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**Flight Procedures Handbook**

T  
Orbital Maneuvering System / Reaction Control System

**(OMS/RCS) On-Orbit Operations**

Crew Training and Procedures Division  
Flight Activities Branch

Preliminary

November 1980

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FLIGHT OPERATIONS DIRECTORATE

OMS/RCS ON-ORBIT OPERATIONS

FLIGHT PROCEDURES

HANDBOOK

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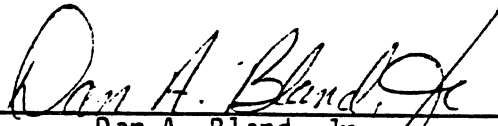
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## FLIGHT PROCEDURES HANDBOOK PUBLICATIONS

The following is a list of the Integrated Flight Procedures Handbooks of which this document is a part. These handbooks document integrated and/or flight procedural sequences covering major STS crew activity plan phases.

| <u>Title</u>                         | <u>JSC No.</u> |
|--------------------------------------|----------------|
| ASCENT/ABORTS                        | 10559          |
| ENTRY                                | 11542          |
| RENDEZVOUS/ORBITAL NAVIGATION        | 10589          |
| OMS/RCS ON-ORBIT OPERATIONS          | 10588          |
| ATTITUDE AND POINTING                | 10511          |
| STS WORKDAY                          | 10541          |
| SPACELAB ACTIVATION                  | 10545          |
| SPACELAB DEACTIVATION                | 12803          |
| CREW DATA MANAGEMENT                 | 12985          |
| PROXIMITY OPERATIONS                 | 12802          |
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## SECTION 1 INTRODUCTION

### 1.1 PURPOSE

This handbook has been prepared for the Space Transportation System (STS) flight crews and ground operations personnel as an on-orbit flight phase training supplement and a ready reference for refresher information. It provides background (documentation) and rationale used in preparation of flight procedures to meet test and operational objectives.

### 1.2 SCOPE

The overall objective of this handbook is to cover, in general, all Orbital Flight Tests (OFT) and early operational flights; however, the dynamic nature of the Shuttle development program precludes complete satisfaction of this objective. Although STS-1 peculiar information has been included as sections 6 and 7 in this edition, the specific requirements of the first flight have influenced the entire publication. The detailed procedures included reflect the STS-1 Orbit Operations Checklist, Preliminary, Revision F. This flight procedures handbook will continue to be subject to an iterative revision process as the STS program matures.

Redundancy of other Shuttle documentation has been avoided except as needed to highlight the procedures. The procedures and techniques presented are the results of blending past crew experience, equipment specifications, system analyses (both theoretical and empirical), and functional simulations. Most of the contents have been discussed in On-Orbit Flight Technique Meetings (OFTM) held at Johnson Space Center (JSC).

### 1.3 REFERENCES

General references for preparation and use of this handbook are as follows.

I/O/D GNC 2102 Insertion/On-Orbit/Deorbit Guidance, Navigation, and Flight Control Workbook.

SFOM, Vol. 13, Shuttle Displays and Controls. Basic. JSC-12770.

STS-1 Flight Data File Data Processing System Dictionary. Preliminary. JSC-12791.

SFOM, Vol. 8C, Orbital Maneuvering System. JSC-12770.

SFOM, Vol. 8D, Reaction Control System. Preliminary. JSC-12770.

Attitude and Pointing Flight Procedures Handbook. JSC-10511.

STS/OV-102 Orbiter Systems Operating Procedures, Baseline. JSC-12766.

Space Shuttle Flight Data File Preparations Standards. Final, Rev. B.  
JSC-09958.

Proximity Operations Flight Procedures Handbook. JSC-12802.

Rendezvous/Orbital Navigation Flight Procedures Handbook. JSC-10589.

STS Work Day Handbook. JSC-10541.

Flight Requirements Document, STS-1. JSC-10780.

STS-1 Flight Data File Crew Activity Plan. JSC-12799.

Minutes, On-Orbit, Deorbit Flight Technique Panels. JSC Memo CG5-79-237,  
Aug. 1979.

OPS C/L Procedures Explanations. JSC Memo CG5-79-237, Aug. 1979.

#### 1.4 ACRONYMS AND ABBREVIATIONS

|             |                                 |
|-------------|---------------------------------|
| ACC         | Acceleration                    |
| ADI         | Attitude Director Indicator     |
| AOS         | Acquisition of Signal           |
| ATT         | Attitude                        |
| AUTO        | Automatic                       |
|             |                                 |
| BFS         | Backup Flight System            |
| BITE        | Built-in Test Equipment         |
|             |                                 |
| CAL         | Calibrate(tion)                 |
| CAP         | Crew Activity Plan              |
| C&W,C/W     | Caution and Warning             |
| cb          | Circuit Breaker                 |
| CDR         | Commander                       |
| c.g.        | Center of Gravity               |
| CK          | Check                           |
| C/L         | Checklist                       |
| CL          | Close                           |
| CLR         | Clear                           |
| CMD         | Command                         |
| C/O         | Cut-off                         |
| COAS        | Crewman Optical Alignment Sight |
| CNTRLR      | Controller                      |
| CONT        | Continuous                      |
| CRT         | Cathode Ray Tube                |
| CUR         | Current                         |
|             |                                 |
| DAP         | Digital Autopilot               |
| DB          | Deadband                        |
| DD/HH:MM:SS | Day/Hour:Minute:Second          |
| DEG         | Degrees                         |
| DEORB       | Deorbit                         |



|        |   |
|--------|---|
| DES    | Deselect                                    |
| DFI    | Development Flight Instrumentation          |
| DIF    | Difference                                  |
| DIP    | Display Interface Processor                 |
| DISC   | Discrete                                    |
| DK     | Display Keyboard                            |
| DPS    | Data Processing System                      |
| EI     | Entry Interface                             |
| ENA    | Enable                                      |
| ENG    | Engine                                      |
| ERR    | Error                                       |
| EXEC   | Execute                                     |
| F, FWD | Forward                                     |
| FA     | Flight Aft (MDM)                            |
| FCS    | Flight Control System                       |
| FDA    | Fault Detection and Annunciation            |
| FDf    | Flight Data File                            |
| FF     | Flight Forward (MDM)                        |
| FLT    | Flight                                      |
| FOD    | Flight Operations Directorate               |
| FRD    | Flight Requirements Document                |
| FRL    | Fuselage Reference Line                     |
| FTO    | Functional Test Objective                   |
| FU     | Fuel  |
| GMBL   | Gimbal                                      |
| GNC    | Guidance, Navigation, and Control           |
| GND    | Ground                                      |
| GPC    | General Purpose Computer                    |
| GSTDN  | Ground Spacecraft Tracking and Data Network |
| H      | Horizontal                                  |
| HA     | Apogee Altitude                             |
| HI     | High  |
| HORIZ  | Horizontal                                  |
| HP     | Perigee Altitude                            |
| HT     | A Guidance Parameter                        |
| ID     | Identification                              |
| IH     | Inertial Hold                               |
| I-LOAD | Initial Data Load                           |
| IMU    | Inertial Measurement Unit                   |
| INRTL  | Inertial                                    |
| ISOL   | Isolation                                   |
| JSC    | Johnson Space Center                        |
| L      | Left  |
| LH     | Left Hand                                   |
| LOS    | Line of Sight, Loss of Signal (time)        |
| LTVC   | Line on Terminal Velocity Constraint        |
| LVLH   | Local Vertical, Local Horizontal            |

|       |  |
|-------|--|
| MAN   | Manual   |
| MCC   | Mission Control Center                               |
| MDM   | Multiplexer-Demultiplexer                            |
| MECO  | Main Engine Cutoff                                   |
| MET   | Mission Elapsed Time                                 |
| MIN   | Minute(s)  |
| MM    | Major Mode   |
|       | Mass Memory  |
| MNVR  | Maneuver   |
| MSG   | Message  |
| MSN   | Mission  |
| M50   | Mean of 1950 (coordinate system)                     |
|       |  |
| NAV   | Navigation   |
| NSP   | Network Signal Processor                             |
|       |  |
| O     | Overhead   |
| OFT   | Orbital Flight Test                                  |
| OFTM  | On-Orbit Flight Technique Meeting                    |
| OMS   | Orbital Maneuvering System                           |
| OP    | Open   |
| OPER  | Operate(tion)  |
| OPS   | Operational Sequence                                 |
| OX    | Oxidizer   |
|       |  |
| P     | Pitch  |
|       | Pressure   |
| PAD   | Preliminary Advisory Data, Parameter and Data (form) |
| PARA  | Paragraph  |
| PASS  | Primary Avionics Software System                     |
| pb    | Pushbutton   |
| pbi   | Pushbutton Indicator                                 |
| Pc    | Chamber Pressure                                     |
| PCM   | Pulse Code Modulation                                |
| PDP   | Post-Insertion Deorbit Preparation                   |
| PEG   | Powered Explicit Guidance                            |
| PLBD  | Payload Bay Door                                     |
| PLT   | Pilot  |
| PNL   | Panel  |
| PNLS  | Panels   |
| POS   | Position   |
| PRCS  | Primary Reaction Control System                      |
| PRES  | Present  |
| PROC  | Procedure  |
| PRPLT | Propellant   |
| PTC   | Passive Thermal Control                              |
| PWR   | Power  |
|       |  |
| R     | Right  |
|       | Roll   |
| RCD   | Record   |
| RCS   | Reaction Control System                              |
| REF   | Reference  |
| REI   | Range from Entry Interface                           |

|                   |                                  |
|-------------------|----------------------------------|
| RELMAT            | Relative Matrix                  |
| REQD              | Required                         |
| RH                | Right Hand                       |
| RHC               | Rotational Hand Controller       |
| RJD               | Reaction Jet Driver              |
| RM                | Redundancy Management            |
| RTN               | Return                           |
| S, SEC            | Second                           |
| SEL               | Selected                         |
| SFOM              | Shuttle Flight Operations Manual |
| SM                | System Management                |
| SOP               | Software Operating Procedure     |
| SPEC              | Subsystem Operating Program      |
| STBY              | Specialist Function              |
| STS               | Standby                          |
| SUMM              | Space Transportation System      |
| SURF              | Summary                          |
| SYS               | Surface                          |
|                   | System                           |
| tb                | Talkback                         |
| TBS               | To Be Supplied                   |
| TEMP              | Temperature                      |
| TERM              | Terminate                        |
| TFF               | Time of Free Fall                |
| TGO               | Time To Go                       |
| TGT               | Target                           |
| TGTS              | Targets                          |
| THC               | Translational Hand Controller    |
| TIG               | Time of Ignition                 |
| TK                | Tank                             |
| TM                | Telemetry                        |
| TMR               | Timer                            |
| TOL               | Tolerances                       |
| TOT               | Total                            |
| TRM               | Trim                             |
| TVC               | Thrust Vector Control            |
| V                 | Vertical                         |
| VGO               | Velocity To Be Gained            |
| VLV               | Valve                            |
| VRCS              | Vernier Reaction Control System  |
| WB                | Wideband                         |
| WT                | Weight                           |
| X, X <sub>0</sub> | X-axis (direction)               |
| Y, Y <sub>0</sub> | Y-axis (direction)               |
|                   | Yaw                              |
| Z, Z <sub>0</sub> | Z-axis (direction)               |

SYMBOLS:

|        |                                     |
|--------|-------------------------------------|
| c1,c2, | Guidance parameters                 |
| HT,θT  |                                     |
| *      | Selected; active                    |
| (no *) | Deselected; not active              |
| ΔMIN   | Elapsed time in minutes             |
| ΔX     | Misalignment in X (direction)       |
| ΔY     | Misalignment in Y (direction)       |
| ΔZ     | Misalignment in Z (direction)       |
| ΔVX    | Change in velocity in X (direction) |
| ΔVY    | Change in velocity in Y (direction) |
| ΔVZ    | Change in velocity in Z (direction) |

## SECTION 2 BACKGROUND

### 2.1 OMS AND RCS SYSTEMS

The Orbital Maneuvering System (OMS) provides the thrust to perform orbit insertion (OMS 1), orbit circularization (OMS 2), orbit transfer, some rendezvous operations, and deorbit. For STS-1, which is not a rendezvous mission, the OMS 3 and OMS 4 burns are to be used for flight test purposes and will be out-of-plane burns (sec. 6). The OMS system consists of a propellant pressurization subsystem, a propellant storage and distribution subsystem, and the engine subsystem (fig. 2-1).

The Reaction Control System (RCS) contains primary thrusters (PRCS) to provide thrust for some rendezvous operations, proximity operations, and attitude control, and vernier thrusters (VRCS) for fine attitude control. Rendezvous and proximity operations are described in section 2.6. Similar to the OMS system, the RCS system contains a propellant pressurization subsystem, a propellant storage and distribution subsystem, and the engines subsystem. In addition, the interconnect/crossfeed subsystem (fig. 2-2) allows the aft RCS system to use propellants from the left or right RCS propellant storage subsystem (crossfeed) or to use propellants from the left or right OMS propellant storage subsystem (interconnect). These procedures are described in section 3. Note that the forward RCS cannot be interconnected with either the OMS or the aft RCS system.

The OMS and RCS systems are contained in three pods (fig. 2-3): one forward (RCS only) and two aft (left and right OMS and RCS).

### 2.2 OMS/RCS - ORBITER SYSTEMS INTERFACES

The OMS/RCS systems interfaces with other Orbiter systems, described in detail in SFOM, Vols. 8c and 8d, are shown in figures 2-4 and 2-5. A detailed description of all these systems interfaces is beyond the scope of this document. However, those aspects essential to understanding the OMS/RCS procedures will be covered in succeeding sections of this handbook.

### 2.3 CRT DISPLAYS

A brief description of the displays used for OMS/RCS operation is included here for reference. They are described in detail in the Data Processing System (DPS) Dictionary, a Flight Data File (FDL) article. The use of the CRT displays is covered in sections 4.2, 4.3, and 5.2 of this handbook as applicable to OMS/RCS procedures.

RCS - This display provides the crew with the capability to select the desired RCS module for display of Redundancy Management (RM) and systems data to monitor and control the RCS RM and to enable the OMS pressurization function for interconnect operations in the DPS Operational Sequence (OPS) 2 RCS burn (fig. 2-6).

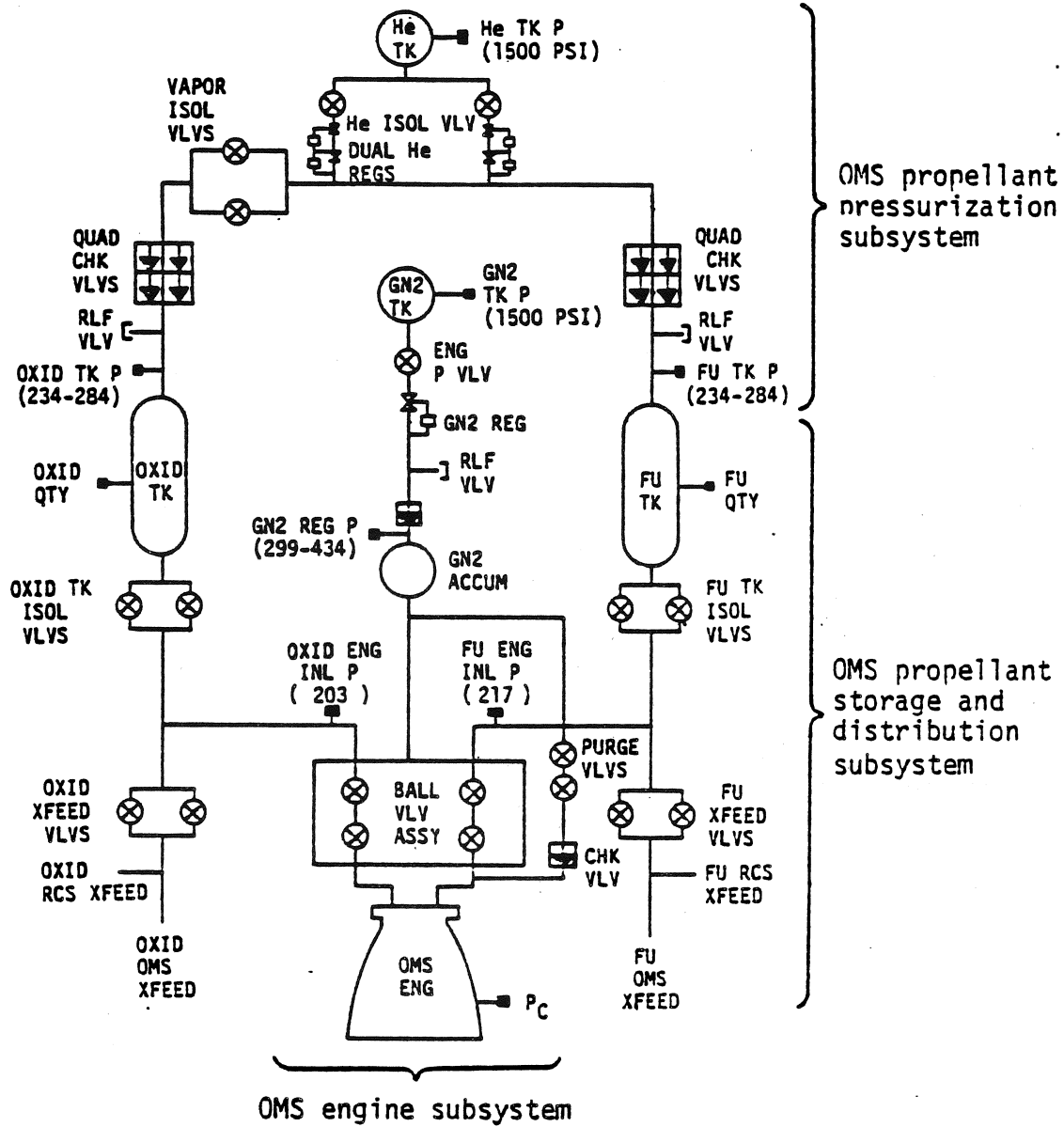
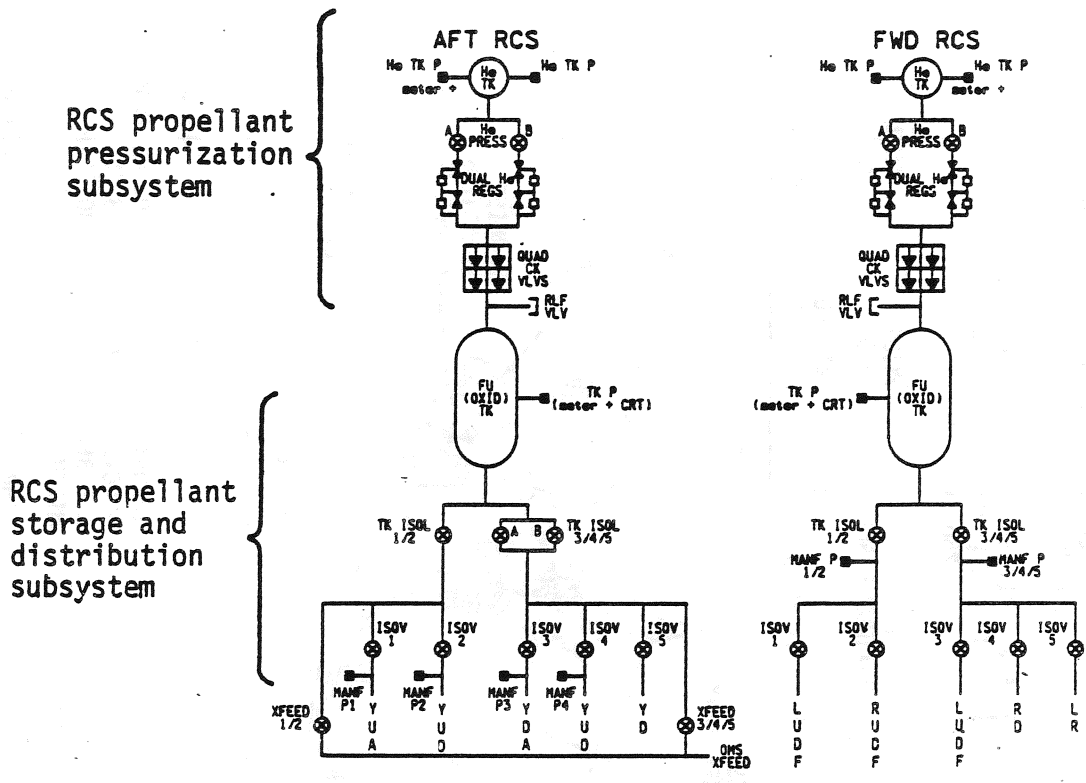


Figure 2-1.- OMS subsystems.



NOTE: For clarity, RCS engine subsystem not shown.

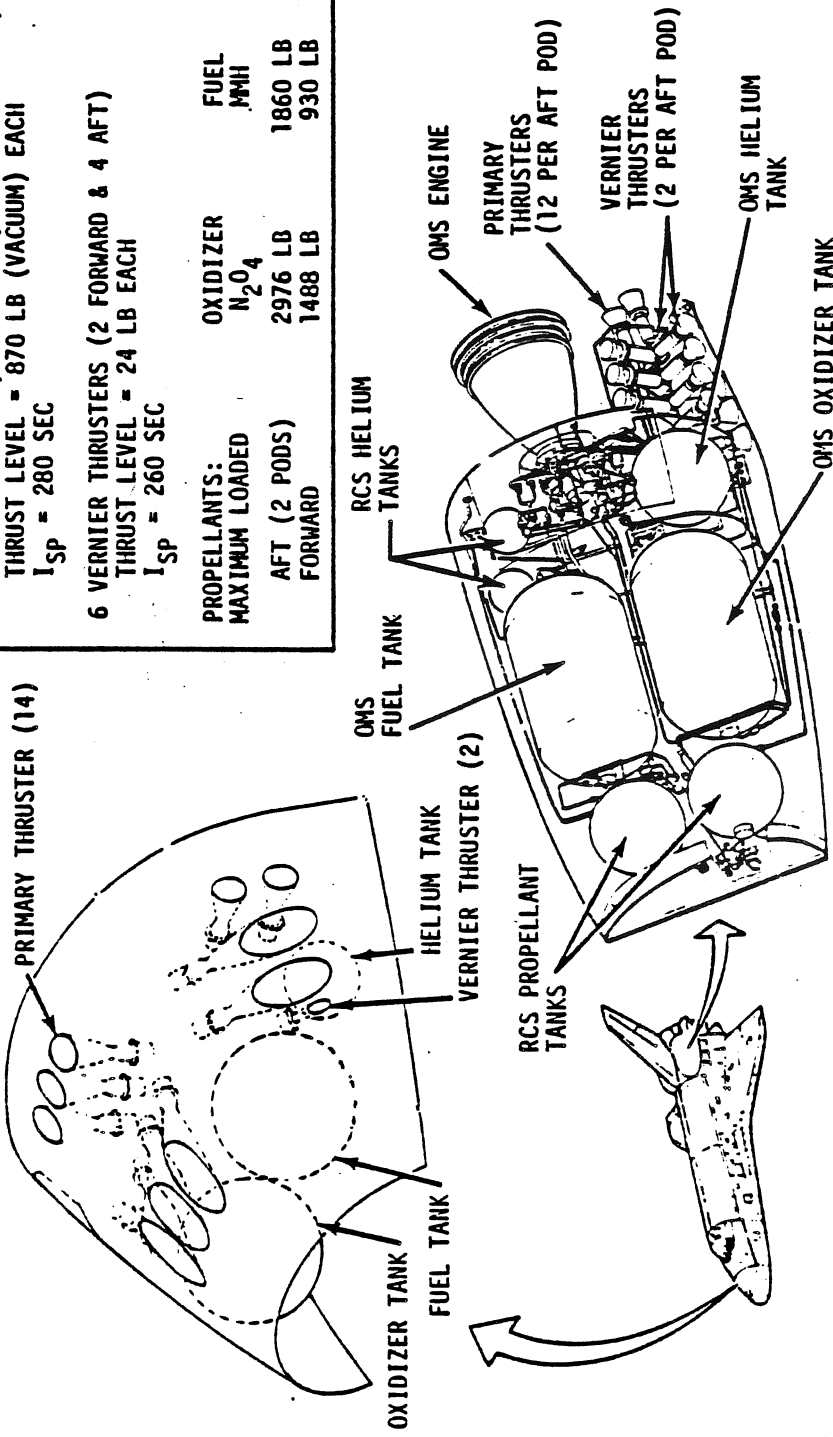
Figure 2-2.- RCS subsystems.

**RCS SYSTEM CHARACTERISTICS**

1 FORWARD RCS MODULE, 2 AFT RCS SUBSYSTEMS IN PODS  
38 MAIN THRUSTERS (14 FORWARD, 12 PER AFT POD)  
THRUST LEVEL = 870 LB (VACUUM) EACH  
I<sub>SP</sub> = 280 SEC

6 VERNIER THRUSTERS (2 FORWARD & 4 AFT)  
THRUST LEVEL = 24 LB EACH  
I<sub>SP</sub> = 260 SEC

| PROPELLANTS:<br>MAXIMUM LOADED | OXIDIZER<br>N <sub>2</sub> O <sub>4</sub> | FUEL<br>MMH |
|--------------------------------|---|-------------|
| AFT (2 PODS)                   | 2976 LB                                   | 1860 LB     |
| FORWARD                        | 1488 LB                                   | 930 LB      |



| BOTH PODS (OMS)        |   | OMS SYSTEM CHARACTERISTICS |                              |
|------------------------|---|----------------------------|------------------------------|
| USABLE OMS PROPELLANT: | 24,265 LBS TOTAL                          | THRUST                     | 6000 LB (VACUUM)             |
| OMS ΔV CAPABILITY:     | 1350 FT/SEC<br>180,000 LBS VEHICLE WEIGHT | SPECIFIC IMPULSE           | 313 SEC                      |
|                        |   | CHAMBER PRESSURE           | 130 PSIA                     |
|                        |   | MIXTURE RATIO              | 1.65                         |
|                        |   | GIMBAL CAPABILITY          | { ±6 DEG PITCH<br>±7 DEG YAW |

Figure 2-3.- OMS/RCS pods.



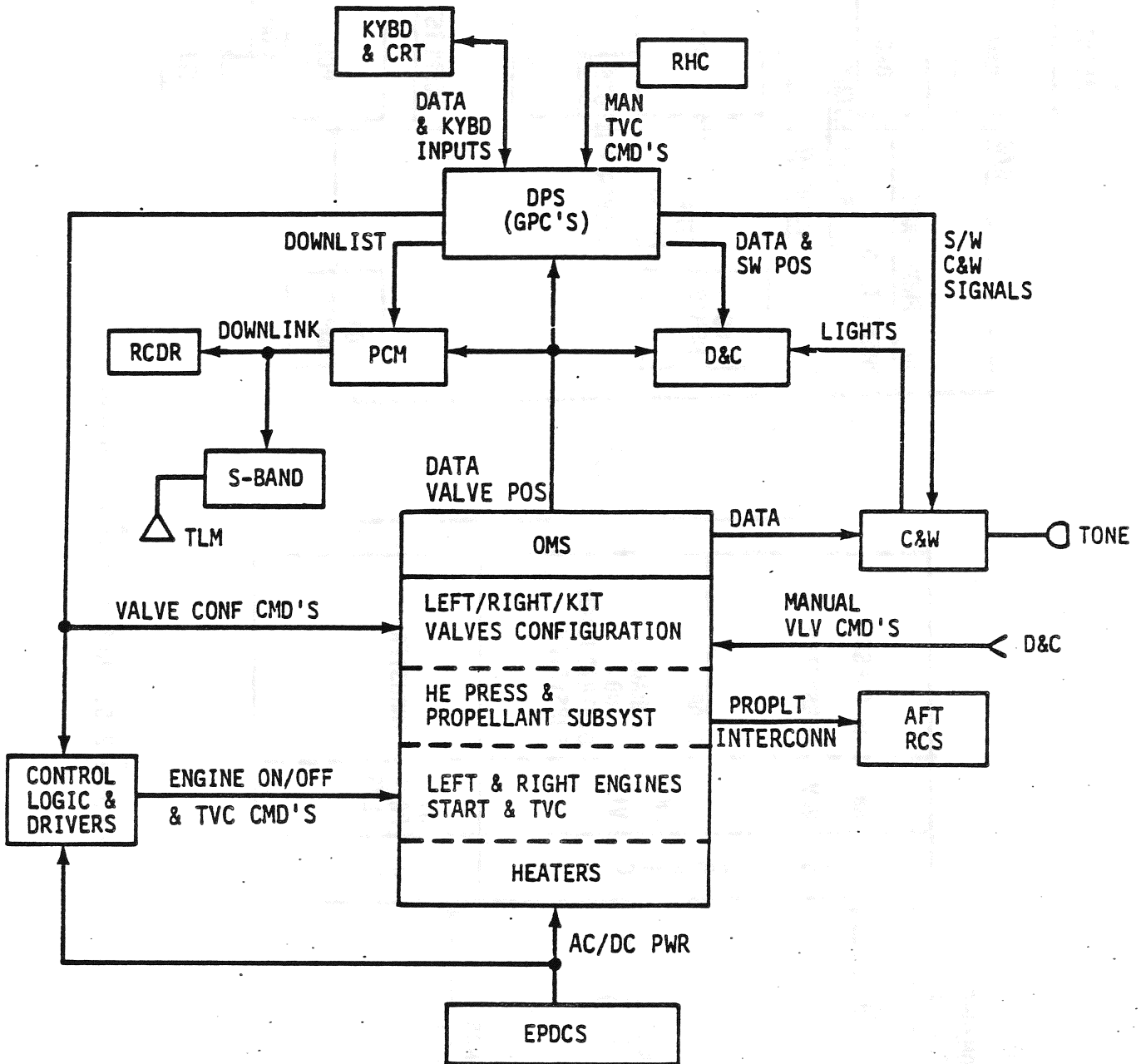


Figure 2-4.- QMS system interfaces.

