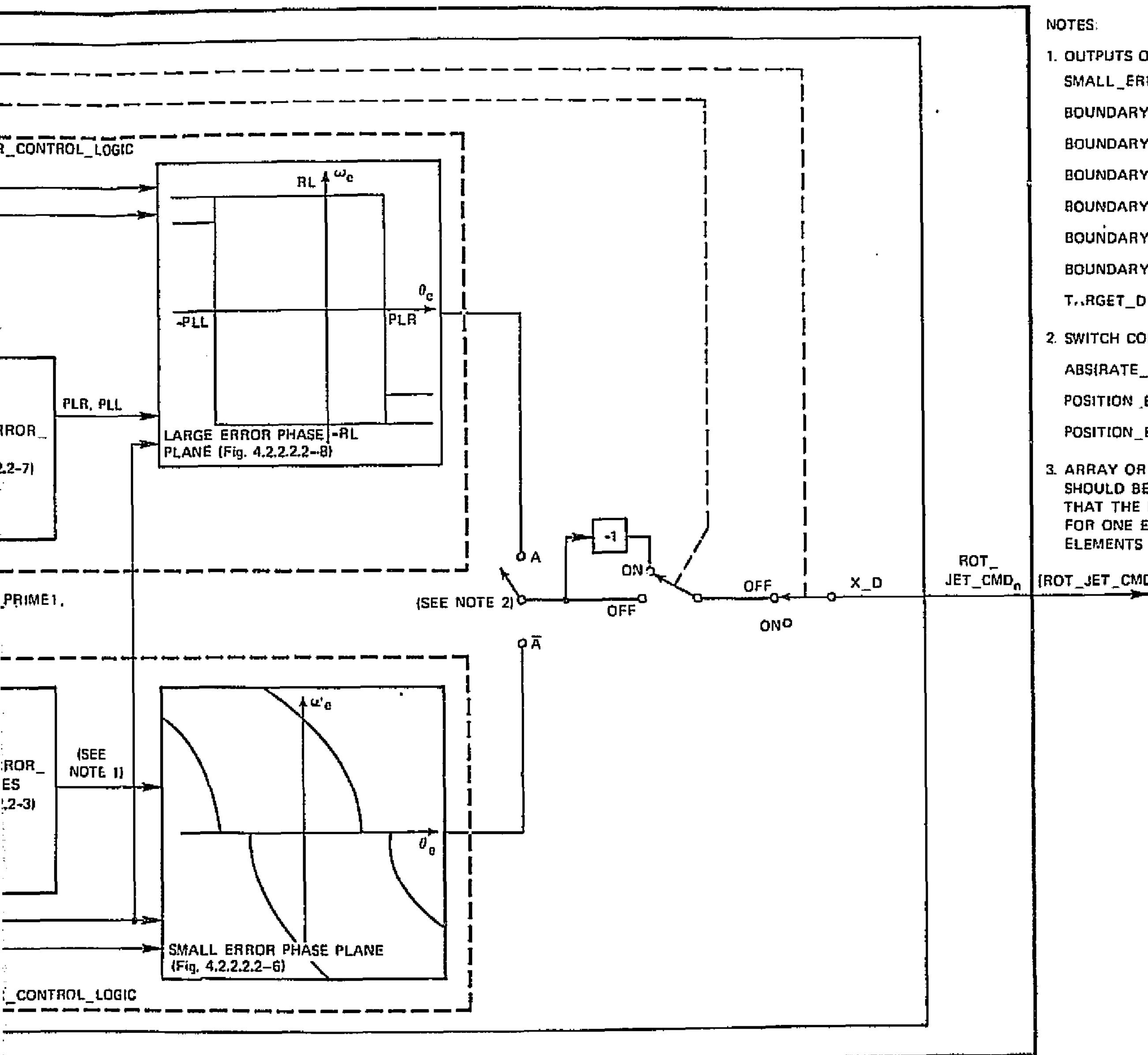

NOTES:

1. OUTPUTS OF SMALL_ERROR_BOUNDARIES:
   BOUNDARY_I_TO_II
   BOUNDARY_II_TO_COAST
   BOUNDARY_I_TO_COAST
   BOUNDARY_IV_TO_COAST
   BOUNDARY_III_TO_COAST
   BOUNDARY_IV_TO_III
   T.,RGET_DISTURB
2. SWITCH CONDITION A:
   ABS(RATE_ERROR) ≥ RL OR
   POSITION_ERROR ≥ PLR OR
   POSITION_ERROR ≤ −PLL
3. ARRAY OR VECTOR SUBSCRIPT n SHOULD BE TAKEN AS INDICATING THAT THE PROCESSING SHOWN IS FOR ONE ELEMENT, AND ALL THREE ELEMENTS ARE PROCESSED.

2.2.2-1. PHASE_PLANE

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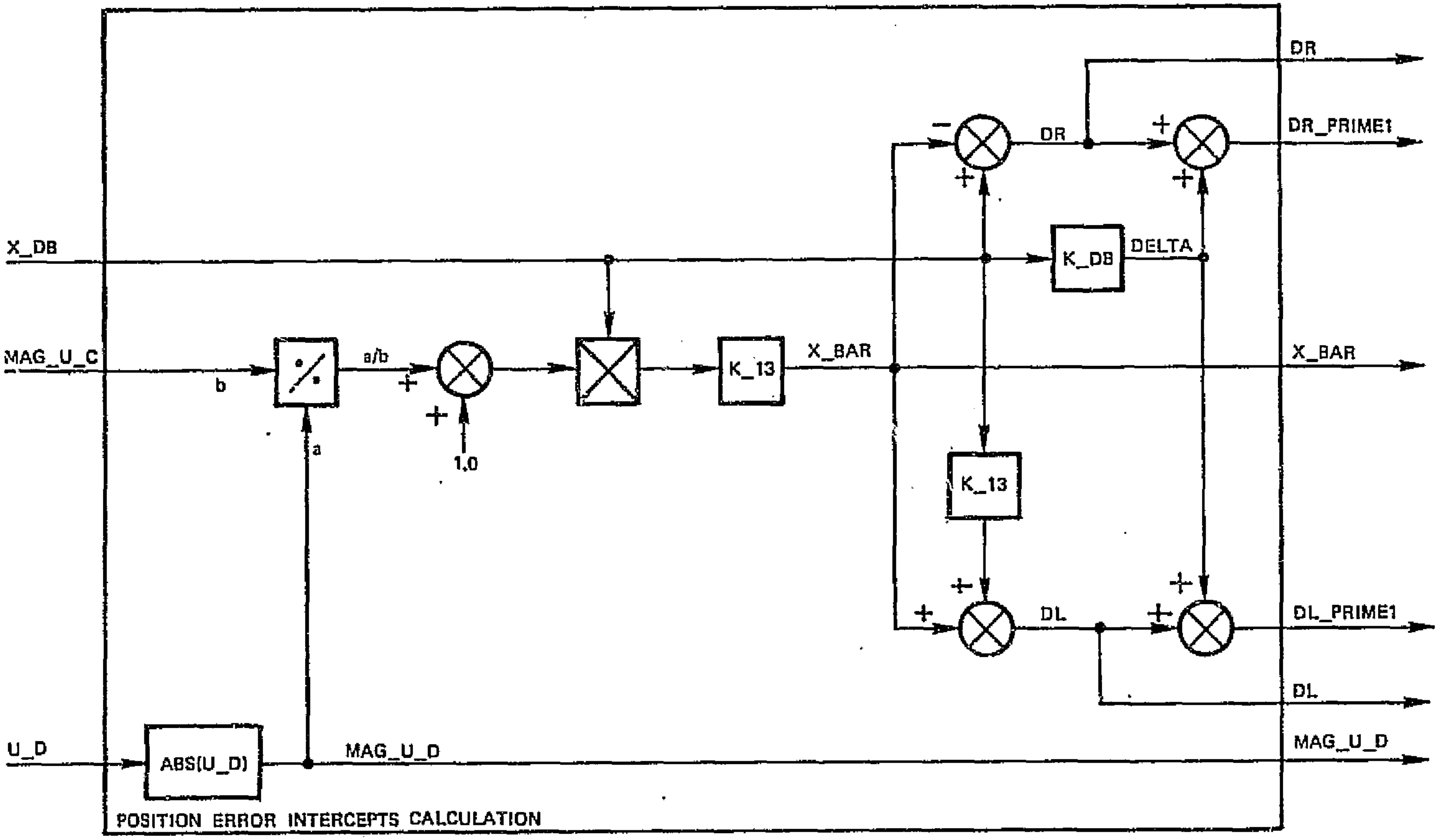

Figure 4.2.2.2.2-2. Position error intercepts calculation.

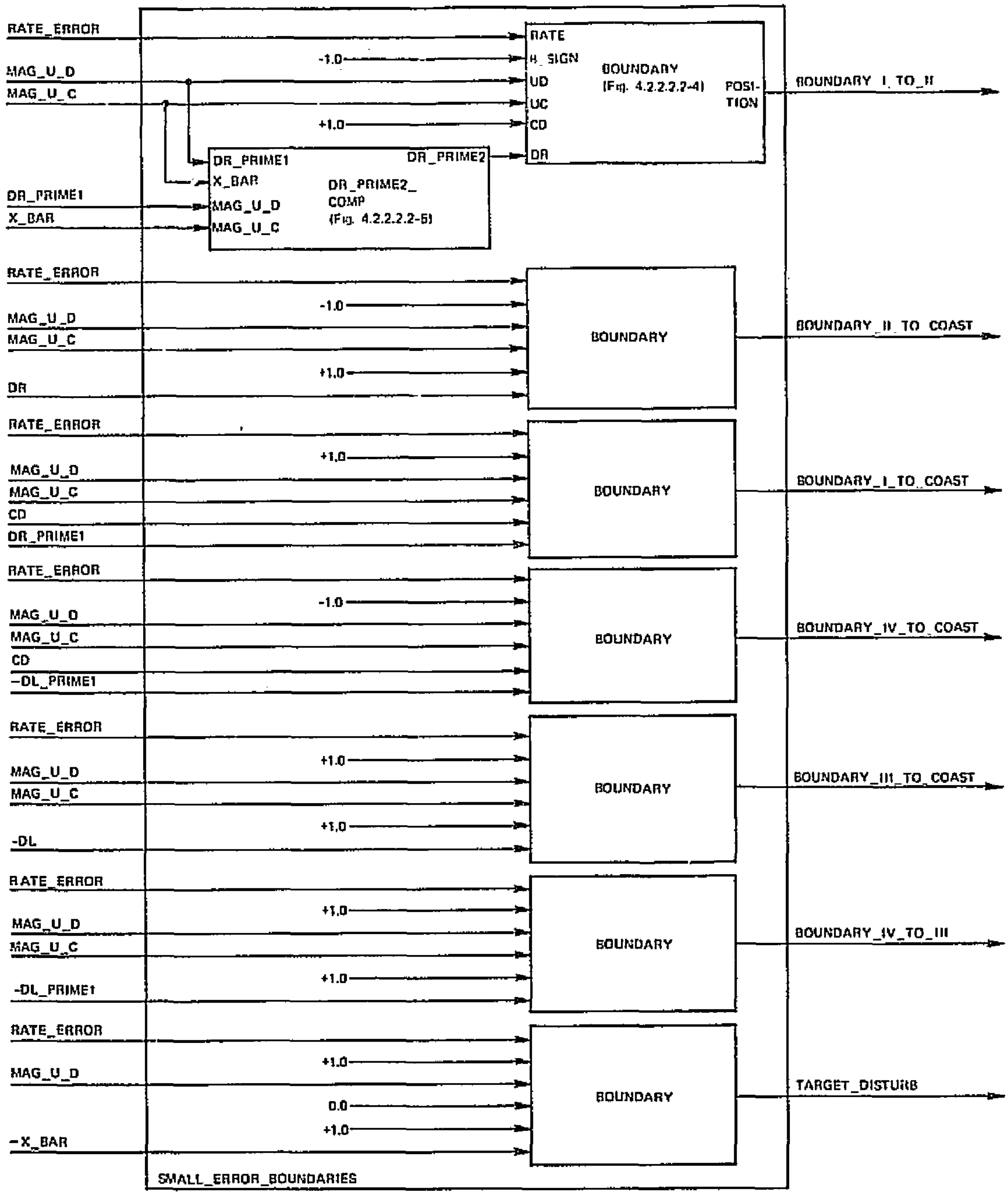

Figure 4.2.2.2.2-3. SMALL_ERROR_BOUNDARIES.

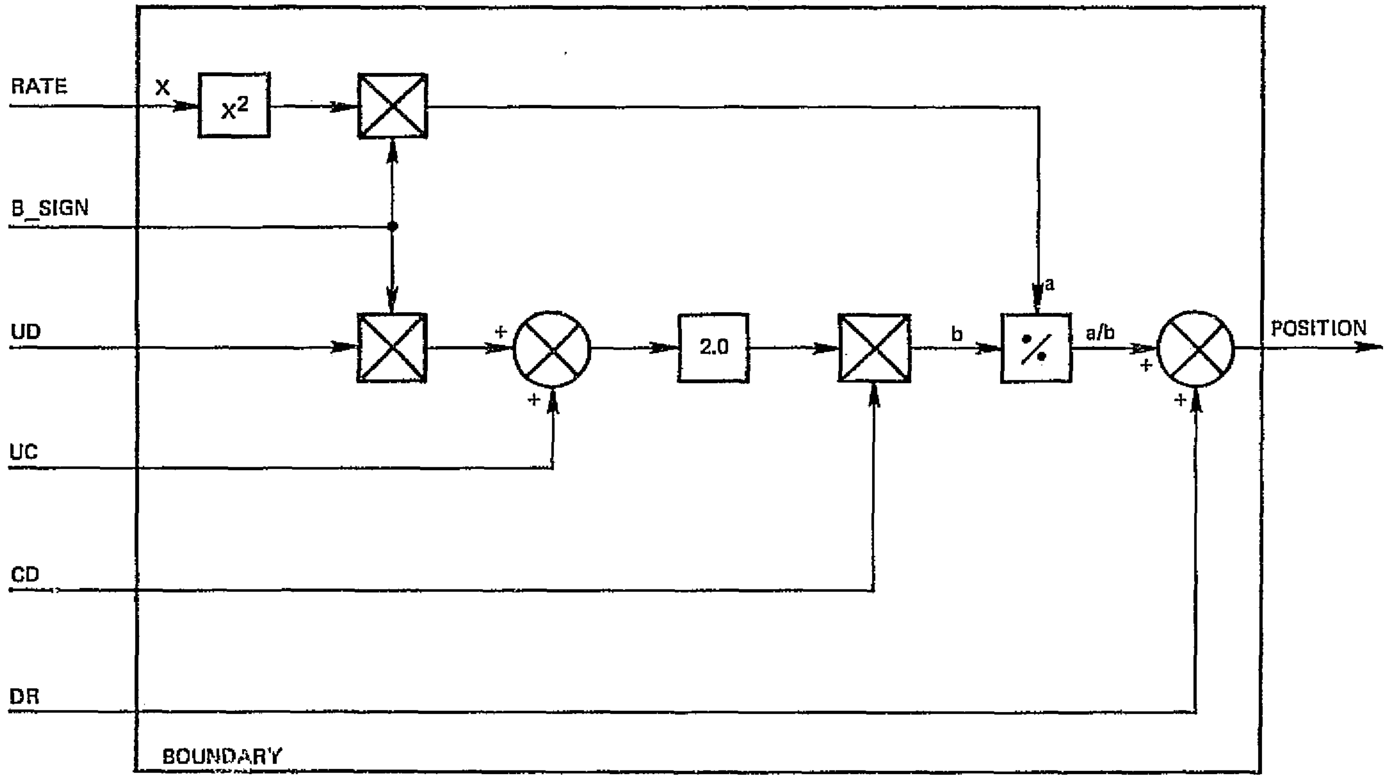

Figure 4.2.2.2.2-4. BOUNDARY.

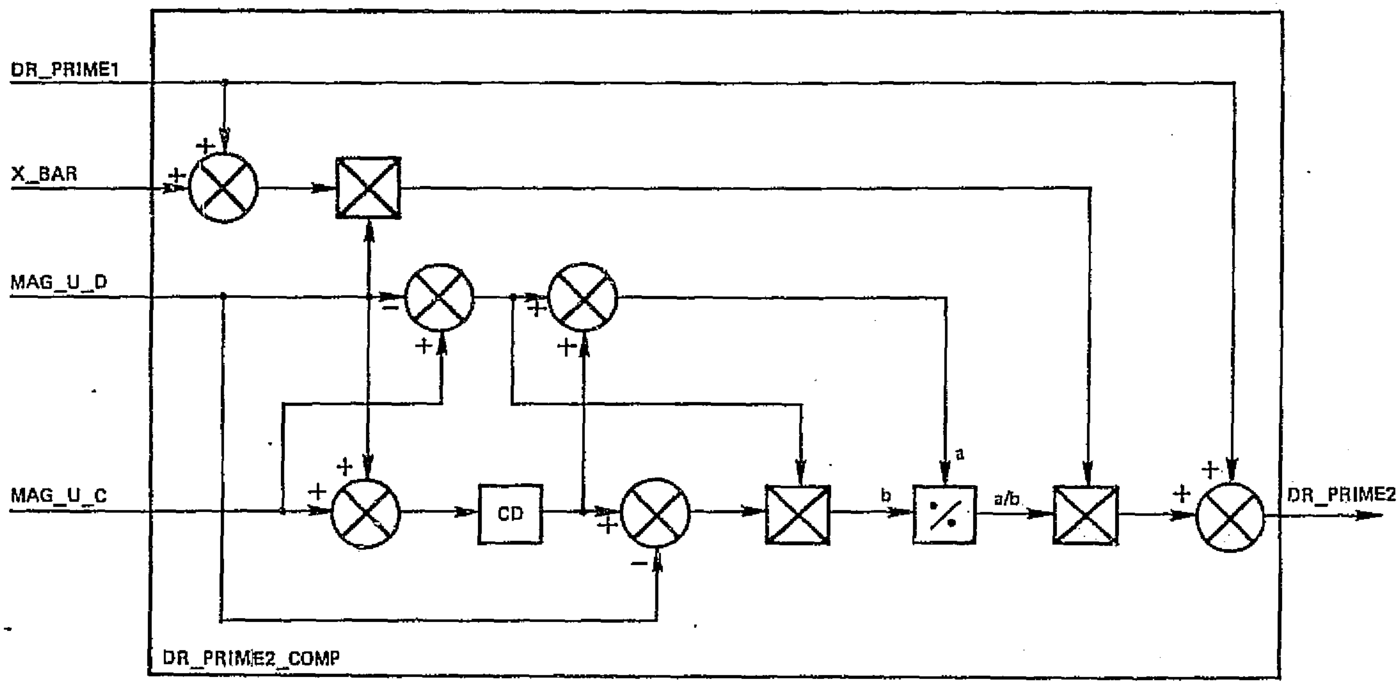

Figure 4.2.2.2.2-5. DR_PRIME_2_COMP.