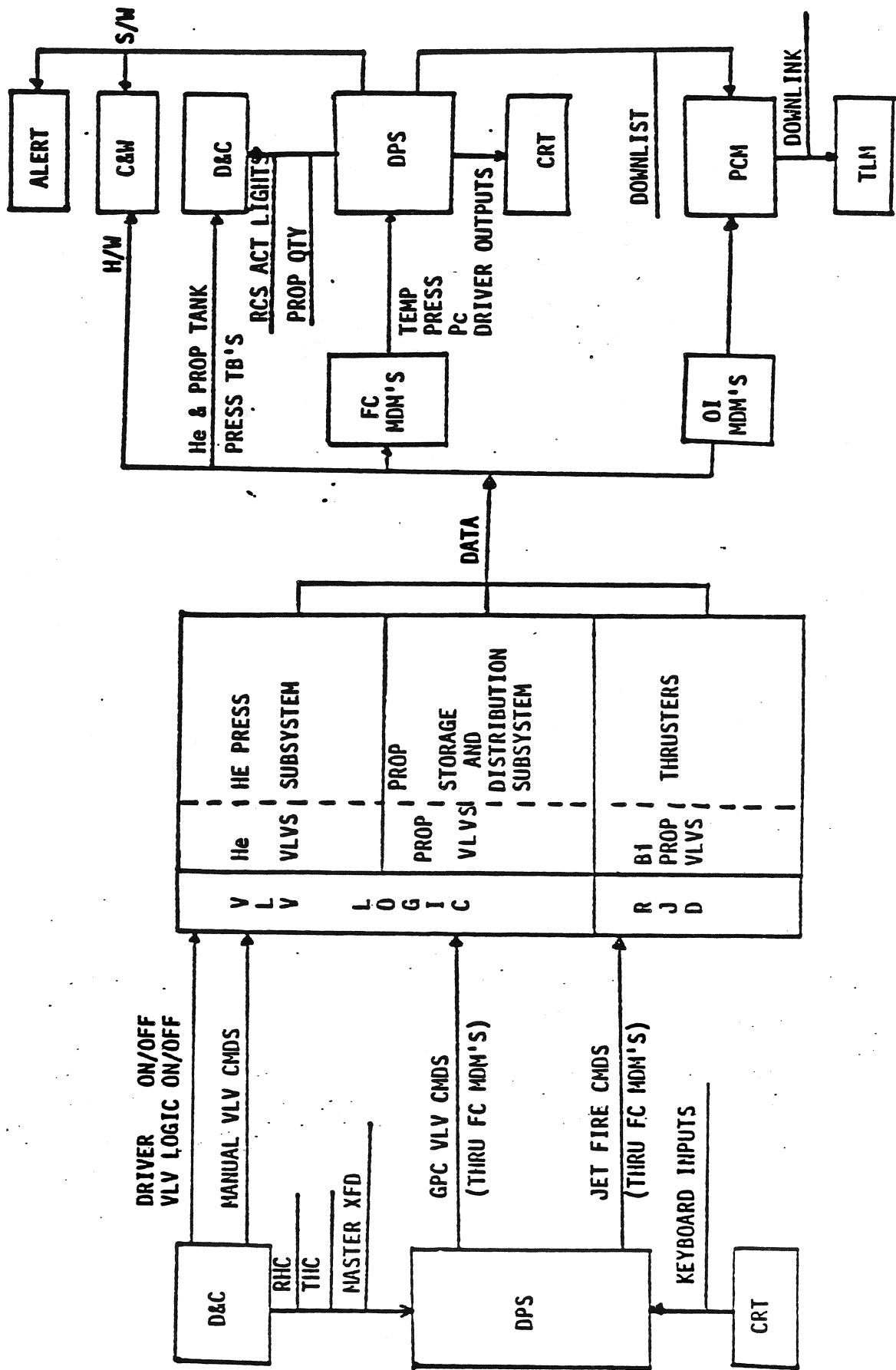


Figure 2-5.- RCS system interfaces.

ORBIT - Available in OPS 2, this display provides the data and controls for the auto attitude control and for thrust monitoring (fig. 2-7).

DAP CONFIG - Available in OPS 2, this display provides the crew with the ability to review and change selected Digital Auto Pilot (DAP) parameters, as required. The principal items of interest here are the translational pulse size (in ft/s), and the attitude phase plane parameters (fig. 2-8).

DEORB MNVR EXEC This display is used during the OPS 3 RCS burn to enable the crew to input translation maneuver target parameters for the guidance function. It is also used for maneuver monitoring and for trimming burn residuals, if required (fig. 2-9).

GNC SYS SUMM 2 (BFS) - This display is used during OPS 2 RCS burns, and the OMS burns to present RCS consumables data and status, manifold jet status, and the OMS consumables data and status (fig. 2-10).

## 2.4 GUIDANCE FUNCTION (PEG 4 AND PEG 7)

There are two on-orbit guidance functions available which use the OMS or RCS to impart a  $\Delta V$  to the vehicle. These guidance functions are described in more detail in the I/O/D GNC 2102 Insertion/On-Orbit/Deorbit Guidance, Navigation, and Flight Control Workbook. Powered Explicit Guidance (PEG) 4, the more complicated of the two, uses a linear terminal velocity constraint algorithm to compute a desired relationship between horizontal and vertical velocity components at a specific target position downrange (defined by the entries C1, C2, HT, and  $\theta T$ ). The problem of hitting these targets is solved by iteration at a rate of once per second during the burn until the guidance algorithm is converged (i.e., the Orbiter is on its new desired orbit and will achieve the specified targets).

PEG 7 is a much simpler guidance function that allows the Orbiter to achieve a  $\Delta V$  along an inertially stable velocity-to-be-gained vector. There are no target position calculations in this function. Since there is no target position feedback, anything but a nominal burn (for example, engine failure) will lengthen the burn time so that the desired cutoff conditions will occur further downrange than expected. This will cause the orbit conditions at cutoff to be different from those expected at pre-burn. The PEG 7 targets ( $\Delta V_X$ ,  $\Delta V_Y$ , and  $\Delta V_Z$ ) are target velocities based on a 'frozen' Local Vertical Local Horizontal (LVLH) coordinate system at Time of Ignition (TIG). In other words, a set of targets such as  $\Delta V_X = 50$  ft/s,  $\Delta V_Y = 0$ ,  $\Delta V_Z = 0$  would result in a  $\Delta V$  of 50 ft/s being imparted on a vector tangent to the orbit and in the orbit plane at TIG.

If a burn is required on-orbit, the ground will target the burn and transmit the appropriate targets, either PEG 4 or PEG 7. The OMS test burns on STS-1 will be accomplished using the PEG 7 guidance function. The crew will verify the target parameters, via the DEORB MNVR EXEC display, as described in the OMS burn amplified procedure section.

```

XXXX/XXX/XXX      RCS      XX X 000/HH:MM:SS
                                000/HH:MM:SS
RCS FWD 1X      JET FAIL      OMS PRESS ENA
  L 2X      4 LIMIT X      L OMS 5X      OMS RCS QTY
  R 3X                                R OMS 6X      L XX.XXS
                                OFF 7X      R XX.XXS

      RM  JET
JET FAIL INH DES
X1X  XXX  8X  9X
  U  XXX 10X 11X
  X  XXX 12X 13X
  X  XXX 14X 15X
X2X  XXX 16X 17X
  U  XXX 18X 19X
  D  XXX 20X 21X
  X  XXX 22X 23X
X3X  XXX 24X 25X
  X  XXX 26X 27X
  D  XXX 28X 29X
  X  XXX 30X 31X
X4X  XXX 32X 33X
  X  XXX 34X 35X
  X  XXX 36X 37X
X5X  XXX 38X 39X
  X  XXX 40X 41X

                                OXID  FU
                                P XXXXS XXXXS
PRPLT TK P XXXS XXXS
                                T XXXS XXXS
                                QTY XXXS XXXS
MANF P XXX XXXS XXXS
                                XXXXX XXXS XXXS
                                X XXXS XXXS
                                X XXXS XXXS
MANF VLVS  STAT OVRO
                                1  XXS  42
                                2  XXS  43
                                3  XXS  44
                                4  XXS  45
                                5  XXS  46

```

(XX)

Figure 2-6.- RCS.

```

2011      ORBIT      XX X 000/HH:MM:SS
                                000/HH:MM:SS
AUTO ATTITUDE MNVR      STATE UPDATE
      LVLH/ROT OPT  XXX/XX:XX:XX
INRTL ATT  BODY VECTOR
1 R XXX.XX 5 P XXX.XX LAND SITE UPDATE
2 P XXX.XX 6 Y XXX.XX 13 PRI XX XXXXX
3 Y XXX.XX 7 O XXX.XX 14 SEC XX XXXXX
                                15 ALT XX XXXXX
MNVR 4X      LVLH 8X
      ROT 9X VENT DOOR CNTL
STOP/ATT HOLD 10X OPEN 16X
      CLOSE 17X
ATT ERR TOT 11X
      OAP 12X

ATT  ROLL  PITCH  YAW      THRUST MONITOR
CURR XXX.XX XXX.XX XXX.XX  ΔVX ±XX.XX
REQD XXX.XX XXX.XX XXX.XX  ΔVZ ±XX.XX
ERR  ±XX.XXX ±XX.XXX ±XX.XXX ΔVZ ±XX.XX
RATE ±XX.XXX ±XX.XXX ±XX.XXX ΔVTOT XXX.XX
                                ΔV RESET COMP 13
                                TOT 19

```

Figure 2-7.- ORBIT.

| XXXX/020    | DAP CONFIG |      | XX X   | DDD/HH:MM:SS | DDD/HH:MM:SS |
|-------------|------------|------|--------|--------------|--------------|
| TRANSLATION | A          |      | B      |              |              |
| PULSE       | 1          | X.XX | 16     | X.XX         |              |
| ROTATION    |            |      |        |              |              |
| DISC RATE   | NORM       | 2    | X.X    | 17           | X.X          |
|             | VERN       | 3    | X.XX   | 18           | X.XX         |
| PULSE       | NORM       | 4    | X.XX   | 19           | X.XX         |
|             | VERN       | 5    | X.XXX  | 20           | X.XXX        |
| COMP        | NORM       | 6    | X.X    | 21           | X.X          |
|             | VERN       | 7    | X.XX   | 22           | X.XX         |
| INERTIAS    |            |      |        |              |              |
|             |            |      |        |              | 31 IX X.XXX  |
|             |            |      |        |              | 32 IY X.XXX  |
|             |            |      |        |              | 33 IZ X.XXX  |
| DEADBAND    |            |      |        |              |              |
| ATT         | R          | 8    | XX.XXX | 23           | XX.XXX       |
|             | P          | 9    | XX.XXX | 24           | XX.XXX       |
|             | Y          | 10   | XX.XXX | 25           | XX.XXX       |
| RATE        | NORM       | 11   | X.X    | 26           | X.X          |
|             | VERN       | 12   | X.X    | 27           | X.X          |
| JET OPT     | P          | 13   | X      | 28           | X            |
|             | Y          | 14   | X      | 29           | X            |
| CNTL ACCEL  |            | 15   | X      | 30           | X            |

(XX)

Figure 2-8.- DAP CONFIG.

| XXXX/XXX/XXX   | DEORB MNVR EXEC |                | XX X       | DDD/HH:MM:SS    | DDD/HH:MM:SS |
|----------------|-----------------|----------------|------------|-----------------|--------------|
| GMBL CK 1X     |                 |                |            |                 | DDD/HH:MM:SS |
| L              | R               | TRIM           | L          | R               |              |
| P ±X.XS ±X.XS  |                 | P              | 12 [±]X.X  |                 |              |
| Y ±X.XS ±X.XS  |                 | Y              | 13 [±]X.X  | 14 [±]X.X       |              |
| SEL            |                 |                |            |                 |              |
| PRI 2X         | 5X              | ENG SEL        | OMS        |                 |              |
| SEC 3X         | 6X              | OMS BOTH       | 15X        | PURGE ENA       | 19X          |
| OFF 4X         | 7X              |                | L          | 16XS            |              |
| BURN ATT       | 8 R XXX         |                | R          | 17XS SURF DRIVE |              |
|                | 9 P XXX         | RCS +X ACC     | 18X        | ON              | 22X          |
|                | 10 Y XXX        | 21 WT XXXXXX   |            | OFF             | 23X          |
| HA             | HP              | F RCS          |            | ARM             | 24X          |
| TGT XXX ±XXX   |                 | XXX XXX        |            | DUMP            | 25X          |
| CUR XXX ±XXX   | TARGET          | OFF 26X        |            |                 |              |
| TXX XX:XX      | 27 TIG          | XXX/XX:XX:XX.X |            |                 |              |
| REI XXXX       | 31 C1           | XXXXX          | 36 ΔVX     | [±]XXXX.X       |              |
|                | 32 C2           | [±]XXXX        | 37 ΔVY     | [±]XXXX.X       |              |
| ΔVTOT XXXX.X   | 33 HT           | XXX.XXX        | 38 ΔVZ     | [±]XXXX.X       |              |
| TGO XX:XX      | 34 θT           | XXX.XXX        |            |                 |              |
| VGO X ±XXXX.XX | 35 PRPLT        | [±]XXXX        |            |                 |              |
| Y =XXX.XX      |                 |                |            |                 |              |
| Z =XXX.XX      | XXXX 39         |                | ST CRT TMR | 40              |              |

(XX)

Figure 2-9.- DEORB MNVR EXEC.

| XXXX/XXX/XXX |         | GNC SYS SUMM 2 |           |     | XX X DDD/HH:MM:SS |         |             |
|--------------|---------|----------------|-----------|-----|-------------------|---------|-------------|
|              |         |                |           |     | DDD/HH:MM:SS      |         |             |
| RCS          |         | JETISOL        |           |     |                   | L       | R           |
|              | OXID    | FU             | MANF-FAIL | VLV | OMS               |         |             |
|              | HE      | PXXXXSXXXXS    | F1XXX     | XXS | TK P              | HE      | XXXXS XXXXS |
|              | TK      | P XXXS XXXS    | 2XXX      | XXS |                   | OXID    | XXXXS XXXS  |
| F            | QTY     | XXXXS XXXS     | 3XXX      | XXS |                   | FU      | XXXXS XXXS  |
|              | 1/2 P   | XXXXS XXXS     | 4XXX      | XXS | N2 TK             | P XXXXS | XXXXS       |
|              | 3/4/5 P | XXXXS XXXS     | 5XXX      | XXS |                   | REG P   | XXXXS XXXS  |
|              | HE      | PXXXXSXXXXS    | L1XXX     | XXS |                   | P VLV   | XXS XXXS    |
|              | TK      | P XXXS XXXS    | 2XXX      | XXS | ENG IN            | P       |             |
| L            | QTY     | XXXXS XXXS     | 3XXX      | XXS |                   | OXID    | XXXXS XXXS  |
|              | 1 P     | XXXXS XXXS     | 4XXX      | XXS |                   | FU      | XXXXS XXXS  |
|              | 2 P     | XXXXS XXXS     | 5XXX      | XXS |                   | VLV 1   | XXXXS XXXS  |
|              | 3 P     | XXXXS XXXS     |           |     |                   | 2       | XXXXS XXXS  |
|              | 4 P     | XXXXS XXXS     |           |     |                   |         |             |
|              | HE      | PXXXXSXXXXS    | R1XXX     | XXS |                   |         |             |
|              | TK      | P XXXS XXXS    | 2XXX      | XXS |                   |         |             |
| R            | QTY     | XXXXS XXXS     | 3XXX      | XXS |                   |         |             |
|              | 1 P     | XXXXS XXXS     | 4XXX      | XXS |                   |         |             |
|              | 2 P     | XXXXS XXXS     | 5XXX      | XXS |                   |         |             |
|              | 3 P     | XXXXS XXXS     |           |     |                   |         |             |
|              | 4 P     | XXXXS XXXS     |           |     |                   |         |             |

Figure 2-10.- GNC SYS SUMM 2.

## 2.5 RELMATS

A RELMAT is a transformation matrix that relates the inertial M50 coordinate system to any desired inertial orientation which then can be used as a reference for the Attitude Direction Indicators (ADI's). This allows orientation of the 0,0,0 indication on the ADI to any inertially fixed direction in space. For example, to have the 0,0,0 ADI indication correspond to the +X body axis pointing out of plane (for instance, along the positive momentum vector with the +Y and +Z axes also constrained as desired), a devised RELMAT will provide the ADI with the appropriate attitude reference for this condition. To point the +X body axis at a certain star and at the same time have a 0,0,0 indication on the ADI, enter an appropriate RELMAT and fly to 0,0,0 on the ADI, thereby orienting the +X body axis in the direction of that star.

Because ADI accuracy decreases as yaw indications approach  $\pm 90^\circ$ , the RELMATS for burns are devised so that the burn attitudes are not close to the  $\pm 90^\circ$  yaw indication on the ADI.

At any one time, there are two RELMATS available for use; one is selected by the INRTL position and the other by the REF position of the ADI ATT switch (panels F6, F8). Although there is also an LVLH position of this switch, the RELMAT associated with this position is of little use during a burn and will not be discussed. RELMATS are covered in detail in the Attitude and Pointing Flight Procedures Handbook.

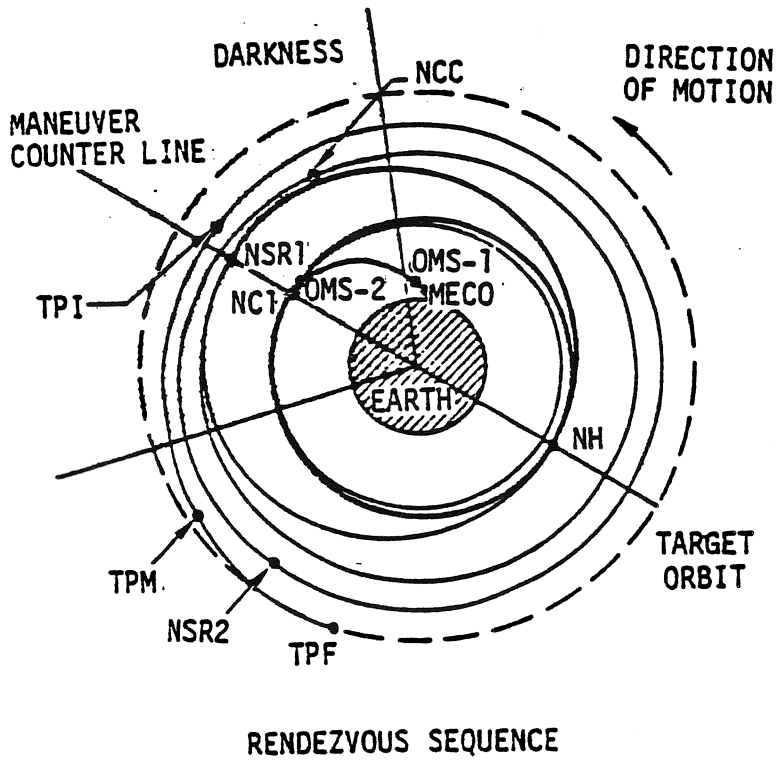
There are two ways to enter new desired ADI RELMATS on orbit. The first is through uplink in GNC OPS 2 or GNC OPS 3. Using this method, Mission Control Center (MCC) will calculate the new desired ADI RELMAT and uplink it into either the INRTL or the REF slot. These RELMATS, however, are good only in the operational sequence of the uplink. Upon transition to a different OPS, they are replaced by the I-loaded RELMATS resident in the new OPS.

The second way to enter a new ADI RELMAT is through the use of the Attitude Reference Pushbutton (ATT REF pb) on F6 and F8. Depressing this pushbutton will cause a new RELMAT for the REF switch position to be calculated that will define an inertial reference coincident with the inertial orientation of the X, Y and Z body axes at that time. This method may be useful when uplink is not available. The crew must be able to align the X, Y, and Z body axes with the new desired reference frame, then after the maneuver is complete, the ATT REF pb is depressed, entering the new desired RELMAT in the REF slot.

## 2.6 RENDEZVOUS AND PROXIMITY OPERATIONS

A series of OMS/RCS burns are executed to effect Orbiter rendezvous with a target (vehicle or position).

A typical Earth-centered orbit-by-orbit rendezvous sequence is presented in fig. 2-11; the target-centered in-plane relative motion profile is shown in fig. 2-12. The profile consists of the gross phase and height control maneuvers (NC1, NH, NSR1) based on ground-determined state vectors



| MANEUVERS |                           |
|-----------|---------------------------|
| MECO      | Main Engine Cutoff        |
| OMS-1     | Insertion                 |
| OMS-2     | Circularization           |
| NC1       | Phasing                   |
| NH        | Height Adjust             |
| NSR1      | First Coelliptic          |
|           | Nav Tracking (S Trk)      |
| NCC       | Corrective Combination    |
| NSR2      | Second Coelliptic         |
|           | Nav Tracking (S Trk)      |
| TPI       | Terminal Phase Initiation |
|           | Nav Tracking (radar)      |
| TPM1      | Terminal Phase Midcourse  |
|           | Nav Tracking (radar)      |
| TPM2      | Terminal Phase Midcourse  |
|           | Braking                   |
|           | Transition to offset      |
|           | Stationkeeping            |
|           | Proximity Operations      |

Figure 2-11.- Earth-centered orbit-by-orbit plan.

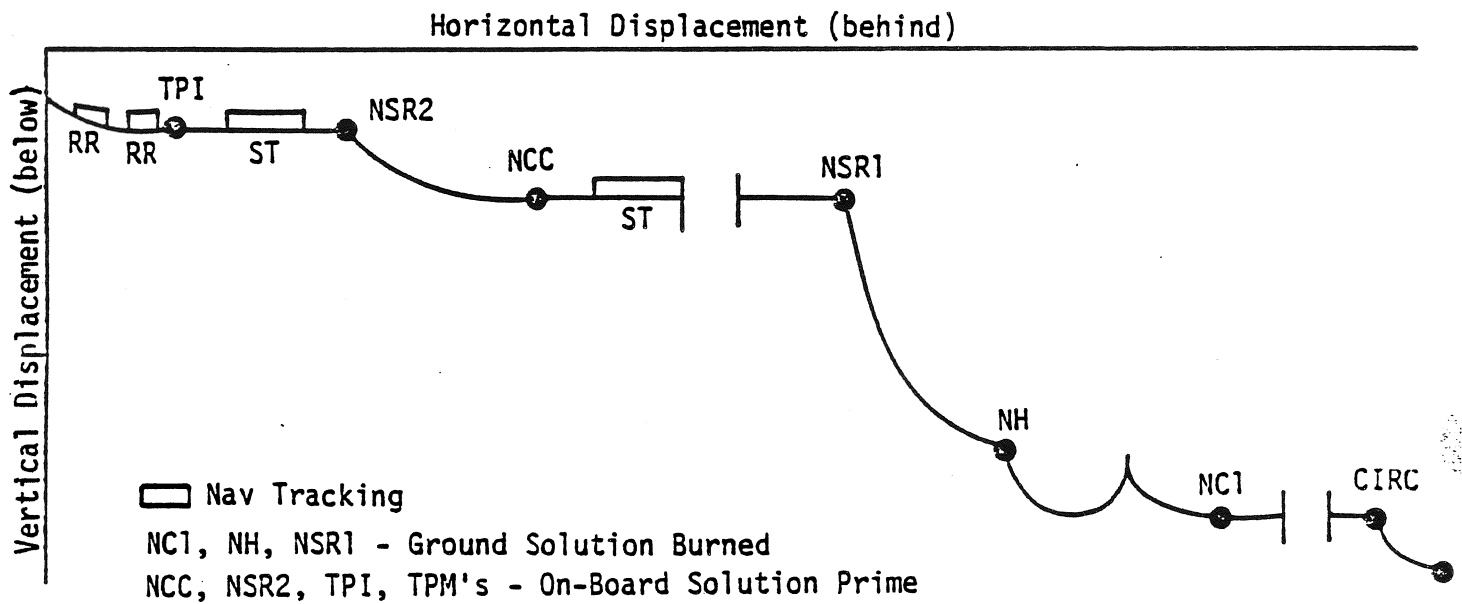


Figure 2-12.- Target-centered relative motion profile.



and ground targeting. The precision phase and height maneuvers (NCC, NSR2, TPI, TPM), using onboard relative state vector determination and onboard targeting, establish a final controlled intercept from which braking is initiated. The final part of the rendezvous (the proximity operations) is made up of maneuvers that establish a controlled approach to the target. A V-type approach is shown in fig. 2-13. The maneuvers up through TPI are OMS burns, and the remainder, including the proximity operations, are RCS burns. These procedures are covered in the Rendezvous/ORB NAV Flight Procedures Handbook and in the Proximity Operations Flight Procedures Handbook.

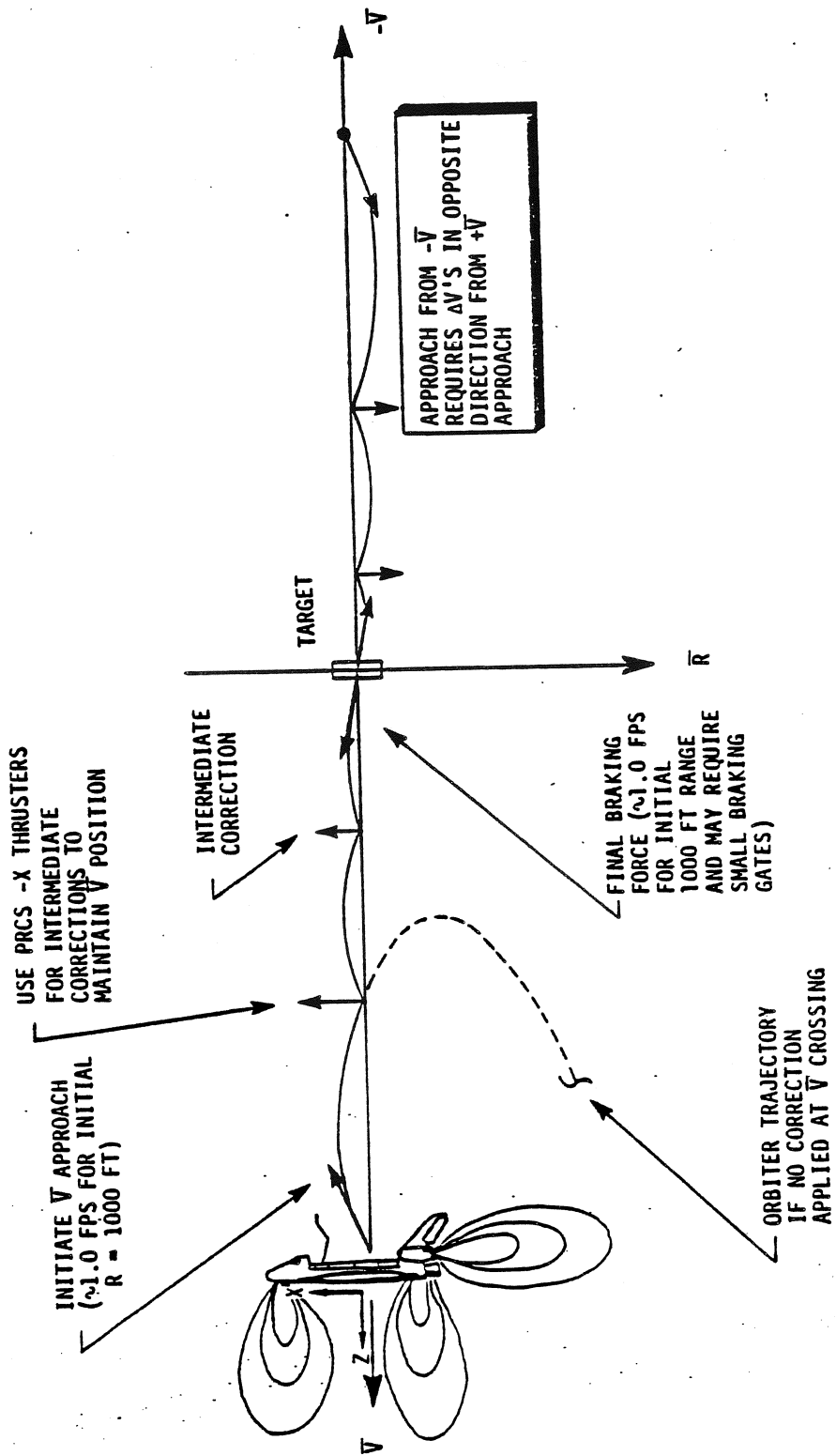


Figure 2-13.-  $V$  approach.

SECTION 3  
INTERCONNECT/CROSSFEED PROCEDURES

3.1 OMS TO RCS INTERCONNECT

These procedures are used on orbit in Operational Sequence (OPS) 2 software to interconnect the RCS jets to either OMS propellant system. For STS-1, interconnect procedures are to be used only in case of emergency. It should be noted that a maximum of 1000 pounds of propellant (approximately 8.0 percent) can be used from each OMS system. Exceeding this amount may cause the communication screens in the OMS tanks to dry out thus allowing helium bubbles to enter propellant lines. Propellant used from the OMS system by the RCS systems is totalized by the OMS PRESS ENA function and displayed on the GNC 23 RCS display (fig. 2-6). Either OMS system may be selected to feed the RCS jets using the following procedure.

L or R OMS to RCS Interconnect

C3        INHIBIT RCS JETS  
          DAP:  MAN  
          DAP ROT: PULSE/PULSE/PULSE

The RCS jets are inhibited to prevent jet firings during the interconnect process. If jet firings occur with the engines isolated from the propellant tanks, temporary fuel starvation, bubbles in the propellant lines, and subsequent engine damage may result.

The RCS jets are inhibited by selecting the manual pulse DAP mode. This puts the Orbiter in a free drift attitude control mode, thus eliminating any General Purpose Computer (GPC) firings of attitude jets. Since the power to the Rotational Hand Controllers/Translational Hand Controllers (RHC/THC) has not been turned on, even accidental displacement of these controllers will not cause jet firings.

CONFIGURE FOR INTERCONNECT

07    AFT L,R RCS TK ISOL (six) - CLOSE (tb-CL)  
               XFEED (four) - OPEN (tb-OP)

.....IF L OMS TO RCS INTERCONNECT.....

.08    L OMS He PRESS/VAP ISOL (A) - GPC                 .  
      ✓L OMS TK ISOL (two) - OPEN (tb-OP)                 .  
      ✓R OMS XFEED (two) - CLOSE (tb-CL)                 .  
      L OMS XFEED (two) - OPEN (tb-OP)                 .  
      .  
      .  
      | GNC 23 RCS |   .  
.CRT    OMS PRESS ENA, L OMS - ITEM 5 EXEC                 .  
.....

The aft left and right tank isolation valves (six) are closed to isolate the RCS propellant tanks from the OMS propellant tanks and from the RCS jets. This precludes OMS tank to RCS tank propellant transfer. The crossfeed valves (four) are opened to provide part of the path for OMS propellant to the RCS jets. The talk back (tb) indicators show when the valves are open (OP) or closed (CL).

The left OMS helium pressurization/vapor isolation valve (A) switch is placed in the GPC position to allow the GPC to command this valve to maintain ullage pressure. The left OMS tank isolation switches (two) and related valves are verified open (normal on-orbit position) to ensure a supply of propellant to the jets. The right OMS crossfeed valves (two) are verified closed (normal on-orbit position) to prevent a back flow into the R OMS propellant tanks. The left OMS crossfeed valves (two) are opened to complete the propellant flow path from the left OMS tanks to the RCS jets.

The left OMS pressure enable item (L OMS PRESS ENA - ITEM 5) on the GNC 23 RCS display will, if executed (via the CRT), enable the GPC to automatically sense and maintain the ullage pressure in the left OMS propellant tanks. This also initiates the gauging of the left OMS propellant fed to the RCS jets. The quantity used can be read on the RCS display under OMS/RCS QTY in terms of percent of L or R OMS tank total quantity (fig. 2-6.)

```

.....IF R OMS TO RCS INTERCONNECT.....
.08   R OMS He PRESS/VAP ISOL (A) - GPC   .
      ✓R OMS TK ISOL (two) - OPEN (tb-OP) .
      ✓L OMS XFEED (two) - CLOSE (tb-CL)  .
      R OMS XFEED (two) - OPEN (tb-OP)   .
      .
      | GNC 23 RCS |
.CRT  OMS PRESS ENA, R OMS - ITEM 6 EXEC .
.....

```

The right OMS TO RCS INTERCONNECT procedure is basically the same as for the left OMS. The only differences are in the propellant flow path (from the R OMS tanks instead of L OMS tanks) and the selection of right OMS ullage pressure maintenance (R OMS PRESS ENA - ITEM 6) on the RCS display to pressurize and gauge the proper tanks.

C3            ENABLE RCS JETS  
DAP - as reqd

The interconnect procedures are complete. The DAP can be configured to enable the RCS JETS as required.

### 3.2 OMS TO RCS INTERCONNECT RETURN

These procedures are used on orbit in OPS 2 software to return from the OMS to RCS interconnect configuration to the nominal on-orbit propellant systems configuration. One return procedure is used regardless of which OMS system was feeding the RCS. Because of this, some switches will already be in the correct position before this procedure is started; for example, if this procedure is used following a left OMS to RCS interconnect configuration, the switches for the right OMS system will already be in the correct position.

#### L or R OMS to RCS Interconnect RTN

C3      INHIBIT RCS JETS  
DAP: MAN  
DAP ROT: PULSE/PULSE/PULSE

As in the OMS to RCS interconnect procedures, the RCS jets are inhibited to prevent jet firings while they are isolated from the propellant tanks.

#### RECONFIGURE SYSTEMS

CRT1      | 1: GNC 23 RCS |  
CRT3      | 3: GNC SYS SUM 2 |  
CRT3      ✓OMS REPRESS CYCLE COMPLETE

#### NOTE

Repress cycle complete 30  
seconds after OMS TK P  
OXID and FU > 236

CRT1      OMS PRESS ENA, OFF - ITEM 7 EXEC  
08      L,R OMS  
         He PRESS/VAP ISOL (four) - CLOSE  
         ✓TK ISOL (four) - OPEN (tb- OP)  
         XFEED (four) - CLOSE (tb- CL)  
07      L,R RCS  
         ✓He PRESS A (two) - GPC (tb-OP)  
         ✓He PRESS B (two) - CLOSE (tb-CL)  
         L,R RCS XFEED (four) - CLOSE (tb-CL)  
         TK ISOL (six) - OPEN (tb-OP)

This part of the procedure restores the system to the nominal on-orbit configuration. Two CRT displays are required to complete this procedure: the GNC 23 RCS display is used to disable the GPC control of the OMS ullage pressure (OMS PRESS ENA, OFF - ITEM 7 EXEC); and the GNC SYS SUM 2 display is used to monitor the OMS oxidizer and fuel tank pressures.

The OMS PRESS ENA function is initiated when ullage pressure drops below 236 psia and it requires 30 seconds to complete. Therefore, it is necessary to verify that the appropriate propellant tank pressures are above this value and then wait 30 seconds before turning the OMS PRESS ENA function OFF. If this is not done it is possible to disable the GPC control during a repressurization cycle (i.e., while a GPC command is present to

open the pressure/vapor isolation valves). If this occurs, the GPC command is not reset at the end of the repress cycle. The next time a helium pressure/vapor isolation switch is placed in the GPC position the helium pressure and vapor isolation valves will open. It is, of course, undesirable to allow these valves to remain open when propellants are not being drawn from the tanks as this may allow propellant vapors to migrate upstream and mix in the helium lines.

The OMS and RCS propellant system switches are repositioned in a sequence that prevents propellant from flowing from one tank into another.

When the above items have been completed, the RCS and OMS have been segregated and the DAP can be configured as required to enable the RCS jets.

C3            ENABLE RCS JETS  
              DAP - as reqd

### 3.3 RCS TO RCS MANUAL CROSSFEED

Since the automatic crossfeed (XFEED) function is not available in OPS 2, it is necessary to manually (MAN) position the RCS propellant system switches whenever an RCS to RCS crossfeed configuration is required. The following procedures configure the aft RCS propellant system to feed all the aft RCS jets from the selected (left or right) RCS system.

#### L OR R RCS TO RCS MAN XFEED

C3            INHIBIT RCS JETS  
              DAP: MAN  
              DAP ROT: PULSE/PULSE/PULSE

As in the previous procedures, the RCS jets are inhibited to prevent jet firings while the engines are isolated from a propellant source.

#### CONFIGURE FOR XFEED

```

.....IF XFEED FROM LEFT.....
.08  ✓L,R OMS XFEED (four) - CLOSE (tb-CL)  .
.07  AFT R RCS                               .
      TK ISOL (three) - CLOSE (tb-CL)       .
      XFEED (two) - OPEN (tb-OP)            .
      AFT L RCS                               .
      ✓He PRESS (A) - GPC (tb-OP)           .
      ✓TK ISOL (three) - OPEN (tb-OP)       .
      XFEED (two) - OPEN (tb-OP)           .
      MASTER RCS XFEED - FEED FROM LEFT    .
.....

```

This portion of the procedure configures the RCS propellant system to feed all the aft RCS jets from the left RCS system. The left and right OMS crossfeed (L, R OMS XFEED) valves are verified closed to ensure that the OMS propellant system is isolated from the RCS system. This is the normal on-orbit position for these valves. The aft right RCS tank isolation (AFT R RCS TK ISOL) valves are closed to isolate the right RCS propellant tanks. The crossfeed valves are opened to provide a propellant flow path to the right RCS engines.

The aft left RCS helium pressurization (AFT L RCS He PRESS) (A) switch is verified in the GPC position to allow the GPC to sense a high ullage pressure and to automatically close the valve as required to prevent over-pressurization of the RCS propellant tanks. The aft left RCS tank isolation (AFT L RCS TK ISOL) valves are verified open to ensure a supply of propellant to the RCS engines. These are the normal on-orbit positions for these valves. The aft left RCS crossfeed (AFT L RCS XFEED) valves are opened to allow left RCS propellant to flow into the crossfeed lines. The master RCS crossfeed switch is placed in the feed from left position to provide the appropriate logical bit to the GPC's to modify the jet-select logic for the crossfeed conditions.

```

.....IF XFEED FROM RIGHT.....
.08  ✓L,R OMS XFEED (four) - CLOSE (tb-CL)  .
.07  AFT L RCS                               .
      TK ISOL (three) - CLOSE (tb-CL)      .
      XFEED (two)     - OPEN (tb-OP)       .
      AFT R RCS                               .
      ✓He PRESS (A)   - GPC (tb-OP)        .
      ✓TK ISOL (three) - OPEN (tb-OP)      .
      XFEED (two)     - OPEN (tb-OP)       .
      MASTER RCS XFEED - FEED FROM RIGHT   .
.....

```

The right RCS to RCS manual crossfeed (R RCS TO RCS MAN XFEED) procedure is similar to the left RCS to RCS manual crossfeed except that the propellant system is configured to supply propellant from the right pod and the master RCS crossfeed switch is placed in the feed from right position to supply the correct logical bit to the GPC's.

C3      ENABLE RCS JETS  
DAP - as reqd

With the configuration complete, the DAP can be reconfigured as required to enable the RCS JETS.

### 3.4 RCS TO RCS MANUAL CROSSFEED RETURN

This procedure is used to restore the RCS system to the nominal on-orbit configuration (automatic crossfeed is not available on orbit). Note that, when executing this procedure, some of the switches will already be correctly positioned; for example, if the RCS system has been in a feed from right configuration, the aft right RCS tank isolation valves will already be open. However, regardless of the crossfeed configuration in use

before executing this procedure, the results will be the nominal on-orbit RCS configuration.

L OR R RCS TO RCS MAN XFEED RTN

C3 INHIBIT RCS JETS  
DAP: MAN  
DAP ROT: PULSE/PULSE/PULSE

As in the crossfeed procedures, the RCS jets are inhibited to prevent jet firings while the RCS engines are isolated from a propellant source.

07 RECONFIGURE TO NORMAL  
MASTER RCS XFEED - OFF  
AFT L,R RCS  
XFEED (four) - CLOSE (tb-CL)  
TK ISOL (six) - OPEN (tb-OP)  
✓He PRESS A (two) - GPC (tb-OP)  
✓He PRESS B (two) - CLOSE (tb-CL)

The reconfiguration of these systems restores them to the normal on-orbit configuration. The master crossfeed switch is placed in the off position to supply appropriate information to the GPC's to restore the jet select logic to the noncrossfeed configuration. Tank isolation valves are opened to supply propellant from the RCS tanks to their respective RCS jets. Note that the crossfeed valves are closed before the tank isolation valves are opened; this is done to prevent undesired transfer of propellants from one RCS tank to the opposite side due to unequal pressures in the tanks.

The helium pressure A switches are verified in the GPC position with the talk back indicators (tb) showing opened and the helium pressure B switches are verified in the close position with the talk back indicators (tb) showing closed. These He PRESS valves are bi-stable valves; i.e., they remain in the last commanded position until the opposite position is commanded (unlike a spring-loaded valve which will return to its normal off position when the on command is removed). The He PRESS A (two) - GPC (tb-OP) switch/valve configuration is achieved by placing these switches in the OPEN position until the talk-backs indicate OP, then placing the switches in the GPC position (the talk-backs will remain OP). With this switch/valve configuration, the RCS propellant tanks will remain pressurized. Should the propellant tank pressure get above 312 psi (due to a He pressure regulator failure, for example), the GPC will close the He PRESS valve. The A-GPC, B-CLOSE switch configuration is used to help isolate malfunctions.

C3 ENABLE RCS JETS  
DAP - as reqd

When the reconfiguration procedure is complete, the DAP can be configured as required to enable the RCS jets.



SECTION 4  
RCS MANEUVER

The normal Reaction Control System (RCS) translation maneuver (MNVR) is a thruster firing to change the vehicle velocity (external  $\Delta V$  burn), accomplished while the Orbiter maintains a fixed inertial attitude. This can be accomplished by a single crewmember using the forward or the aft crew station and Operational Sequence (OPS) 2 or OPS 3 software. The major activities associated with an RCS burn are listed in table 4-I in the order of their occurrence. These activities, which are similar for OPS 2 and OPS 3, are described in detail in sections 4.2 and 4.3.

TABLE 4-I.- RCS BURN TIME LINE

| $\Delta$ Time,<br>min | Activity            | Comments   |
|-----------------------|---------------------|--|
| 02:00                 | MNVR PAD UPDATE     | Must be accomplished during a GSTDN contact period, preferably as close to TIG as possible |
| 01:00                 | RCS SYSTEMS CHECKS  | Should be performed as close to TIG as possible (TIG - 11:00)                              |
| 02:00                 | RCS BURN PREP       | TIG - 10:00  |
| <u>&lt;05:00</u>      | MNVR TO BURN ATT    | TIG - 08:00  |
| 02:00                 | DAP CONFIGURATION   | TIG - 03:00  |
|                       | IGNITION SEQUENCE   |  |
| Burn Duration         |                     |  |
| +01:00                | DAP RECONFIGURATION | C/O + 01:00  |
| 02:00                 | INTERCONNECT RETURN | C/O + 03:00 (if required)  |
| 02:00                 | PROCEDURE COMPLETE  | C/O + 05:00  |

## 4.1 ASSUMPTIONS, GUIDELINES, AND CONSTRAINTS

### 4.1.1 Use of OPS Mode

On-orbit RCS translations may be accomplished using either OPS 2 or OPS 3 software. Some of the features of these OPS modes are listed.

Using OPS 2:

- A. The auto maneuver capability of the ORBIT display is available.
- B.  $\Delta V$ 's imparted are monitored using the THRUST MONITOR portion of the ORBIT display.
- C. The capability exists to change attitude and rate deadbands through the use of the DAP CONFIG display.
- D. Neither Powered Explicit Guidance (PEG 4) nor PEG 7 is available.
- E. No capability exists for monitoring orbit parameters ( $H_a$  and  $H_p$ ) as the burn progresses.

Using OPS 3:

- A. There is manual attitude maneuver capability only.
- B.  $\Delta V$ 's are monitored using the burn data displayed on the MNVR display. Time to Go (TGO) is also available on this display.
- C. No capability exists for changing attitude phase plane parameters.
- D. Current attitudes and attitude error information is available via the Attitude Direction Indicator (ADI) only.
- E. PEG 4 and PEG 7 are available providing more accurate burn capability.
- F. Capability exists for monitoring  $H_a$  and  $H_p$  during the RCS burn.
- G. Data Processing System (DPS) configuration is required for use of OPS 3 on-orbit.

Due to the procedural complexity associated with transitioning into OPS 3, and back into OPS 2, and since it is unlikely that the accuracy gained using the guidance function available in OPS 3 is worth the time required for OPS moding, it is recommended that RCS translations be accomplished using OPS 2 and the ORBIT display. Procedures are provided, however, for use in either OPS mode.

#### 4.1.2 Use of the Aft Station

RCS translation maneuvers are normally accomplished using the forward station as given in the procedures. If the aft station is to be used for the OPS 2 burn, the crewman should complete the procedures to the point of AUTO MNVR TO BURN ATTITUDE at the forward station. The translation maneuver can then be executed at the aft station. The crewman would return to the forward station for the INTERCONNECT RETURN procedure, if required.

Note that there is only one CRT in the aft station, so the crewman will have limited display monitoring capability during the course of the burn. Due to this limitation and the use of a cue-card format, the OPS 3 burn procedures are performed at the forward station only.

#### 4.1.3 Orbiter Translation Axis Selection

There are inefficiencies associated with translations in each of the three axes. RCS jet thrust off the center of mass of the vehicle, jet scarfing, canting, and plume impingement induce rotational velocities and off-axis translational velocities. These effects contribute to different levels of translational efficiency associated with each axis.

The differing translation effectiveness levels, expressed in terms of propellant used (lb) per velocity change (ft/s), are illustrated in figure 4-1 for each Orbiter body axis.

The graph shows that the two most efficient (minimum propellant usage per  $\Delta V$  achieved) methods of translation are along the +Z and +X body axes. Due to their obvious inefficiency, translations along the Y axes are considered to be the least desirable alternatives.

In deciding which axis to use, it should be recognized that, although translations along the +Z axis are more efficient, the +Z translations use forward RCS pod fuel that cannot be supplemented through the use of the OMS to RCS interconnect. On the other hand, while translating along the +X axis is less efficient, the amount of fuel available for the burn may be supplemented by the use of the OMS to RCS interconnect. The effects of propellant usage on the vehicle center of gravity (c.g.) should also be considered.

The axis selection method should include consideration of the constraints imposed by the mission propellant usage profile as well as the constraints imposed by rendezvous, proximity operations, and other mission requirements. If the forward RCS pod propellant remaining is critical, it may be necessary to accept the relative inefficiency of a +X translation. If there is sufficient forward RCS fuel available (according to the mission usage profile), the maneuver may be performed in the more efficient +Z direction. This implies that when the Orbiter attitude or axis of translation is fixed by other mission requirements, sufficient propellants must be allocated for the maneuver.

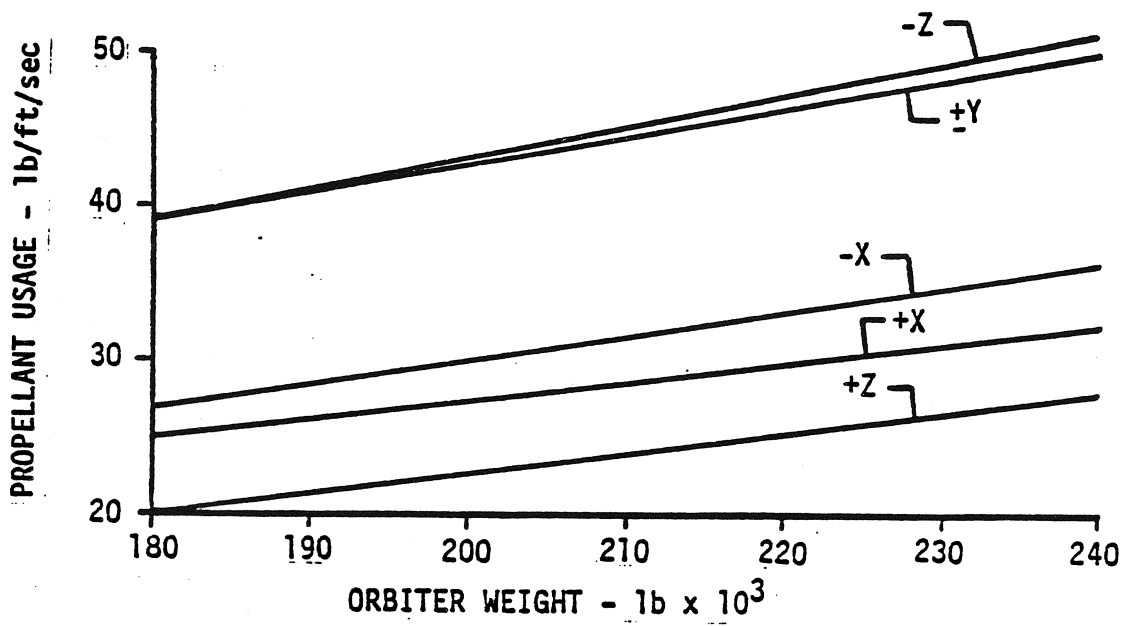


Figure 4-1.- RCS translation effectiveness.

#### 4.1.4 Translation Cross-Coupling Compensation

The factors noted in the previous section cause cross-coupling, resulting in undesired translation and rotation rates. For example, a high +Z (with no crossfeed/interconnect) translation maneuver will fire six upward-firing jets aft and three upward-firing jets forward. These firings will result in a desired +Z acceleration of approximately 250,000 lb-ft/s<sup>2</sup>, an undesired acceleration in the +X direction of approximately 3900 lb-ft/s<sup>2</sup>, and an undesired 0.30/s pitchup rotation. Table 4-II summarizes these effects.

To compensate for the cross-coupling into rotation, the Digital Autopilot (DAP) can select (as the attitude crosses a phase plane limit) jets to counteract the rotation. Note that the DAP must not be in a free-drift mode for this compensation to occur (RCS Burn Prep, sec. 4.2.3).

The translation/translation cross-coupling effects are not automatically counteracted; therefore, an attitude should be selected to compensate for this translational cross-coupling by aligning the resultant acceleration with the desired velocity-vector (fig. 4-2). That is, the translation maneuver velocity-vector is not aligned along an Orbiter body axis but is slightly off body axis so that  $\Delta V_X$ ,  $\Delta V_Z$ , and  $\Delta V_{TOT}$  are achieved simultaneously. Undesired residuals may be trimmed at the completion of the burn if required.

TABLE 4-II.- TRANSLATION CROSS-COUPLING

On-orbit DAP, normal jets, based on 0.080 sec pulse

| Translation axis         | Translation acceleration,<br>lb-ft/s <sup>2</sup><br>(slug-ft/s <sup>2</sup> ) |                         |                          | Rotation acceleration,<br>deg/s <sup>2</sup> |          |          |
|--------------------------|--|-------------------------|--------------------------|--|----------|----------|
|                          | X  | Y                       | Z                        | Roll   | Pitch    | Yaw      |
| High +Z (no crossfeed)   | +3936.0<br>(+122.25)   | 0<br>(0)                | +252,577.0<br>(+7844.00) | 0  | +0.32550 | 0        |
| High +Z (with crossfeed) | +427.0<br>(+13.25)   | 0<br>(0)                | +196,557.0<br>(+6104.75) | 0  | -0.23550 | 0        |
| Normal +Z                | +1312.0<br>(+40.75)  | 0<br>(0)                | +84,195.0<br>(+2614.75)  | 0  | +0.10875 | 0        |
| -Z                       | +41,602.0<br>(+120.12)   | 0<br>(0)                | -112,507.0<br>(-3494.00) | 0  | -0.00700 | 0        |
| +X                       | +55,191.0<br>(+1714.00)  | 0<br>(0)                | +9724.0<br>(+302.00)     | 0  | -0.01800 | 0        |
| -X                       | -56,414.0<br>(-1752.00)  | 0<br>(0)                | +5538.0<br>(+172.00)     | 0  | -0.07050 | 0        |
| +Y                       | -515.0<br>(-16.00)   | +56,092.0<br>(+1742.00) | +451.0<br>(+14.00)       | +0.39025                                     | 0        | +0.15275 |
| -Y                       | -515.0<br>(-16.00)   | -56,092.0<br>(-1742.00) | +451.0<br>(+14.00)       | -0.39025                                     | 0        | -0.15275 |

Due to propellant system limitations, only seven jets are fired while in the crossfeed configuration (sec. 4.1.5).

NOTE: ACCELERATION VALUES GIVEN HERE  
ARE FOR A 180,000-LB ORBITER.

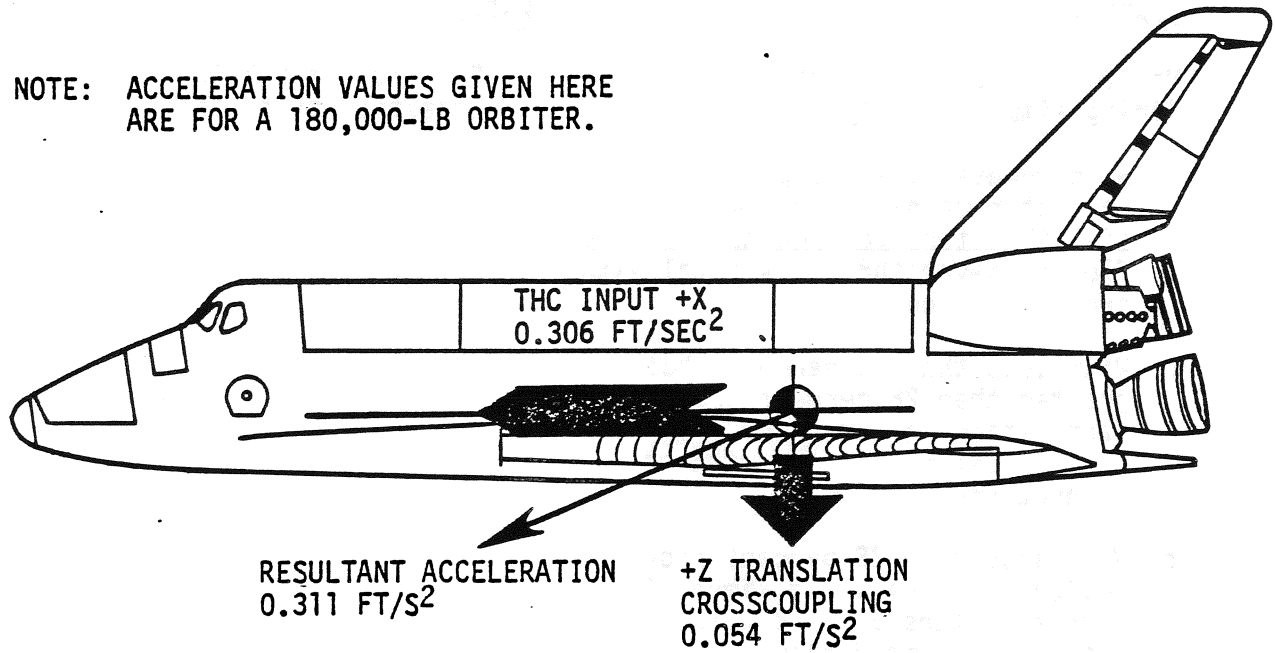


Figure 4-2.- Translation crosscoupling.

#### 4.1.5 RCS Systems Limitations

##### LIMITATION

- o Maximum number of thrusters firing simultaneously
  - o With greater than 32 percent propellant remaining - maximum of five thrusters per pod no crossfeed flow or seven thrusters total with crossfeed flow
  - o With less than 32 percent, but greater than 28 percent propellant remaining - maximum of five thrusters per pod with or without crossfeed flow
  - o With less than 28 percent propellant remaining - maximum of four thrusters per pod with or without crossfeed flow
- o Maximum thruster firing duration
  - o Fwd RCS primary thrusters - 150 sec single burn, normal or contingency
  - o AFT RCS primary thrusters - 150 sec single burn, normal; 500 sec single burn, contingency (+X only); 300 sec single burn, contingency (all other aft thrusters)
  - o Vernier thrusters - 125 sec single burn, normal or contingency
- o Minimum firing time/off time
  - o Primary thrusters - 0.080 sec on/0.080 sec off
  - o Vernier thrusters - 2000 pulses in one hour max.
- o 185 psia minimum ullage pressure, all RCS propellant tanks

##### RATIONALE

- o Prevent gas bubble ingestion by thrusters
- o Effects of thermal soakback into surrounding Orbiter structure
- o Valve cycle time
- o Over-temp pressure transducer
- o Achieve stable ignition



- o RCS thrusters on a manifold will not be fired if that manifold isolation valve is closed. (Software inhibits thrusters when manifold isolation valve is closed.)
- o An evacuated manifold, downstream of a closed manifold isolation valve, shall not be reactivated. (Results from a manifold isolation following a thruster leak or failed on thruster.)
- o All manifold isolation valves and aft RCS tank isolation valves limited to 20 cycles maximum for STS-1. (Cycles include all ground cycles and expected flight cycles.)
- o Prevents manifold evacuation by thruster firings, and/or gas bubble ingestion
- o Prevents valve damage due to hydraulic hammering
- o Valve assembly and actuator gear train life limitation

#### ADDITIONAL STS-1 LIMITATIONS

- o The following additional constraints are imposed on STS-1 on-orbit operations
  - o Translation maneuver while cross-feeding prohibited
  - o High -Z translation prohibited
  - o Multiaxis translation maneuver prohibited
  - o  $\pm Z$  translations limited to 20 sec steady state burn time maximum
  - o Thruster firings limited to not more than 3 jets per pod
- o Prevent gas bubble ingestion by thrusters due to helium drawn through acquisition screens

#### 4.2 PROCEDURAL DESCRIPTION - OPS 2 RCS BURN

The following procedure is used when the RCS system is utilized to impart a specific  $\Delta V$  at a specific time and in a predetermined direction. The basic steps to complete this procedure are:

1. Obtain and/or confirm most current burn data (MNVR PAD UPDATE)
2. Verify that required systems are nominal (OMS/RCS SYSTEM DATA CK)
3. Configure propellant system as required (RCS BURN PREP)
4. Maneuver to the proper burn attitude (AUTO MNVR TO BURN ATTITUDE)

5. Configure the DAP as required (DAP CONFIGURATION)
6. Execute burn at appropriate Time of Ignition (TIG) (IGNITION SEQUENCE)
7. Restore normal on-orbit configuration as required (DAP RECONFIGURATION)

These steps are broken down and described in detail in sections 4.2.1 through 4.2.7.

#### 4.2.1 MNVR Pad Update

A pad (form for recording data entries) is provided for crew convenience and to minimize the possibilities for errors related to the verbal communication of burn parameters (fig. 4-3). Burn pad items are:

- A. INRTL ATT is the vehicle attitude (roll, pitch, and yaw) in which the burn will be accomplished. These numbers will be entered on the Orbit display and define an inertial attitude based on the current inertial Relative Matrix (RELMAT).
- B. TIG is the time of ignition in hours:minutes:seconds. (For crew convenience this should correspond to the MISSION TIME in use.)
- C. BURN DURATION is the predicted length of time of the burn in minutes:seconds. There may be some variation from this time in achieving the required  $\Delta V$ 's due to the attitude at TIG and/or variation in thrust or vehicle mass. However, significant differences between actual burn duration and predicted burn duration may be an indication of a malfunction.
- D. BURN  $\Delta$  VELOCITY TARGETS are the velocities to be gained in the X, Y, and Z body axes and the total velocity change  $\Delta VTOT$ . These are monitored using the THRUST MONITOR portion of the Orbit display. When these values (primarily  $\Delta VTOT$ ) are achieved, the engines are cut off by releasing the Translational Hand Controller (THC).
- E. BURN DIRECTION (BODY) is the body axis along which the burn is to be accomplished.
- F. INTERCONNECT indicates the propellant system configuration; i.e., RCS interconnected to the L or R OMS propellant system or no interconnect to either OMS propellant system (NONE).

#### 4.2.2 OMS/RCS System Data Check

The OMS/RCS propellant systems are checked to ensure that their status is nominal before continuing with the procedure. The possible system malfunctions connected with these status checks are beyond the scope of this document. However, it should be noted that the use of these systems with an out of limits condition may damage the system and/or prevent its use later in the mission (RCS Systems Limitations, sec. 4.1.5).

##### OMS/RCS SYSTEM DATA CK

```
.....IF L(R) OMS TO RCS INTERCONNECT.....  
.C F7 OMS PRESS .....  
.   He TK P L,R > 1500 psia .....  
.P O3 RCS/OMS PRESS - OMS PRPLT .....  
.   ✓L,R OMS OX,FU PRESS > 200 psia .....  
.....
```

# OPS 2 RCS ON-ORBIT BURN

## MNVR PAD UPDATE

| RCS TRANSLATION MNVR PAD<br>( $\Delta V$ using ORBIT display) |                                     |                                     |
|---|-------------------------------------|-------------------------------------|
| INRTL ATT   | R _ _ . _ _                         | INTERCONNECT                        |
|   | P _ _ . _ _                         | <input type="checkbox"/> L OMS      |
|   | Y _ _ . _ _                         | <input type="checkbox"/> R OMS      |
| TIG   | _ _ : _ _ : _ _                     | <input type="checkbox"/> NONE       |
| BURN DURATION   | _ _ : _ _                           |                                     |
| BURN $\Delta$ VELOCITY TARGETS                                |                                     |                                     |
|   | $\Delta V_X$ [ ] _ _ . _ _          |                                     |
|   | $\Delta V_Y$ [ ] _ _ . _ _          |                                     |
|   | $\Delta V_Z$ [ ] _ _ . _ _          |                                     |
|   | $\Delta V_{TOT}$ _ _ . _ _          |                                     |
| BURN DIRECTION<br>(BODY)                                      | <input type="checkbox"/> <u>+</u> X | <input type="checkbox"/> <u>+</u> Y |
|   |                                     | <input type="checkbox"/> <u>+</u> Z |

Figure 4-3.- OPS 2 RCS translation maneuver pad.

```

.....IF NO L(R) OMS TO RCS INTERCONNECT.....
.P 03 RCS/OMS PRESS - RCS PRPLT .
.     ✓L,R RCS OX,FU PRESS > 190 psia .
.     RCS/OMS PRESS - RCS He x 10 .
.     ✓L,R RCS He PRESS > 500 psia .
.....

```

|   |
|---|
| <p><b>WARNING</b></p> <p>If OMS/RCS pressures not<br/>within limits, do not<br/>execute on-orbit burn</p> |
|---|

If OMS propellant is to be used, those steps in box labeled IF OMS TO RCS INTERCONNECT are completed. The OMS He TK P L, R is checked to ascertain nominal OMS He Tank pressures and OMS propellant quantities. Then the L and R OMS OX and FU pressures are verified to be nominal. OMS OX and FU pressures ( L or R) should be 253 to 261 psia. The tank pressure will be directly related to the amount of propellants used (assuming no leaks) and should be checked against the mission usage profile.