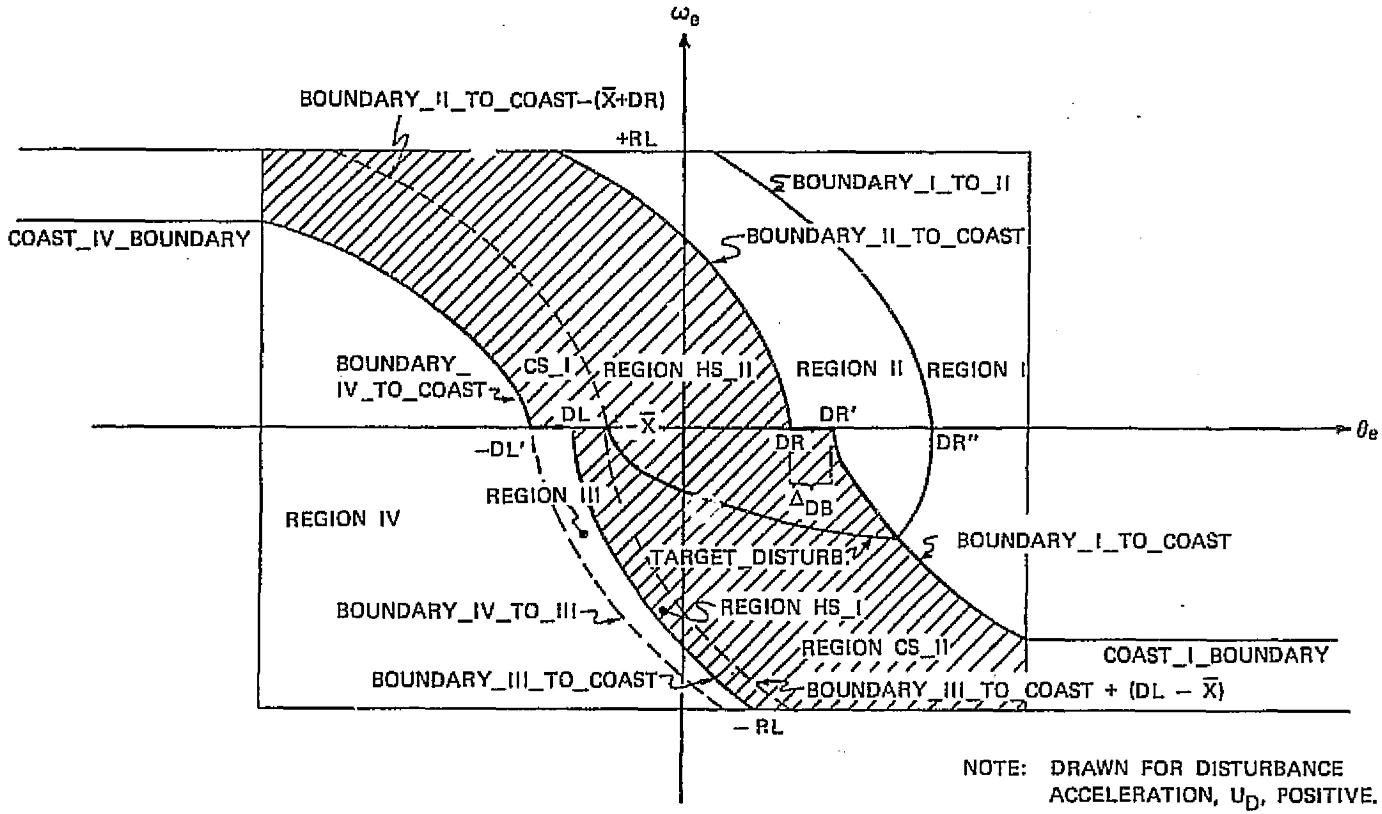

Figure 4.2.2.2.2-6. Small error phase plane.

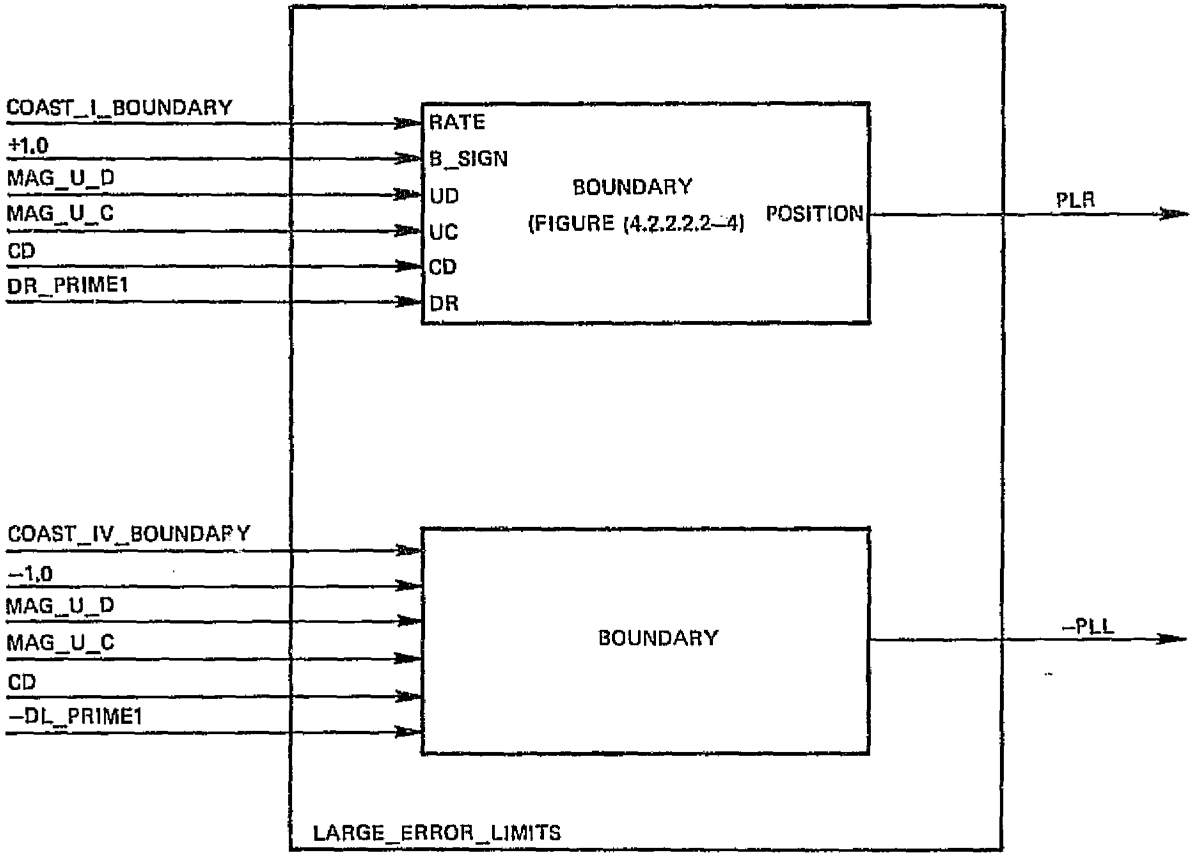

Figure 4.2.2.2.2-7. LARCE_ERROR_LIMITS.

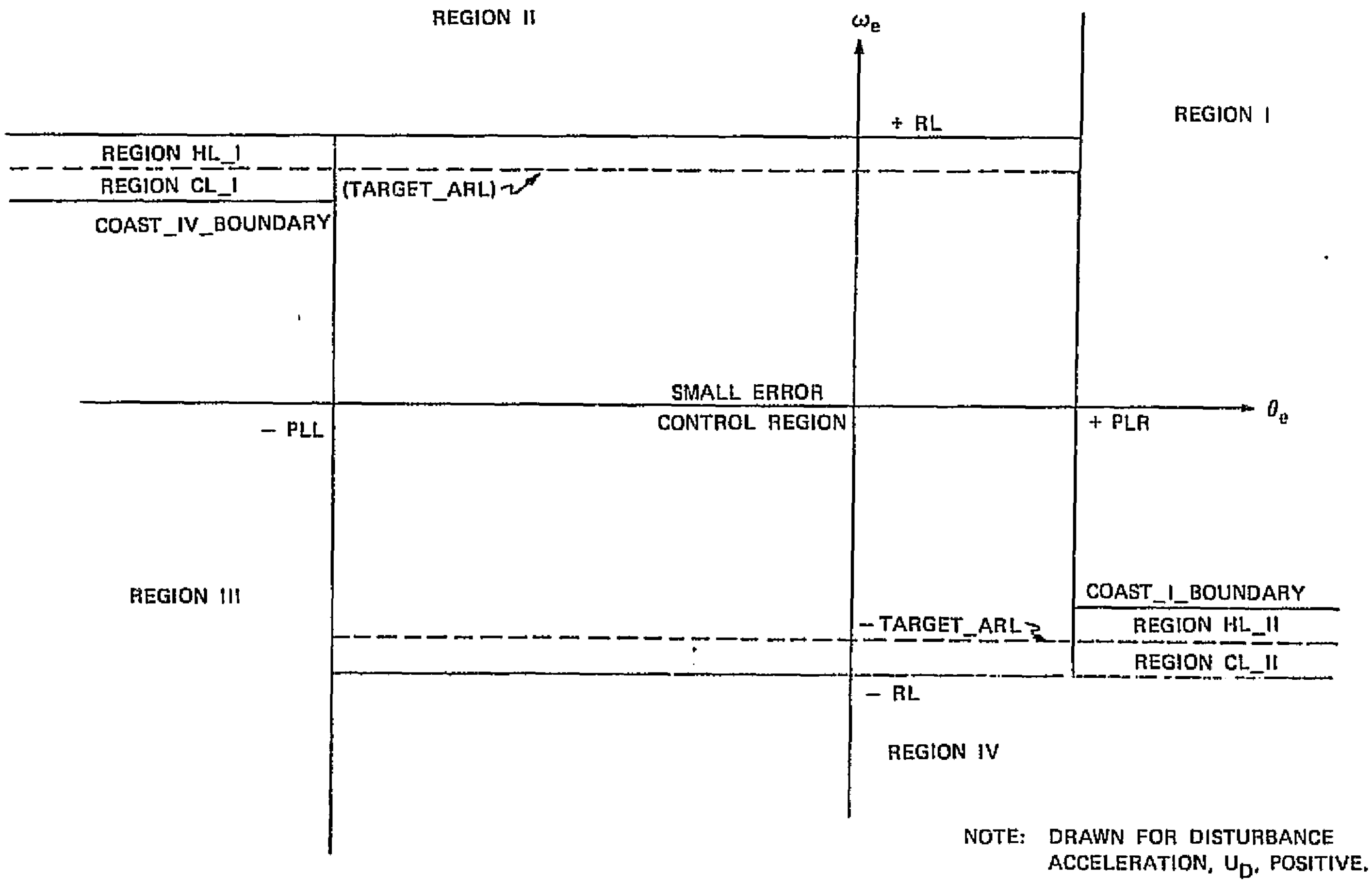

Figure 4.2.2.2.2-8. Large error phase plane.

Table 4.2.2.2.2-1. Control actions in small error control regions.

REGION	CONTROL ACTION, X_D VALUE
I	Drive state to BOUNDARY_I_TO_COAST, -1
II	Drive state to TARGET_DISTURB, -1
III	Drive state to zero rate, +1
IV	Drive state to BOUNDARY_IV_TO_COAST, +1
HS_I	If X_D_OLD = +1 (i.e., if coming from LARGE_ERROR_CONTROL_LOGIC or REGION_III) then Command +1 until zero rate is acnieved, else Command 0.
HS_II	If X_D_OLD = -1 (i.e., if coming from LARGE_ERROR_CONTROL_LOGIC or REGION_II) then Command -1 until TARGET_DISTURB is reached, else Command 0.
CS_I	Coast, 0
CS_II	Coast, 0

Table 4.2.2.2.2-2. Control actions in large error control regions.

REGION	CONTROL ACTION, X_D VALUE
I	Drive state to -(TARGET_ARL), -1
II	Drive state to TARGET_ARL, -1
III	Drive state to COAST_IV_BOUNDARY, +1
IV	Drive state to -RL, +1
HL_I	If X_D_OLD = -1 (i.e., if coming from Region II) then Command -1 until TARGET_ARL is reached, else Command 0.
HL_II	IF X_D_OLD = -1 (i.e., if coming from Region I) then Command -1 until -(TARGET_ARL) is reached, else Command 0.
CL_I	Coast, 0
CL_II	Coast, 0

TABLE 4.2.2.2.2-3 PHASE_PLANE INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
BYPASS	Non-execution command, by axis (1=do not execute; 0=execute)	OFC_RECON	A(3)B	0,1	none	25
ATTITUDE_ERROR	Body angle error	Roll Component: RCS_ERRORS or RCS_ASSIST_ROLL Pitch and yaw components: RCS_ERRORS or RCS_ASSIST_PITCH_YAW	V(3)S	TBD	deg	25
RATE_ERROR	Body angular rate error	Roll component: RCS_ERRORS or RCS_ASSIST_ROLL Pitch and yaw components: RCS_ERRORS or RCS_ASSIST_PITCH_YAW	V(3)S	TBD	deg/s	25
UNDESIRED_ACCEL	Total undesired body angular acceleration	PART1_FILTER	V(3)S	TBD	deg/((s)(s))	25
DEADBAND	Attitude deadband	PANEL_SWITCH_INTERP	A(3)S	TBD	deg	25
ROT_JET_CMD	Rotation command from previous cycle	PHASE_PLANE, ROT_ACCEL, ROT_PULSE or OFC_RECON	A(3)I	-1,0,1	none	25
INIT_PHASE_PLANE	Module initialization flag	OFC_RECON	B	0,1	none	25
Outputs						
ROT_JET_CMD	Rotation command	JET_SELECT	A(3)I	-1,0,1	none	25

TABLE 4.2.2.2.2-4 PHASE_PLANE CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
CD	SWITCH CURVE DESIGN PARAMETER	S	0.8	NONE
COAST_I_BOUNDARY	Rate error boundary of lower coasting region of large error phase plane	S	-3.0	deg/s
COAST_IV_BOUNDARY	Rate error boundary of upper coasting region of large error phase plane	S	COAST_I_BOUNDARY	deg/s
K_DB	Fraction of deadband to be used for "ledges" (delta$(DB) in small error phase plane)	S	0.2	none
K_13	Limit cycle design parameter	S	1.0/3.0	none
RL	Rate error boundary between large and small error phase planes	S	4.0	deg/s
TARGET_ARL	Target average rate limit inside large and small error phase plane coast region	S	(COAST_I_BOUNDARY + RL) / 2.0	deg/s
CONTROL_ACCELERATION_MAGNITUDE	Magnitude of available control acceleration for each axis	A(3)S	TBD	deg/((s)(s))

TABLE 4.2.2.2.2-5 PHASE_PLANE INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_PHASE_PLANE = OFF	INIT_PHASE_PLANE = ON	ROT_JET_CMD	0

4.2.2.2.3 RCS_ERRORS

A. Function: This module obtains the vehicle attitude and angular rate errors, based upon commands from the attitude drivers and measurement data from the IMU and the State Estimator. It also performs the incrementation required to interface position commands from the attitude drivers, some of which operate at 5/6 Hz, to the RCS DAP rate of 25 Hz. The desired gimbal angles are updated by the smoothing increment and the result subtracted from the actual gimbal angles. The remainder is the gimbal angle error, which is converted to body coordinates to yield body angle or attitude error. The angular rate error is obtained as the difference between the estimated and desired body rates.