If RCS propellant is to be used, the steps in the box labeled IF NO OMS TO RCS INTERCONNECT are completed. These items are similar to those above but are concerned with the RCS propellant system. RCS OX and FU pressure should be 240 to 246 psia and, as in the OMS case above, the He tank pressure should be checked against the mission usage profile.

#### 4.2.3 RCS Burn Preparation

The RCS BURN PREP prepares the propellant systems for the burn. In configuring the propellant system there may be a short time while the RCS manifolds are isolated from a propellant source. If the RCS jets are not inhibited, the crew may receive a class 2 alarm (backup C&W light plus RCS JET light), a fault message (jet fail), and fail OFF indications on the RCS display. These indications are driven by a General Purpose Computer (GPC) sensing a low Chamber pressure (Pc) as a result of low propellant pressures. There is also the possibility of causing voids in the propellant lines and engine damage. For these reasons the RCS JETS are inhibited by placing the DAP in a free-drift mode.

#### RCS BURN PREP

##### INHIBIT RCS JETS

C3 DAP: MAN  
DAP ROT: PULSE/PULSE/PULSE

```

.....IF L(R) OMS TO RCS INTERCONNECT.....
.
.
.
.P 07   GNC 23 RCS
.       AFT L,R RCS:
.         TK ISOL (six) - CLOSE (tb-CL)
.         XFEED (four) - OPEN (tb-OP)
.P 08   ✓L,R OMS TK ISOL A,B (four) - OPEN (tb-OP)
.       ✓R(L) OMS XFEED A,B (two) - CLOSE (tb-CL)
.       L(R) OMS XFEED A,B (two) - OPEN (tb-OP)
.       OMS PRESS ENA, L(R) OMS - ITEM 5(6) EXEC
.
.....

```

```

.....IF NO OMS TO RCS INTERCONNECT.....
.P 07   AFT L,R RCS:
.       ✓He PRESS A (two) - GPC (tb-OP)
.       ✓He PRESS B (two) - CLOSE (tb-CL)
.       ✓TK ISOL (six) - OPEN (tb-OP)
.       ✓XFEED (four) - CLOSE (tb-CL)
.
.....

```

If OMS propellant is to be used, those items in the box labeled IF OMS TO RCS INTERCONNECT are completed. These steps connect the RCS manifolds to the left (L) or right (R) OMS propellant tanks and are sequenced in such a way that there is never an open line between the OMS tanks and the RCS tanks. Pressure differences between the OMS and RCS tanks is great enough to cause propellant to flow from one tank to another; however, this procedure sequence precludes this occurrence.

Note, also, that the proper OMS pressure enable (OMS PRESS ENA) must be selected on the GNC 23 RCS display (ITEM 5 for L, or ITEM 6 for R). This permits the GPC to maintain ullage pressure in the OMS tanks from which propellant is being used. The OMS PRESS ENA function also keeps track of the amount (percentage) of OMS propellant used by the RCS.

If RCS propellants are to be used for the burn, the procedure in the box labeled IF NO OMS TO RCS INTERCONNECT will be used. These steps verify that the RCS propellant system is properly configured for the burn.

When the propellant systems have been properly configured, the RCS jets can be enabled by selecting DAP items as required by mission objectives and constraints.

#### 4.2.4 Maneuver to Burn Attitude

F6 AUTO MNVR TO BURN ATTITUDE  
ADI ATT - INRTL

1: GNC ORBIT

CRT1 R - ITEM 1 + - - - . - - EXEC  
P - ITEM 2 + - - - . - - EXEC  
Y - ITEM 3 + - - - . - - EXEC  
C3 DAP - as reqd for mnvr  
CRT1 MNVR - ITEM 4 EXEC  
✓CURRENT ATTITUDE = REQD ATTITUDE when  
maneuver complete

The vehicle is maneuvered to the proper burn attitude by entering the roll, pitch, and yaw (R, P, and Y) items in the GNC ORBIT display. When MNVR - ITEM 4 is selected, the DAP will perform an eigen axis maneuver to bring the Orbiter to the correct inertial attitude. Appendix A lists fuel consumption estimates for various attitude maneuvers. To enable the crew to verify when the correct attitude has been established, the ADI ATT should be set to INRTL.

#### 4.2.5 DAP Configuration

DAP CONFIGURATION

3: GNC 20 DAP CONFIG

CRT3 ✓DAP A DEADBAND ATT R,P,Y - 10°  
✓DAP B DEADBAND ATT R,P,Y - 1°  
Adjust other DAP options as reqd

In final preparation for the translation burn the DAP A and B deadbands will be verified as well as adjusting the DAP options as required to ensure that the undesired rotation is sufficiently controlled to minimize translation errors due to misalignment between the desired velocity vector and the achieved velocity vector.

The selection of phase plane parameters (deadband limits) is constrained by tolerances on the undesired inertial  $\Delta V$ 's, i.e., the more stringent the restriction on undesired inertial  $\Delta V$ 's the tighter the deadband limits must be, with a concurrent increase in fuel usage.

#### 4.2.6 Ignition Sequence

##### IGNITION SEQUENCE

|             |   |
|-------------|---|
| TIG - 01:00 | FLT CNTLR PWR - ON                      |
|             | ADI ERROR - LOW                         |
|             | RATE - LOW                              |
| TIG - :30   | DAP: B/AUTO/NORM                        |
|             | DAP TRANS: as reqd                      |
|             | DAP ROT: DISC/DISC/DISC                 |
| TIG         | Deflect THC (until $\Delta V$ achieved) |

When  $\Delta V$  at desired level:

|       |                     |
|-------|---------------------|
|       | Release THC         |
| C3    | DAP: A/AUTO/NORM    |
| F6,F8 | FLT CNTLR PWR - OFF |

The IGNITION SEQUENCE procedure is begun by enabling the THC (FLT CNTLR PWR -ON). LOW ADI ERROR and RATE scales are selected to permit the crew to verify attitude control using the most accurate scale available.

At 30 seconds prior to ignition (TIG - 00:30 sec), DAP B/AUTO/NORM is selected (panel C3). DAP B is the narrow deadband, AUTO enables automatic attitude maintenance, and NORM selects the PRCS. The normal translation mode selection in all 3 axes (DAP TRANS: NORM/NORM/NORM) will keep the jets on as long as the THC is deflected and affects the number and orientation of jets used for the translation maneuver.

The discrete rotation mode (DAP ROT: DISC/DISC/DISC) is selected in all three axes to preclude the DAP being downmoded into a free-drift mode (if the RHC is deflected, for example) during the burn. The DAP is covered in detail in I/O/D GNC 2102, Insertion/On-Orbit/ Deorbit Guidance, Navigation, and Flight Control Workbook.

At TIG the THC must be deflected in the appropriate direction and held to execute the burn. When  $\Delta V_X$ ,  $\Delta V_Y$ ,  $\Delta V_Z$  and  $\Delta V_{TOT}$  have reached the desired levels the THC is released terminating the burn. At this time, the wider deadband is selected (DAP: A/AUTO/NORM) to conserve fuel during normal attitude holding and the FLT CNTLR PWR is turned off to prevent inadvertent thruster firings.



#### 4.2.7 DAP Reconfiguration

After the completion of the burn, the Orbiter system should be returned to nominal. The DAP is configured as required for on-orbit operations; deadbands, auto attitude maintenance, free-drift, etc. (Appendix B lists fuel consumption estimates for various attitude maintenance options.) If OMS propellant was not used, CRT 3 can be placed in the standby mode to conserve power. If OMS propellant was used, the L or R OMS TO RCS INTERCONNECT RETURN procedure should be executed at this time. This action completes this RCS burn procedure.

#### DAP RECONFIGURATION

|3: GNC 20 DAP CONFIG|

Adjust DAP A and B DEADBANDS as reqd for on-orbit ops

.....If OMS TO RCS INTERCONNECT used:.....  
·           Go to INTERCONNECT/XFEED, L OR R OMS   ·  
·           to RCS INTERCONNECT RTN, 6-3           ·  
.....  
.....If OMS TO RCS INTERCONNECT not used:.....  
·           CRT 3 PWR - STBY                     ·  
.....

#### 4.3 PROCEDURAL DESCRIPTION - OPS 3 RCS BURN

This procedure would be used whenever it is desirable to utilize the PEG 4 or PEG 7 guidance function available in OPS 3 (sec. 2.4) or when the Data Processing System (DPS) is in GNC OPS 3 for other operational reasons. As a result, the crew is able to utilize the RCS system to impart a specific  $\Delta V$ , at a specific time, along the +X body axis. The basic steps to complete this procedure are

1. Obtain and/or confirm most current burn data (OPS 3 ON-ORBIT RCS BURN PAD)
2. Verify required systems are nominal (OMS/RCS SYSTEM DATA CK)
3. Configure propellant systems as required (RCS BURN PREP)
4. Maneuver to proper attitude (LOAD TGTS AND MNVR)
5. Execute ignition sequence (CUE CARD)
6. Restore normal on-orbit systems configuration as required (RCS POST BURN RECONFIGURATION)

These steps are explained and described in detail in sections 4.3.1 through 4.3.6.

#### 4.3.1 OPS 3 On-Orbit RCS Burn Pad

The OPS 3 RCS Burn Pad (fig. 4-4) is formatted to closely resemble the MNVR display (fig. 2-9) where the data will be entered. Burn pad items are identified as follows:

- A. BURN ATT - The inertial burn attitude (R, P, Y), computed by guidance software, is displayed in degrees (items 8, 9, 10 on the MNVR display) once LOAD (item 39 on the display) is executed. The ground computed values are provided on the burn pad to enable the crew to cross-check Orbiter-computed values.
- B. BURN DATA - This section contains guidance-predicted target parameters. They are provided on this pad for crew reference. These parameters are as follows: the targeted (TGT) apogee (HA) and perigee (HP) in nautical miles above the surface of the earth.  $\Delta VTOT$  is the total change in velocity (ft/s) of the targeted maneuver and VGO X, Y, and Z are the velocities to be gained in the X, Y, and Z body axes. These are displayed when LOAD (item 39) is executed. They are updated cyclically to account for current body attitude.
- C. ENG SEL - This entry indicates to guidance which engines will be used for the translation maneuver. Item 18, RCS +X ACC must be selected for the RCS burn.
- D. WT - This is the Orbiter weight to be used in the guidance function for computation of burn targets.
- E. Target information - These items (27 through 38) are entered by the crew or may be uplinked from the ground and verified by the crew prior to executing LOAD. TIG is the time of ignition (days/hr:min:sec) in mission time in use (i.e., EET, MET, etc.). Targeting may be done by specifying the PEG 4 parameters C1, C2, HT,  $\theta T$ , and PRPLT (Items 31, 32, 33, 34, and 35). These define the flight path angle coefficients C1 (ft/sec), C2 (dimensionless value), HT (target radius in nautical miles),  $\theta T$  (target central angle in degrees), and PRPLT (total propellant in pounds) to be used by the maneuver. The sign (+ or -) on PRPLT (item 35) defines which side of the orbital plane fuel should be wasted (if at all). Targeting may also be accomplished by entering PEG 7 parameters (external  $\Delta V$ ) in items 36, 37, and 38 ( $\Delta VX$ ,  $\Delta VY$ , and  $\Delta VZ$  respectively).

NOTE: A thorough treatment of these parameters is provided in the I/O/D GNC 2102 workbook (Insertion/On-Orbit/Deorbit Guidance, Navigation, and Flight Control).

OPS 3 ON-ORBIT  
RCS\_BURN\_PAD

|             |     |     |     |     |     |
|-------------|-----|-----|-----|-----|-----|
| TRIM        |     | L   |     |     | R   |
| P           | 12  | ( ) | ( ) | ( ) | ( ) |
| Y           | 13  | ( ) | ( ) | 14  | ( ) |
| ENG SEL     |     |     |     |     |     |
| O           | M S | B   | O   | T   | H   |
|             | 15  | /   | /   | /   | /   |
| L           | 16  | /   | /   | /   | /   |
| R           | 17  | /   | /   | /   | /   |
| RCS + X ACC |     | 18  | *   |     |     |
| 21          | W   | T   |     |     |     |

|          |   |   |  |  |  |
|----------|---|---|--|--|--|
| BURN ATT | 8 | R |  |  |  |
| 9        | P |   |  |  |  |
| 10       | Y |   |  |  |  |

|     |     |     |
|-----|-----|-----|
| TGT | HA  | HP  |
| ( ) | ( ) | ( ) |

|     |   |   |   |   |
|-----|---|---|---|---|
| TXX | / | / | / | / |
| REI | / | / | / | / |

|       |     |  |   |  |  |
|-------|-----|--|---|--|--|
| ΔVTOT |     |  |   |  |  |
| TGO   |     |  | : |  |  |
| X     | ( ) |  |   |  |  |
| Y     | ( ) |  |   |  |  |
| Z     | ( ) |  |   |  |  |

|    |   |   |     |   |   |     |   |   |   |
|----|---|---|-----|---|---|-----|---|---|---|
| 27 | T | I | G   | / | : | :   | : | : | : |
| 31 | C | 1 |     |   |   |     |   |   |   |
| 32 | C | 2 | ( ) |   |   |     |   |   |   |
| 33 | H | T |     |   |   |     |   |   |   |
| 34 | θ | T |     |   |   |     |   |   |   |
| 35 | P | R | P   | L | T | ( ) |   |   |   |

|    |   |   |   |     |  |  |  |  |  |
|----|---|---|---|-----|--|--|--|--|--|
| 36 | Δ | V | X | ( ) |  |  |  |  |  |
| 37 | Δ | V | Y | ( ) |  |  |  |  |  |
| 38 | Δ | V | Z | ( ) |  |  |  |  |  |

Figure 4-4.- OPS 3 RCS burn pad.

### 4.3.2 OMS/RCS System Data Check

The OMS/RCS systems are checked at this time to ensure these systems are nominal before continuing with the burn procedures (sec. 4.2.2).

#### OMS/RCS SYSTEM DATA CK

```
.....IF L(R) OMS TO RCS INTERCONNECT.....
.C F7   OMS PRESS
        He TK P L,R > 1500 psia
.P 03   RCS/OMS PRESS - OMS PRPLT
        ✓L,R OMS OX, FU PRESS > 200 psia
.....
.....IF NO L(R) OMS TO RCS INTERCONNECT.....
.P 03   RCS/OMS PRESS - RCS PRPLT
        ✓L,R RCS OX, FU PRESS > 190 psia
        RCS/OMS PRESS - RCS He x 10
        ✓L,R RCS He PRESS > 500 psia
.....
```

|  |
|--|
| <p style="text-align: center;"><b>WARNING</b><br/>IF OMS/RCS pressures not<br/>within limits, do not<br/>execute on-orbit burn</p> |
|--|

If OMS propellant is to be used, those steps in the box labeled IF OMS TO RCS INTERCONNECT are completed. The OMS He TK P L,R is checked to ascertain nominal OMS He tank pressures and OMS propellant quantities. Then the L and R OMS OX and FU pressures are verified to be nominal. OMS OX and FU pressures (L or R) should be 253 to 261 psia. He tank pressure will be directly related to the amount of propellants used, assuming no leaks, and should be checked against the mission usage profile.

If RCS propellant is to be used, the steps in the box labeled IF NO OMS TO RCS INTERCONNECT are completed. These items are similar to those above but are concerned with the RCS propellant system. RCS OX and FU pressure should be 240 to 246 psia; and, as in the OMS case above, the He tank pressure should be checked against the mission usage profile.

Note that the nominal RCS propellant tank pressures are slightly lower than the nominal OMS propellant tank pressure. This is done to ensure that RCS propellants do not flow out of the RCS propellant tanks and into the OMS tanks during that short interval when the OMS and RCS tanks are interconnected (RCS Burn Prep, secs. 4.2.3 and 4.3.3).

### 4.3.3 RCS Burn Preparation

#### RCS BURN PREP

- .....IF L(R) OMS TO RCS INTERCONNECT.....
- .P 08    ✓L,R OMS TK ISOL A,B (four) - OPEN (tb-OP)    .
  - ✓R(L) OMS XFEED A,B (two) - CLOSE (tb-CL)    .
  - L(R) OMS XFEED A,B (two) - OPEN (tb-OP)    .
  - .P 07    AFT L,R RCS:    .
  - XFEED (four) - OPEN (tb-OP)    .
  - TK ISOL (six) - CLOSE (tb-CL)    .
- .....
- .....IF NO L(R) OMS TO RCS INTERCONNECT.....
- .P 07    AFT L,R RCS:    .
  - ✓He Press A (two) - GPC (tb-OP)    .
  - ✓He Press B (two) - CLOSE (tb-CL)    .
  - ✓TK ISOL (six) - OPEN (tb-OP)    .
  - ✓XFEED (four) - CLOSE (tb-CL)    .
- .....

If the burn is to be completed using OMS propellant, the steps within the box labeled IF OMS TO RCS INTERCONNECT should be completed. If RCS propellants are to be used, those steps within the box labeled IF NO OMS TO RCS INTERCONNECT should be completed. These steps verify that the RCS propellant system is properly configured for the burn. Unlike the OPS 2 procedures, it is not possible to inhibit the RCS jets during the OMS to RCS interconnect process. Consequently, it is necessary to perform this OMS to RCS interconnect procedure in a sequence that does not isolate the RCS jets from a propellant source (RCS Burn Prep, sec. 4.2.3). As a result of this requirement, there is a flow path open momentarily between the OMS tanks and the RCS tanks, which may allow OMS propellants to flow into the RCS tanks. Because of this, the interconnect procedures should be completed promptly.

#### 4.3.4 Load Targets and Maneuver

The burn targets are entered into the GPC using the GNC DEORB MNVR EXEC display (see OPS 3 ON-ORBIT RCS BURN PAD section for a description of these items). The BFS, GNC SYS SUMM 2 display will be used to monitor RCS and/or OMS system parameters (sec. 2.3, CRT Displays). The flight controller (FLT CNTLR) power must be on to enable the RHC's and THC's. The inertial ADI mode (ADI ATT (two) -INRTL) is selected to permit the crew to maneuver to the correct inertial attitude for the burn. This is accomplished by manually maneuvering the vehicle to achieve the burn attitude indicated on the MNVR display (after the burn parameters have been calculated by the GPC's).

#### LOAD TGTS AND MNVR

|  |  |                        |
|--|--|------------------------|
|  |  | 1: GNC DEORB MNVR EXEC |
|  |  | 3: BFS, GNC SYS SUMM 2 |

B F6/F8 FLT CNTLR POWER (two) - ON  
ADI ATT (two) - INRTL  
ERROR (two) - as reqd  
RATE (two) - as reqd

C CRT1 Load TGT DATA per BURN PAD  
Confirm loaded data  
LOAD - ITEM 39 EXEC  
ST CRT TMR - ITEM 40 EXEC

Confirm BURN DATA per BURN PAD

RHC MnvR to BURN ATTITUDE  
(Compare ADI ATT with CRT BURN ATT)

#### 4.3.5 Ignition Sequence - Cue Card

Perform OPS 3 ON-ORBIT RCS BURN  
Cue Card, then:

The crew is directed to use the procedures listed on the cue card then return to complete the subsequent steps in the Orbit OPS Checklist.

At TIG - 2 minutes, the crew transitions to the OPS 3 ON-ORBIT RCS BURN cue card (fig. 4-5) for the execution of the RCS translation.

A cue-card format is used to standardize this procedure, as much as possible, with other procedures used throughout the flight. This cue card covers the time from TIG - 2 minutes through cutoff. Certain critical items are verified: RCS BURN PREP - propellant system configuration; GPC's must be in major mode (MM) 302 to execute the burn; item 18 - RCS +X ACC, which indicates to the GPC's what engines and thrust level will be used for the translation and affects the computation of guidance parameters; and ADI ATT - INRTL is verified to ensure that the proper reference frame is displayed.

HOOK  
VELCRO

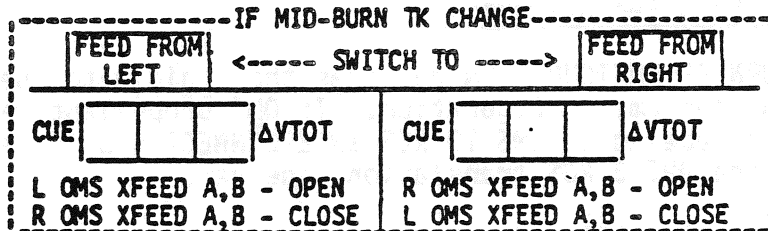
OPS 3  
ON-ORBIT  
RCS BURN

HOOK  
VELCRO

TIG-2 /RCS BURN PREP  
(INTERCONNECT: L(R) OMS TO RCS)  
/MM 302  
/ITEM 18

V: ADI ATT - INRTL  
H:E:  
O:L: ---IF OMS TO RCS INTERCONNECT---  
O:C: L,R OMS  
K:R: He PRESS/VAP ISOL A (two) - OPEN  
O: ... Wait 2 sec... B (two) - OPEN

:00 TIG Deflect THC +X  
Maintain ATT  
Monitor OMS DATA  
Monitor  $\Delta$ VTOT



CUTOFF Release THC when:  
TGO = ZERO or  
 $\Delta$ VTOT = TGT VALUE  
Trim RESIDUALS > 2 fps  
/POST BURN ATT

O/O: 10/16/79

Figure 4-5.- OPS 3 on-orbit RCS burn cue card.

If OMS propellant is to be used, the OMS tanks are pressurized by opening the He PRESS/VAP ISOL valves. Both left and right He PRESS/VAP ISOL valves are opened to facilitate a mid-burn tank change. The A (two) - OPEN ... Wait 2 sec ... B (two) - OPEN sequence is used to prevent overpressurization of the He lines caused by simultaneous opening of all four valves.

At TIG the THC is deflected in the +X direction to initiate the burn. During the burn the crew should maintain the proper attitude, monitor OMS system data, and monitor  $\Delta VTOT$ . Note that  $\Delta VTOT$  is the primary indicator for burn completion and for mid-burn tank change, if required. If a mid-burn tank change (OMS propellant) is planned, the items under FEED FROM LEFT or FEED FROM RIGHT are completed, as applicable, when the  $\Delta VTOT$  cue (noted on card) is reached. These switches are sequenced to prevent fuel starvation of the engines during the burn. The burn is terminated by releasing the THC when TGO = ZERO or when  $\Delta VTOT$  = target value. Burn residuals greater than 1 ft/s are trimmed and the post burn attitude is verified. This completes the cue card and the crew will return to the checklist for the post burn reconfiguration procedures.

#### 4.3.6 RCS Post Burn Reconfiguration

The RCS POST BURN RECONFIGURATION restores the vehicle to the nominal on-orbit propellant systems configuration. If OMS propellant was used, those steps in the box labeled IF OMS TO RCS INTERCONNECT should be completed. This completes the OPS 3 RCS translation maneuver.

#### RCS POST BURN RECONFIGURATION

F6,F8 FLT CNTLR PWR (two) - OFF

```

.....IF L(R) OMS TO RCS INTERCONNECT.....
.
.P 07 AFT L,R RCS TK ISOL (six) - OPEN (tb-OP) .
.           XFEED (four) - CLOSE (tb-CL) .
.P 08 L,R OMS He PRESS/VAP ISOL (four) - CLOSE .
.           (tb-CL).
.           XFEED A,B (two) - CLOSE (tb-CL) .
.....

```



## SECTION 5 OMS MANEUVER

The normal on-orbit Orbital Maneuvering System (OMS) translation maneuver is accomplished in Guidance Navigation and Control (GNC) Operational Sequence (OPS) 3, using linear terminal velocity constraint guidance (PEG 4) or external delta velocity guidance (PEG 7). This maneuver is similar to the deorbit burn. The major differences lie in the Data Processing System (DPS) configuration (sec. 5.1.2) and the downmoding philosophy. The on-orbit OMS burn will normally be planned as a two-engine burn. However, the capability is provided for a one-engine burn with or without propellant crossfeed. INTERCONNECT/CROSSFEED PROCEDURES are described in sec. 3. Note that these procedures are not intended to provide for downmoding from two engines to one engine. In the event of a malfunction, the burn will normally be terminated. Should it be necessary, the remaining burn  $\Delta V$  could be achieved with one engine (sec. 5.3). These procedures assume the DPS transition procedures (ORBIT OPS C/L) have already been completed. The major activities associated with a burn are listed below in table 5-1. These activities are similar for both 1-OMS and 2-OMS burns, which are described in detail in sections 5.3 and 5.2, respectively.

### 5.1 ASSUMPTION, GUIDELINES, AND CONSTRAINTS

A brief description of the CRT displays, cue cards, burn pads, and other background information is included here as reference for the amplified flight procedures sections that follow.

#### 5.1.1 CRT Displays

The following CRT displays are used in the on-orbit OMS burn procedure:

DEORBIT MNVR EXEC - The deorbit maneuver execute display provides the crew with the means to input guidance parameters and evaluate maneuver effects on the trajectory (when applicable). It assists the crew in establishing Orbiter attitude and burn monitoring, and is used for trimming burn residuals if required. In addition, it enables the crew to inhibit the OMS engine purge. Controls are provided to allow for the verification and selection of the active gimbal drive system. Actual engine gimbal angle readouts are provided to monitor Thrust Vector Control (TVC) operation and status (fig. 2-9).

GNC SYS SUMM 2 (BFS) - The GNC system summary 2, backup flight system display is used to monitor OMS consumables and system status. Particular note should be taken of the nitrogen pressure (N2 P) valve status (percent open) indicated on this display. If this valve fails to open, there may be only enough N2 gas remaining in the accumulator for one more operation of the OMS engine ball valves. (fig. 2-1 OMS subsystems and fig. 2-10 GNC SYS SUMM 2 display)

### 5.1.2 The Use of GNC OPS 3

To accomplish an OMS burn, the vehicle must have GNC OPS 3 running in at least one GPC. The software required to execute an OMS burn on orbit is not available in any other software configuration. (GNC OPS 1 has the software required for accomplishment of OMS burns, but this software is not accessible after the ascent OMS 2 burn.)

There are some important differences between the OPS 3 GPC configuration used for on-orbit burns and the OPS 3 GPC configuration used for entry. The OPS 3 on-orbit configuration is summarized in table 5-II. Most significantly, the on-orbit burn will be accomplished with only two GNC OPS 3 GPC's in the redundant set; whereas, there are normally four GNC OPS 3 GPC's in the redundant set for entry. This configuration was adopted for on-orbit OMS burns in order to maintain use of the System Management Fault Detection and Annunciation (SM FDA) function available in SM OPS 2.

A step-by-step explanation of the transition from the on-orbit OPS 2 configuration to the on-orbit OPS 3 burn configuration may be obtained from the orbit OPS checklist procedures explanations. It is appropriate here, however, to discuss the rationale for specific GPC assignments and Display Keyboard (DK) bus to GPC assignments as they pertain to the on-orbit OPS 3 burn configuration. The string to GPC assignments are arranged so that the two Network Signal Processors (NSP's) are not driven by the same GPC (NSP 1 on MDM FF1 assigned to GPC 1; NSP 2 on MDM FF3 assigned to GPC 2). Also, OMS primary and secondary Thrust Vector Controls (TVC) are separated (L, R OMS primary TVC on strings 1, 4 assigned to GPC 1; L, R OMS secondary TVC on strings 2, 3 assigned to GPC 2).

The DK Bus to GPC assignments are arranged so that when the CRT major function switches are in the GNC position, GPC 1 will be commanding CRT 1 and GPC 2 will be commanding CRT 2 and 3. Arrangement in this manner prevents all CRT's from being assigned to the same GNC GPC, a configuration that would result in CRT isolation if the assigned GPC should fail.

TABLE 5-I.- OMS BURN TIME LINE

| $\Delta$ Time,<br>min | Activity   | Comments   |
|-----------------------|--|--|
| 02:00                 | MNVR PAD UPDATE                                  | Must be accomplished during a GSTDN contact period, preferably as close to TIG as possible |
| 11:00                 | OMS SYSTEMS CHECKS AND MANEUVER TO BURN ATTITUDE | Should be performed as close to TIG as possible<br>TIG - 13:00                             |
| 01:00                 | OMS BURN PREP                                    | TIG - 04:00  |
| 03:00                 | IGNITION SEQUENCE (CUE CARD)                     | TIG - 03:00 → c/o  |
| 02:00                 | POST BURN RECONFIGURATION                        | c/o → c/o + 02:00  |

TABLE 5-II.- GPC CONFIGURATION FOR ON-ORBIT OMS BURNS

|                       | GPC 1 | GPC 2 | GPC 3      | GPC 4   | GPC 5      |
|-----------------------|-------|-------|------------|---------|------------|
| <u>MAJOR FUNCTION</u> | GNC 3 | GNC 3 | GNC 3 (FD) | SM 2    | BFS (STBY) |
| <u>STRING</u>         | 1, 4  | 2, 3  | -          | -       | -          |
| <u>DK BUS</u>         | 1     | 2, 3  | -          | 1, 2, 3 | -          |

### 5.1.3 Effects of Thrust Vector Misalignment at TIG

There are two general ways that the actual thrust vector can be misaligned from the desired thrust vector:

- A. The engine gimbal trim angles may not align the thrust vector through the center of mass of the vehicle (fig. 5-1).
- B. The actual vehicle attitude may not coincide precisely with the desired attitude.

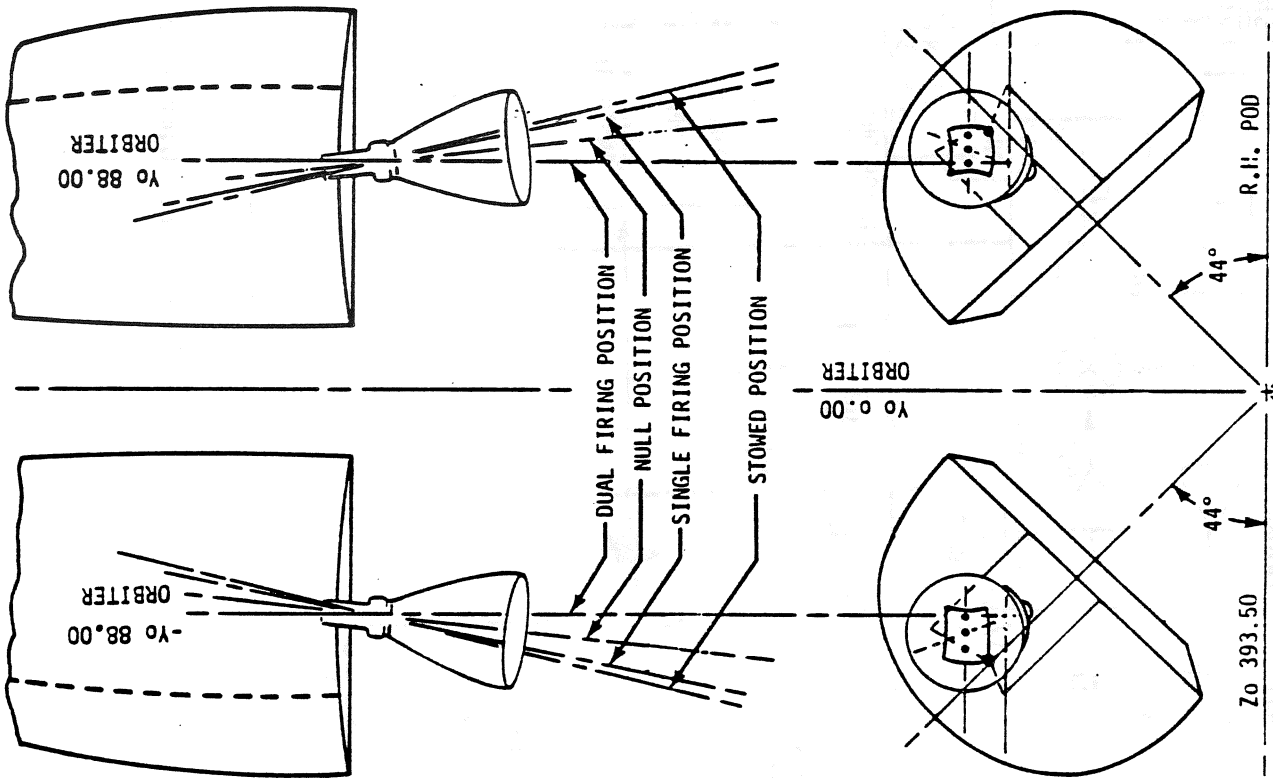
Either of these conditions at Time of Ignition (TIG) will cause PEG 7 guidance to miss the target position to some degree. PEG 4 guidance will reach the target position, but it will expend more fuel.