B. Block Diagram: Figure 4.2.2.2.3-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.2.3-1

E. Constants: none

F. Initialization Requirements: Table 4.2.2.2.3-2

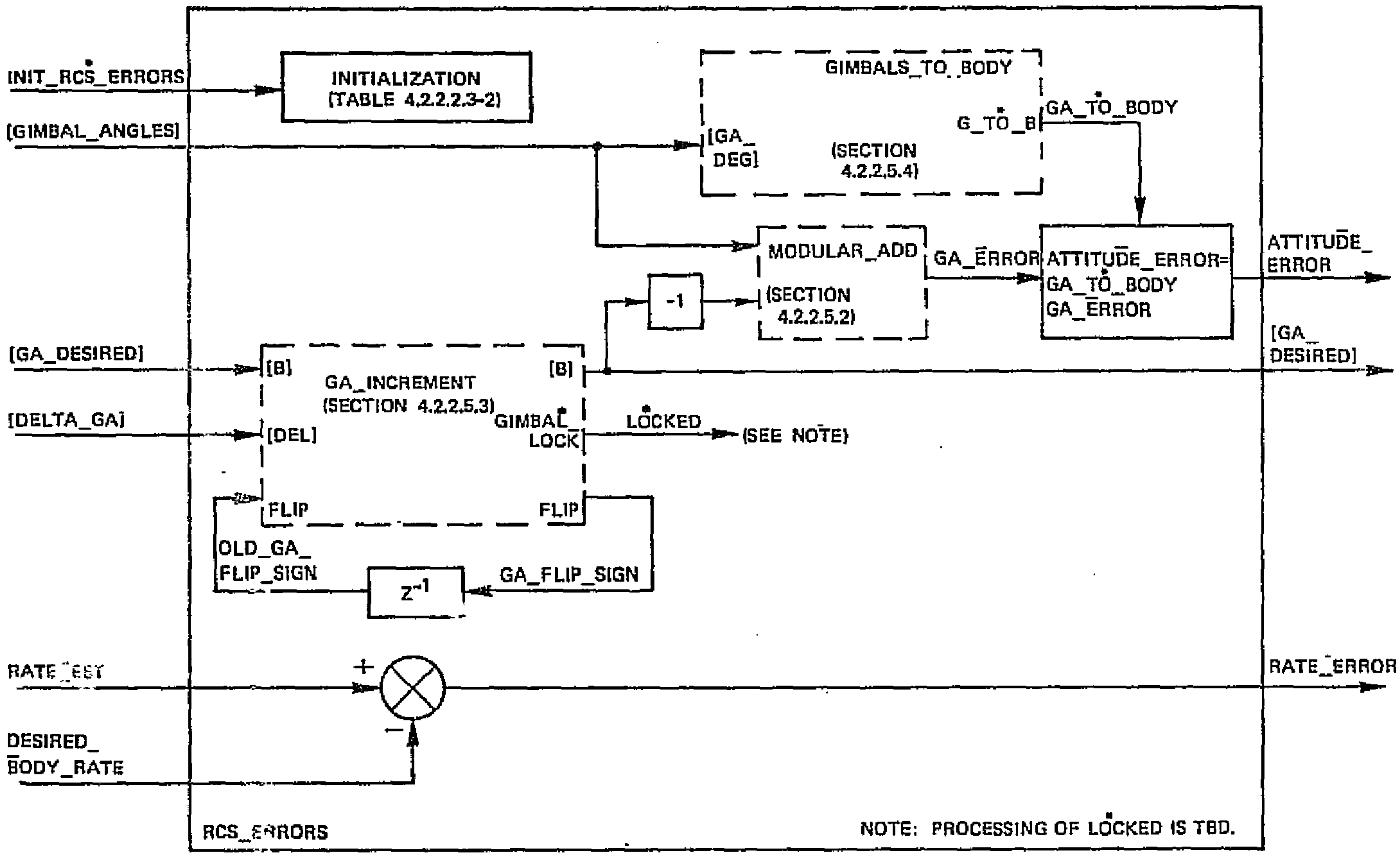

Figure 4.2.2.2.3-1. RCS_ERRORS.

TABLE 4.2.2.2.3-1 RCS_ERRORS INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
GA_DESIRED	Desired IMU gimbal angles	ATTITUDE_HOLD, ATTITUDE_LCL_VERTICA-L, BARBEQUE, MISC_TRACKING, OMS_PRETHRUST_MANEUV-ER, PAYLOAD_SUPPLIED_CMDS, ROT_DISC, THREE_AXIS_ATTITUDE_-MANEUVER, or TWO_AXIS_ ATTITUDE_MANEUVER or RCS_ERRORS	A(3)S	-180 < x <= 180	deg	25
DELTA_GA	Desired IMU gimbal angle increments	ATTITUDE_HOLD, ATTITUDE_LCL_VERTICA-L, BARBEQUE, MISC_TRACKING, OMS_PRETHRUST_MANEUV-ER, PAYLOAD_SUPPLIED_CMDS, ROT_DISC, THREE_AXIS_ATTITUDE_-MANEUVER, or TWO_AXIS_ATTITUDE_MA-NEUVER	A(3)S	TBD	deg	25
DESIRED_BODY_RATE	Desired body angular rate	ATTITUDE_HOLD, ATTITUDE_LCL_VERTICA-L, BARBEQUE, MISC_TRACKING, OMS_PRETHRUST_MANEUV-ER, PAYLOAD_SUPPLIED_CMDS, ROT_DISC, THREE_AXIS_ATTITUDE_-MANEUVER, or TWO_AXIS_ATTITUDE_MA-NEUVER	V(3)S	TBD	deg/s	25
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	25

TABLE 4.2.2.2.3-1 RCS_ERRORS INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
RATE_EST	Body angular rate estimate	PART1_FILTER	V(3)S	TBD	deg/s	25
INIT_RCS_ERRORS	Module initialization flag	OFC_RECON	B	0,1	none	25
Outputs						
ATTITUDE_ERROR	Body angle error	PHASE_PLANE	V(3)S	TBD	deg	25
RATE_ERROR	Body angular rate error	D&C, PHASE_PLANE	V(3)S	TBD	deg/s	25
GA_DESIRED	Desired IMU gimbal angles	D&C, RCS_ERRORS, ATTITUDE_LCL_VERTICA-L, BARBEQUE, ROT_DISC	A(3)S	-180 < x <= 180	deg	25

TABLE 4.2.2.2.3-2 RCS_ERRORS INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_RCS_ERRORS = OFF	INIT_RCS_ERRORS = ON	OLD_GA_FLIP_SIGN	TBD

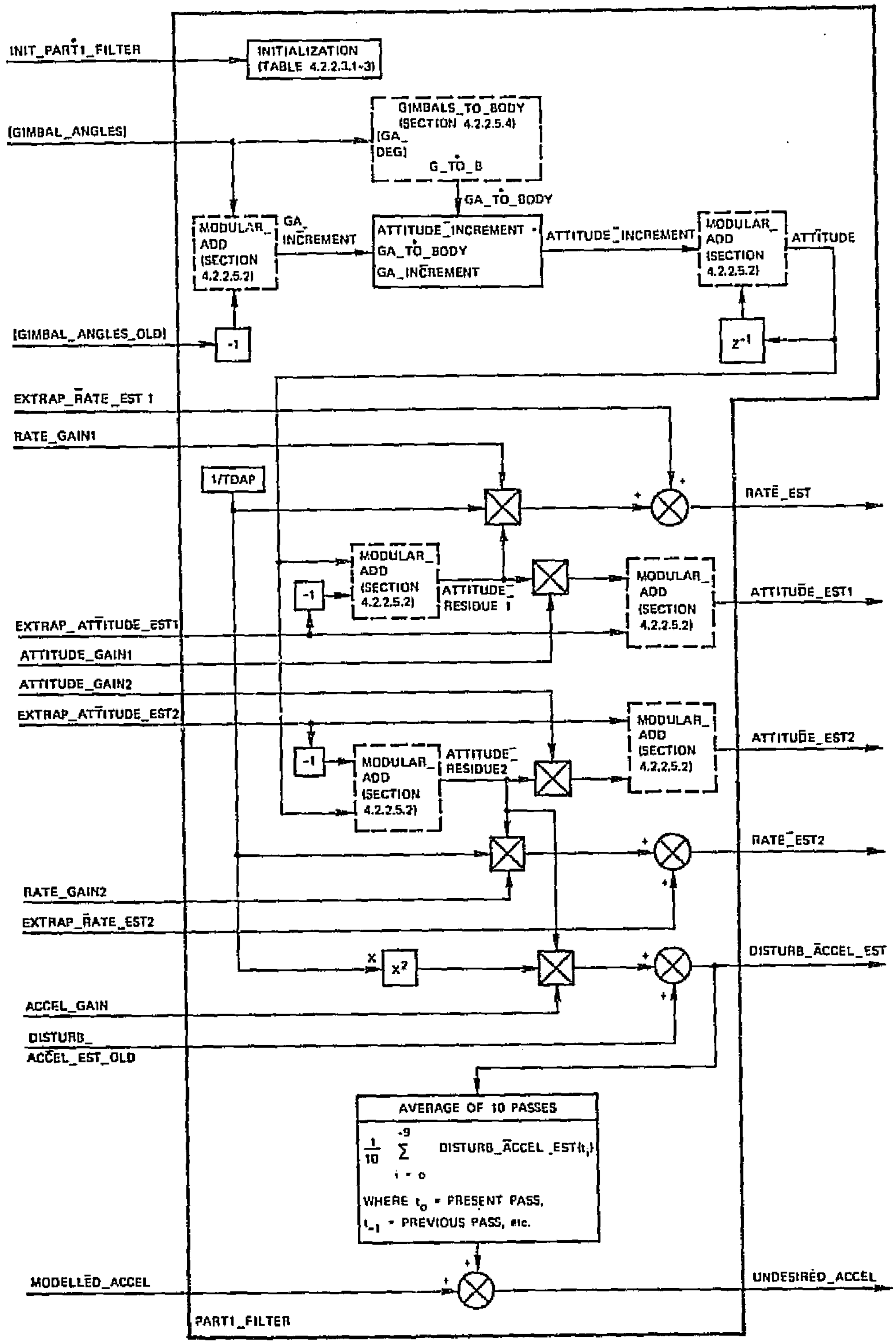

Figure 4.2.2.2.3-1. PART1_FILTER.

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TABLE 4.2.2.3.1-1 PART1_FILTER INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	25
GIMBAL_ANGLES_OLD	IMU gimbal angles from previous cycle	PART2_FILTER	A(3)S	-180 < x <= 180	deg	25
EXTRAP_ATTITUDE_EST1	Extrapolated filter 1 body angle estimate from previous cycle	PART2_FILTER	V(3)S	-180 < x <= 180	deg	25
EXTRAP_RATE_EST1	Extrapolated filter 1 body angular rate estimate from previous cycle.	PART2_FILTER	V(3)S	TBD	deg/s	25
DISTURB_ACCEL_EST_O-LD	Body angular disturbance acceleration estimate from previous cycle	PART2_FILTER	V(3)S	TBD	deg/((s)(s))	25
MODELLED_ACCEL	Modelled undesired body angular acceleration from previous cycle	PART2_FILTER	V(3)S	TBD	deg/((s)(s))	25
ATTITUDE_GAIN1	Filter 1 gain for attitude term	OFC_RECON	S	TBD	none	25
ATTITUDE_GAIN2	Filter 2 gain for attitude term	OFC_RECON	S	TBD	none	25
RATE_GAIN1	Filter 1 gain for rate term	OFC_RECON	S	TBD	none	25
RATE_GAIN2	Filter 2 gain for rate term	OFC_RECON	S	TBD	none	25
ACCEL_GAIN	Filter 2 gain for acceleration term	OFC_RECON	S	TBD	none	25
INIT_PART1_FILTER	Module initialization flag	OFC_RECON	B	0,1	none	25
EXTRAP_ATTITUDE_EST2	Extrapolated filter 2 body angle estimate from previous cycle	PART2_FILTER	V(3)S	-180 < x <= 180	deg	25
EXTRAP_RATE_EST2	Extrapolated filter 2 body angular rate estimate from previous cycle	PART2_FILTER	V(3)S	TBD	deg/s	25

TABLE 4.2.2.3.1-1 PART1_FILTER INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Outputs						
ATTITUDE_EST1	Filter 1 body angle estimate	PART2-FILTER	V(3)S	-180 < x <= 180	deg	25
RATE_EST	Filter 1 body angular rate estimate	D&C, PART2_FILTER, RCS_ERRORS, ROT_PULSE Roll component: RCS_ASSIST_ROLL Pitch and yaw components: RCS_ASSIST_PITCH_YAW, PITCH_YAW_ASSIST_COMPUTATION	V(3)S	TBD	deg/s	25
UNDESIRED_ACCEL	Total undesired body angular acceleration	PHASE_PLANE, PART2_FILTER	V(3)S	TBD	deg/((s)(s))	25
DISTURB_ACCEL_EST	Body angular disturbance acceleration estimate	PART2_FILTER Roll component: RH	V(3)S	TBD	deg/((s)(s))	25
ATTITUDE_EST2	Filter 2 body angle estimates	PART2_FILTER	V(3)S	-180 < x <= 180	deg	25
RATE_EST2	Filter 2 body angular rate estimate	PART2_FILTER	V(3)S	TBD	deg/s	25

TABLE 4.2.3.1-2 PART1_FILTER CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
TDAP	Period of state estimator cycle	S	0.04	s

TABLE 4.2.2.3.1-3 PART1_FILTER INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_PART1_FILTER = OFF	INIT_PART1_FILTER = ON	GIMBAL_ANGLES_OLD	GIMBAL_ANGLES
		ATTITUDE	0
		EXTRAP_ATTITUDE_EST1	0
		EXTRAP_ATTITUDE_EST2	0
		EXTRAP_RATE_EST1	0
		EXTRAP_RATE_EST2	0
		DISTURB_ACCEL_EST_OLD	0
		DISTURB_ACCEL_EST for previous 9 passes (stored in "average of 10 passes" function)	0

4.2.2.3.2 PART2_FILTER

A. Function: This module extrapolates the vehicle state for the next FC cycle as a function of the estimated present state and the expected angular rate changes due to control effector use; it also models angular acceleration. It first computes the extrapolated angular rate increment as the sum of the control-effector and undesired-acceleration rate increments. This rate increment is then filtered with attitude and angular rate estimates in two parallel filters (a "rate" filter and an "acceleration" filter) to obtain attitude and angular rate extrapolations. Angular acceleration modelling is TBD.

B. Block Diagram: Figure 4.2.2.3.2-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.3.2-1

E. Constants: Table 4.2.2.3.2-2

F. Initialization Requirements: none

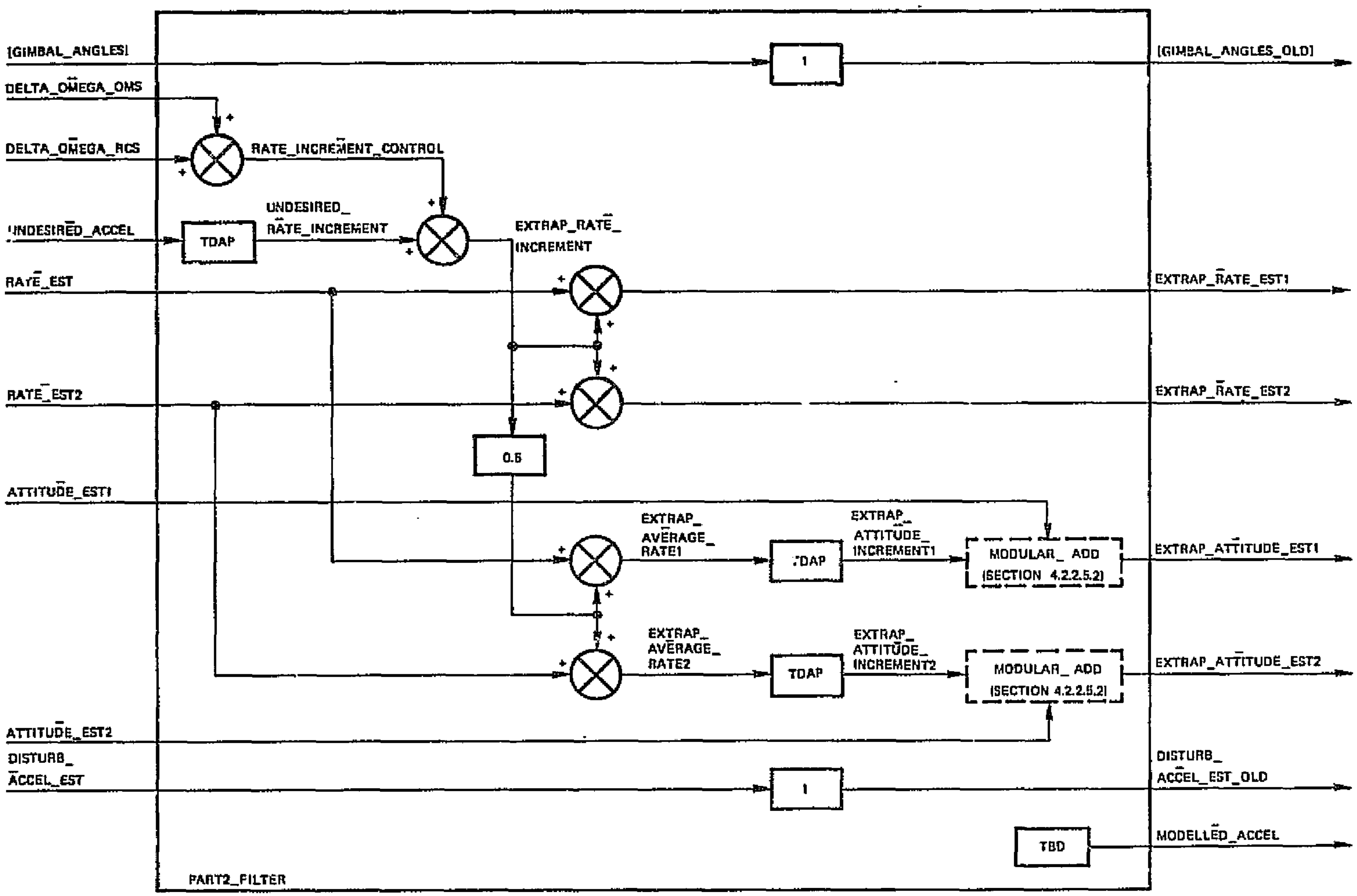

Figure 4.2.2.3.2-1. PART2_FILTER.

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TABLE 4.2.2.3.2-1 PART2_FILTER INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
ATTITUDE_EST1	Filter 1 body angle estimate	PART1_FILTER	V(3)S	-180 < x <= 180	deg	25
RATE_EST	Filter 1 body angular rate estimate	PART1_FILTER	V(3)S	TBD	deg/s	25
ATTITUDE_EST2	Filter 2 body angle estimate	PART1_FILTER	V(3)S	-180 < x <= 180	deg	25
RATE_EST2	Filter 2 body angular rate estimate	PART1_FILTER	V(3)S	TBD	deg/s	25
UNDESIRED_ACCEL	Total undesired body angular acceleration	PART1_FILTER	V(3)S	TBD	deg/((s)(s))	25
DISTURB_ACCEL_EST	Body angular disturbance acceleration estimate	PART1_FILTER	V(3)S	TBD	deg/((s)(s))	25
DELTA_OMEGA_OMS	Modelled body angular rate increment due to OMS TVC	DELTA_OMEGA_OMS_ENGINE or PART2_FILTER	V(3)S	TBD	deg/s	25
DELTA_OMEGA_RCS	Modelled body angular rate increment due to RCS jet firings	JET_SELECT or PART2_FILTER	V(3)S	TBD	deg/s	25
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	25
Outputs						
EXTRAP_ATTITUDE_EST1	Extrapolated filter 1 body angle estimate	PART1_FILTER	V(3)S	-180 < x <= 180	deg	25
EXTRAP_RATE_EST1	Extrapolated filter 1 body angular rate estimate	PART1_FILTER	V(3)S	TBD	deg/s	25
DISTURB_ACCEL_EST_OLD	Body angular disturbance acceleration estimate	PART1_FILTER	V(3)S	TBD	deg/((s)(s))	25

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TABLE 4.2.2.3.2-1 PART2_FILTER INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
MODELLED_ACCEL	Modelled undesired body angular acceleration	PART1_FILTER	V(3)S	TBD	deg/((s)(s))	25
EXTRAP_ATTITUDE_EST2	Extrapolated filter 2 body angle estimate	PART1_FILTER	V(3)S	-180 < x <= 180	deg	25
EXTRAP_RATE_EST2	Extrapolated filter 2 body angular rate estimate	PART1_FILTER	V(3)S	TBD	deg/s	25
GIMBAL_ANGLES_OLD	IMU gimbal angles	PART1_FILTER	A(3)S	-180 < x <= 180	deg	25

TABLE 4.2.2.3.2-2 PART2_FILTER CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
TDAP	Period of FC cycle	S	0.04	s

4.2.2.4 TVC DAP

4.2.2.4.1 DELTA_OMEGA_OMS_ENGINE

A. Function: This module computes the modelled body angular rate increment due to torque from the OMS engines during a TVC burn.

B. Block Diagram: Figure 4.2.2.4.1-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.4.1-1

E. Constants: Table 4.2.2.4.1-2

F. Initial ·ation Requirements: none

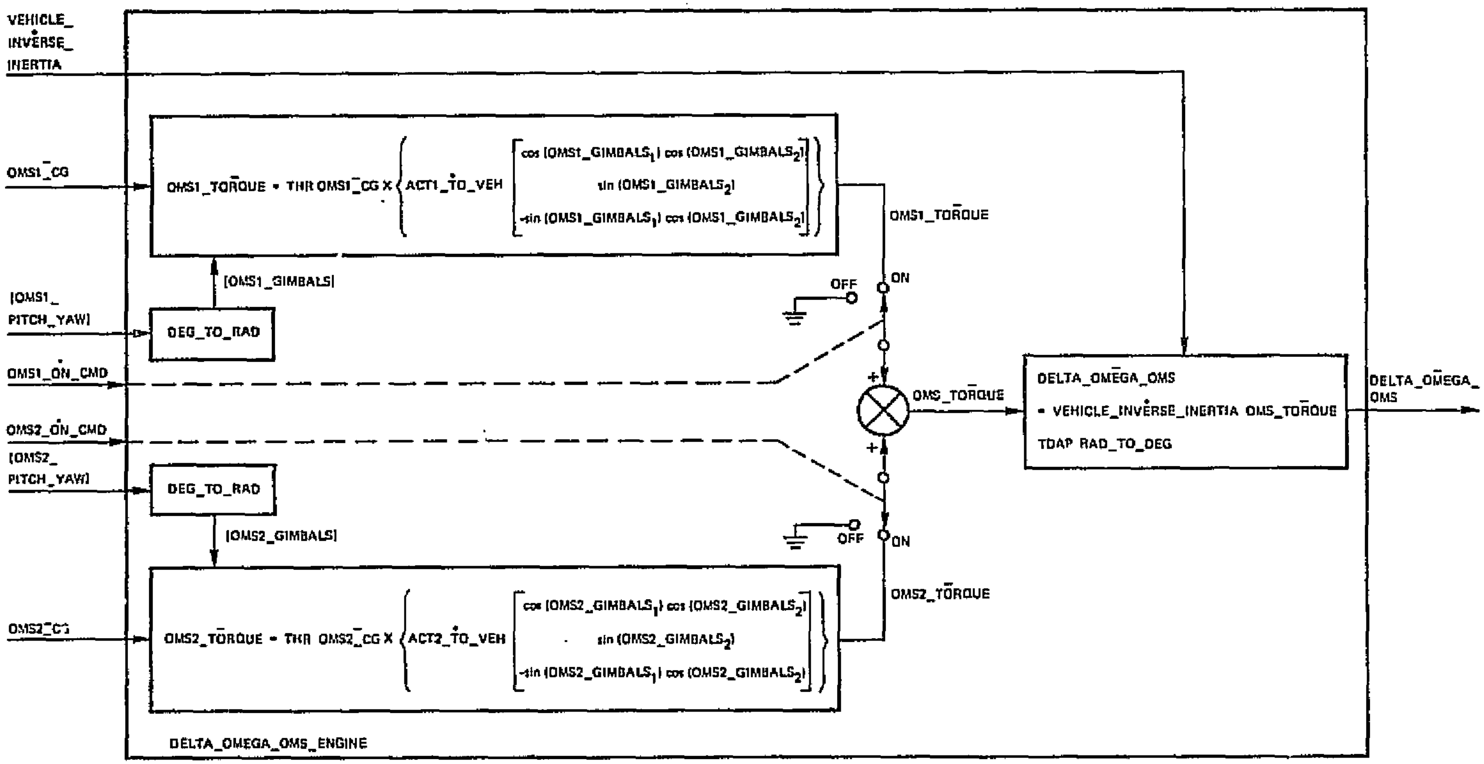

Figure 4.2.2.4.1-1. DELTA_OMEGA_OMS_ENGINE.

TABLE 4.2.2.4.1-1 DELTA_OMEGA_OMS_ENGINE INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
OMS1_CG	Vector from OMS1 hinge point to vehicle cg, in body axes	OMS_PRETHRUST_MANEUV-ER	V(3)S	TBD	f	25
OMS2_CG	Vector from OMS2 hinge point to vehicle cg, in body axes	OMS_PRETHRUST_MANEUV-ER	V(3)S	TBD	f	25
OMS1_PITCH_YAW	OMS1 engine pitch and yaw	SOP	A(2)S	TBD	deg	25
OMS2_PITCH_YAW	OMS2 engine pitch and yaw	SOP	A(2)S	TBD	deg	25
OMS1_ON_CMD	OMS1 on command	OMS_ENG_CMD	B	0,1	none	25
OMS2_ON_CMD	OMS2 on command	OMS_ENG_CMD	B	0,1	none	25
VEHICLE_INVERSE_INE-RTIA	Inverse of vehicle inertia	SF	M(3,3)S	TBD	1/((slug)(f)-(f))	25
Outputs						
DELTA_OMEGA_OMS	Modelled body angular rate increment due to OMS TVC	PART2_FILTER	V(3)S	TBD	deg/s	25

TABLE 4.2.2.4.1-2 DELTA_OMEGA_OMS_ENGINE CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
ACT1_TO_VEH	OMS1 actuator axes to vehicle axes transformation matrix	M(3,3)S	See Note 1	none
ACT2_TO_VEH	OMS2 actuator axes to vehicle axes transformation matrix	M(3,3)S	See Note 2	none
THR	Nominal thrust of a single OMS engine	S	6000	lbf
TDAP	Autopilot minor cycle time	S	.04	s
DEG_TO_RAD	Degrees to radians conversion factor	S	pi/180	rad/deg
RAD_TO_DEG	Radians to degrees conversion factor	S	180/pi	deg/rad

Note 1:

$$\text{ACT1\_TO\_VEH} = \begin{bmatrix} -\cos(x)\cos(y) & -\cos(x)\sin(y) & \sin(x) \\ -\sin(y) & \cos(y) & 0 \\ -\sin(x)\cos(y) & -\sin(x)\sin(y) & -\cos(x) \end{bmatrix}$$

where $x = 15.8167$ deg
$y = 6.5$ deg

Note 2:

$$\text{ACT2\_TO\_VEH} = \begin{bmatrix} -\cos(x)\cos(y) & \cos(x)\sin(y) & \sin(x) \\ \sin(y) & \cos(y) & 0 \\ -\sin(x)\cos(y) & \sin(x)\sin(y) & -\cos(x) \end{bmatrix}$$

where $x = 15.8167$ deg
$y = 6.5$ deg

4.2.2.4.2 ENGINE_CG_CMD

A. Function: This module computes the OMS1 and OMS2 engine pitch and yaw servo trim commands necessary to point both engines through the vehicle center of gravity.

B. Block Diagram: Figure 4.2.2.4.2-1

C. Processing Rate: 1/maneuver

D. Interface Requirements: Table 4.2.2.4.2-1

E. Constants: Table 4.2.2.4.2-2

F. Initialization Requirements: none

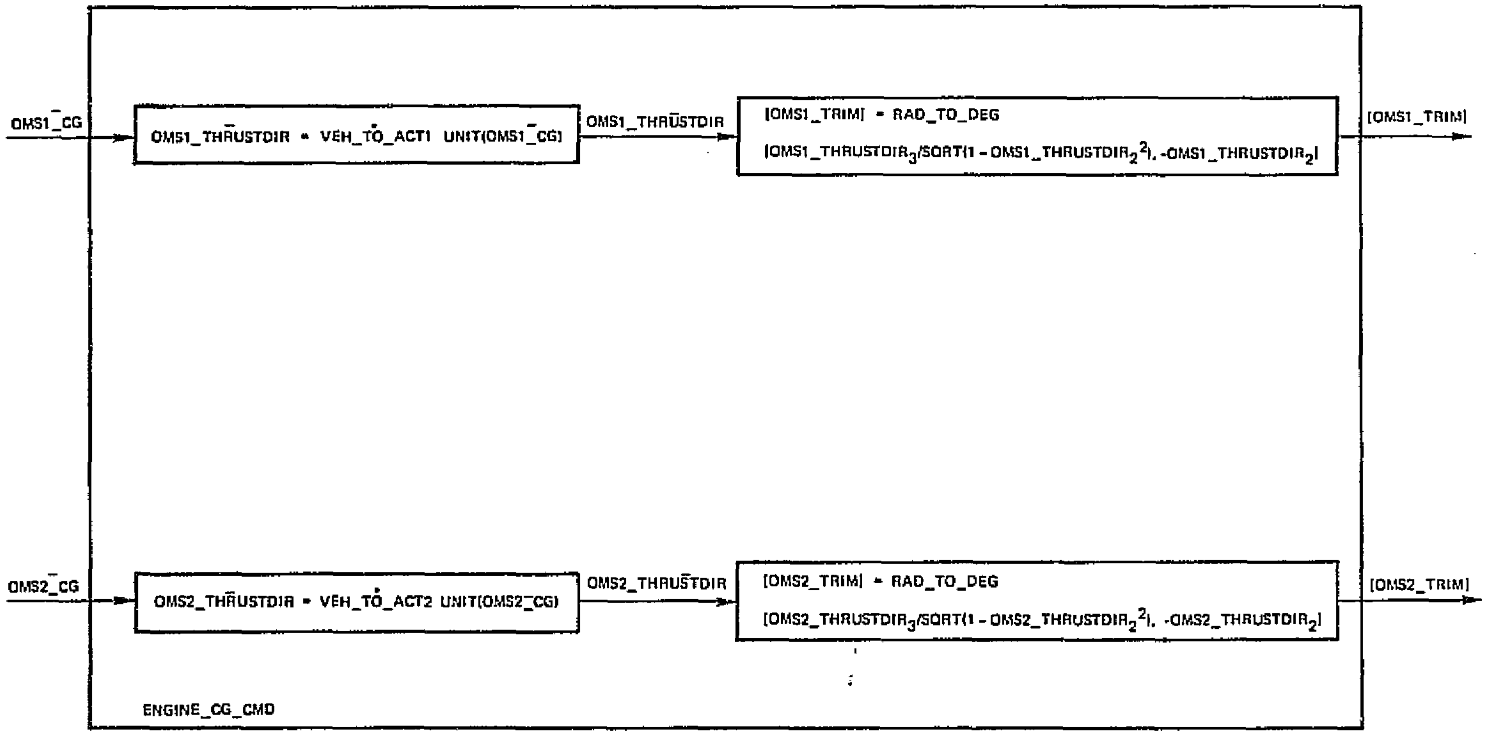

Figure 4.2.2.4.2-1. ENGINE_CG_CMD.

TABLE 4.2.2.4.2-1 ENGINE_CG_CMD INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
OMS1_CG	Vector from OMS1 hinge point to vehicle cg, in body axes	OMS_PRETHRUST_MANEUV-ER	V(3)S	TBD	f	1/maneuver
OMS2_CG	Vector from OMS2 hinge point to vehicle cg, in body axes	OMS_PRETHRUST_MANEUV-ER	V(3)S	TBD	f	1/maneuver
Outputs						
OMS1_TRIM	OMS1 engine pitch and yaw trim values	TVC_LAW_PITCH-YAW	A(2)S	TBD	deg	1/maneuver
OMS2_TRIM	OMS2 engine pitch and yaw trim values	TVC_LAW_PITCH_YAW	A(2)S	TBD	deg	1/maneuver

TABLE 4.2.2.4.2-2 ENGINE_CG_CMD CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
VEH_TO_ACT1	Vehicle axes to OMS1 actuator axes transformation matrix	M(3,3)S	See Note 1	none
VEH_TO_ACT2	Vehicle axes to OMS2 actuator axes transformation matrix	M(3,3)S	See Note 2	none
RAD_TO_DEG	Radians to degrees conversion factor	S	180/pi	deg/rad

Note 1:

$$VEH\_TO\_ACT1 = \begin{bmatrix} -\cos(x)\cos(y) & -\sin(y) & -\sin(x)\cos(y) \\ -\cos(x)\sin(y) & \cos(y) & -\sin(x)\sin(y) \\ \sin(x) & 0 & -\cos(x) \end{bmatrix}$$

where x = 15.8167 deg
y = 6.5 deg

Note 2:

$$VEH\_TO\_ACT2 = \begin{bmatrix} -\cos(x)\cos(y) & \sin(y) & -\sin(x)\cos(y) \\ \cos(x)\sin(y) & \cos(y) & \sin(x)\sin(y) \\ \sin(x) & 0 & -\cos(x) \end{bmatrix}$$

where x = 15.8167 deg
y = 6.5 deg

4.2.2.4.3 ENGINE_PRETHRUST_TRIM

A. Function: This module computes the OMS1 and OMS2 engine yaw and pitch servo trim commands such that the engine thrust vectors are parallel and there is no net torque on the vehicle.

B. Block Diagram: Figure 4.2.2.4.3-1

C. Processing Rate: 1/maneuver

D. Interface Requirements: Table 4.2.2.4.3-1

E. Constants: Table 4.2.2.4.3-2

F. Initialization Requirements: none

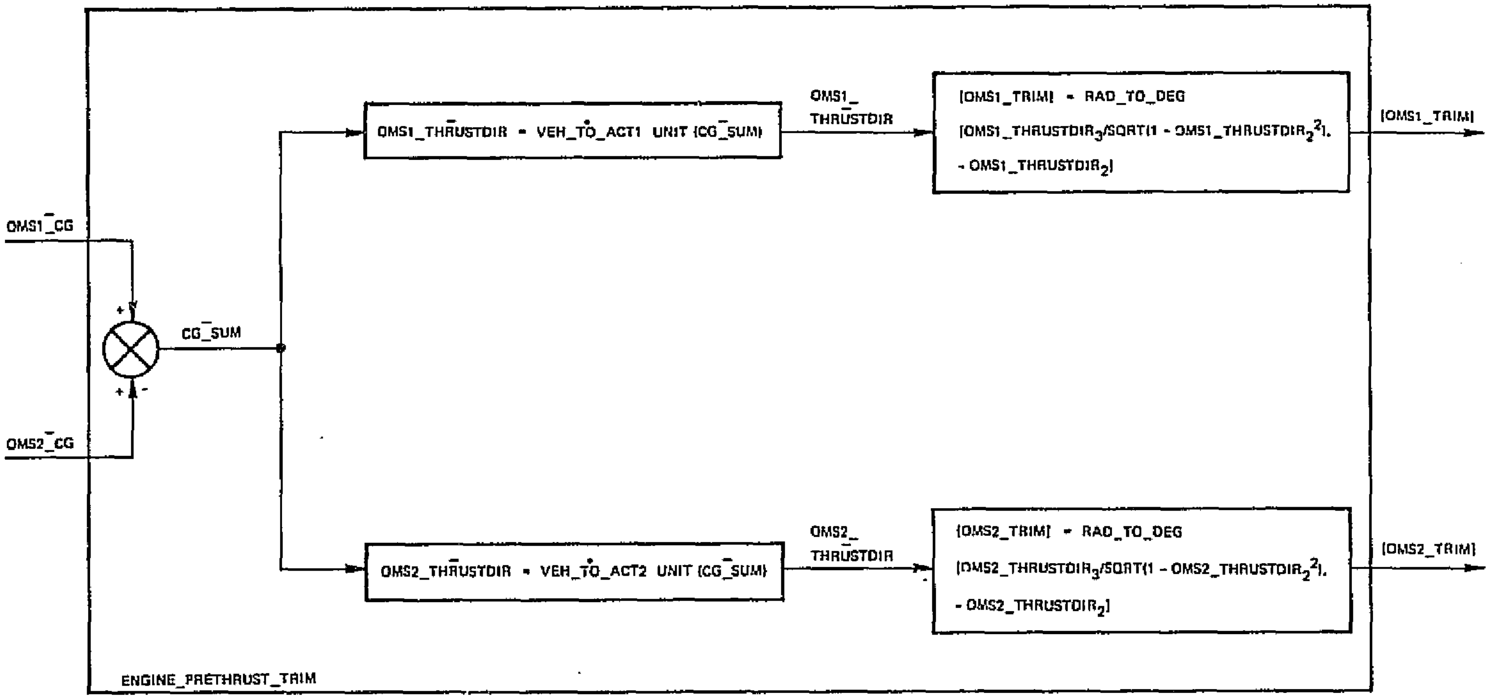

Figure 4.2.2.4.3-1. ENGINE_PRETHRUST_TRIM.