NOTE: If the misalignment is large ( $>45^\circ$ ), the guidance algorithm may fail to converge, and correct target parameters will not be computed.

After ignition, PEG 7 guidance will attempt to achieve and maintain the correct inertial attitude during the burn (sec. 2.4, Guidance Functions). Consequently, the larger the attitude and/or engine trim misalignment at TIG, the larger the undesired  $\Delta V$ 's at cutoff will be. Depending on their magnitude and the objective of the burn, these residuals may need to be nulled out. On the other hand, PEG 4 guidance will maneuver the vehicle during the burn to achieve the target position (if the burn time is long enough). However, this maneuver will consume additional fuel; the larger the initial errors, the greater the quantity of 'wasted' fuel. The initial engine gimbal angle error has a much smaller impact on the burn than attitude errors have because of the rate at which the engines can be gimballed to the correct position. The OMS gimbal actuator subsystem interface is shown in figure 5-2.

### 5.1.4 On-Orbit OMS Burn Pads and Cue Cards

A burn pad is provided for the on-orbit OMS burn procedure to minimize possibilities for errors in copying burn parameters verbally transmitted from Mission Control Center (MCC) and to standardize the burn procedures. The OMS burn pads (figs. 5-3 and 5-4) are formatted to reflect the DEORB MNVR EXEC display to facilitate data input and comparison. A detailed description of these pads follows.



\* NOTE: GIMBAL ANGLES REFERENCED TO ORBITER PLANES

| ENGINE POSITION          | PITCH ANGLE*       | YAW ANGLE*        | L P/Y        | R P/Y        |
|--------------------------|--------------------|-------------------|--------------|--------------|
| NULL STOWED              | 15° 49'<br>9° 7'   | 6° 30'<br>14° 14' | 0<br>+6/+7   | 0<br>+6/-7   |
| DUAL FIRE<br>SINGLE FIRE | 15° 49'<br>15° 49' | 0°<br>12° 25'     | 0/-6<br>0/+5 | 0/+6<br>0/-5 |

Figure 5-1.- OMS engine gimbal angles.

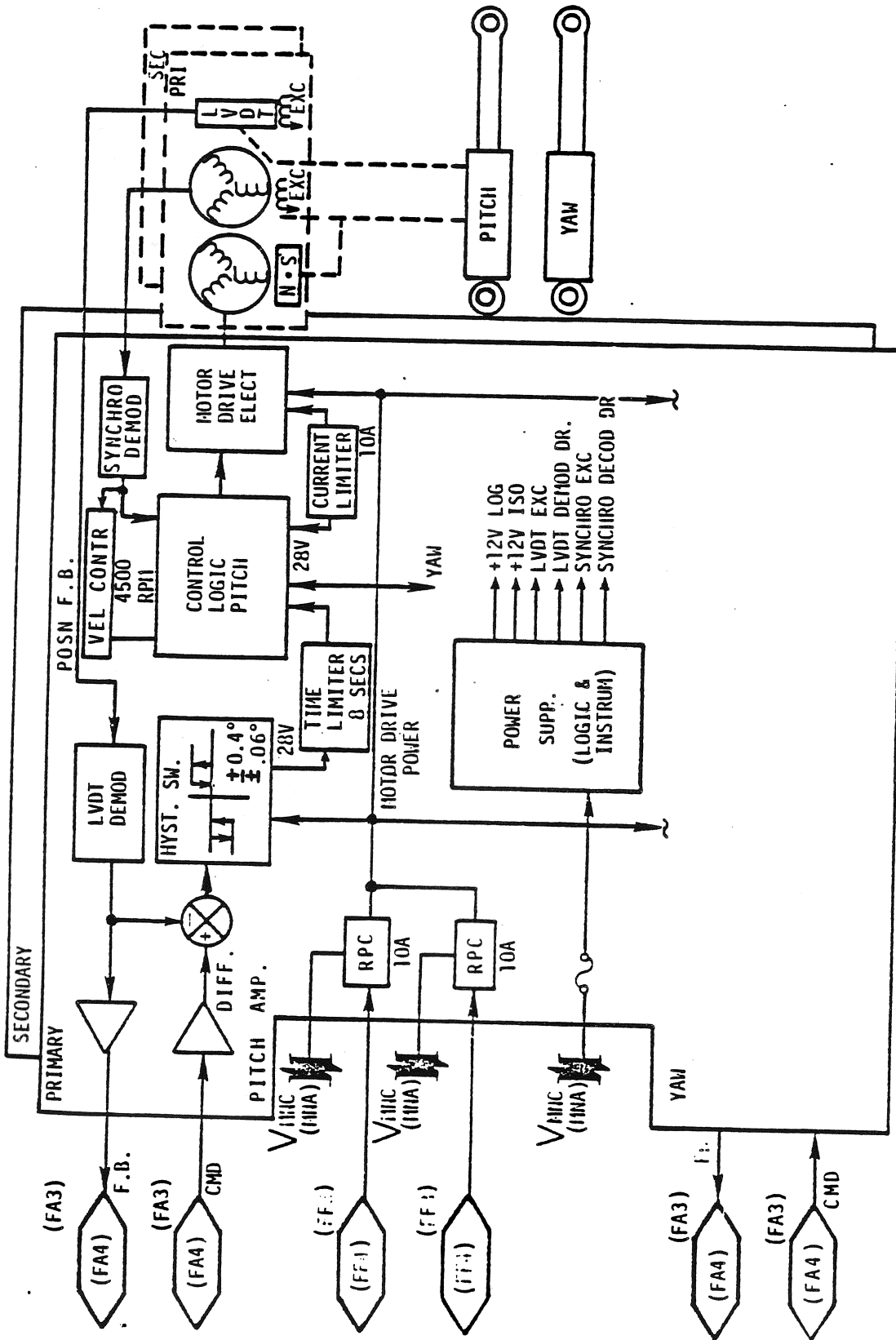


Figure 5-2.- Gimbal interface.

5.1.4.1 2-OMS On-Orbit Burn Pad. - The 2-OMS on-orbit burn pad (fig. 5-3), used for recording burn parameters transmitted from MCC, is formatted to reflect the DEORB MNVR EXEC display to facilitate data input and comparison. There is a one-to-one correspondence between item numbers on the burn pad and item numbers on the display. For example, item 21 WT on the burn pad corresponds to item 21 WT on the DEORB MNVR EXEC display.

The burn pad is divided into two major sections: Target Data and Burn Data. Target Data is the information loaded into the GPC's for guidance computation. Burn Data is the displayed results of the GPC's computation.

#### TARGET DATA:

TRIM - These are the gimbal angles for the OMS engines. These angles are selected to position the engines properly, before ignition, to minimize propellant wasted due to misaligned thrust vector at TIG. Item 12 is the pitch value and items 13 and 14 are the yaw values for the left and right engines respectively (fig. 5-3). The engines will be driven to the angles shown on the display at TIG - 10 sec. The gimbal angles will be controlled by the digital auto pilot (DAP) (DAP mode in AUTO) during the burn.

ENG SEL - This parameter provides information to the DAP on which engines will be used. For the 2-OMS burn item 15, (OMS BOTH) should be selected. Items 15, 16, 17, and 18 are mutually exclusive.

WT - This item is the total Orbiter weight and should be as accurate as possible to minimize guidance computation errors. For STS-1, this item is not updated by the GPC's and must be uplinked or input by the crew.

TIG - Time of ignition is entered in mission time (days/hr:min:sec)

NOTE: Mission Time is controlled by the TIME display which is not available in MM302. Hence, the TIG time must be entered in the time reference currently active in the DEORB MNVR EXEC display.

$\Delta V_X$ ,  $\Delta V_Y$ ,  $\Delta V_Z$  - These are the external delta velocity target parameters for PEG 7 guidance and are input in Local Vertical Local Horizontal (LVLH) coordinates. These values are related to M50 coordinates via the RELMAT, and an inertial burn attitude is computed. Thrust will be directed along the inertial velocity-to-be-gained vector until the specified velocity change has been achieved.





PRPLT - This item is for propellant wasting and will normally be zero for on-orbit burns. (None of the  $\Delta V$  is for the purpose of fuel wasting.) Propellant wasting, if required, will normally be accomplished during the deorbit burn.

The following items on the burn pad are the guidance computed values expected to be displayed on DEORB MNVR EXEC display after the LOAD (item 39) has been executed.

#### BURN DATA:

BURN ATT - The burn attitude is the required inertial attitude at TIG, given in degrees for roll, pitch, and yaw (R,P,Y). Attitude information is also available to the crew on the ADI (error needles) in the form of attitude error (showing the difference between desired and actual attitude) for maneuvering to the burn attitude and monitoring the attitude during the burn.

TGT HA and HP - These are the computed target values (n. mi.) for height of apogee and perigee after the burn.

$\Delta VTOT$ , TGO, VGO X, Y, and Z - These values are the guidance predicted values for the total change in velocity in ft/s ( $\Delta VTOT$ ), the time to go to OMS cutoff in min:sec (TGO), and the velocity-to-be-gained (relative to body coordinate system) in ft/s (VGO X, Y, and Z).

5.1.4.2 1-OMS On-Orbit Burn Pad.- The 1-OMS burn pad (fig. 5-4) is similar to the 2-OMS burn pad (fig. 5-3). The differences are in the gimbal trim angle, the ENG SEL, and the propellant crossfeed cues (in the upper left hand corner of the burn pad). The gimbal trim angles are selected to position the engines to compensate for the offset thrust line due to 1-OMS engine operation. The ENG SEL OMS L (or R) item is selected to indicate to guidance which engine will be used to obtain the specified  $\Delta V$ 's. If a crossfeed is planned, (for example, for c.g. control), the point (CUE) at which the switch is to be performed is indicated in percent of propellant used (L (or R) OMS PRPLT) or total change in velocity ( $\Delta VTOT$ , ft/s). The use of  $\Delta VTOT$  is the preferable cue for switchover because of greater accuracy.

5.1.4.3 Cue card.- A cue card displaying the ignition sequence is used to standardize each procedure with the other burn procedures used throughout the flight. Detailed descriptions of the cue card steps are given in the amplified procedures, sections 5.2 and 5.3. The 2-OMS and the 1-OMS Cue Cards are shown in figures 5-5 and 5-6, respectively.



HOOK  
VELCRO

HOOK  
VELCRO

ON-ORBIT  
2 OMS BURN

TIG-2:00 ✓CNTLR PWR (two) - ON  
✓MM 302  
✓GMBL TRIM - CORRECT  
✓ENG SEL - ITEM 15  
✓ATT - CORRECT  
✓ADI ATT - INRTL  
ERR - HIGH

-1:00 L,R OMS He PRESS/VAP ISOL A (two) - GPC  
✓B (two) - CLOSE

DAP - AUTO  
DFI RCDRS PCM - CONT RCD (tb-gray)  
WB MSN - CONT RCD (tb-gray)

L,R OMS ENG (two) - ARM/PRESS  
✓N2 P VLV (two) - OP (on CRT 3)

V  
H:E  
O:L  
O:C  
K:R  
O:

WARNING  
If both N2 P VLV not OP,  
do not execute on-orbit burn

-:10 EXEC (Guidance initiate, Gimbals Trim)

TIG ✓Pc, ΔVTOT, ENG vlv  
L,R OMS He PRESS/VAP ISOL B (two) - GPC

CUTOFF  
+:02 ✓Purge complete  
L,R OMS ENG (two) - OFF

Figure 5-5.- 2-OMS burn cue card.

HOOK  
VELCRO

ON-ORBIT  
1 OMS BURN

HOOK  
VELCRO

TIG -2:00 ✓CNTLR PWR (two) - ON  
✓MM302  
✓GMBL TRIM - CORRECT  
✓ENG SEL - CORRECT  
✓ATT - CORRECT  
✓ADI ATT - INRTL  
ERR - HIGH

-1:00 Selected OMS He PRESS/VAP ISOL A - OPEN  
...wait 2 sec... B - OPEN

.....If MID-BURN XFEED planned.....  
.Other OMS He PRESS/VAP ISOL A - OPEN .  
. ...wait 2 sec... B - OPEN .  
.....

DAP - AUTO  
DFI RCDRS PCM - CONT RCD (tb-gray)  
WB MSN - CONT RCD (tb-gray)

V:  
H:E:  
O:L:  
O:C:  
K:R:  
O:

Selected OMS ENG - ARM/PRESS  
✓Other OMS ENG - OFF  
✓Selected N2 P VLV - OP (CRT 3)

WARNING  
If selected N2 P VLV not OP,  
do not execute on-orbit burn

:-10 EXEC (Guidance initiate, Gimbals trim)  
TIG ✓Pc, ΔVTOT, ENG VLV

.....If MID BURN XFEED.....  
. CUE [ ] ΔVTOT ( [ ] % SEL OMS PRPLT) .  
. L,R OMS XFEED - OPEN .  
. SEL OMS TK ISOL - CLOSE .  
.....

CUTOFF  
+:02 ✓PURGE COMPLETE  
L,R OMS ENG - OFF

Figure 5-6.- 1-OMS burn cue card.

### 5.1.5 Mid-Burn Crossfeed

The 1-OMS burn procedures include the option of performing a mid-burn crossfeed. This gives the crew the capability to start the burn on one propellant system and then, on a specified cue (usually  $\Delta V$  total), to change to the opposite propellant system. This procedure is useful when the burn would cause an undesirable lateral c.g. imbalance or when it is desirable to achieve a specific  $\Delta V$  and restore proper c.g. balance later (sec. 3, Interconnect/Crossfeed Procedures).

### 5.1.6 OMS Systems Limitations

| <u>Limitation</u>   | <u>Rationale</u>   |
|---|--|
| <p>o <u>MINIMUM ENGINE OFF-TIME BETWEEN FIRINGS</u></p> <p>The OMS engine should be purged after shutdown. The minimum engine off-time between firing is 240 sec for normal operation and 30 sec for launch abort operations. If a post shutdown purge is not accomplished, the engine must not be restarted until 10 min after shutdown.</p> | <p>o Possible propellant freezing in injector and hard starts</p>  |
| <p>o <u>MINIMUM CHAMBER PRESSURE</u></p> <p>Chamber pressure must be <u>&gt;80 percent.</u></p>   | <p>o Unstable engine operation or possible burnout of fuel regeneration jacket</p>                                       |
| <p>o <u>MINIMUM LAUNCH PROPELLANT LOAD</u></p> <p>Minimum propellant load in the OMS propellant tanks at launch is 2038 lb fuel and 3362 lb of oxidizer per pod (~43 percent of tank capacity).</p>   | <p>o Aft compartment bulkhead screen may dry out in the boost phase allowing helium to enter the propellant lines</p>    |
| <p>o <u>MINIMUM PROPELLANT FOR ORBIT START</u></p> <p>Minimum propellant in the OMS propellant tanks' aft compartment for normal zero-g engine start up is 504 lb fuel and 831 lb of oxidizer (~28 percent of tank capacity).</p>   | <p>o May not have adequate communication between the tank acquisition galleries and forward-oriented bulk propellant</p> |

o MINIMUM OMS  $\Delta V$  MANEUVER

The minimum OMS  $\Delta V$  maneuver to be planned should be approximately 6 ft/s for a two-engine burn and 3 ft/s for a one-engine burn.

o MAXIMUM NUMBER OF OMS STARTS

The number of OMS starts is limited by the number of post-fire purges or by the amount of OMS propellant used by the RCS.

o OMS starts with post-fire purges are limited to 12 to 17 per mission.

o OMS starts are limited to 10 per mission with the use of 1000 lb of OMS propellant per pod by the RCS or 17 starts with no RCS usage of OMS propellants.

o ENGINE FIRING DURATION

Engine firing of less than 2 sec is prohibited. If, for any reason, an engine shuts down in less than 2 sec after it is started, it should not be restarted.

o Safe burn time duration based on available engine data

o Would exceed nitrogen storage system specifications

o May not have adequate propellant in the aft compartment for zero-g start

o Possible propellant freezing in injector and/or injector manifold explosion

## 5.2 2-OMS ON-ORBIT BURN FLIGHT PROCEDURE

Prior to the beginning of this procedure, a crewmember will have copied the MCC transmission of the initial burn pad data (fig. 5-3). This transmission is dependent on when ground coverage is available. A detailed description of the 2-OMS on-orbit burn pad is given in section 5.1.4.1. The procedure starts with the crew in position and the GPC's appropriately configured for an on-orbit OMS burn. This GPC configuration has been covered in section 5.1.2. The procedure is complete when the post burn status is checked and the OMS system has been returned to the nominal on-orbit configuration.

### 5.2.1 General Preparations

#### 2 OMS ON-ORBIT BURN

R11 DFI WB MSN PWR - ON  
✓DFI WB MSN RCDR - FWD CONTROL  
B C6 Install ON-ORBIT 2 OMS BURN  
Cue Cards (two)(F6/F8)  
CRT1 ✓GNC, OPS 302

|                        |
|------------------------|
| 1: GNC DEORB MNVR EXEC |
| 3: BFS, GNC SYS SUMM 2 |

C F7 ✓OMS PRESS  
He TK P L,R > 2500 psia  
N2 TK P L,R > 2250 psia

The 2-OMS BURN Cue Cards (fig. 5-5) are installed on panels F6 and F8, in plain view, with the provided Velcro patches. A cue-card format is used to standardize this burn procedure, as much as possible, with other burn procedures used throughout the flight. A detailed description of the cue card is given in section 5.2.5.

The GNC DEORB MNVR EXEC display should be up on CRT 1 and the GNC SYS SUMM 2 should be on CRT 3. These displays are described in section 5.1.1 and in section 2.2.1, CRT Displays.

|  |
|--|
| <p style="text-align: center;"><u>WARNING</u><br/>If OMS PRESS not within limits,<br/>do not execute on-orbit burn</p> |
|--|

The crew checks the status of the OMS pressure systems via the dedicated displays on panel F7. The OMS PRESS N2/He TANK switch must be placed in the He position to select the OMS He TANK pressure to be displayed on the OMS PRESS N2/He TANK indicator. The He tank pressure is dependent on the quantity of propellants remaining and should not be less than 2500 psia for the on-orbit burn. Placing the OMS PRESS N2/He TANK switch in the N2 position causes the OMS system N2 tank pressure to be displayed on the

OMS PRESS N2/He TANK indicator. The N2 pressure is dependent on the number of past engine burns (valve openings) and engine purges, and should not be less than 2250 psia.

These minimum values of N2 and He pressures are established to ensure an adequate supply of nitrogen and helium for the deorbit OMS burn.

### 5.2.2 OMS TVC Gimbal Check

#### GIMBAL CHECK

C CRT1 SECONDARY CHECK  
Perform SEC L,R GMBL CK  
PRIMARY CHECK  
Perform PRI L,R GMBL CK

- \* If down arrow(s) or M's: \*
- \* Select GOOD GMBL \*

The OMS Thrust Vector Control (TVC) gimbal check is performed via the DEORB MNVR EXEC display (fig. 2-9.) The controls and data for this are provided in the upper left-hand corner of the display (sec. 2.3 CRT Displays, and fig. 5-1). The GMBL CK function is used to verify the proper operation of the OMS gimbal drive actuators approximately 4 minutes before TIG. The OMS TVC Redundancy Management (RM) compares the commanded gimbal rates and position with the actual rates and position to detect a failure (fig. 5-2). A down arrow (↓) is displayed in the status column of the affected gimbal if a failure is detected. A gimbal failure is a class two fault which results in the annunciation of the master alarm, a tone, the backup C/W alarm, and the OMS TVC light on the C/W panel. A flashing message is displayed on the fault message line and the message is added to the FAULT display. A detailed description of the FAULT display is given in the DPS dictionary.

The secondary gimbals are selected for verification by executing items 3 and 6 on the maneuver display for left and right gimbals, respectively. When item 1 is executed, the GMBL CK is initiated. The gimbals are given a maximum positive pitch and yaw command, a maximum negative pitch and yaw command, and a zero pitch and yaw command for 6 seconds duration each. The gimbals then return to the position just prior to the gimbal check.

NOTE: The gimbals are not driven to the trim angles until 10 sec before TIG.

The primary gimbal drives are selected via items 2 (L) and 5 (R). If any down arrows were displayed for the secondary system, they will be blanked by this action. If there are no gimbal failures (no down arrows), the primary gimbal system should be used. If there are any failed gimbals, or missing gimbal data, and it is elected to continue with the burn, the non-failed system will be used. The capability also exists, via items 4 (L) and 7 (R), to turn the gimbal drive off should that be required as a result of gimbal drive malfunctions (runaway gimbal drive, for example).



### 5.2.3 Load Target Data and Maneuver to Attitude

LOAD TGT DATA MNVR

|     |       |                                     |
|-----|-------|-------------------------------------|
| B   | F6/F8 | FLT CNTLR PWR (two) - ON            |
|     |       | ADI ATT (two) - INRTL               |
|     |       | ERROR (two) - as reqd               |
|     |       | RATE (two) - as reqd                |
| C   | CRT1  | Load TGT DATA per BURN PAD          |
|     |       | Confirm loaded data                 |
|     |       | LOAD - ITEM 39 EXEC                 |
|     |       | ST CRT TMR - ITEM 40 EXEC           |
|     |       | Confirm BURN DATA per BURN PAD      |
| RHC |       | Mnvr to BURN ATTITUDE               |
|     |       | (Compare ADI ATT with CRT BURN ATT) |

Before the Orbiter can be maneuvered to the proper burn attitude, the hand controllers must be enabled and the proper attitude reference selected for the Attitude Direction Indicator (ADI) (RELMATS, sec. 2.2.3). Both crewmen will turn their respective flight controller power (FLT CNTLR PWR) switches on (F6/F8). This enables the Rotational Hand Controller (RHC) and the Translational Hand Controller (THC). The RHC provides signals to the GPC's to activate the appropriate RCS jets and/or OMS engine gimbaling during the burn. Deflection of the RHC will be used to manually maneuver to the proper burn attitude for STS-1, since automatic rotational maneuvering is not available in OPS 3.

The THC is available to trim residual velocities with the PRCS after OMS cutoff if required. The residuals will not, however, be trimmed for STS-1 on-orbit OMS burns.

The ADI Attitude (ADI ATT) switches will be placed in the Inertial (INRTL) position. This selects the inertial attitude reference for display on the ADI. This attitude reference will be used by the crew to monitor the attitude before and during the burn. (See BURN ATT in 2-OMS On-Orbit Burn Pad, sec. 5.1.4.1).

The ADI ERROR switches will be selected as required by the crew. The three positions available are: HIGH, MED, and LOW ( $\pm 10^\circ$ ,  $\pm 5^\circ$ , and  $\pm 1^\circ$ , respectively).

The ADI RATE switches will be selected as required by the crew. The three rate scales available are HIGH, MED, and LOW ( $\pm 10$  deg/s,  $\pm 5$  deg/s, and  $\pm 1$  deg/s, respectively).

The crew will load or verify target data via the DEORB MNVR EXEC display (sec. 5.1.1) for guidance computations and certain OMS engine controls. When the display is called, the data presented consists of the OMS trim information, current engine selection, current weight, and PEG 7 TGT parameters as ground uplink or crew inputs. The crew has the option of changing these data via item entries to incorporate the most current information available prior to transferring it to the GPC's for guidance computation. The crew will confirm loaded data per burn pad before LOAD (item 39) is executed. The LOAD item (which is flashing prior to execution) initiates

the computation of the maneuver-related data for display; i.e., burn attitude, TGT HA and HP, burn time (TGO), and the delta velocity in body coordinates (VGO X, Y, and Z). When ST CRT TMR (item 40) is executed, the CRT timer will start counting down to TIG. When guidance has completed its computations, the burn data items should be confirmed per final burn pad.

Discrepancies between items computed by guidance and corresponding items copied on the burn pad may indicate a data entry error. Any discrepancies should be resolved to avoid a delayed and/or improper burn. It may be necessary to reenter target data and reexecute LOAD (item 39) and ST CRT TMR (item 40).

When the crew is satisfied that the target and computed burn data parameters are correct, the commander will maneuver the Orbiter to the burn attitude. (The attitude error needles are nulled to achieve the proper attitude.)

#### 5.2.4 Propellant System

```
                2-OMS BURN PREP
TIG-4
      L, R OMS
P 08      ✓TK ISOL (four) - OPEN (tb-OP)
          ✓XFEED (four) - CLOSE (tb-CL)
          014:F ✓L OMS ENG VLV - ON
          016:F ✓R OMS ENG VLV - ON
```

The 2-OMS BURN PREP consists of verifying the OMS propellant system valves in the configuration required for the OMS burn.

The TK ISOL valves must be open to allow propellant flow from the tanks to the engine. The XFEED valves are closed to prevent propellant from flowing from one tank into the other fuel or oxidizer tank due to unequal tank pressures between the left and right systems. The talk-back (tb) indicators (OP or CL) display the position of the valve associated with the switch. The talk-back will be barber pole while the valve is in transit. The L and R OMS ENG VLV switches must be ON enabling the OMS engine control valves and allowing these valves to be commanded open by the GPC's if the OMS ENG L and OMS ENG R switches are in the ARM or ARM/PRESS position.

### 5.2.5 On-Orbit 2-OMS Burn Cue Card

At approximately TIG - 2, the crew will initiate the procedures on the cue card.

#### ON ORBIT 2-OMS BURN

TIG-2:00 ✓CNTLR PWR (two) - ON  
✓MM 302  
✓GMBL TRIM - CORRECT  
✓ENG SEL - ITEM 15  
✓ATT - CORRECT  
✓ADI ATT - INRTL  
ERR - HIGH

The crew will verify critical items just prior to TIG to provide an extra margin of safety.

-1:00 L,R OMS He PRESS/VAP ISOL A (two) - GPC  
✓B (two) - CLOSE

The helium pressure/vapor isolation (He PRESS/VAP ISOL A and B) switches are placed in the GPC position allowing the GPC to control the pressurization of the OMS propellant system through leg A of the He pressurization systems. In the GPC mode, the GPC's command the He PRESS, and the VAP ISOL valves 1 and 2 open simultaneously with the engine valves at TIG. The He PRESS/VAP ISOL B switches are left in the CLOSE position until immediately after TIG, then placed in the GPC position. This reduces the possibility of over pressurizing the propellant system due to the parallel He PRESS valves (A and B) being opened simultaneously by the GPC at TIG. The overpressurization problem can occur as a result of a 'hydraulic hammering' effect due to rapidly filling the lines between the He PRESS/VAP ISOL valves and the check valves. If the lines between these two points are in a low pressure condition, the pressure surge, due to both He PRESS/VAP ISOL valves A and B being commanded open simultaneously, can rupture a burst disc. (Relief pressure is 286 psi and burst pressure is 308 to 313 psi.) At OMS cutoff, the He PRESS/VAP ISOL valves will be commanded closed simultaneously with the engine valves (fig. 2-1).

DAP - AUTO  
DFI RCDRS PCM - CONT RCD (tb-gray)  
WB MSN - CONT RCD (tb-gray)

L,R OMS ENG (two) - ARM/PRESS  
✓N2 P VLV (two) - OP (on CRT 3)

|   |
|---|
| <p style="text-align: center;"><b>WARNING</b></p> <p>If both N<sub>2</sub> P VLV not OP, do not execute on-orbit burn</p> |
|---|

--:10 EXEC (Guidance initiate, Gimbals Trim)

TIG        ✓Pc, ΔVTOT, ENG vlv  
            L, R OMS He PRESS/VAP ISOL B (two) - GPC

CUTOFF  
      +:02 ✓Purge complete  
            L,R OMS ENG (two) - OFF

DAP - AUTO is selected to operate the TVC in the AUTO mode.

The DFI RCDRS PCM switch and the WB MSN switch are placed in the CONT RCD position to initiate continuous recording of the Development Flight Instrumentation (DFI) parameters. Because of the extensive use of tape (15 IPS) in this mode, this step should be delayed as long as possible before TIG.

Both OMS ENG switches located on panel C3 are placed in the ARM/PRESS position for the 2-OMS burn. This enables the left and right engine control valves (1 and 2) through the left and right OMS ENG VLV switches (on panels 014,016). When commanded open by the GPC's, these valves allow N2 pressure to flow to open the OMS engine bipropellant valves, thus firing the engines. The ARM/PRESS switch position also provides a control signal to open the nitrogen pressurization valve (N2 P VLV) providing a continuous supply of nitrogen from the N2 tank for bipropellant valve operation and engine purge.

The crew is warned not to execute the burn if both N2 P valves are not open. The status of the N2 P valves is shown on the GNC SYS SUMM 2 (BFS) display on CRT 3. If these valves are not open (indicating a failed closed condition), operation of the OMS engines will deplete the N2 from the accumulator, thus preventing subsequent OMS burns needed for deorbit.

At TIG - 10 sec, the word EXEC begins to flash on the DEORB MNVR EXEC display. The crew should, at this time, press the EXEC push-button on the CRT keyboard. Guidance is initiated enabling the GPC's to fire the engine automatically at TIG, and the engine gimbals are driven to their trim position.

At TIG, the crew should verify the proper OMS engine chamber pressure (Pc) indication on panel F7, the ΔVTOT is incrementing properly (on the DEORB MNVR EXEC DISPLAY), and the proper ENG valve position (displayed on the GNC SYS SUMM 2 DISPLAY as a percent of full open). The left and right OMS He PRESS/VAP ISOL B switches should be placed in the GPC position at this time to ensure He pressure redundancy for the OMS propellant tanks.

In the case of He pressure failure in either system, the recommended procedure is to continue the burn until reaching chamber pressure or inlet pressure red line, and to shutdown on the red line. At 37 percent remaining or less, the propellant system has almost full blowdown capability, i.e., nearly all the propellant remaining can be utilized even with a propellant pressurization failure.