TABLE 4.2.2.4.3-1 ENGINE_PRETHRUST_TRIM INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
OMS1_CG	Vector from OMS1 hinge point to vehicle cg, in body axes	OMS_PRETHRUST_MANEUV-ER	V(3)S	TBD	f	1/maneuver
OMS2_CG	Vector from OMS2 hinge point to vehicle cg, in body axes	OMS_PRETHRUST_MANEUV-ER	V(3)S	TBD	f	1/maneuver
Outputs						
OMS1_TRIM	OMS1 engine pitch and yaw trim values	TVC_LAW_PITCH_YAW	A(2)S	TBD	deg	1/maneuver
OMS2_TRIM	OMS2 engine pitch and yaw trim values	TVC_LAW_PITCH_YAW	A(2)S	TBD	deg	1/maneuver

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TABLE 4.2.2.4.3-2 ENGINE_PRETHRUST_TRIM CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
VEH_TO_ACT1	Vehicle axes to OMS1 actuator axes transformation matrix	M(3,3)S	See Note 1	none
VEH_TO_ACT2	Vehicle axes to OMS2 actuator axes transformation matrix	M(3,3)S	See Note 2	none
RAD_TO_DEG	Radians to degrees conversi factor	S	180/pi	deg/rad

Note 1:

$$VEH\_TO\_ACT1 = \begin{bmatrix} -\cos(x)\cos(y) & -\sin(y) & -\sin(x)\cos(y) \\ -\cos(x)\sin(y) & \cos(y) & -\sin(x)\sin(y) \\ \sin(x) & 0 & -\cos(x) \end{bmatrix}$$

where x = 15.8167 deg
y = 6.5 deg

Note 2:

$$VEH\_TO\_ACT2 = \begin{bmatrix} -\cos(x)\cos(y) & \sin(y) & -\sin(x)\cos(y) \\ \cos(x)\sin(y) & \cos(y) & \sin(x)\sin(y) \\ \sin(x) & 0 & -\cos(x) \end{bmatrix}$$

where x = 15.8167 deg
y = 6.5 deg

4.2.2.4.4 GUIDANCE_COMPENSATION

A. Function: This module provides gain and compensation filtering for the guidance loop in pitch and yaw during normal burns in the auto TVC submode.

B. Block Diagram: Figure 4.2.2.4.4-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.4.4-1

E. Constants: none

F. Initialization Requirements: Table 4.2.2.4.4-2

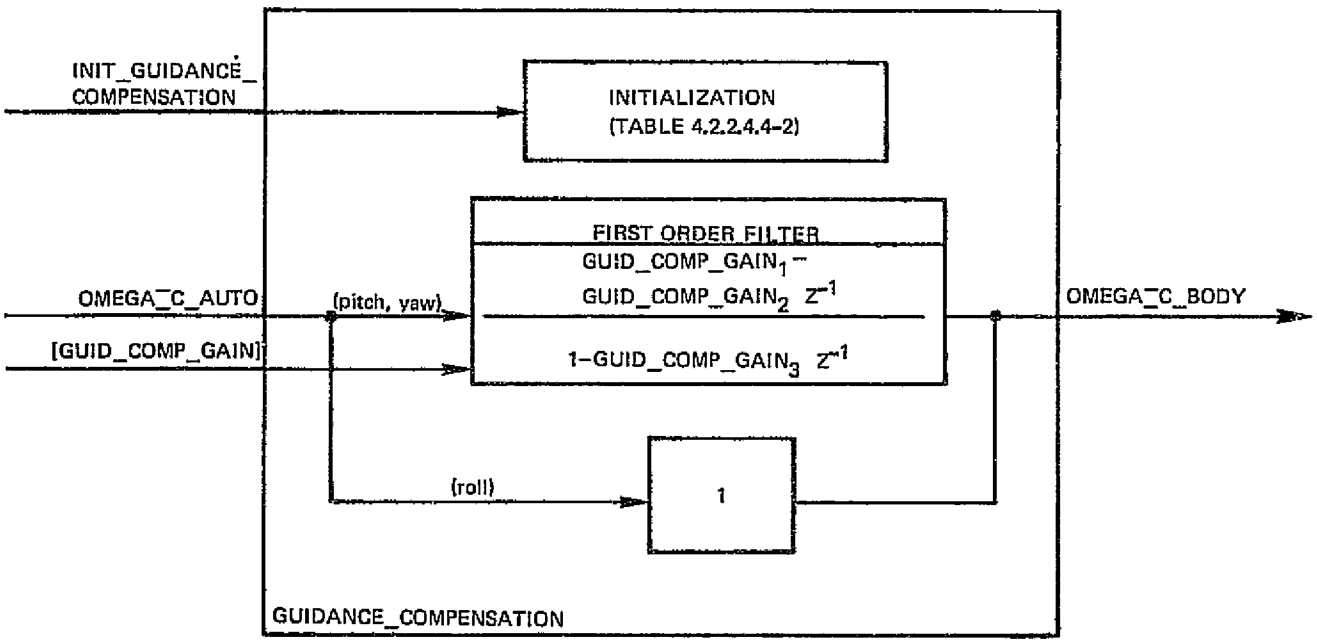

Figure 4.2.2.4.4-1. GUIDANCE_COMPENSATION.

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TABLE 4.2.2.4.4-1 GUIDANCE_COMPENSATION INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
OMEGA_C_AUTO	Commanded body angular rate	AUTO_TVC	V(3)S	TBD	deg/s	25
GUID_COMP_GAIN	TVC compensation gains	OFC_RECON	A(3)S	2-engine burn: (0.034, 0.03332, 0.9932); 1-engine burn: TBD	none	25
INIT_GUIDANCE_COMPE-NSATION	Module initialization flag	OFC_RECON	B	0,1	none	25
Output						
OMEGA_C_BODY	Commanded body angular rate	Roll component: RCS_ASSIST_ROLL, TVC_LAW_ROLL Pitch and yaw components: TVC_LAW_PITCH_YAW	V(3)S	TBD	deg/s	25

TABLE 4.2.2.4.4-2 GUIDANCE_COMPENSATION INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_GUIDANCE_COMPENSATION = OFF	INIT_GUIDANCE_COMPENSATION = ON	FIRST ORDER FILTER MODE	0

4.2.2.4.5 GUIDANCE_GAIN_RCS_ASSIST

A. Function: This module provides gain reduction for the guidance loop in pitch and yaw when the RCS DAP is helping to control the vehicle attitude in the auto TVC submode.

B. Block Diagram: Figure 4.2.2.4.5-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.4.5-1

E. Constants: Table 4.2.2.4.5-2

F. Initialization Requirements: none

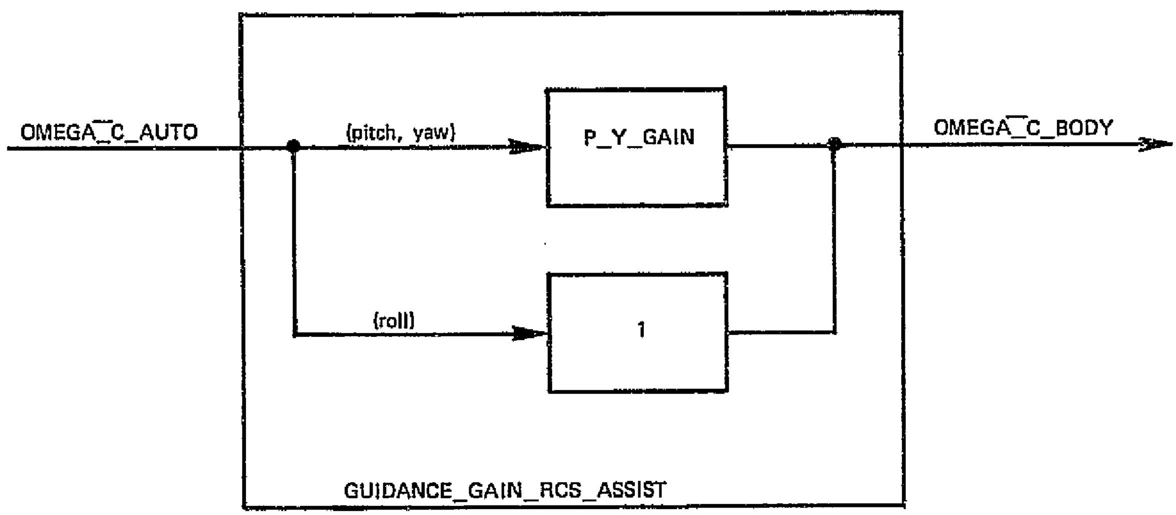


Figure 4.2.2.4.5-1. GUIDANCE_GAIN_RCS_ASSIST.

TABLE 4.2.2.4.5-1 GUIDANCE_GAIN_RCS_ASSIST INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Input						
OMEGA_C_AUTO	Commanded body angular rate	AUTO_TVC	V(3)S	TBD	deg/s	25
Output						
OMEGA_C_BODY	Commanded body angular rate	RCS_ASSIST_ROLL, RCS_ASSIST_PITCH_YAW	V(3)S	TBD	deg/s	25

TABLE 4.2.2.4.5-2 GUIDANCE_GAIN_RCS_ASSIST CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
P_Y_GAIN	Pitch and yaw command gain	S	0.16	none

4.2.2.4.6 OMS_ENG_CMD

A. Function: This module computes the OMS1 and OMS2 engine on commands.

B. Block Diagram: Figure 4.2.2.4.6-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.4.6-1

E. Constants: none

F. Initialization Requirements: Table 4.2.2.4.6-2

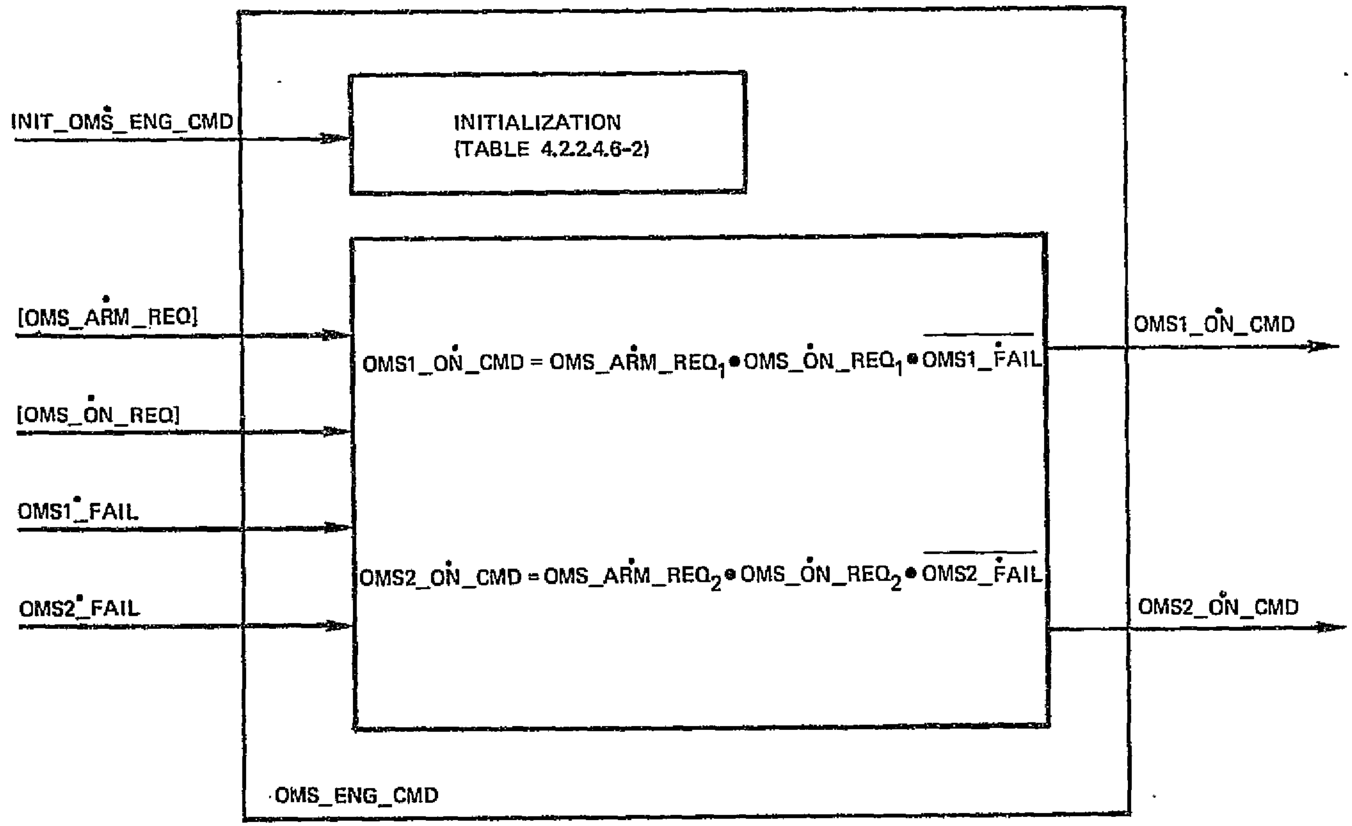


Figure 4.2.2.4.6-1. OMS_ENG_CMD.

TABLE 4.2.2.4.6-1 OMS_ENG_CMD INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
OMS_ARM_REQ	OMS arming request	MSC	A(2)B	0,1	none	25
OMS_ON_REQ	OMS turn-on request	MSC	A(2)B	0,1	none	25
OMS1_FAIL	OMS1 failure identified	RM	B	0,1	none	25
OMS2_FAIL	OMS2 failure identified	RM	B	0,1	none	25
INIT_OMS_ENG_CMD	Module initialization flag	OFC_RECON	B	0,1	none	25
Outputs						
OMS1_ON_CMD	OMS1 on command	SOP, RM, DELTA_OMEGA_OMS_ENGINE	B	0,1	none	25
OMS2_ON_CMD	OMS2 on command	SOP, RM, DELTA_OMEGA_OMS_ENGINE	B	0,1	none	25

TABLE 4.2.2.4.6-2 OMS_ENG_CMD INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_OMS_ENG_CMD = OFF	INIT_OMS_ENG_CMD = ON	OMS1_FAIL	OFF
		OMS2_FAIL	OFF

4.2.2.4.7 PITCH_YAW_ASSIST_COMPUTATION

A. Function: This module determines whether the TVC DAP requires assistance from the RCS DAP for yaw and pitch control, on the basis of the body rate estimate from the State Estimator. Hysteresis is incorporated to prevent noise from causing unnecessary cycling.

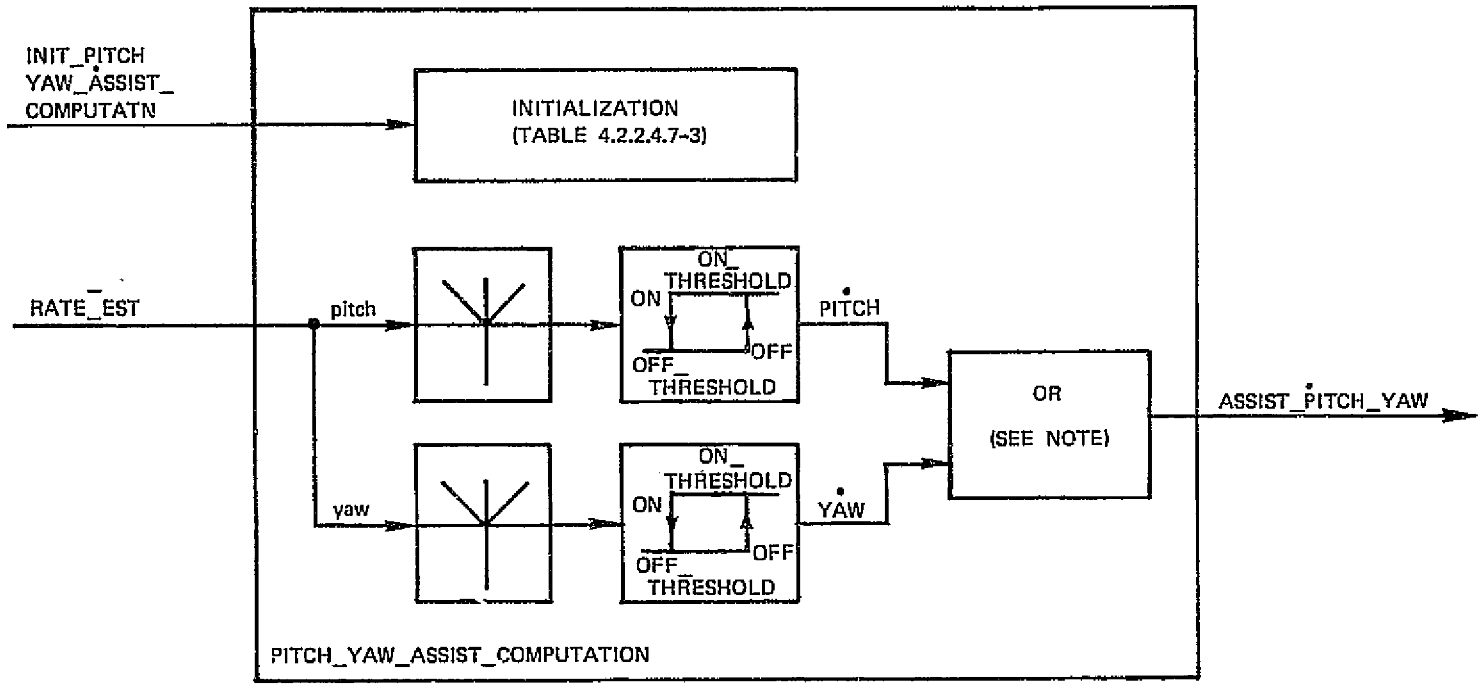
B. Block Diagram: Figure 4.2.2.4.7-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.4.7-1

E. Constants: Table 4.2.2.4.7-2

F. Initialization Requirements: Table 4.2.2.4.7-3



NOTE: LOGICAL OPERATION.

Figure 4.2.2.4.7-1. PITCH_YAW_ASSIST_COMPUTATION.

TABLE 4.2.2.4.7-1 PITCH_YAW_ASSIST_COMPUTATION INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
RATE_EST (pitch and yaw components)	BODY ANGULAR RATE ESTIMATE	PART1_FILTER	V(3)S	TBD	deg/s	25
INIT_PITCH_YAW_ASSI-ST_COMPUTATION	Module initialization flag	OFC_RECON	B	0,1	none	25
Output						
ASSIST_PITCH_YAW	Flag requesting RCS assistance of TVC for pitch and yaw control (1=request)	OFC_RECON	B	0,1	none	25

TABLE 4.2.2.4.7-2 PITCH_YAW_ASSIST_COMPUTATION CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
ON_THRESHOLD	Body angular rate threshold for initiation or resumption of RCS DAP assist of TVC DAP for pitch and yaw control	S	0.3	deg/s
OFF_THRESHOLD	Body angular rate threshold for termination of RCS DAP assistance of TVC DAP for pitch and yaw control	S	0.25	deg/s

TABLE 4.2.2.4.7-3 PITCH_YAW_ASSIST_COMPUTATION INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_PITCH_YAW_ASSIST_COMPU-TATN = OFF	INIT_PITCH_YAW_ASSIST_COMPU-TATN = ON	PITCH	ON
		YAW	ON

4.2.2.4.8 RCS_ASSIST_PITCH_YAW

A. Function: During the RCS assist mode of TVC operation, this module forms the pitch and yaw components of vehicle attitude and angular rate errors. Desired attitude is the integral of the commanded body rates; measured attitude is the integral of the body attitude increments derived from gimbal angle increments. Both integrals are zeroed at initialization. Attitude error is the difference between the desired and measured quantities. Rate error is the difference between the commanded and estimated body rates.

B. Block Diagram: Figure 4.2.2.4.8-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.4.8-1

E. Constants: Table 4.2.2.4.8-2

F. Initialization Requirements: Table 4.2.2.4.8-3

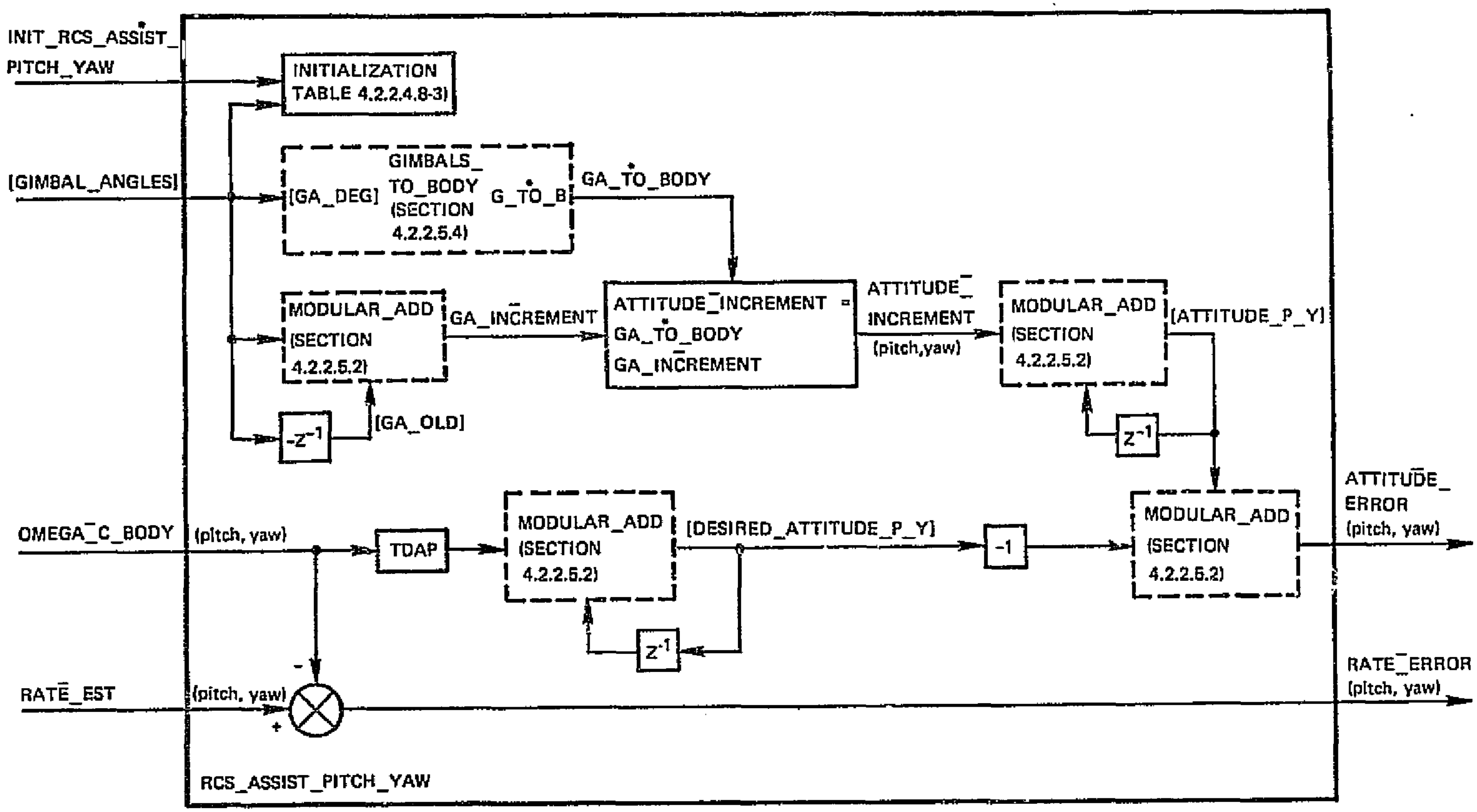


Figure 4.2.2.4.8-1. RCS_ASSIST_PITCH_YAW.

TABLE 4.2.2.4.8-1 RCS_ASSIST_PITCH_YAW INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
OMEGA_C_BODY (pitch and yaw components)	Commanded body angular rate	GUIDANCE_GAIN_RCS_ASSIST or MANUAL_TVC	V(3)S	TBD	deg/s	25
RATE_EST (pitch and yaw components)	Body angular rate estimate	PART1_FILTER	V(3)S	TBD	deg/s	25
INIT_RCS_ASSIST_PITCH_YAW	Module initialization flag	OPC_RECON	B	0,1	none	25
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)	-180 < x <= 180	deg	25
Outputs						
ATTITUDE_ERROR (pitch and yaw components)	Body angle error	PHASE_PLANE	V(3)S	TBD	deg	25
RATE_ERROR (pitch and yaw components)	Body angular rate error	D&C, PHASE_PLANE	V(3)	TBD	deg/s	25

TABLE 4.2.2.4.8-2 RCS_ASSIST_PITCH_YAW CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
TDAP	Period of TVC DAP cycle	S	0.04	s

TABLE 4.2.2.4.8-3 RCS_ASSIST_PITCH_YAW INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_RCS_ASSIST_PITCH_YAW = OFF	INIT_RCS_ASSIST_PITCH_YAW = ON	DESIRED_ATTITUDE_P_Y	0
		ATTITUDE_P_Y	0
		GA_OLD	GIMBAL_ANGLES

4.2.2.4.9 RCS_ASSIST_ROLL

A. Function: During the RCS assist mode of TVC operation, this module forms the roll component of vehicle attitude and angular rate errors. Desired attitude is the integral of the commanded body rates; measured attitude is the integral of the attitude increments derived from gimbal angle increments; both integrations are zeroed at initialization. Attitude error is the difference between the desired and measured quantities. Rate error is the difference between the commanded and estimated body rates.

B. Block Diagram: Figure 4.2.2.4.9-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.4.9-1

E. Constants: Table 4.2.2.4.9-2

F. Initialization Requirements: Table 4.2.2.4.9-3

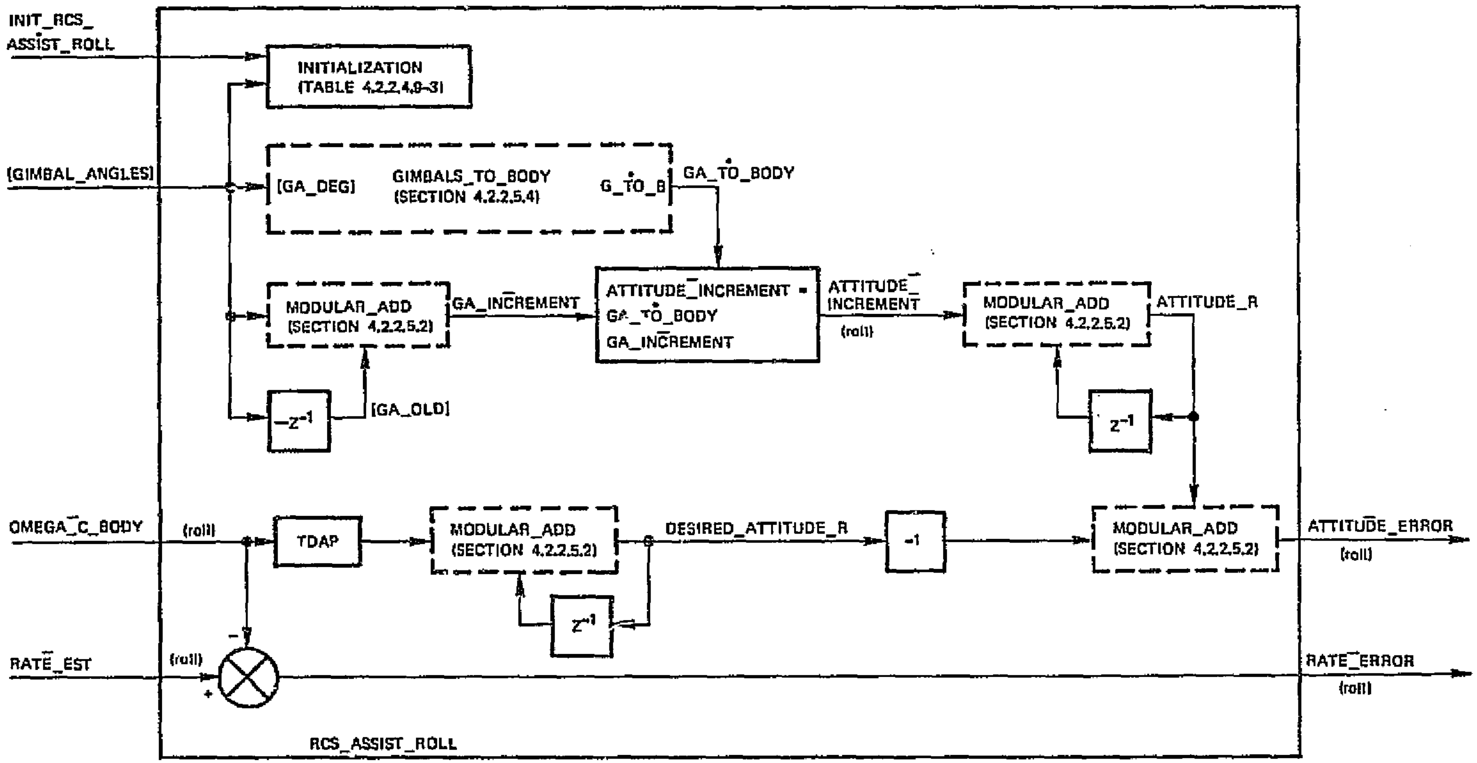


Figure 4.2.2.4.9-1. RCS_ASSIST_ROLL.

TABLE 4.2.2.4.9-1 RCS_ASSIST_ROLL INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
OMEGA_C_BODY (roll component)	Commanded body angular rate	GUIDANCE_GAIN_RCS_ASSIST, GUIDANCE_COMPENSATION or MANUAL_TVC	V(3)	TBD	deg/s	25
INIT_RCS_ASSIST_ROLL	Module initialization flag	OPC_RECON	B	0,1	none	25
RATE_EST (roll component)	Body angular rate estimate	PART1_FILTER	V(3)S	TBD	deg/s	25
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	25
Outputs						
ATTITUDE_ERROR (roll component)	Body angle error	PHASE_PLANE	V(3)S	TBD	deg	25
RATE_ERROR (roll component)	Body angular rate error	D&C, PHASE_PLANE	V(3)S	TBD	deg/s	25

TABLE 4.2.2.4.9-2 RCS_ASSIST_ROLL CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
TDAP	Period of TVC DAP cycle	S	0.04	s

TABLE 4.2.2.4.9-3 RCS_ASSIST ROLL INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_RCS_ASSIST_ROLL = OFF	INIT_RCS_ASSIST_ROLL = ON	DESIRED_ATTITUDE_R	0
		ATTITUDE_R	0
		GA_OLD	GIMBAL_ANGLES

4.2.2.4.10 TVC_LAW_PITCH_YAW

A. Function: This module closes the inner loop of the TVC DAP when RCS DAP assistance in pitch and yaw is not required. Vehicle pitch and yaw rates are derived by back-differencing the IMU angles, dividing by the time step and transforming from IMU rates to body rates. The body rates are subtracted from the commanded rates to form rate errors, which are processed by compensation filters and passed through proportional-plus-integral paths. The outputs are limited and passed on as position commands to the OMS engine actuator servos. The pitch channel compensation filter contains a sign reversal to account for a second reversal that takes place in the engine-vehicle relationship (in which positive engine pitch induces negative vehicle pitch). The yaw channel does not require such a reversal because the vehicle and actuator coordinate frames have approximately opposed Z axes, and thus positive engine yaw about the actuator Z axis induces positive vehicle yaw about the vehicle Z axis.

The initialization of this module includes two significant actions. The TVC DAP gains are set as an inverse function of the number of OMS engines operating; re-initialization is thus required if this number changes. Secondly, depending on the value of the initialization flag (which for this module is an integer), the integrators in the proportional-plus-integral processing may either be allowed to remain containing the final values from the previous TVC burn, or initialized to a value computed outside the module. In either case the integrator contents are immediately passed on as initial engine trim commands.

B. Block Diagram: Figure 4.2.2.4.10-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.4.10-1

E. Constants: Table 4.2.2.4.10-2

F. Initialization Requirements: Table 4.2.2.4.10-3

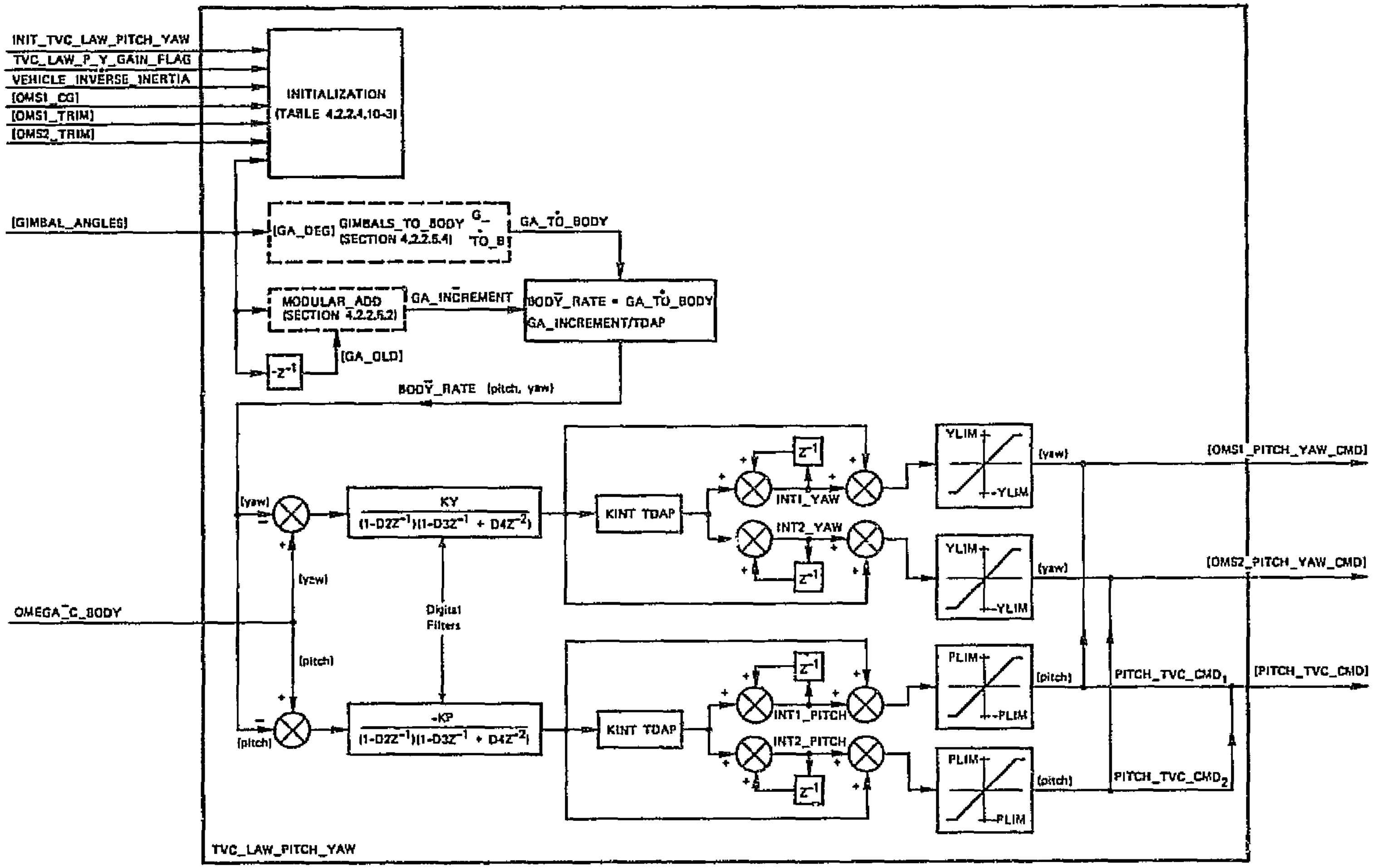


Figure 4.2.2.4.10-1. TVC_LAW_PITCH_YAW.