The crew should observe OMS system information to verify proper systems operation. After observing proper Pc indications, the OMS oxidizer and fuel tank pressures displayed on panel 03 should be monitored to ensure that the He pressure valves and vapor isolation valves are functioning properly.

The expected pressure (249 to 257 psia) will be maintained throughout the burn provided the pressure regulators are working properly. The engine inlet pressure (ENG IN P) for the fuel and oxidizer (FU and OXID) on the GNC SYS SUMM 2 (BFS) display will be lower than their pre-burn values because of pressure drop due to propellant flow through the system, but should be in the range - OXID 192 to 212 psia and FU 209 to 228 psia. The ENG BALL VLV (bipropellant valves) positions displayed on the GNC SYS SUMM 2 (BFS) display should indicate 100 percent open. Intermediate positions may indicate a problem either in the GN<sub>2</sub> pressure system or in the valves themselves.

In the event of loss of GN<sub>2</sub> pressure during the burn (indicated by the N<sub>2</sub> REG PRESS on the GNC SYS SUMM 2 display dropping to zero) and if it is necessary to continue the burn on the remaining good engine, the propellants for the failed engine are available to the good engine via the crossfeed lines. Crossfeed may be called for as required to be consistent with mission rules and when required to keep the Orbiter Y-body axis center of gravity within acceptable limits.

During the burn, the crew should monitor the ADI error needles, TGO, and VGO. The ADI error needles will indicate how well flight control is conforming to guidance commands (i.e., pointing the thrust vector in the desired direction). TGO and VGO should be decrementing at the expected rate. If TGO is counting down at a rate different than 1 second of TGO per second of real time, one of the following conditions may exist.

- A. Orbiter weight (WT, item 21) may be inaccurate and thus cause acceleration levels to differ from those expected by guidance.
- B. One or both of the OMS are experiencing abnormal thrust levels.

The crew should frequently monitor the GMBL CK portion of the DEORB MNVR EXEC display during the burn for indications of a hardover condition (persisting indications of  $\pm 7^\circ$  gimbal yaw and/or  $\pm 6^\circ$  gimbal pitch). If a hardover condition exists, the crew should select the redundant gimbal actuator (via the DEORB MNVR EXEC display). Delay in this case causes extended use of the RCS jets for attitude control, thus rapidly depleting the RCS propellants. The crew confirms engine cutoff by monitoring the OMS PRESS Pc displays on panel F7. The expected values of VGO, TGO, and CURR HA and HP should be verified on the DEORB MNVR EXEC display. Residual velocities may be nulled, if required, using the THC. Due to the cross-coupling of -Z translation into +X, residuals should be nulled in the following order  $\pm Y$ ,  $\pm Z$ ,  $\pm X$ . After the crew observes cutoff indications (Pc = 0), they should verify, via the GNC SYS SUMM 2 (BFS) display, that the OMS ENG VLV's are closed and they should monitor the OMS N<sub>2</sub> TK P (nitrogen tank pressure) for a 100 psi drop indicating the engine purge has taken place. The purge is complete after cutoff +2 seconds. After the engine purge is complete, the OMS ENG switches are placed in the OFF position. This disables the engine control valves and closes the OMS N<sub>2</sub> P VLV (CL indication on GNC SYS SUMM 2 BFS display). The OMS ENG switches are not set to OFF until after the purge has taken place to ensure that the nitrogen accumulator is pressurized. Note that the OMS ENG switches must be in the

ARM/PRESS position and PURGE ENA (item 19) must be selected on the MNVR display (fig. 2-9) for the nitrogen purge of the OMS engines to occur.

### 5.2.6 Post Burn Activities

.....IF BURN NOT NOMINAL.....

Δ TIG    ( )    :   

| VGO | RESIDUALS | POST TRIM | ATT |
|-----|-----------|-----------|-----|
| X   | ( )    o  | R         |     |
| Y   | ( )    o  | P         |     |
| Z   | ( )    o  | Y         |     |

.....

Following the completion of the procedures on the cue card, the crew returns to the Orbit OPS Checklist to complete the OMS burn procedures. If the burn was not nominal (i.e., the Orbiter fails to achieved the desired ΔV), the above information is recorded for relaying to the ground.

#### POST BURN RECONFIGURATION

B F6/F8    FLT CNTLR PWR (two) - OFF  
 C C3        DFI RCDRS WB MSN - STBY (tb-bp)  
 P 08        L,R OMS He PRESS/VAP ISOL (four) - CLOSE  
 R11        DFI WB MSN PWR - OFF

#### NOTE

DFI RCDRS PCM - HI SAMPLE  
 at C/O +15:00

The OMS propellant system is returned to the normal on-orbit configuration by closing the four L,R OMS He PRESS/VAP ISOL valve switches on panel 08. The WB MSN recorders are switched to OFF to conserve power.

### 5.3 1-OMS ON-ORBIT BURN FLIGHT PROCEDURE

The 1-OMS on-orbit burn procedure is similar to the 2-OMS burn procedure. However, the mid-burn crossfeed option necessitates subtle differences, which are explained in this section.

#### 5.3.1 General Preparations

##### 1-OMS BURN, ON-ORBIT

R11 DFI WB MSN PWR - ON  
√DFI WB MSN RCDR - FWD CNTL  
B C6 Install ON-ORBIT 1 OMS BURN Cue Card (two)  
(F6,F8)  
CRT1 √GNC, OPS 302

|                        |
|------------------------|
| 1: GNC DEORB MNVR EXEC |
| 3: BFS, GNC SYS SUMM 2 |

C F7 OMS PRESS  
He TK P L,R > 2500 psia  
N2 TK P L,R > 2250 psia

|   |
|---|
| - WARNING   |
| If OMS PRESS not within limits,<br>do not execute on-orbit burn |

#### 5.3.2 OMS TVC Gimbal Check

##### GIMBAL CK

C CRT1 SECONDARY CHECK  
Perform SEC L(R) GMBL CK  
PRIMARY CHECK  
Perform PRI L(R) GMBL CK

\* If down arrow(s) or M's: \*  
\* Select good GMBL \*

### 5.3.3 Load Target Data and Maneuver to Attitude

LOAD TGT DATA and MNVR  
B F6/F8 FLT CNTLR PWR (two) - ON  
ADI ATT (two) - INRTL  
ERR (two) - as reqd  
RATE (two) - as reqd  
C CRT1 Load TGT DATA per BURN PAD  
Confirm loaded data  
LOAD - ITEM 39 EXEC  
ST CRT TMR - ITEM 40 EXEC  
Confirm BURN DATA per BURN PAD:  
RHC Mnvr to BURN ATTITUDE  
(Compare ADI ATT with CRT BURN ATT)

### 5.3.4 Propellant Systems

OMS BURN PREP  
TIG-4  
✓L,R OMS TK ISOL (four) - OPEN (tb-OP)  
✓L,R OMS XFEED (four) - CLOSE (tb-CL)  
014:F ✓L(R) OMS ENG VLV - ON  
(016:F)

The 1-OMS burn preparation consists of changing the OMS system propellant valves to support a burn either with or without a mid-burn crossfeed (sec. 5.1.5, Mid-burn Crossfeed).

The TK ISOL and XFEED valves are configured the same as for the 2-OMS burn. The L OMS ENG VLV switch must be ON enabling the OMS engine control valve and allowing this valve to be commanded open by the GPC's at the appropriate time. Note that for a right OMS burn the R OMS ENG VLV must be on.

At this point the crew refers to the 1-OMS BURN Cue Cards mounted on F6/F8.

### 5.3.5 1-OMS Burn Cue Card

PERFORM ON-ORBIT 1-OMS BURN  
Cue Card, then:

ON ORBIT  
1-OMS BURN  
TIG -2:00 ✓CNTLR PWR (two) - ON  
✓MM302  
✓GMBL TRIM - CORRECT  
✓ENG SEL - CORRECT  
✓ATT - CORRECT  
✓ADI ATT - INRTL  
ERR - HIGH



On entering the 1-OMS BURN Cue Card, the crew verifies critical items on the DEORB MNVR EXEC display. If any changes are made to items other than TRIM, the guidance function must be updated by reexecuting LOAD (item 39). If LOAD is reexecuted, the CRT timer must also be restarted (item 40).

The He PRESS/VAP ISOL A and B switches for the selected system are opened at 2-second intervals to reduce the possibility of a pressure surge adversely affecting the He pressure lines between the He PRESS/VAP ISOL valves and the check valves. If the lines between these two points are in a low pressure condition, the pressure surge due to both He PRESS/VAP ISOL valves A and B being commanded open simultaneously may rupture the burst disc.

```
-1:00 Selected OMS He PRESS/VAP ISOL A - OPEN
      .....wait 2 sec...           B - OPEN

      .....If MID-BURN XFEED planned.....
      .Other OMS He PRESS/VAP ISOL A - OPEN .
      .....wait 2 sec...           B - OPEN .
      .....
```

If the crossfeed is planned, both L and R He PRESS/VAPOR ISOL A and B switches are opened to allow pressurization of the L and R OMS propellant tanks. The GPC position is not usable here since the L OMS burn software only opens the corresponding (left) He PRESS/VAPOR ISOL valves. Switching propellant tanks mid-burn would cause feed from the unpressurized right propellant system.

```
DAP - AUTO
DFI RCDRS PCM - CONT RCD (tb-gray)
WB MSN - CONT RCD (tb-gray)
```

```
Selected OMS ENG - ARM/PRESS
✓Other OMS ENG - OFF
✓Selected N2 P VLV - OP (CRT 3)
```

|   |
|---|
| <p><b>WARNING</b><br/>         If selected N2 P VLV not OP,<br/>         do not execute on-orbit burn</p> |
|---|

```
-:10 EXEC (Guidance initiate, Gimbals Trim)
TIG ✓Pc, ΔVTOT, ENG VLV
```

The remaining steps on the cue card are the same as the 2-OMS burn, unless a mid-burn crossfeed is accomplished.

```
.....If MID BURN XFEED.....
.
. CUE [ ] [ ] ΔVTOT ( [ ] [ ] % SEL OMS PRPLT) .
. L,R OMS XFEED - OPEN .
. SEL OMS TK ISOL - CLOSE .
.....
```

If a mid-burn crossfeed (sec. 5.1.5) is to be accomplished, the PLT will monitor the cues, percent L OMS PRPLT, and  $\Delta V$  TOT, for indications to start the crossfeed operation. It is assumed in this procedure that the L OMS burn will initially use L OMS propellants. (Likewise it is assumed that a R OMS burn will initially use R OMS propellants.) The PLT will accomplish the switching sequence at the instant the percent L OMS PRPLT or  $\Delta V$  TOT reaches the appropriate values. The  $\Delta V$  TOT is the more accurate of the two indications, and, given a disparity between the cues, it should be used. Note that these procedures can be executed starting with either OMS engine.

During the crossfeed reconfiguration (which should be accomplished as quickly as possible) it can be seen that there is momentarily an open line between the left and right propellant tanks (during the steps L,R OMS XFEED - OPEN and SEL OMS TK ISOL - CLOSE). This brief condition is necessary to ensure that there is always propellant under pressure being supplied to the operating engine.

The L OMS He PRESS/VAP ISOL A,B valves are closed after the crossfeed configuration to prevent unnecessary pressurization of the L OMS propellant system.

CUTOFF  
 +:02 ✓PURGE COMPLETE  
 L,R OMS ENG - OFF

The procedures at OMS engine cutoff are the same as those for the 2-OMS burn (sec. 5.2.5).

### 5.3.6 Post Burn Activities

The post burn activities for the 1-OMS burn are similar to the 2-OMS procedures (sec. 5.2.6).

.....IF BURN NOT NOMINAL.....

|              |     |  |   |  |  |
|--------------|-----|--|---|--|--|
| $\Delta$ TIG | ( ) |  | : |  |  |
|--------------|-----|--|---|--|--|

| VGO RESIDUALS |     |  |   | POST TRIM ATT |  |  |
|---------------|-----|--|---|---------------|--|--|
| X             | ( ) |  | o |               |  |  |
| Y             | ( ) |  | o |               |  |  |
| Z             | ( ) |  | o |               |  |  |

.....

### 5.3.7 1-OMS Post Burn Reconfiguration

#### OMS POST BURN RECONFIGURATION

|     |       |                                  |
|-----|-------|----------------------------------|
| B   | F6/F8 | FLT CNTLR PWR (two) - OFF        |
| C   | C3    | DFI RCDRS WB MSN - STBY (tb-bp)  |
| P   | 08    | L,R OMS                          |
|     |       | He PRESS/VAP ISOL (four) - CLOSE |
|     |       | XFEED (four) - CLOSE (tb-CL)     |
|     |       | TK ISOL (four) - OPEN (tb-OP)    |
| R11 |       | DFI WB MSN PWR - OFF             |

#### NOTE

DFI RCDRS PCM - HI SAMPLE  
at C/O + 15:00

Both propellant systems are returned to the standard on-orbit configuration. The reconfiguration sequence given may call for some switches to be moved to their current position. This sequence was adopted for the sake of simplicity and the need to cover all options that may have been used.

The DFI WB MSN power is turned off after seat egress. Note also that, since the DFI PCM recorders were left on at the completion of this procedure (to satisfy FRD requirements), they must be turned off 15 minutes later.



SECTION 6  
DTO 142 OMS PERFORMANCE PROCEDURES

## 6.1 INTRODUCTION

This section describes the procedures that are currently planned to accomplish Detailed Test Objective (DTO) 142 (OMS 3 and OMS 4 on STS-1). Because of the similarity to the 1-OMS burn procedures with crossfeed (sec. 5.3), a detailed step-by-step breakdown of the checklist procedures will not be given here. Only those areas that are unique to these procedures will be covered.

## 6.2 BACKGROUND

The purpose of the Functional Test Objectives (FTO's) comprising this DTO is to verify the performance of the OMS propellant crossfeed subsystem in a low-g environment. Two burns are planned to meet these objectives. The first FTO burn (3rd mission burn, OMS 3) will be accomplished by thrusting with the right OMS using propellants from the left OMS pod (FTO 142-01). The second FTO burn (OMS 4) will be accomplished by thrusting with the left OMS using propellants from the right OMS pod (FTO 142-02). Both of these burns are PEG 7 (external  $\Delta V$ ) burns with only  $\Delta VY$  targeted velocities ( $\Delta VX$  and  $\Delta VZ$  are set to zero). This means that the onboard guidance will target the selected thrust vector at the true Local Vertical, Local Horizontal (LVLH) +Y axis for the selected Time of Ignition (TIG). Figure 6-1 shows the effect these out-of-plane burns will have on the orbit. The direction of LVLH +Y does not perceptibly change between OMS 3 and OMS 4. Onboard guidance also adds a 'heads down' constraint (LVLH roll =  $180^\circ$ ) to arrive at the attitude displayed on the MNVR display.

Figure 6-2 shows that to maintain a heads-down attitude and align the correct OMS thrust vector for each burn, the crew would have to pitch the vehicle  $35^\circ$ , roll  $-123^\circ$ , and yaw  $19^\circ$  between OMS 3 and OMS 4. Note that this is not a pure roll maneuver because of the orientation of the thrust vector for each OMS engine (fig. 6-3). For the purposes of these burns, this is an unnecessary maneuver.

Performing a body yaw of  $-24^\circ$  (left) following the OMS 3 burn would align the left OMS thrust vector with adequate accuracy for the OMS 4 burn. Note that a body yaw of  $-24^\circ$  will show up on the ADI as  $+24^\circ$  due to the vehicle orientation with respect to the RELMAT (i.e., roll =  $180^\circ$ ).

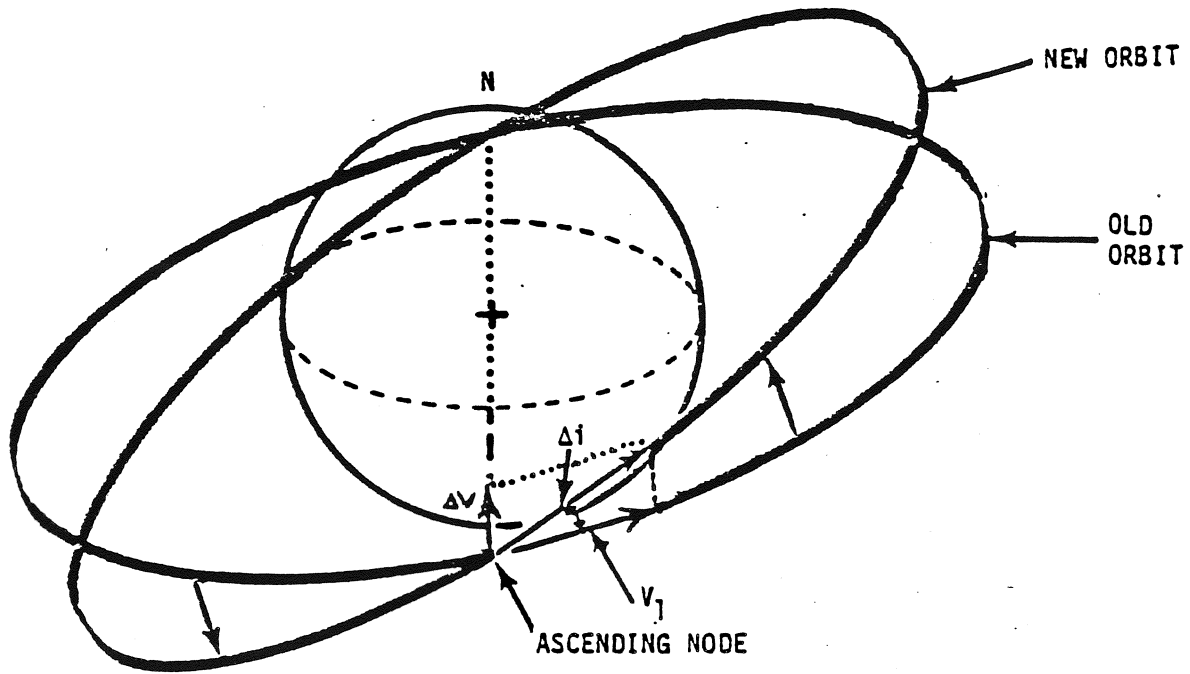


Figure 6-1.- Orbital plane change.

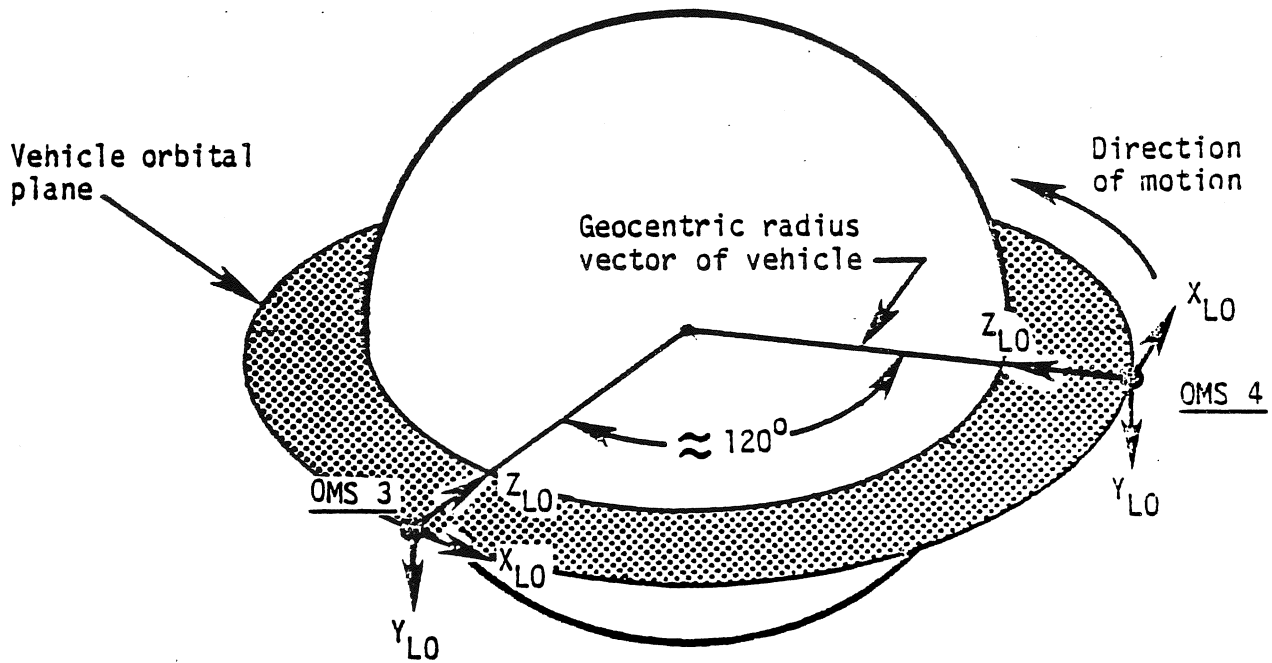


Figure 6-2.- LVLH reference frame.

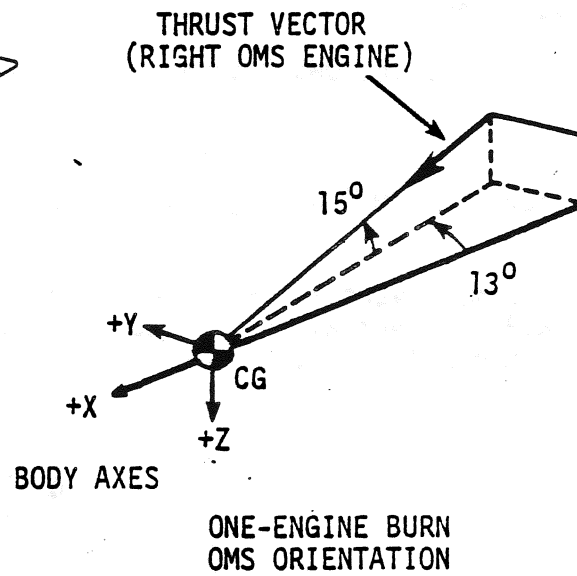
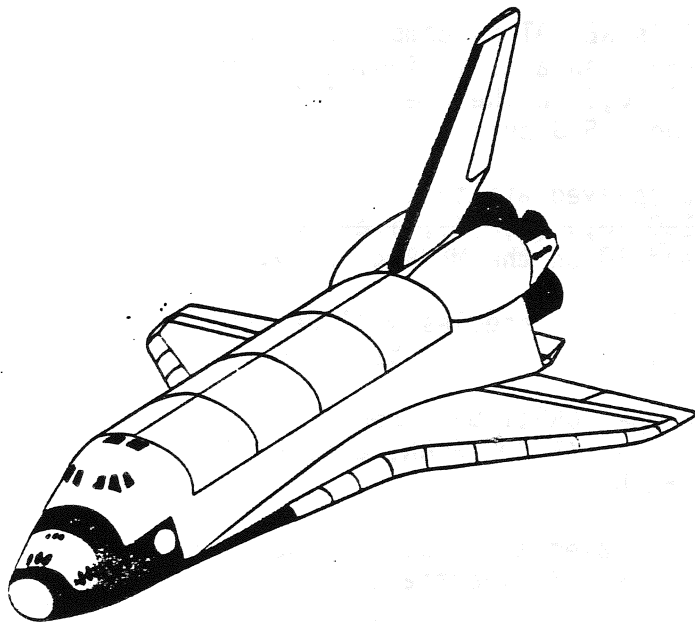


Figure 6-3.- OMS engine alignment.

### 6.3 SYNOPSIS OF THE OMS 3/OMS 4 PROCEDURES

| <u>Procedure Step</u>   | <u>Comments</u>   |
|---|---|
| 1. MCC will uplink new OPS 3 RELMAT and burn pads for OMS 3 and OMS 4.      | o This RELMAT is computed to give the crew a R,P,Y indication of 180,0,0 on the inertial ADI for the OMS 3 burn.  |
| 2. Crew loads OMS 3 targets and selects INRTL on the ADI.                   | o Displayed attitude should be; 180, 0,0 (R,P,Y); items 8, 9, and 10 on the MNVR display.   |
| 3. Crew maneuvers to the OMS 3 attitude.                                    | o ADI error needles will center and ADI ball will be 180,0,0.   |
| 4. Crew executes OMS 3 burn.  | o As per ORBIT OPS Checklist p. 9-9 (R OMS BURN, L to R XFEED).   |
| 5. Crew loads OMS 4 targets.  | o Displayed attitude will be 57,35, 19 (R,P,Y) inertial.  |
| 6. Crew maneuvers to 180,0,24 (R,P,Y) inertial (displayed on the ADI ball). | o The crew can arrive at this attitude by executing a left (-) body yaw of 24° from the OMS 3 attitude, as explained in section 6-2.<br>o This will <u>not</u> center the error needles at this point; these are referenced to the attitude displayed on the MNVR display (57,35,19).   |
| 7. Crew executes OMS 4 burn.  | o As per ORBIT OPS Checklist, p. 9-13 (L OMS BURN, R TO L XFEED).<br>o As soon as the burn initiates, the error needles will indicate the thrust vector misalignment. They will no longer be referenced to the MNVR display attitude. Therefore, once the burn begins, the error needles should drop to acceptable limits and will provide appropriate indication of the engine gimbal health. Widely divergent error needles would be cause to terminate the burn. |



SECTION 7  
DTO 174 GNC, FLIGHT CONTROL AND  
RCS MANEUVER PERFORMANCE

## 7.1 INTRODUCTION

This section describes the procedures that are currently planned to accomplish Detail Test Objective (DTO) 174. Because of the similarity to the RCS translation procedures covered in section 4, a detailed explanation of the checklist procedures will not be given here. Instead, only those areas will be covered that are unique to these procedures. The Flight Requirements Document (FRD) should be referenced for a detailed description of test requirements.

## 7.2 BACKGROUND

The purpose of this test is twofold: first, to demonstrate the combined inflight operation of the Guidance, Navigation, and Control (GNC) System; the Flight Control System; the RCS System; and pertinent software by performing representative maneuvers in various control modes and, second, to allow an initial confidence level to be established in the Orbiter control system.

Table 7-I shows typical attitudes and propellant consumption for the RCS Functional Test Objectives (FTO's). Some FTO's will be accomplished through normal operation of the vehicle, while others will be performed during dedicated on-orbit tests. On STS-1, only RCS rotation FTO's are currently planned (see STS-1 Crew Activity Plan, JSC-12799), due to the limited RCS propellant budget.

Table 7-II lists the current schedule for STS-1 RCS FTO's. The procedures for these RCS rotation tests have been developed for STS-1 and are described in section 7.3. The procedures for the remaining RCS FTO's (see Flight Requirements Document, JSC-10780) will be developed for subsequent test flights and included in revisions to this handbook.

TABLE 7-I.- RCS FUNCTIONAL TEST OBJECTIVES<sup>a</sup>

| Event <sup>b</sup>                         | Roll,<br>deg | Attitude<br>pitch,<br>deg | Yaw,<br>deg | Attitude<br>reference | Propellant<br>consumed,<br>lb |
|--|--------------|---------------------------|-------------|-----------------------|-------------------------------|
| AUTO MNVR TO +XLV, YPOP                    | 0            | 270.0                     | 0           | LVLH                  | 21.0                          |
| MAN XLAT ACCEL TEST (174-06)               | 0            | 270.0                     | 0           | LVLH                  | 427.4                         |
| MAN XLAT PULSE TEST (174-05)               | 0            | 270.0                     | 0           | LVLH                  | 14.0                          |
| MAN ROT DISC TEST (174-03)<br>(VERN JETS)  | 0            | 318.0                     | 0           | LVLH                  | 17.1                          |
| MAN ROT PULSE TEST (174-01)<br>(VERN JETS) | 0            | 334.0                     | 0           | LVLH                  | .8                            |
| MAN ROT ACCEL TEST (174-02)<br>(VERN JETS) | .3           | 354.3                     | .2          | LVLH                  | 4.6                           |
| MAN ROT ACCEL TEST (174-02)<br>(PRCS)      | N/A          | N/A                       | N/A         | N/A                   | 46.7                          |
| MAN ROT PULSE TEST (174-01)<br>(PRCS)      | N/A          | N/A                       | N/A         | N/A                   | 14.4                          |
| MAN ROT DISC TEST (174-03)<br>(PRCS)       | N/A          | N/A                       | N/A         | N/A                   | 65.5                          |

<sup>a</sup>N/A indicates attitude cannot be predicted pre-flight due to uncontrolled cross-coupling in DAP free drift mode.  
<sup>b</sup>FTO 174-04 has been deleted.

TABLE 7-II.- RCS FUNCTIONAL TEST OBJECTIVE SCHEDULE FOR STS-1<sup>a</sup>

| FTO<br>number | Title                                       | Scheduled<br>DD/HH:MM:SS MET   | Remarks  |
|---------------|---|--|--|
| 174-01        | Manual rotation pulse test                  | Not specifically<br>scheduled  | Accomplished by normal<br>operations during COAS<br>calibrations.                                    |
| 174-02        | Manual rotation accel test                  | 01/08:59:00<br>01/09:03:00   | DAP: A with PRCS<br>DAP: B with VRCS   |
| 174-03        | Manual rotation disc rate<br>test           | 01/08:55:00<br>01/09:09:00   | DAP: A with PRCS<br>DAP: B with VRCS   |
| 174-04        | Auto RCS rotational<br>maneuver performance | Not specifically<br>scheduled  | Data taken throughout<br>flight  |
| 174-08        | Attitude hold<br>performance                | 01/09:35:00<br>01/10:05:00<br>01/10:37:00<br>00/04:00:00<br>00/04:30:00<br>00/03:25:00 | 8.1 -ZLV, YPOP: PRCS 20 DB<br>8.2 60 DB<br>8.3 100 DB<br>8.4 VRCS 10 DB<br>8.5 .50 DB<br>8.6 1.00 DB |
| 174-09        | PTC performance                             | 00/10:20:00<br>00/10:54:00<br>00/08:40:00<br>00/09:50:00                               | 9.1 PTC: PRCS 50 DB<br>9.2 150 DB<br>9.3 VRCS 10 DB<br>9.4 50 DB                                     |

<sup>a</sup>These schedule times taken from CAP dated 04/14/80 and are subject to change.

### 7.3 MANUAL ROTATION FTO's

The manual rotation FTO's are not dependent on the initial vehicle attitude<sup>1</sup> and they can be initiated from any desired inertial attitude. Figure 7-1 (DAP CONFIG DISPLAY) shows the Digital Auto Pilot (DAP) parameters planned for the RCS FTO's.

#### 7.3.1 Manual Rotation Discrete Rate Test (Verniers) (FTO 174-03)

This test is accomplished with the DAP in B/MAN/VERN and DAP ROT: DISC/DISC/DISC. The test is accomplished by deflecting the RHC in each axis sequentially, holding it 30 seconds, returning it to the detent and waiting another 30 seconds before proceeding with the next axis. Care should be taken to ensure the RHC is deflected far enough to activate the jets, yet not exceed the soft stop. Also, care should be taken to deflect the RHC in only one axis at a time to ensure each command is a pure one-axis command.