TABLE 4.2.2.4.10-1 TVC_LAW_PITCH_YAW INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
OMEGA_C_BODY (pitch and yaw components)	Commanded body angular rate	GUIDANCE_COMPENSATION or MANUAL_TVC	V(3)S	TBD	deg/s	25
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	25
OMS1_CG	Vector from OMS1 hinge point to vehicle cg, in body axes	OMS_PRETHRUST_MANEUV-ER	V(3)S	TBD	f	1/maneuver
VEHICLE_INVERSE_INE-RTIA (pitch and yaw moments)	Inverse of vehicle inertia	SF	M(3,3)S	TBD	1/((slug)(f)-(f))	1/maneuver
TVC_LAW_P_Y_GAIN_FL-AG	Flag indicating number of OMS engines to burn 1 = 1 engine 2 = 2 engines	OFC_RECON	I	1,2	none	1/maneuver
INIT_TVC_LAW_PITCH_-YAW	Module initialization flag 0 = no init 1 = init using trim value derived from previous OMS burn 2 = init using OMS1_TRIM and OMS2_TRIM	CFC_RECON	I	0,1,2	none	25
OMS1_TRIM	OMS1 engine pitch and yaw trim values	ENGINE_CG_CMD or ENGINE_PRETHRUST_TRIM	A(2)S	TBD	deg	1/maneuver
OMS2_TRIM	OMS2 engine pitch and yaw trim values	ENGINE_CG_CMD or ENGINE_PRETHRUST_TRIM	A(2)S	TBD	deg	1/maneuver

TABLE 4.2.2.4.10-1 TVC_LAW_PITCH_YAW INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Outputs						
PITCH_TVC_CMD	Pitch component of pitch servo command, for OMS1 and OMS2 engines	TVC_MIXER	A(2)S	pitch: -6 <= x <= 6 yaw: -7 <= x <= 7	deg	25
OMS1_PITCH_YAW_CMD	OMS1 engine pitch and yaw servo commands	SOP	A(2)S	pitch: -6 <= x <= 6 yaw: -7 <= x <= 7	deg	25
OMS2_PITCH_YAW_CMD	OMS2 engine pitch and yaw servo commands	SOP	A(2)S	pitch: -6 <= x <= 6 yaw: -7 <= x <= 7	deg	25

TABLE 4.2.2.4.10-2 TVC_LAW_PITCH_YAW CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
K	Pitch/yaw autopilot-vehicle gain product	S	0.0109	none
PLIM	OMS1 and OMS2 pitch command limit	S	6	deg
YLIM	OMS1 and OMS2 yaw command limit	S	7	deg
KINT	Integrator gain	S	0.16	none
D2	Filter coefficient	S	0.7857	none
D3	Filter coefficient	S	1.7376	none
D4	Filter coefficient	S	0.78845	none
T	Two-engine thrust value	S	12000	lbf
TDAP	Period of TVC DAP cycle	S	0.04	s

TABLE 4.2.2.4.10-3 TVC_LAW_PITCH_YAW INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_TVC_LAW_PITCH_YAW = 0	INIT_TVC_LAW_PITCH_YAW = 1 or 2	KY	Note 1
		KP	Note 2
		Nodes (3 each)	0
		GA_OLD	GIMBAL_ANGLES
INIT_TVC_LAW_PITCH_YAW = 0	INIT_TVC_LAW_PITCH_YAW = 2	INT1_PITCH	OMS1_TRIMS(1)
		INT1_YAW	OMS1_TRIMS(2)
		INT2_PITCH	OMS2_TRIMS(1)
		INT2_YAW	OMS2_TRIMS(2)

Note 1:

$$\frac{2K}{T\ \mathrm{VEHICLE\_INVERSE\_INERTIA}_{3,3}\ \mathrm{OMS1\_CG}_1\ \mathrm{TVC\_LAW\_P\_Y\_GAIN\_FLAG}}$$

Note 2:

$$\frac{2K}{T\ \mathrm{VEHICLE\_INVERSE\_INERTIA}_{2,2}\ \mathrm{OMS1\_CG}_1\ \mathrm{TVC\_LAW\_P\_Y\_GAIN\_FLAG}}$$

4.2.2.4.11 TVC_LAW_ROLL

A. Function: This module provides control of the vehicle in roll during two-engine TVC burns.

B. Block Diagram: Figure 4.2.2.4.11-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.4.11-1

E. Constants: Table 4.2.2.4.11-2

F. Initialization Requirements: Table 4.2.2.4.11-3

C.3

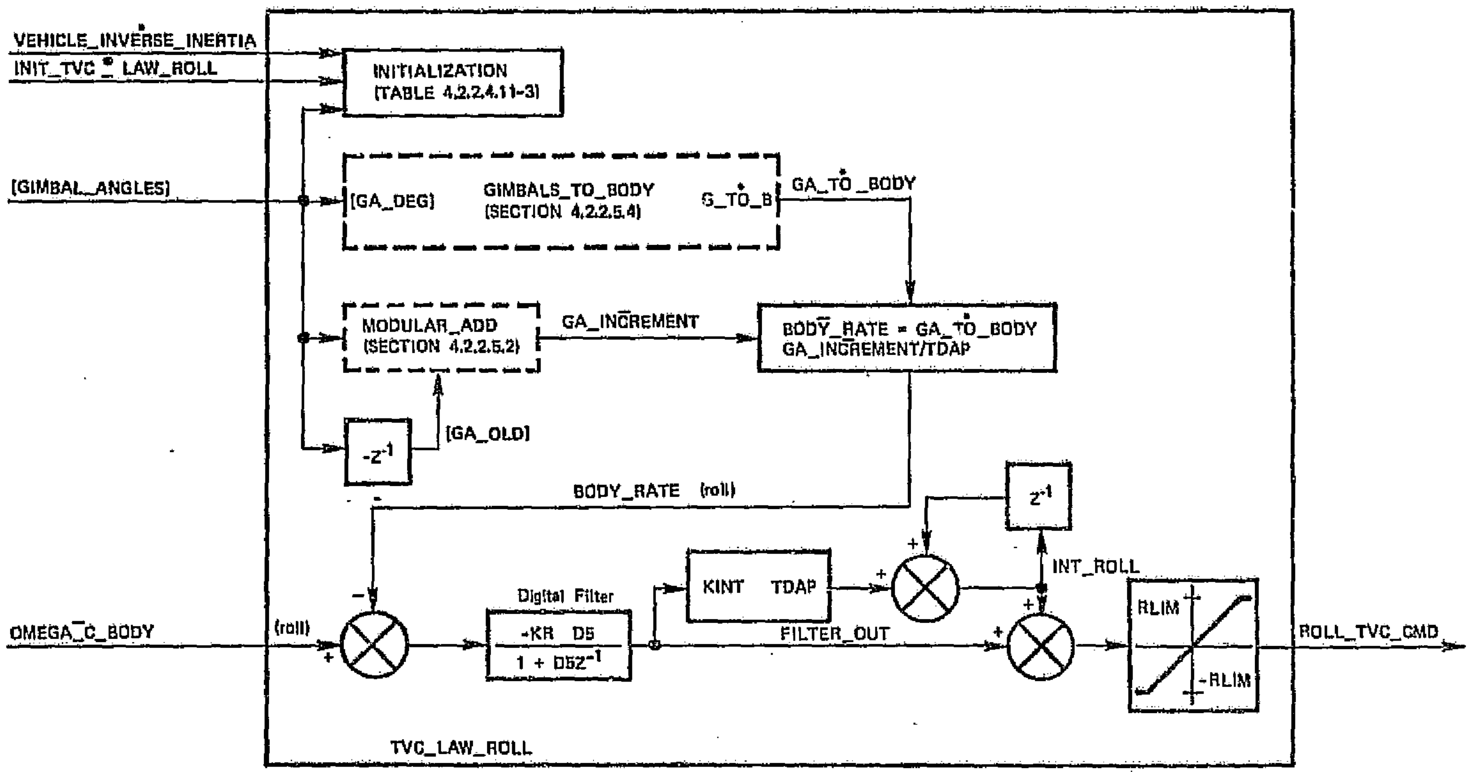


Figure 4.2.2.4.11-1. TVC_LAW_ROLL

TABLE 4.2.2.4.11-1 TVC_LAW_ROLL INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
OMEGA_C_BODY (roll component)	Commanded body angular rate	GUIDANCE_COMPENSATION or MANUAL_TVC	V(3)S	TBD	deg/s	25
INIT_TVC_LAW_ROLL	Module initialization flag	OFC_RECON	B	0,1	none	25
GIMBAL_ANGLES	IMU gimbal angles	SOP	A(3)S	-180 < x <= 180	deg	25
VEHICLE_INVERSE_INERTIA (roll moment)	Inverse of vehicle inertia	SF	M(3,3)S	TBD	1/((slug)(f)-(f))	25
Outputs						
ROLL_TVC_CMD	Roll component of pitch servo command for OMS engines	TVC_MIXER	S	TBD	deg	25

TABLE 4.2.2.4.11-2 TVC_LAW_ROLL CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
K	Roll autopilot-vehicle gain product	S	TBD	none
RLIM	Limiting value for roll component of pitch servo command for OMS engines	S	TBD	deg
KINT	Integrator gain	S	TBD	none
D5	Filter coefficient	S	TBD	none
T	Two-engine thrust value	S	12000	lbf
LY	OMS engines Y-axis separation	S	14.7	f
TDAP	Period of TVC DAP cycle	S	0.04	s

TABLE 4.2.2.4.11-3 TVC_LAW_ROLL INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_TVC_ROLL = OFF	INIT_TVC_ROLL = ON	KR	Note 1
		FILTER_OUT	0
		GA_OLD	GIMBAL_ANGLES
		INT_ROLL	0

Note 1:

$$\frac{K}{T\ LY\ VEHICLE\_INVERSE\_INERTIA_{1,1}}$$

4.2.2.4.12 TVC_MIXER

A. Function: This module derives the OMS1 and OMS2 pitch actuator servo commands as the difference and sum respectively of the pitch and roll TVC commands.

B. Block Diagram: Figure 4.2.2.4.12-1

C. Processing Rate: 25 Hz

D. Interface Requirements: Table 4.2.2.4.12-1

E. Constants: none

F. Initialization Requirements: none

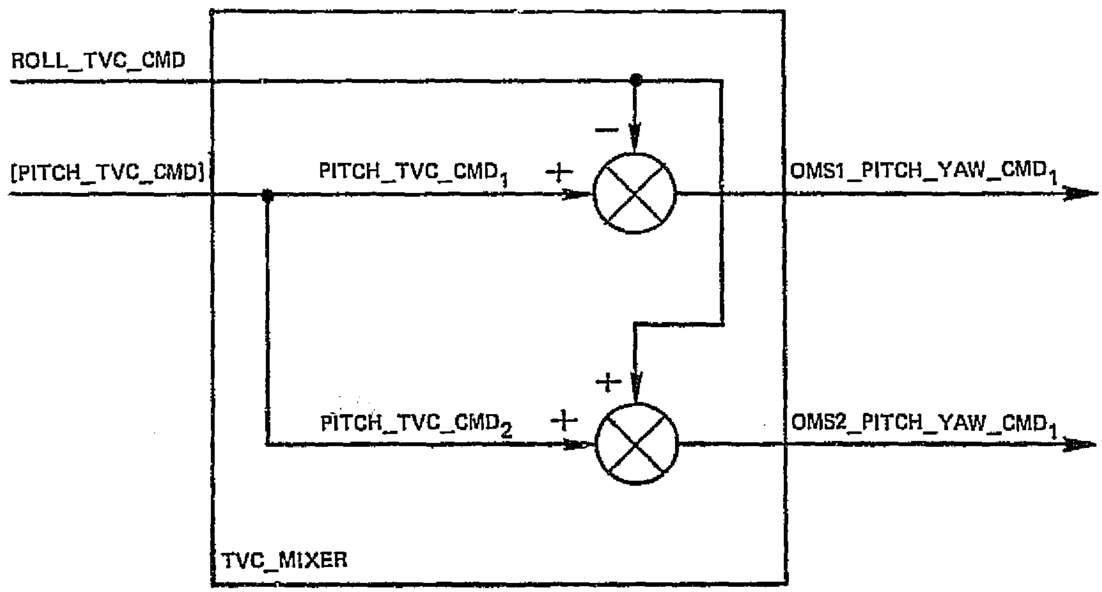


Figure 4.2.2.4.12-1. TVC_MIXER

TABLE 4.2.2.4.12-1 TVC_MIXER INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
ROLL_TVC_CMD	Roll component of pitch servo command for OMS engines	TVC_LAW_ROLL	S	TBD	deg	25
PITCH_TVC_CMD	Pitch component of pitch servo command, for OMS1 and OMS2 engines	TVC_LAW_PITCH_YAW	A(2)S	TBD	deg	25
Ouputs						
OMS1_PITCH_YAW_CMD (pitch element)	OMS1 engine pitch and yaw servo commands	SOP, RM	A(2)S	TBD	deg	25
OMS2_PITCH_YAW_CMD (pitch element)	OMS2 engine pitch and yaw servo commands	SOP, RM	A(2)S	TBD	deg	25

4.2.2.5 Service

4.2.2.5.1 ANGLES_TO_DCM

A. <u>Function</u>: This module generates a direction cosine matrix that transforms a vector in body coordinates to one in IMU stable member coordinates. The matrix is rectangular and thus its transpose may be used for the inverse transformation.

B. <u>Block Diagram</u>: Figure 4.2.2.5.1-1

C. <u>Processing Rate</u>: As called

D. <u>Interface Requirements</u>: Table 4.2.2.5.1-1

E. <u>Constants</u>: Table 4.2.2.5.1-2

F. <u>Initialization Requirements</u>: none

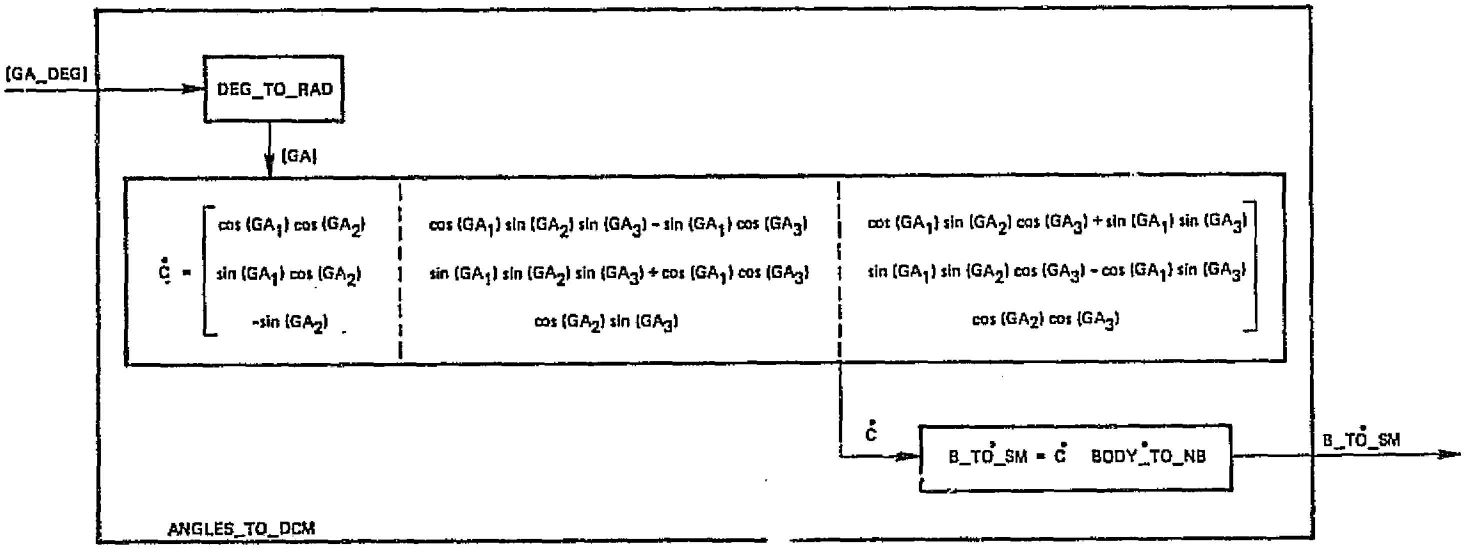


Figure 4.2.2.5.1-1. ANGLES_TO_DCM.

TABLE 4.2.2.5.1-1 ANGLES_TO_DCM INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Input						
GA_DEG (Note 1)	IMU gimbal angles	Calling routine	A(3)S	-180 < x <= 180	deg	1/call
Output						
B_TO_SM (Note 2)	Body to stable member transformation matrix	Calling routine	M(3,3)S	-1 <= x <= 1	none	1/call
	Note 1. Input parameter name. Calling routine may use any legal name. Note 2. Assign parameter name. Calling routine may use any legal name.					