#### 7.3.2 Manual Rotation Acceleration Test (Verniers) (FTO 174-02)

This test is accomplished for each axis sequentially (R,P,Y) by deflecting the RHC in the positive direction for 5 seconds, returning it to the detent for 30 seconds, then deflecting it in the negative direction for 5 seconds, and waiting 30 seconds before testing the next axis. The test is performed with the DAP in a free drift mode, therefore rotation rates will build up due to cross-coupling. No attempt should be made to manually null these cross-coupled rates during the test; they are nulled at the completion of the test by selecting DAP: DISC/DISC/DISC.

#### 7.3.3 Manual Rotation Acceleration Test (PRCS) (FTO 174-02)

This test is very similar to the vernier accel mode test except, of course, for the jets selected and length of time the RHC is deflected in each axis.

---

<sup>1</sup>It is desirable to have the Earth visible out the windows.

| 2021/020/<br>TRANSLATION |      | DAP CONFIG |               | XX X  | XXX/XX:XX:XX  |
|--------------------------|------|------------|---------------|-------|---------------|
| PULSE                    |      | A          | 16            | B     | XXX/XX:XX:XX  |
|                          |      | 1          | <u>0.08</u>   |       | <u>0.05</u>   |
| ROTATION                 |      |            |               |       |               |
| DISC RATE                | NORM | 2          | <u>0.5</u>    | 17    | <u>0.5</u>    |
|                          | VERN | 3          | <u>0.20</u>   | 18    | <u>0.10</u>   |
| PULSE                    | NORM | 4          | <u>0.10</u>   | 19    | <u>0.04</u>   |
|                          | VERN | 5          | <u>0.010</u>  | 20    | <u>0.002</u>  |
| COMP                     | NORM | 6          | <u>.00</u>    | 21    | <u>.00</u>    |
|                          | VERN | 7          | <u>.000</u>   | 22    | <u>.000</u>   |
| INERTIAS                 |      |            |               |       |               |
|                          |      |            |               | 31 IX | <u>X.XXX</u>  |
|                          |      |            |               | 32 IY | <u>X.XXX</u>  |
|                          |      |            |               | 33 IZ | <u>X.XXX</u>  |
| DEADBAND                 |      |            |               |       |               |
| ATT                      | R    | 8          | <u>10.000</u> | 23    | <u>01.000</u> |
|                          | P    | 9          | <u>10.000</u> | 24    | <u>01.000</u> |
|                          | Y    | 10         | <u>10.000</u> | 25    | <u>01.000</u> |
| RATE                     | NORM | 11         | <u>0.2</u>    | 26    | <u>0.2</u>    |
|                          | VERN | 12         | <u>.02</u>    | 27    | <u>.02</u>    |
| JET OPT                  | P    | 13         | <u>1</u>      | 28    | <u>1</u>      |
|                          | Y    | 14         | <u>1</u>      | 29    | <u>1</u>      |
| CNTL ACCEL               |      | 15         | <u>0</u>      | 30    | <u>0</u>      |

Figure 7-1.- DAP CONFIG for RCS test.

#### 7.3.4 Manual Rotation Disc Rate Test (PRCS) (FTO-03)

This test is similar to the vernier discrete rate test. Upon test completion, the vernier jets are selected to conserve propellant.

#### 7.4 POST TESTING CLEANUP

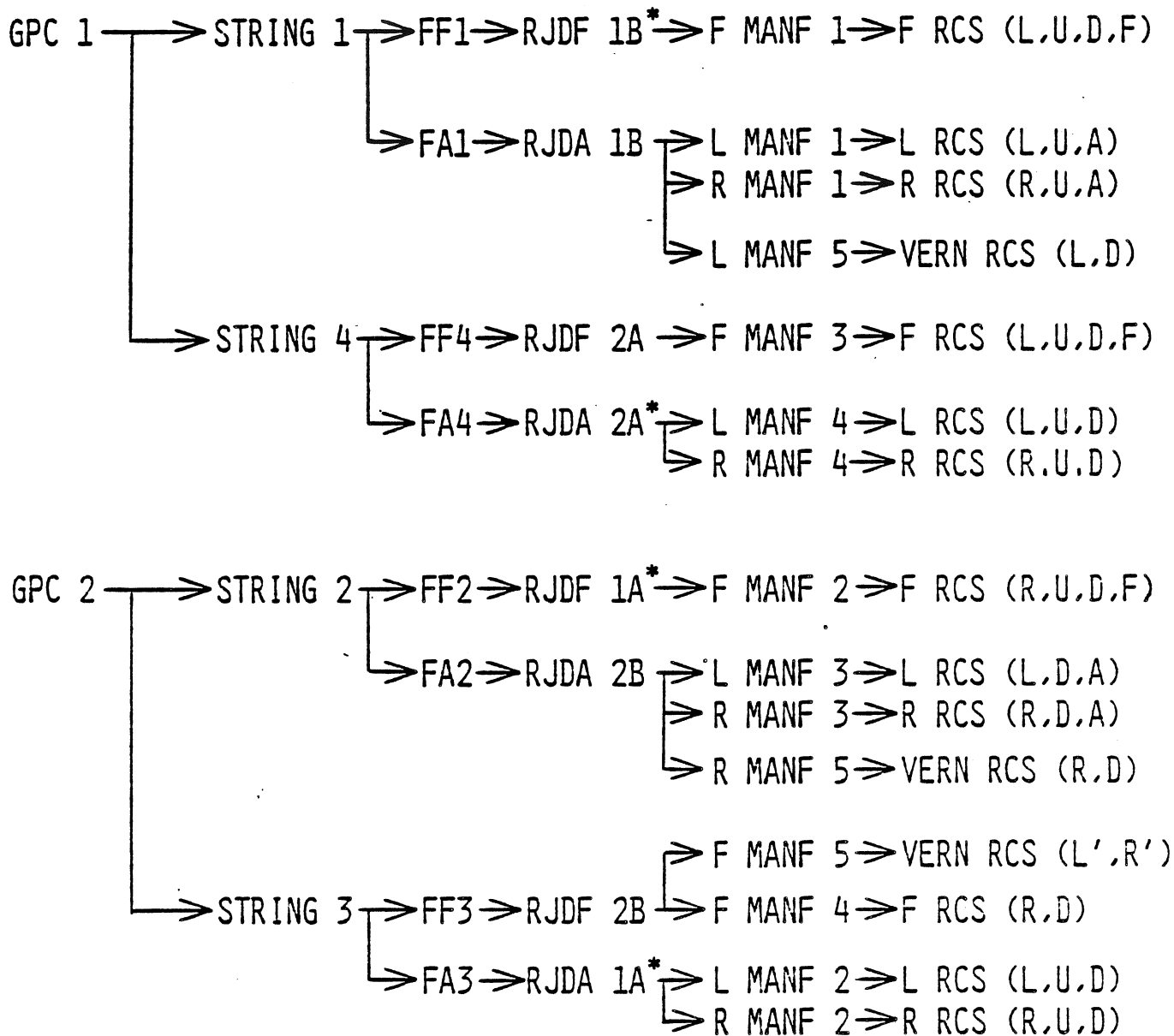
Following the completion of the RCS FTO's, several items are entered in the DAP CONFIG display to restore it to the nominal on-orbit configuration. STOP/ATT HOLD should be verified on the ORBIT display. The DAP is verified to be in the nominal configuration and FLT CNTLR PWR is turned off.



APPENDIX

MISCELLANEOUS INFORMATION

This appendix contains information that is STS-1 particular and is included here for reference.



NOTE: RJD's marked (\*) normally powered off during OPS 2 operations.

Figure A-1.- RCS command path for on-orbit operations (STS-1).



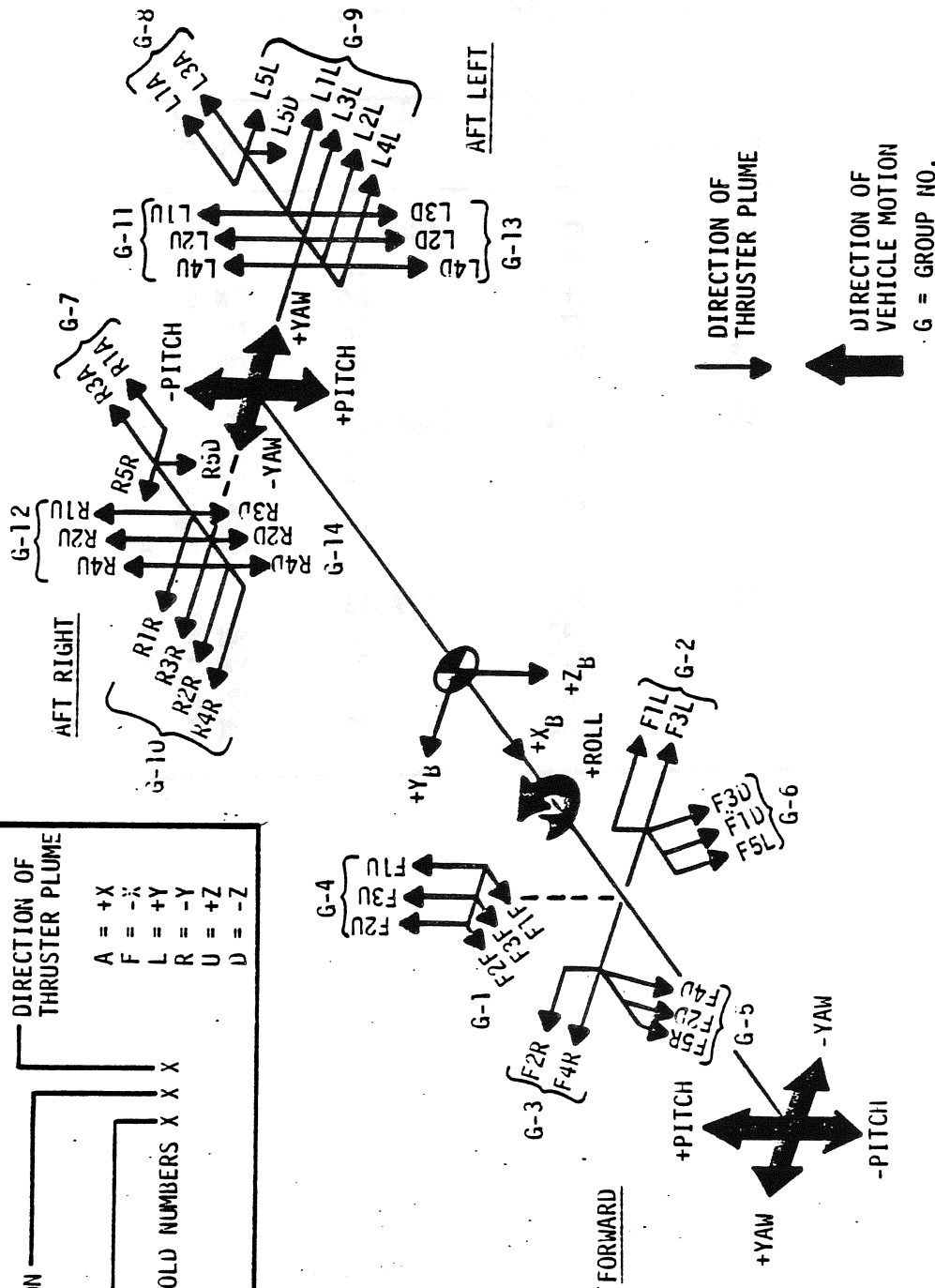
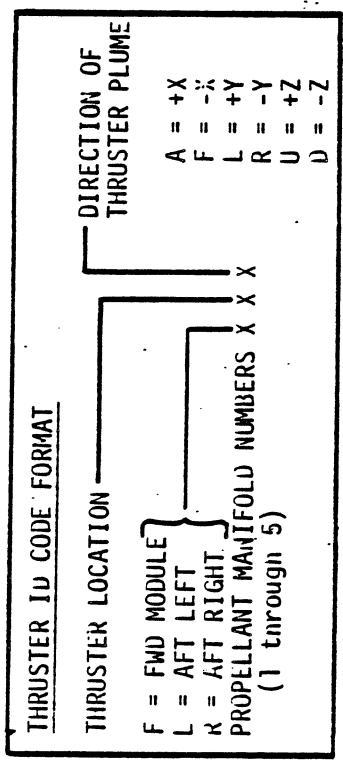


Figure A-2.- RCS jet location and thruster ID.

TABLE A-I.- FIRE COMMAND POWER MAP

| Jet manifold | Fire cmd MDM | RJD     | Driver power |
|--------------|--------------|---------|--------------|
| F1           | FF1          | RJDF-1B | MN A         |
| 2            | FF2          | 1A      | MN B         |
| 3            | FF4          | 2A      | MN C         |
| 4            | FF3          | 2B      | MN C         |
| 5            | FF3          | 2B      | MN C         |
| L1           | FA1          | RJDA-1B | MN B, A      |
| 2            | FA3          | 1A      | MN A, C      |
| 3            | FA2          | 2B      | MN C, B      |
| 4            | FA4          | 2A      | MN A, C      |
| 5            | FA1          | 1B      | MN B, A      |
| R1           | FA1          | RJDA-1B | MN B, A      |
| 2            | FA3          | 1A      | MN A, C      |
| 3            | FA2          | 2B      | MN C, B      |
| 4            | FA4          | 2A      | MN A, C      |
| 5            | FA2          | 2B      | MN C, B      |

TABLE A-II.- ATTITUDE MANEUVER FILE

| Rcd<br>no. | Event      | RCS<br>jets | Deadband |      | Discrete<br>rate,<br>deg/s | RCS propellant |              |              | Total<br>used,<br>lb |
|------------|------------|-------------|----------|------|----------------------------|----------------|--------------|--------------|----------------------|
|            |            |             | ATT      | Rate |                            | Fwd,<br>lb     | L Aft,<br>lb | R Aft,<br>lb |                      |
| 1          | 10° ROLL   | NORM        | N/A      | N/A  | 0.1                        | 0.75           | 1.75         | 1.75         | 4.25                 |
| 2          | 10° ROLL   | NORM        | N/A      | N/A  | 0.2                        | 0.50           | 2.00         | 2.00         | 4.50                 |
| 3          | 10° ROLL   | NORM        | N/A      | N/A  | 0.5                        | 0.75           | 4.21         | 4.21         | 9.17                 |
| 4          | 10° ROLL   | NORM        | N/A      | N/A  | 1.0                        | 1.00           | 7.87         | 7.87         | 16.74                |
| 5          | 10° +PITCH | NORM        | N/A      | N/A  | 0.1                        | 2.74           | 2.00         | 2.00         | 6.74                 |
| 6          | 10° +PITCH | NORM        | N/A      | N/A  | 0.2                        | 2.74           | 2.00         | 2.00         | 6.74                 |
| 7          | 10° +PITCH | NORM        | N/A      | N/A  | 0.5                        | 5.19           | 3.70         | 3.70         | 12.59                |
| 8          | 10° +PITCH | NORM        | N/A      | N/A  | 1.0                        | 9.60           | 6.89         | 6.89         | 23.38                |
| 9          | 10° -PITCH | NORM        | N/A      | N/A  | 0.1                        | 1.50           | 1.00         | 1.00         | 3.50                 |
| 10         | 10° -PITCH | NORM        | N/A      | N/A  | 0.2                        | 2.75           | 1.99         | 1.99         | 6.73                 |
| 11         | 10° -PITCH | NORM        | N/A      | N/A  | 0.5                        | 4.45           | 3.22         | 3.22         | 10.89                |
| 12         | 10° -PITCH | NORM        | N/A      | N/A  | 1.0                        | 9.35           | 6.64         | 6.64         | 22.63                |
| 13         | 10° YAW    | NORM        | N/A      | N/A  | 0.1                        | 1.75           | 1.75         | 1.50         | 5.00                 |
| 14         | 10° YAW    | NORM        | N/A      | N/A  | 0.2                        | 1.99           | 2.25         | 2.25         | 6.49                 |
| 15         | 10° YAW    | NORM        | N/A      | N/A  | 0.5                        | 4.42           | 3.71         | 3.71         | 11.85                |
| 16         | 10° YAW    | NORM        | N/A      | N/A  | 1.0                        | 9.36           | 8.67         | 8.67         | 26.70                |
| 17         | 10° ROLL   | VERN        | N/A      | N/A  | 0.05                       | 0.33           | 0.38         | 0.39         | 1.10                 |
| 18         | 10° ROLL   | VERN        | N/A      | N/A  | 0.1                        | 0.70           | 0.82         | 0.87         | 2.39                 |
| 19         | 10° ROLL   | VERN        | N/A      | N/A  | 0.2                        | 1.26           | 1.44         | 1.44         | 4.14                 |
| 20         | 10° ROLL   | VERN        | N/A      | N/A  | 0.5                        | 2.72           | 3.18         | 3.20         | 9.10                 |
| 21         | 10° +PITCH | VERN        | N/A      | N/A  | 0.05                       | 0.52           | 0.35         | 0.34         | 1.21                 |
| 22         | 10° +PITCH | VERN        | N/A      | N/A  | 0.1                        | 1.03           | 0.72         | 0.72         | 2.47                 |
| 23         | 10° +PITCH | VERN        | N/A      | N/A  | 0.2                        | 1.90           | 1.16         | 1.17         | 4.23                 |

TABLE A-II.- ATTITUDE MANEUVER FILE (Concluded)

| Rcd no. | Event            | RCS jets | Deadband |      | Discrete rate, deg/s | RCS propellant |           |           | Total used, lb |
|---------|------------------|----------|----------|------|----------------------|----------------|-----------|-----------|----------------|
|         |                  |          | ATT      | Rate |                      | Fwd, lb        | L Aft, lb | R Aft, lb |                |
| 24      | 10° +PITCH       | VERN     | N/A      | N/A  | 0.5                  | 4.18           | 2.75      | 2.75      | 9.68           |
| 25      | 10° -PITCH       | VERN     | N/A      | N/A  | 0.05                 | 0.45           | 0.35      | 0.35      | 1.15           |
| 26      | 10° -PITCH       | VERN     | N/A      | N/A  | 0.1                  | 0.98           | 0.65      | 0.67      | 2.30           |
| 27      | 10° -PITCH       | VERN     | N/A      | N/A  | 0.2                  | 2.05           | 1.36      | 1.36      | 4.77           |
| 28      | 10° -PITCH       | VERN     | N/A      | N/A  | 0.5                  | 3.95           | 2.49      | 2.49      | 8.93           |
| 29      | 10° YAW          | VERN     | N/A      | N/A  | 0.05                 | 0.47           | 0.57      | 0.59      | 1.63           |
| 30      | 10° YAW          | VERN     | N/A      | N/A  | 0.1                  | 1.16           | 1.29      | 1.33      | 3.78           |
| 31      | 10° YAW          | VERN     | N/A      | N/A  | 0.2                  | 2.26           | 2.63      | 2.64      | 7.53           |
| 32      | 10° YAW          | VERN     | N/A      | N/A  | 0.5                  | 3.61           | 4.37      | 4.35      | 12.33          |
| a33     | 3-axis auto MNVR | NORM     | 1.0      | 0.2  | 0.2                  | .0782          | .0836     | .0824     | .2443          |
| a34     | 3-axis auto MNVR | NORM     | 3.0      | 0.2  | 0.2                  | .0412          | .0480     | .0476     | .1367          |
| a35     | 3-axis auto MNVR | NORM     | 5.0      | 0.2  | 0.2                  | .0423          | .0447     | .0444     | .1314          |
| a36     | 3-axis auto MNVR | NORM     | 10.0     | 0.2  | 0.2                  | .0426          | .0394     | .0398     | .1213          |
| a37     | 3-axis auto MNVR | NORM     | 1.0      | 0.2  | 0.5                  | .0810          | .0680     | .0685     | .2175          |
| a38     | 3-axis auto MNVR | NORM     | 3.0      | 2.0  | 0.5                  | .0763          | .0624     | .0608     | .1995          |
| a39     | 3-axis auto MNVR | NORM     | 5.0      | 0.2  | 0.5                  | .0798          | .0655     | .0643     | .2096          |
| a40     | 3-axis auto MNVR | NORM     | 10.0     | 0.2  | 0.5                  | .0763          | .0627     | .0607     | .1997          |
| a41     | 3-axis auto MNVR | VERN     | 1.0      | 0.02 | 0.2                  | .0212          | .0224     | .0224     | .0659          |
| a42     | 3-axis MNVR XDAP | NORM     | 3.5      | 0.3  | 0.5                  | .1087          | .1660     | .1660     | .3407          |

<sup>a</sup>Propellant used per degree of MNVR based on 135° MNVR, limited data.

TABLE A-III.-- IH, LVLH, PTC FILE

| Rcd no. | Event              | RCS jets | Deadband |      | Discrete rate, deg/s | RCS propellant |              |              | Total used, lb/hr |
|---------|--------------------|----------|----------|------|----------------------|----------------|--------------|--------------|-------------------|
|         |                    |          | ATT      | Rate |                      | Fwd, lb/hr     | L Aft, lb/hr | R Aft, lb/hr |                   |
| 1       | IH X-POP 100 n.mi. | NORM     | 0.5      | 0.2  | N/A                  | 41.40          | 47.10        | 47.00        | 135.50            |
| 2       | IH X-POP 100 n.mi. | NORM     | 1.0      | 0.2  | N/A                  | 21.20          | 22.80        | 22.70        | 66.70             |
| 3       | IH X-POP 100 n.mi. | NORM     | 3.0      | 0.2  | N/A                  | 7.70           | 9.20         | 9.00         | 25.90             |
| 4       | IH X-POP 100 n.mi. | NORM     | 5.0      | 0.2  | N/A                  | 4.70           | 6.20         | 6.00         | 16.90             |
| 5       | IH X-POP 100 n.mi. | NORM     | 10.0     | 0.2  | N/A                  | 3.10           | 5.50         | 5.20         | 13.80             |
| 6       | IH X-POP 100 n.mi. | NORM     | 20.0     | 0.2  | N/A                  | 2.70           | 4.80         | 3.80         | 11.30             |
| 7       | IH X-POP 100 n.mi. | VERN     | 0.1      | 0.01 | N/A                  | 2.28           | 2.35         | 2.16         | 6.79              |
| 8       | IH X-POP 100 n.mi. | VERN     | 0.5      | 0.01 | N/A                  | 2.12           | 2.17         | 1.99         | 6.30              |
| 9       | IH X-POP 100 n.mi. | VERN     | 1.0      | 0.01 | N/A                  | 2.02           | 2.05         | 1.95         | 6.02              |
| 10      | IH X-POP 100 n.mi. | VERN     | 5.0      | 0.01 | N/A                  | 2.25           | 2.07         | 2.01         | 6.33              |
| 11      | IH X-POP 150 n.mi. | NORM     | 0.5      | 0.2  | N/A                  | 32.20          | 42.60        | 42.30        | 117.10            |
| 12      | IH X-POP 150 n.mi. | NORM     | 1.0      | 0.2  | N/A                  | 15.70          | 21.20        | 21.00        | 57.90             |
| 13      | IH X-POP 150 n.mi. | NORM     | 3.0      | 0.2  | N/A                  | 6.20           | 7.70         | 7.50         | 21.40             |
| 14      | IH X-POP 150 n.mi. | NORM     | 5.0      | 0.2  | N/A                  | 4.00           | 5.20         | 4.80         | 14.00             |
| 15      | IH X-POP 150 n.mi. | NORM     | 10.0     | 0.2  | N/A                  | 3.10           | 3.00         | 3.20         | 9.30              |
| 16      | IH X-POP 150 n.mi. | NORM     | 20.0     | 0.2  | N/A                  | 1.50           | 2.10         | 2.20         | 5.80              |
| 17      | IH X-POP 150 n.mi. | VERN     | 0.1      | 0.01 | N/A                  | 0.62           | 0.56         | 0.56         | 1.74              |
| 18      | IH X-POP 150 n.mi. | VERN     | 0.5      | 0.01 | N/A                  | 0.49           | 0.35         | 0.35         | 1.19              |
| 19      | IH X-POP 150 n.mi. | VERN     | 1.0      | 0.01 | N/A                  | 0.53           | 0.39         | 0.41         | 1.33              |
| 20      | IH X-POP 150 n.mi. | VERN     | 5.0      | 0.01 | N/A                  | 0.47           | 0.36         | 0.38         | 1.21              |
| 21      | IH Y-POP 100 n.mi. | NORM     | 0.5      | 0.2  | N/A                  | 41.20          | 41.70        | 41.70        | 124.60            |
| 22      | IH Y-POP 100 n.mi. | NORM     | 1.0      | 0.2  | N/A                  | 21.50          | 21.00        | 20.90        | 63.40             |
| 23      | IH Y-POP 100 n.mi. | NORM     | 3.0      | 0.2  | N/A                  | 7.30           | 7.20         | 7.00         | 21.50             |
| 24      | IH Y-POP 100 n.mi. | NORM     | 5.0      | 0.2  | N/A                  | 5.80           | 6.30         | 6.20         | 18.30             |

TABLE A-III.- IH, LVLH, PTC FILE (Continued)

| Rcd<br>no. | Event              | RCS<br>jets | Deadband |      | Discrete<br>rate,<br>deg/s | RCS propellant |                 |                 | Total<br>used,<br>lb/hr |
|------------|--------------------|-------------|----------|------|----------------------------|----------------|-----------------|-----------------|-------------------------|
|            |                    |             | ATT      | Rate |                            | Fwd,<br>lb/hr  | L Aft,<br>lb/hr | R Aft,<br>lb/hr |                         |
| 25         | IH Y-POP 100 n.mi. | NORM        | 10.0     | 0.2  | N/A                        | 4.00           | 4.30            | 4.20            | 12.50                   |
| 26         | IH Y-POP 100 n.mi. | NORM        | 20.0     | 0.2  | N/A                        | 2.00           | 2.30            | 2.30            | 6.60                    |
| 27         | IH Y-POP 100 n.mi. | VERN        | 0.1      | 0.01 | N/A                        | 1.29           | 0.85            | 0.87            | 3.01                    |
| 28         | IH Y-POP 100 n.mi. | VERN        | 0.5      | 0.01 | N/A                        | 1.29           | 0.83            | 0.83            | 2.95                    |
| 29         | IH Y-POP 100 n.mi. | VERN        | 1.0      | 0.01 | N/A                        | 1.33           | 0.85            | 0.86            | 3.04                    |
| 30         | IH Y-POP 100 n.mi. | VERN        | 5.0      | 0.01 | N/A                        | 1.20           | 0.76            | 0.87            | 2.83                    |
| 31         | IH Y-POP 150 n.mi. | NORM        | 0.5      | 0.2  | N/A                        | 33.90          | 41.20           | 41.40           | 116.40                  |
| 32         | IH Y-POP 150 n.mi. | NORM        | 1.0      | 0.2  | N/A                        | 20.90          | 22.00           | 22.00           | 64.90                   |
| 33         | IH Y-POP 150 n.mi. | NORM        | 3.0      | 0.2  | N/A                        | 11.20          | 10.30           | 10.30           | 31.80                   |
| 34         | IH Y-POP 150 n.mi. | NORM        | 5.0      | 0.2  | N/A                        | 5.20           | 5.00            | 4.80            | 15.00                   |
| 35         | IH Y-POP 150 n.mi. | NORM        | 10.0     | 0.2  | N/A                        | 3.30           | 3.00            | 3.00            | 9.30                    |
| 36         | IH Y-POP 150 n.mi. | NORM        | 20.0     | 0.2  | N/A                        | 2.30           | 1.90            | 2.00            | 6.20                    |
| 37         | IH Y-POP 150 n.mi. | VERN        | 0.1      | 0.01 | N/A                        | 1.33           | 0.91            | 0.91            | 3.15                    |
| 38         | IH Y-POP 150 n.mi. | VERN        | 0.5      | 0.01 | N/A                        | 1.20           | 0.73            | 0.73            | 2.66                    |
| 39         | IH Y-POP 150 n.mi. | VERN        | 1.0      | 0.01 | N/A                        | 1.19           | 0.75            | 0.75            | 2.69                    |
| 40         | IH Y-POP 150 n.mi. | VERN        | 5.0      | 0.01 | N/A                        | 1.14           | 0.71            | 0.67            | 2.53                    |
| 41         | IH Z-POP 100 n.mi. | NORM        | 0.5      | 0.2  | N/A                        | 40.00          | 47.90           | 47.90           | 135.80                  |
| 42         | IH Z-POP 100 n.mi. | NORM        | 1.0      | 0.2  | N/A                        | 20.70          | 23.70           | 23.50           | 67.90                   |
| 43         | IH Z-POP 100 n.mi. | NORM        | 3.0      | 0.2  | N/A                        | 7.50           | 9.30            | 9.70            | 27.00                   |
| 44         | IH Z-POP 100 n.mi. | NORM        | 5.0      | 0.2  | N/A                        | 6.50           | 7.70            | 7.50            | 21.70                   |
| 45         | IH Z-POP 100 n.mi. | NORM        | 10.0     | 0.2  | N/A                        | 4.30           | 5.50            | 5.50            | 15.30                   |
| 46         | IH Z-POP 100 n.mi. | NORM        | 20.0     | 0.2  | N/A                        | 2.10           | 3.70            | 3.70            | 9.50                    |
| 47         | IH Z-POP 100 n.mi. | VERN        | 0.1      | 0.01 | N/A                        | 3.52           | 3.72            | 3.49            | 10.73                   |
| 48         | IH Z-POP 100 n.mi. | VERN        | 0.5      | 0.01 | N/A                        | 3.23           | 3.33            | 3.15            | 9.71                    |