TABLE 4.2.2.5.1-2 ANGLES_TO_DCM CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
DEG_TO_RAD	Degrees to radians conversion factor	S	pi/180	rad/deg
BODY_TO_NB	Vehicle to IMU navigation base transformation matrix	M(3,3)S	See Note	none

Note 1:

$$\text{BODY\_TO\_NB} = \begin{bmatrix} \cos(11°) & 0 & \sin(11°) \\ 0 & 1 & 0 \\ -\sin(11°) & 0 & \cos(11°) \end{bmatrix}$$

4.2.2.5.2 MODULAR_ADD

A. <u>Function</u>: This module adds two angles such that the sum is in the range -180 to 180 degrees.

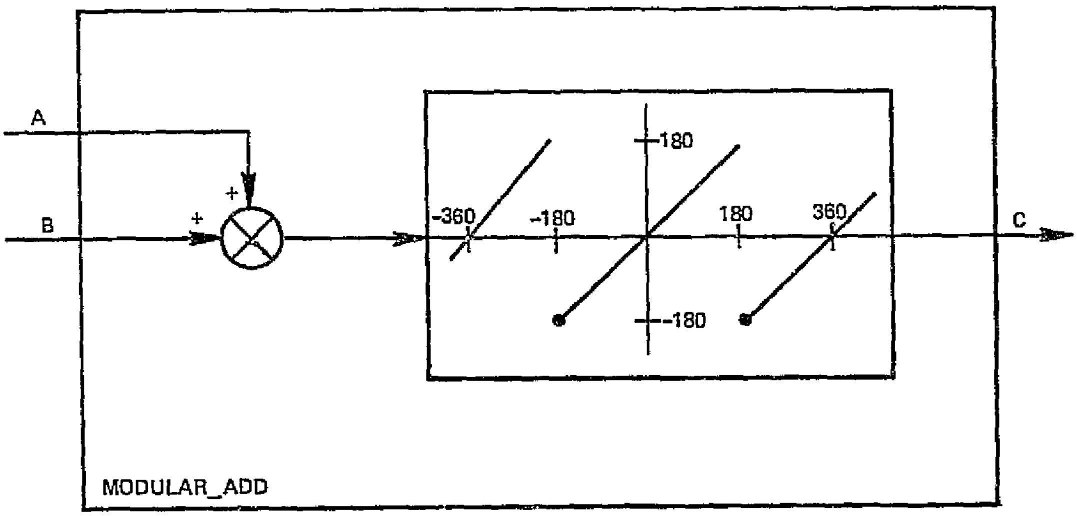
B. <u>Block Diagram</u>: Figure 4.2.2.5.2-1

C. <u>Processing Rate</u>: As called

D. <u>Interface Requirements</u>: Table 4.2.2.5.2-1

E. <u>Constants</u>: none

F. <u>Initialization Requirements</u>: none



NOTE: This is a scalar operation. For vector or array inputs, it is performed once for each element.

Figure 4.2.2.5.2-1. MODULAR_ADD.

TABLE 4.2.2.5.2-1 MODULAR_ADD INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
A,B (Note 1)	Angles to be added	Invoking routine	S	TBD	deg	1/invocation
Output						
C (Note 2)	Modular sum of A and B	Invoking routine	S	-180 < x <= 180	deg	1/invocation
	Note 1. Input parameter name. Calling routine may use any legal name. Note 2. Return parameter name. Calling routine may use any legal name.					

4.2.2.5.3 GA_INCREMENT

A. Function: This module increments a set of desired IMU gimbal angles, and predicts and accommodates an IMU gimbal flip. It also warns of a gimbal lock condition. The desired increments are multiplied by a sign variable (+1 or -1) and added to the desired gimbal angles, and the sum is tested to see if attainment of the new desired angles will result in lock (outer-middle gimbal angle within 1/2 degree of +90 or -90 degrees) or in flip (desired outer-middle gimbal angle greater than +90 degrees or less than -90 degrees). If lock is detected, a flag is set. If an impending flip is detected the module does the following:

   (1) Increments the desired inner and outer gimbal angles by 180 degrees such that the result is in the range -180 to +180 degrees.

   (2) Reflects the desired outer-middle gimbal angle about the value (+90 or -90 degrees) just passed through; e.g., 91 degrees becomes 89 degrees.

   (3) Reverses the sign of the sign variable for future incrementations.

B. Block Diagram: Figure 4.2.2.5.3-1

C. Processing Rate: As called

D. Interface Requirements: Table 4.2.2.5.3-1

E. Constants: none

F. Initialization Requirements: none

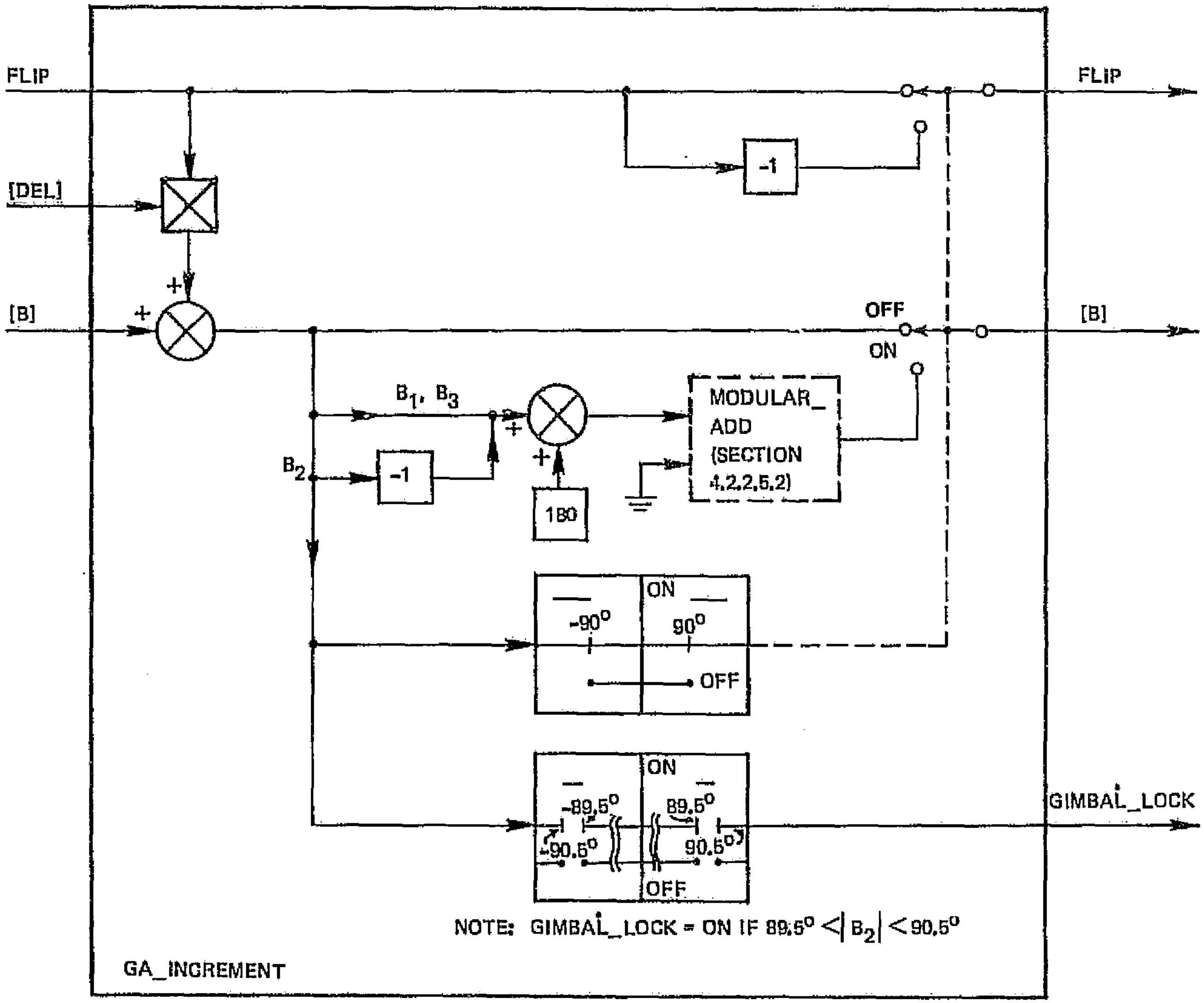


Figure 4.2.2.5.3-1. GA_INCREMENT.

TABLE 4.2.2.5.3-1 GA_INCREMENT INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Inputs						
FLIP (Note 1)	Indicator of flipped state of IMU gimbal system	Calling routine	I	-1,1	none	1/call
DEL (Note 2)	IMU gimbal angle increments	Calling routine	A(3)S	-180 < x <= 180	deg	1/call
B (Note 1)	IMU gimbal angles	Calling routine	A(3)S	-180 < x <= 180	deg	1/call
Outputs						
FLIP (Note 1)	Indicator of flipped state of IMU gimbal system	Calling routine	I	-1,1	none	1/call
B (Note 1)	Incremented IMU gimbal angles	Calling routine	A(3)S	-180 < x <= 180	deg	1/call
GIMBAL_LOCK (Note 1)	Flag indicating B$(2) is in lock region	Calling routine	B	0,1	none	1/call
	Note 1. Assign parameter name. Calling routine may use any legal name. Note 2. Input parameter name. Calling routine may use any legal name.					

4.2.2.5.4 GIMBALS_TO_BODY

A. Function: This module generates a matrix that transforms IMU gimbal angle rates to vehicle body rates.

B. Block Diagram: Figure 4.2.2.5.4-1

C. Processing Rate: As called

D. Interface Requirements: Table 4.2.2.5.4-1

E. Constants: Table 4.2.2.5.4-2

F. Initialization Requirements: none

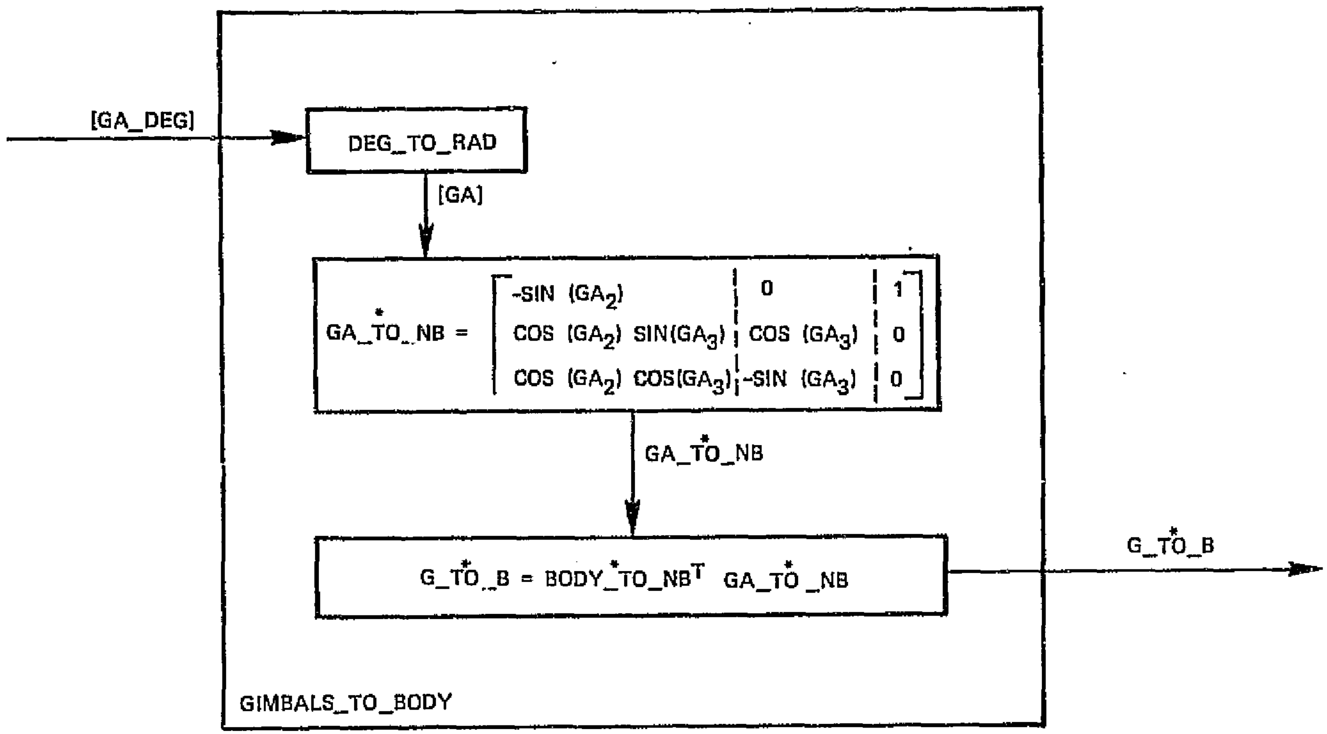


Figure 4.2.2.5.4-1. GIMBALS_TO_BODY.

TABLE 4.2.2.5.4-1 GIMBALS_TO_BODY INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Input						
GA_DEG (Note 1)	IMU gimbal angles	Calling routine	A(3)S	-180 < x <= 180	deg	1/call
Output						
G_TO_B (Note 2)	IMU gimbal rotation to body rotation transformation matrix	Calling routine	M(3,3)S	-1 <= x <= 1	none	1/call
	Note 1. Input parameter name. Calling routine may use any legal name. Note 2. Assign parameter name. Calling routine may use any legal name.					

TABLE 4.2.2.5.4-2 GIMBALS_TO_BODY CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
DEG_TO_RAD	Degrees to radians conversion factor	S	pi/180	rad/deg
BODY_TO_NB	Vehicle TO IMU navigation base transformation matrix	M(3,3)S	See Note	none

Note 1:

$$\text{BODY\_TO\_NB} = \begin{bmatrix} \cos(11^\circ) & 0 & \sin(11^\circ) \\ 0 & 1 & 0 \\ -\sin(11^\circ) & 0 & \cos(11^\circ) \end{bmatrix}$$

4.2.2.5.5 BODY_TO_GIMBALS

A. Function: This module generates a matrix that transforms vehicle body rates to IMU gimbal angle rates.

B. Block Diagram: Figure 4.2.2.5.5-1

C. Processing Rate: As called

D. Interface Requirements: Table 4.2.2.5.5-1

E. Constants: Table 4.2.2.5.5-2

F. Initialization Requirements: none

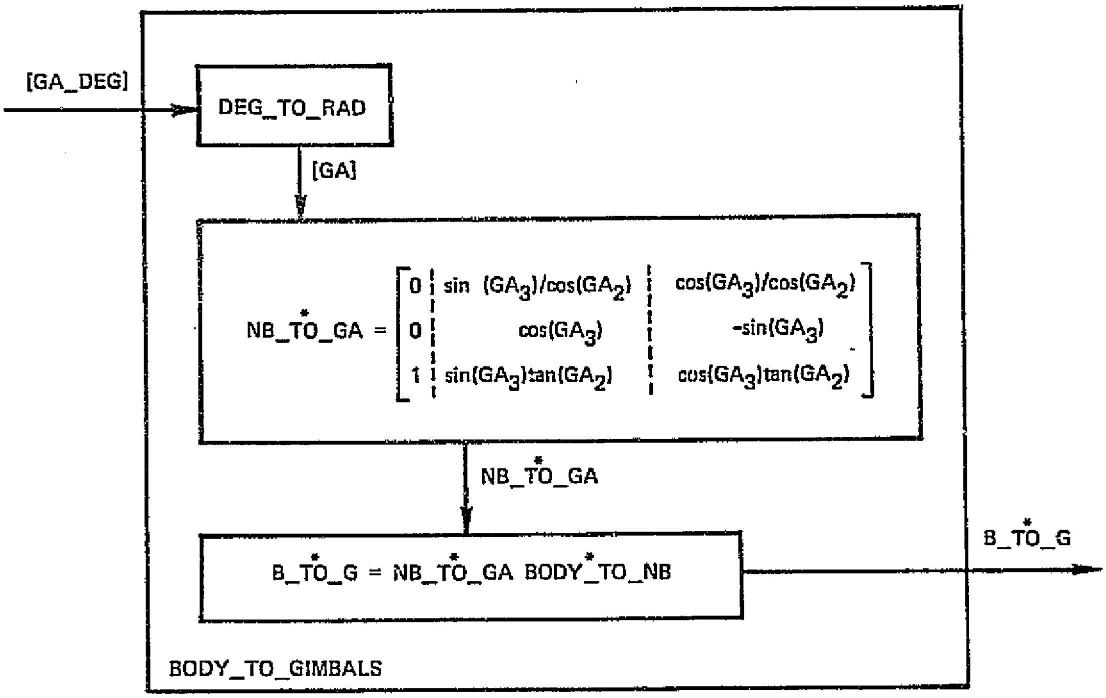


Figure 4.2.2.5.5-1. BODY_TO_GIMBALS.

TABLE 4.2.2.5.5-1 BODY_TO_GIMBALS INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	RANGE	UNIT	SAMPLE RATE (HZ)
Input						
GA_DEG (Note 1)	IMU gimbal angles	Calling routine	A(3)S	-180 < x <= 180	deg	1/call
Output						
B_TO_G (Note 2)	Body rotation to IMU gimbal rotation transformation matrix	Calling routine	M(3,3)S	-1 <= x <= 1	none	1/call
	Note 1. Input parameter name. Calling routine may use any legal name. Note 2. Assign parameter name. Calling routine may use any legal name.					

TABLE 4.2.2.5.5-2 BODY_TO_GIMBALS CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
DEG_TO_RAD	egrees to radians conversion factor	S	pi/180	rad/deg
BODY_TO_NB	Vehicle to IMU navigation base transformation matrix	M(3,3)S	See Note 1	none

Note 1:

$$\text{BODY\_TO\_NB} = \begin{bmatrix} \cos(11^\circ) & 0 & \sin(11^\circ) \\ 0 & 1 & 0 \\ -\sin(11^\circ) & 0 & \cos(11^\circ) \end{bmatrix}$$