TABLE A-III.- IH, LVLH, PTC FILE (Continued)

| Rcd no. | Event                  | RCS jets | Deadband |      | Discrete rate, deg/s | RCS propellant |              |              | Total used, lb/hr |
|---------|------------------------|----------|----------|------|----------------------|----------------|--------------|--------------|-------------------|
|         |                        |          | ATT      | Rate |                      | Fwd, lb/hr     | L Aft, lb/hr | R Aft, lb/hr |                   |
| 49      | IH Z-POP 100 n.mi.     | VERN     | 1.0      | 0.01 | N/A                  | 3.08           | 3.32         | 3.09         | 9.49              |
| 50      | IH Z-POP 100 n.mi.     | VERN     | 5.0      | 0.01 | N/A                  | 2.85           | 3.14         | 2.98         | 8.97              |
| 51      | IH Z-POP 150 n.mi.     | NORM     | 0.5      | 0.2  | N/A                  | 41.20          | 43.20        | 43.00        | 127.40            |
| 52      | IH Z-POP 150 n.mi.     | NORM     | 1.0      | 0.2  | N/A                  | 21.70          | 23.20        | 23.00        | 67.90             |
| 53      | IH Z-POP 150 n.mi.     | NORM     | 3.0      | 0.2  | N/A                  | 9.30           | 9.00         | 8.70         | 27.00             |
| 54      | IH Z-POP 150 n.mi.     | NORM     | 5.0      | 0.2  | N/A                  | 7.80           | 6.70         | 6.70         | 21.20             |
| 55      | IH Z-POP 150 n.mi.     | NORM     | 10.0     | 0.2  | N/A                  | 1.90           | 2.30         | 2.30         | 6.50              |
| 56      | IH Z-POP 150 n.mi.     | NORM     | 20.0     | 0.2  | N/A                  | 1.70           | 1.30         | 1.80         | 4.80              |
| 57      | IH Z-POP 150 n.mi.     | VERN     | 0.1      | 0.01 | N/A                  | 1.31           | 1.69         | 1.67         | 4.67              |
| 58      | IH Z-POP 150 n.mi.     | VERN     | 0.5      | 0.01 | N/A                  | 1.27           | 1.55         | 1.53         | 4.35              |
| 59      | IH Z-POP 150 n.mi.     | VERN     | 1.0      | 0.01 | N/A                  | 1.28           | 1.54         | 1.57         | 4.39              |
| 60      | IH Z-POP 150 n.mi.     | VERN     | 5.0      | 0.01 | N/A                  | 1.37           | 1.45         | 1.51         | 4.33              |
| 61      | LV,XPOP,-ZLV,100 n.mi. | NORM     | 0.5      | 0.2  | N/A                  | 36.90          | 45.00        | 46.40        | 128.30            |
| 62      | LV,XPOP,-ZLV,100 n.mi. | NORM     | 1.0      | 0.2  | N/A                  | 24.40          | 28.20        | 29.50        | 82.10             |
| 63      | LV,XPOP,-ZLV,100 n.mi. | NORM     | 3.0      | 0.2  | N/A                  | 9.00           | 11.80        | 13.20        | 34.00             |
| 64      | LV,XPOP,-ZLV,100 n.mi. | NORM     | 5.0      | 0.2  | N/A                  | 6.10           | 9.70         | 11.20        | 27.00             |
| 65      | LV,XPOP,-ZLV,100 n.mi. | NORM     | 10.0     | 0.2  | N/A                  | 2.50           | 6.00         | 7.20         | 15.70             |
| 66      | LV,XPOP,-ZLV,100 n.mi. | NORM     | 20.0     | 0.2  | N/A                  | 2.20           | 5.30         | 6.20         | 13.70             |
| 67      | LV,XPOP,-ZLV,100 n.mi. | VERN     | 0.1      | 0.01 | N/A                  | 6.44           | 10.02        | 1.53         | 17.99             |
| 68      | LV,XPOP,-ZLV,100 n.mi. | VERN     | 0.5      | 0.01 | N/A                  | 5.36           | 9.43         | 0.93         | 15.72             |
| 69      | LV,XPOP,-ZLV,100 n.mi. | VERN     | 0.1      | 0.01 | N/A                  | 5.28           | 9.58         | 1.19         | 16.05             |
| 70      | LV,XPOP,-ZLV,100 n.mi. | VERN     | 5.0      | 0.01 | N/A                  | 5.31           | 9.15         | 1.23         | 15.69             |
| 71      | LV,XPOP,-ZLV,150 n.mi. | NORM     | 0.5      | 0.2  | N/A                  | 41.50          | 47.90        | 47.90        | 137.30            |
| 72      | LV,XPOP,-ZLV,150 n.mi. | NORM     | 1.0      | 0.2  | N/A                  | 20.50          | 23.00        | 23.20        | 66.70             |

TABLE A-III.- IH, LVLH, PTC FILE (Continued)

| Rcd<br>no. | Event                  | RCS<br>jets | Deadband |      | Discrete<br>rate,<br>deg/s | RCS propellant |                 |                 | Total<br>used,<br>lb/hr |
|------------|------------------------|-------------|----------|------|----------------------------|----------------|-----------------|-----------------|-------------------------|
|            |                        |             | ATT      | Rate |                            | Fwd,<br>lb/hr  | L Aft,<br>lb/hr | R Aft,<br>lb/hr |                         |
| 73         | LV,XPOP,-ZLV,150 n.mi. | NORM        | 3.0      | 0.2  | N/A                        | 9.30           | 10.00           | 10.20           | 29.50                   |
| 74         | LV,XPOP,-ZLV,150 n.mi. | NORM        | 5.0      | 0.2  | N/A                        | 6.20           | 7.00            | 7.00            | 20.20                   |
| 75         | LV,XPOP,-ZLV,150 n.mi. | NORM        | 10.0     | 0.2  | N/A                        | 2.30           | 2.70            | 3.00            | 8.00                    |
| 76         | LV,XPOP,-ZLV,150 n.mi. | NORM        | 20.0     | 0.2  | N/A                        | 1.00           | 2.30            | 2.20            | 5.50                    |
| 77         | LV,XPOP,-ZLV,150 n.mi. | VERN        | 0.1      | 0.01 | N/A                        | 1.13           | 1.25            | 0.64            | 3.03                    |
| 78         | LV,XPOP,-ZLV,150 n.mi. | VERN        | 0.5      | 0.01 | N/A                        | 0.91           | 0.95            | 0.35            | 2.21                    |
| 79         | LV,XPOP,-ZLV,150 n.mi. | VERN        | 1.0      | 0.01 | N/A                        | 1.00           | 0.98            | 0.39            | 2.37                    |
| 80         | LV,XPOP,-ZLV,150 n.mi. | VERN        | 5.0      | 0.01 | N/A                        | 1.36           | 1.09            | 0.41            | 2.86                    |
| 81         | LV,YPOP,-ZLV,100 n.mi. | NORM        | 0.5      | 0.2  | N/A                        | 48.70          | 38.20           | 38.20           | 125.10                  |
| 82         | LV,YPOP,-ZLV,100 n.mi. | NORM        | 1.0      | 0.2  | N/A                        | 23.10          | 18.30           | 18.30           | 59.70                   |
| 83         | LV,YPOP,-ZLV,100 n.mi. | NORM        | 3.0      | 0.2  | N/A                        | 6.90           | 5.80            | 5.80            | 18.50                   |
| 84         | LV,YPOP,-ZLV,100 n.mi. | NORM        | 5.0      | 0.2  | N/A                        | 2.70           | 2.80            | 2.30            | 8.30                    |
| 85         | LV,YPOP,-ZLV,100 n.mi. | NORM        | 10.0     | 0.2  | N/A                        | 3.00           | 3.00            | 3.00            | 9.00                    |
| 86         | LV,YPOP,-ZLV,100 n.mi. | NORM        | 20.0     | 0.2  | N/A                        | 2.50           | 2.20            | 2.30            | 7.00                    |
| 87         | LV,YPOP,-ZLV,100 n.mi. | VERN        | 0.1      | 0.01 | N/A                        | 0.69           | 0.15            | 0.16            | 1.00                    |
| 88         | LV,YPOP,-ZLV,100 n.mi. | VERN        | 0.5      | 0.01 | N/A                        | 0.66           | 0.06            | 0.09            | 0.91                    |
| 89         | LV,YPOP,-ZLV,100 n.mi. | VERN        | 1.0      | 0.01 | N/A                        | 0.61           | 0.03            | 0.03            | 0.67                    |
| 90         | LV,YPOP,-ZLV,100 n.mi. | VERN        | 5.0      | 0.01 | N/A                        | 0.69           | 0.09            | 0.15            | 0.93                    |
| 91         | LV,YPOP,-ZLV,150 n.mi. | NORM        | 0.5      | 0.2  | N/A                        | 48.40          | 38.50           | 38.50           | 125.40                  |
| 92         | LV,YPOP,-ZLV,150 n.mi. | NORM        | 1.0      | 0.2  | N/A                        | 23.30          | 18.30           | 18.30           | 59.90                   |
| 93         | LV,YPOP,-ZLV,150 n.mi. | NORM        | 3.0      | 0.2  | N/A                        | 6.20           | 5.00            | 5.00            | 16.20                   |
| 94         | LV,YPOP,-ZLV,150 n.mi. | NORM        | 5.0      | 0.2  | N/A                        | 4.20           | 4.90            | 4.80            | 13.80                   |
| 95         | LV,YPOP,-ZLV,150 n.mi. | NORM        | 10.0     | 0.2  | N/A                        | 3.00           | 3.00            | 3.00            | 9.00                    |
| 96         | LV,YPOP,-ZLV,150 n.mi. | NORM        | 20.0     | 0.2  | N/A                        | 2.40           | 1.80            | 1.30            | 6.00                    |



TABLE A-III.- IH, LVLH, PTC FILE (Continued)

| Rcd no. | Event                  | RCS jets | Deadband |      | Discrete rate, deg/s | RCS propellant |              |              | Total used, lb/hr |
|---------|------------------------|----------|----------|------|----------------------|----------------|--------------|--------------|-------------------|
|         |                        |          | ATT      | Rate |                      | Fwd, lb/hr     | L Aft, lb/hr | R Aft, lb/hr |                   |
| 97      | LV,YPOP,-ZLV,150 n.mi. | VERN     | 0.1      | 0.01 | N/A                  | 0.82           | 0.11         | 0.14         | 1.07              |
| 98      | LV,YPOP,-ZLV,150 n.mi. | VERN     | 0.5      | 0.01 | N/A                  | 0.76           | 0.03         | 0.05         | 0.84              |
| 99      | LV,YPOP,-ZLV,150 n.mi. | VERN     | 1.0      | 0.01 | N/A                  | 0.76           | 0.04         | 0.07         | 0.87              |
| 100     | LV,YPOP,-ZLV,150 n.mi. | VERN     | 5.0      | 0.01 | N/A                  | 0.72           | 0.12         | 0.08         | 0.92              |
| 101     | PTC,X+ORB PL,100 n.mi. | NORM     | 0.5      | 0.2  | N/A                  | 44.20          | 51.60        | 51.20        | 147.00            |
| 102     | PTC,X+ORB PL,100 n.mi. | NORM     | 1.0      | 0.2  | N/A                  | 23.00          | 26.40        | 26.20        | 75.60             |
| 103     | PTC,X+ORB PL,100 n.mi. | NORM     | 3.0      | 0.2  | N/A                  | 8.30           | 9.70         | 9.50         | 27.50             |
| 104     | PTC,X+ORB PL,100 n.mi. | NORM     | 5.0      | 0.2  | N/A                  | 4.70           | 6.30         | 6.00         | 17.00             |
| 105     | PTC,X+ORB PL,100 n.mi. | NORM     | 10.0     | 0.2  | N/A                  | 4.50           | 4.60         | 4.00         | 13.80             |
| 106     | PTC,X+ORB PL,100 n.mi. | NORM     | 20.0     | 0.2  | N/A                  | 6.20           | 5.30         | 6.00         | 17.50             |
| 107     | PTC,X+ORB PL,100 n.mi. | VERN     | 0.1      | 0.01 | N/A                  | 3.56           | 3.51         | 2.60         | 9.67              |
| 108     | PTC,X+ORB PL,100 n.mi. | VERN     | 0.5      | 0.01 | N/A                  | 2.88           | 2.73         | 1.81         | 7.42              |
| 109     | PTC,X+ORB PL,100 n.mi. | VERN     | 1.0      | 0.01 | N/A                  | 2.67           | 2.51         | 1.57         | 6.75              |
| 110     | PTC,X+ORB PL,100 n.mi. | VERN     | 5.0      | 0.01 | N/A                  | 2.51           | 2.33         | 1.33         | 6.17              |
| 111     | PTC,X+ORB PL,150 n.mi. | NORM     | 0.5      | 0.2  | N/A                  | 36.10          | 45.20        | 45.20        | 126.50            |
| 112     | PTC,X+ORB PL,150 n.mi. | NORM     | 1.0      | 0.2  | N/A                  | 24.00          | 26.90        | 26.90        | 77.80             |
| 113     | PTC,X+ORB PL,150 n.mi. | NORM     | 3.0      | 0.2  | N/A                  | 9.50           | 10.20        | 10.20        | 29.90             |
| 114     | PTC,X+ORB PL,150 n.mi. | NORM     | 5.0      | 0.2  | N/A                  | 4.40           | 5.20         | 5.20         | 14.00             |
| 115     | PTC,X+ORB PL,150 n.mi. | NORM     | 10.0     | 0.2  | N/A                  | 4.00           | 3.00         | 3.30         | 10.30             |
| 116     | PTC,X+ORB PL,150 n.mi. | NORM     | 20.0     | 0.2  | N/A                  | 3.30           | 3.20         | 3.80         | 10.30             |
| 117     | PTC,X+ORB PL,150 n.mi. | VERN     | 0.1      | 0.01 | N/A                  | 2.90           | 2.91         | 2.07         | 7.88              |
| 118     | PTC,X+ORB PL,150 n.mi. | VERN     | 0.5      | 0.01 | N/A                  | 2.16           | 2.10         | 1.23         | 5.49              |
| 119     | PTC,X+ORB PL,150 n.mi. | VERN     | 1.0      | 0.01 | N/A                  | 1.98           | 1.89         | 0.96         | 4.83              |
| 120     | PTC,X+ORB PL,150 n.mi. | VERN     | 5.0      | 0.01 | N/A                  | 1.87           | 1.82         | 1.02         | 4.71              |

TABLE A-III.- IH, LVLH, PTC FILE (Continued)

| Rcd<br>no. | Event                  | RCS<br>jets | Deadband |      | Discrete<br>rate,<br>deg/s | RCS propellant. |                 |                 | Total<br>used,<br>lb/hr |
|------------|------------------------|-------------|----------|------|----------------------------|-----------------|-----------------|-----------------|-------------------------|
|            |                        |             | ATT      | Rate |                            | Fwd,<br>lb/hr   | L Aft,<br>lb/hr | R Aft,<br>lb/hr |                         |
| 121        | PTC,X@45°,100 n.mi.    | NORM        | 0.5      | 0.2  | N/A                        | 44.00           | 49.30           | 49.20           | 142.50                  |
| 122        | PTC,X@45°,100 n.mi.    | NORM        | 1.0      | 0.2  | N/A                        | 29.40           | 31.90           | 31.60           | 92.90                   |
| 123        | PTC,X@45°,100 n.mi.    | NORM        | 3.0      | 0.2  | N/A                        | 9.80            | 11.90           | 11.70           | 33.40                   |
| 124        | PTC,X@45°,100 n.mi.    | NORM        | 5.0      | 0.2  | N/A                        | 4.50            | 6.20            | 6.30            | 17.00                   |
| 125        | PTC,X@45°,100 n.mi.    | NORM        | 10.0     | 0.2  | N/A                        | 4.00            | 4.50            | 4.20            | 12.70                   |
| 126        | PTC,X@45°,100 n.mi.    | NORM        | 20.0     | 0.2  | N/A                        | 2.10            | 3.50            | 2.70            | 3.30                    |
| 127        | PTC,X@45°,100 n.mi.    | VERN        | 0.1      | 0.01 | N/A                        | 3.60            | 3.55            | 2.72            | 9.87                    |
| 128        | PTC,X@45°,100 n.mi.    | VERN        | 0.5      | 0.01 | N/A                        | 3.29            | 3.16            | 2.27            | 8.72                    |
| 129        | PTC,X@45°,100 n.mi.    | VERN        | 1.0      | 0.01 | N/A                        | 3.01            | 2.71            | 1.77            | 7.49                    |
| 130        | PTC,X@45°,100 n.mi.    | VERN        | 5.0      | 0.01 | N/A                        | 2.98            | 2.72            | 1.93            | 7.53                    |
| 131        | PTC,X@45°,150 n.mi.    | NORM        | 0.5      | 0.2  | 0.2                        | 52.72           | 53.73           | 54.03           | 160.48                  |
| 132        | PTC,X@45°,150 n.mi.    | NORM        | 1.0      | 0.2  | 0.2                        | 22.73           | 25.33           | 25.33           | 73.39                   |
| 133        | PTC,X@45°,150 n.mi.    | NORM        | 3.0      | 0.2  | 0.2                        | 8.33            | 9.13            | 9.23            | 26.69                   |
| 134        | PTC,X@45°,150 n.mi.    | NORM        | 5.0      | 0.2  | 0.2                        | 4.33            | 4.33            | 4.33            | 12.99                   |
| 135        | PTC,X@45°,150 n.mi.    | NORM        | 10.0     | 0.2  | 0.2                        | 3.03            | 2.13            | 3.03            | 3.19                    |
| 136        | PTC,X@45°,150 n.mi.    | NORM        | 20.0     | 0.2  | 0.2                        | 5.53            | 2.63            | 4.53            | 12.69                   |
| 137        | PTC,X@45°,150 n.mi.    | VERN        | 0.1      | 0.01 | 0.2                        | 2.36            | 2.26            | 1.40            | 6.02                    |
| 138        | PTC,X@45°,150 n.mi.    | VERN        | 0.5      | 0.01 | 0.2                        | 1.95            | 1.80            | 0.93            | 4.68                    |
| 139        | PTC,X@45°,150 n.mi.    | VERN        | 1.0      | 0.01 | 0.2                        | 1.68            | 1.56            | 0.63            | 3.87                    |
| 140        | PTC,X@45°,150 n.mi.    | VERN        | 5.0      | 0.01 | 0.2                        | 1.77            | 1.47            | 0.59            | 3.33                    |
| 141        | PTC,X@45°,150 n.mi.    | NORM        | 5.0      | 0.2  | 2.0                        | 5.76            | 45.33           | 45.33           | 96.42                   |
| 142        | IH XPOP,XDAP,100 n.mi. | NORM        | 3.5      | 0.3  | 1                          | 10.40           | 9.57            | 9.57            | 29.54                   |
| 143        | IH XPOP,XDAP,150 n.mi. | NORM        | 3.5      | 0.3  | 1                          | 10.07           | 9.26            | 9.26            | 28.59                   |
| 144        | IH XPOP,XDAP,30x149    | NORM        | 3.5      | 0.3  | 1                          | 10.00           | 9.20            | 9.20            | 29.40                   |

TABLE A-III.- IH, LVLH, PTC FILE (Concluded)

| Rcd<br>no. | Event                  | RCS<br>jets | Deadband |      | Discrete<br>rate,<br>deg/s | RCS propellant |                 |                 | Total<br>used,<br>lb/hr |
|------------|------------------------|-------------|----------|------|----------------------------|----------------|-----------------|-----------------|-------------------------|
|            |                        |             | ATT      | Rate |                            | Fwd,<br>lb/hr  | L Aft,<br>lb/hr | R Aft,<br>lb/hr |                         |
| 145        | IH YPOP,XDAP,100 n.mi. | NORM        | 3.5      | 0.3  | 1                          | 7.09           | 8.69            | 8.69            | 24.47                   |
| 146        | IH YPOP,XDAP,150 n.mi. | NORM        | 3.5      | 0.3  | 1                          | 8.33           | 10.21           | 10.21           | 28.75                   |
| 147        | IH YPOP,XDAP,80x149    | NORM        | 3.5      | 0.3  | 1                          | 8.13           | 9.97            | 9.97            | 28.07                   |
| 148        | -ZLV,TAIL,150 n.mi.    | NORM        | 10.0     | 0.5  | 0.5                        | 0.00           | 4.50            | 4.50            | 9.00                    |
| 149        | IH GEN 150 n.mi.       | VERN        | 1.0      | 0.01 | N/A                        | 1.00           | 0.89            | 0.91            | 2.80                    |
| 150        | IH+APUs,XDAP,150 n.mi. | NORM        | 3.5      | 0.3  | 1.0                        | 41.40          | 93.10           | 93.10           | 227.60                  |
| 151        | IH CONST ALPHA         | NORM        | N/A      | N/A  | N/A                        | 0.00           | 146.40          | 146.40          | 292.80                  |

TABLE A-IV.- TRANSLATION MANEUVER

| Rcd<br>no. | Event               | RCS<br>jets | Deadband |      | Discrete<br>rate,<br>deg/s | RCS propellant |                |                | Total<br>used,<br>lb/s |
|------------|---------------------|-------------|----------|------|----------------------------|----------------|----------------|----------------|------------------------|
|            |                     |             | ATT      | Rate |                            | Fwd,<br>lb/s   | L Aft,<br>lb/s | R Aft,<br>lb/s |                        |
| 1          | +X 10 sec THC INPUT | NORM        | N/A      | N/A  | N/A                        | 0.15           | 3.18           | 3.18           | 6.51                   |
| 2          | -X 10 sec THC INPUT | NORM        | N/A      | N/A  | N/A                        | 6.81           | 0.30           | 0.30           | 7.41                   |
| 3          | +Y 10 sec THC INPUT | NORM        | N/A      | N/A  | N/A                        | 1.71           | 4.30           | 1.29           | 7.30                   |
| 4          | -Y 10 sec THC INPUT | NORM        | N/A      | N/A  | N/A                        | 1.71           | 1.29           | 4.30           | 7.30                   |
| 5          | +Z(HIGH) 10 sec THC | NORM        | N/A      | N/A  | N/A                        | 9.31           | 8.33           | 8.33           | 25.97                  |
| 6          | +Z(NORM) 10 sec THC | NORM        | N/A      | N/A  | N/A                        | 3.10           | 2.82           | 2.82           | 8.74                   |
| 7          | -Z 10 sec THC INPUT | NORM        | N/A      | N/A  | N/A                        | 6.21           | 6.21           | 6.21           | 18.63                  |

NOTE: Includes ATT HOLD during MNVR.  
Not currently scheduled on STS-1 due to RCS limitations.

TABLE A-V.- STS-1 TYPICAL MANEUVERS-PROPELLANTS USED

| Event                   | PRPLT used<br>each event,<br>lb | RCS PRPLT        |                    |                    | OMS PRPLT<br>L,R - TOT,<br>lb |
|-------------------------|---------------------------------|------------------|--------------------|--------------------|-------------------------------|
|                         |                                 | Fwd - TOT,<br>lb | L Aft - TOT,<br>lb | R Aft - TOT,<br>lb |                               |
| ATT HOLD POST MECO      | 45.0                            | 15.00            | 15.00              | 15.00              | 0.00                          |
| ET SEP (4ft/s,-Z)       | 158.0                           | 65.00            | 69.00              | 69.00              | 0.00                          |
| Y SEP (22 sec,+Y)       | 160.6                           | 102.62           | 163.60             | 97.38              | 0.00                          |
| OMS-1 BURN ATT MNVR     | 50.1                            | 121.58           | 179.16             | 112.94             | 0.00                          |
| OMS-1 BURN (197 ft/s)   | 4164.0                          | 121.58           | 179.16             | 112.94             | 4164.00                       |
| ATT HOLD FOR MPS DUMP   | 6.0                             | 123.58           | 181.16             | 114.94             | 4164.00                       |
| ATT HOLD (trans DAP)    | 5.2                             | 125.09           | 183.01             | 116.79             | 4164.00                       |
| OMS-2 BURN ATT MNVR     | 50.1                            | 144.05           | 198.57             | 132.35             | 4164.00                       |
| ATT HOLD (trans DAP)    | 8.5                             | 146.51           | 201.58             | 135.36             | 4164.00                       |
| OMS-2 BURN (166 ft/s)   | 3358.0                          | 146.51           | 201.58             | 135.36             | 7522.00                       |
| ATT HOLD (trans DAP)    | 5.5                             | 148.10           | 203.54             | 137.32             | 7522.00                       |
| ATT HOLD (orbit DAP)    | 1.7                             | 148.71           | 204.09             | 137.87             | 7522.00                       |
| PLBD OPENING ATT MNVR   | 21.0                            | 155.71           | 211.09             | 144.87             | 7522.00                       |
| ATT HOLD                | 19.8                            | 161.37           | 218.46             | 151.67             | 7522.00                       |
| COAS CAL ATT MNVR       | 21.0                            | 168.37           | 225.46             | 158.67             | 7522.00                       |
| COAS CALIBRATION        | 9.0                             | 171.37           | 228.46             | 161.67             | 7522.00                       |
| IMU ALIGN ATT MNVR      | 21.0                            | 178.37           | 235.46             | 168.67             | 7522.00                       |
| ATT HOLD                | 0.7                             | 178.62           | 235.68             | 168.90             | 7522.00                       |
| IMU ALIGN VERN ATT MNVR | 21.0                            | 185.62           | 242.68             | 175.90             | 7522.00                       |
| ATT HOLD                | 1.4                             | 186.12           | 243.12             | 176.35             | 7522.00                       |
| MNVR TO -ZLV ATT        | 21.0                            | 193.12           | 250.12             | 183.35             | 7522.00                       |
| -ZLV ATT (174-08.3)     | 3.9                             | 194.42           | 251.42             | 184.65             | 7522.00                       |
| -ZLV ATT (174-08.2)     | 7.8                             | 196.80           | 254.14             | 187.37             | 7522.00                       |
| PTC ATT MNVR            | 21.0                            | 203.80           | 261.14             | 194.37             | 7522.00                       |

TABLE A-V.- STS-1 TYPICAL MANUEVERS - PROPELLANTS USED (Continued)

| Event                          | PRPLT used<br>each event,<br>lb | RCS PRPLT        |                    |                    | OMS PRPLT<br>L,R - TOT,<br>lb |
|--------------------------------|---------------------------------|------------------|--------------------|--------------------|-------------------------------|
|                                |                                 | Fwd - TOT,<br>lb | L Aft - TOT,<br>lb | R Aft - TOT,<br>lb |                               |
| START 0.2 deg/PTC              | 2.3                             | 204.05           | 262.14             | 195.37             | 7522.00                       |
| PTC ATT (174-09.2)             | 4.1                             | 205.57           | 263.21             | 196.89             | 7522.00                       |
| PTC ATT (174-09.1)             | 6.5                             | 207.73           | 265.37             | 199.05             | 7522.00                       |
| PTC ATT (174-09.4)             | 2.1                             | 208.71           | 266.18             | 199.38             | 7522.00                       |
| INCR PTC RATE to 2 deg/s       | 16.7                            | 209.71           | 274.05             | 207.25             | 7522.00                       |
| PTC for COMM TEST (172-04)     | 53.0                            | 212.88           | 298.98             | 232.18             | 7522.00                       |
| STOP 2 deg/s PTC               | 16.7                            | 213.88           | 306.85             | 240.05             | 7522.00                       |
| IMU ALIGN ATT MNVR             | 21.0                            | 220.88           | 313.85             | 247.05             | 7522.00                       |
| ATT HOLD                       | 0.7                             | 221.14           | 314.09             | 247.29             | 7522.00                       |
| COAS VERN #1 (173-06)          | 9.0                             | 224.14           | 317.09             | 250.29             | 7522.00                       |
| COAS IMU ALIGN #1 (173-06)     | 9.0                             | 227.14           | 320.09             | 253.29             | 7522.00                       |
| AUTO MNVR TO COAS ALIGN #2 ATT | 21.0                            | 234.14           | 327.09             | 260.29             | 7522.00                       |
| COAS IMU ALIGN #2 (173-02)     | 9.0                             | 237.14           | 330.09             | 263.29             | 7522.00                       |
| COAS VERN #2 (173-06)          | 9.0                             | 240.14           | 333.09             | 266.29             | 7522.00                       |
| ATT HOLD                       | 0.6                             | 240.36           | 333.28             | 266.49             | 7522.00                       |
| COAS VER #3 (173-06)           | 9.0                             | 243.36           | 336.28             | 269.49             | 7522.00                       |
| AUTO MNVR TO IMU ALIGN ATT     | 21.0                            | 250.36           | 343.28             | 276.49             | 7522.00                       |
| ATT HOLD                       | 0.5                             | 250.58           | 343.42             | 276.63             | 7522.00                       |
| IMU ACCELEROMETER CAL          | 0.0                             | 250.58           | 343.42             | 276.63             | 7522.00                       |
| AUTO MNVR TO IMU ALIGN ATT     | 21.0                            | 257.58           | 350.42             | 283.63             | 7522.00                       |
| ATT HOLD                       | 1.9                             | 258.26           | 351.03             | 284.25             | 7522.00                       |
| AUTO MNVR TO -ZLV ATT          | 21.0                            | 265.26           | 358.03             | 291.25             | 7522.00                       |
| -ZLV 2deg DB; NORM (174-08.1)  | 21.6                            | 272.08           | 365.36             | 298.73             | 7522.00                       |

TABLE A-V.- STS-1 TYPICAL MANUEVERS - PROPELLANTS USED (Continued)

| Event                                | PRPLT used<br>each event,<br>lb | RCS PRPLT        |                    |                    | OMS PRPLT<br>L,R - TOT,<br>lb |
|--------------------------------------|---------------------------------|------------------|--------------------|--------------------|-------------------------------|
|                                      |                                 | Fwd - TOT,<br>lb | L Aft - TOT,<br>lb | R Aft - TOT,<br>lb |                               |
| START 2 deg/s PTC                    | 16.7                            | 280.08           | 380.23             | 313.60             | 7522.00                       |
| PTC for COMM TEST (172-01,02)        | 24.1                            | 281.52           | 391.57             | 324.93             | 7522.00                       |
| STOP 2 deg/s PTC                     | 16.7                            | 282.52           | 399.44             | 332.80             | 7522.00                       |
| AUTO MNVR TO -ZLV ATT                | 21.0                            | 289.52           | 406.44             | 339.80             | 7522.00                       |
| -ZLV, TAIL ONLY TEST (174-07)        | 11.1                            | 289.52           | 411.99             | 345.35             | 7522.00                       |
| -ZLV, 0.1 deg DB, VERN<br>(174-08.4) | 0.7                             | 290.08           | 412.06             | 345.45             | 7522.00                       |
| AUTO MNVR TO IMU ALIGN ATT           | 21.0                            | 297.08           | 419.06             | 352.45             | 7522.00                       |
| ATT HOLD                             | 1.1                             | 297.48           | 419.42             | 352.81             | 7522.00                       |
| AUTO MNVR TO PTC ATT                 | 21.0                            | 304.48           | 426.42             | 359.81             | 7522.00                       |
| START 0.2 deg/s PTC                  | 2.1                             | 305.11           | 427.14             | 360.53             | 7522.00                       |
| PTC, 1 deg DB, VERN (174-09.3)       | 37.2                            | 321.27           | 442.14             | 366.59             | 7522.00                       |
| STOP 0.2 deg/s PTC                   | 2.1                             | 321.90           | 442.86             | 367.31             | 7522.00                       |
| AUTO MNVR TO IMU ALIGN ATT           | 21.0                            | 328.90           | 449.86             | 374.31             | 7522.00                       |
| ATT HOLD                             | 1.3                             | 329.35           | 450.26             | 374.72             | 7522.00                       |
| COAS CALIBRATION                     | 9.0                             | 332.35           | 453.26             | 377.72             | 7522.00                       |
| AUTO MNVR TO PTC ATT                 | 21.0                            | 339.35           | 460.26             | 384.72             | 7522.00                       |
| START 0.2 deg/s PTC                  | 2.1                             | 339.98           | 460.98             | 385.44             | 7522.00                       |
| PTC 1 deg DB, VERN                   | 5.6                             | 342.41           | 463.24             | 386.35             | 7522.00                       |
| STOP 0.2 deg/s PTC                   | 2.1                             | 343.04           | 463.96             | 387.07             | 7522.00                       |
| AUTO MNVR TO FCS C/O ATT             | 21.0                            | 350.04           | 470.96             | 394.07             | 7522.00                       |
| FCS C/O ATT w/o APUs on              | 0.0                             | 350.04           | 470.96             | 394.07             | 7522.00                       |
| FCS C/O ATT with APUs on             | 40.6                            | 362.14           | 485.21             | 408.32             | 7522.00                       |
| FCS C/O ATT w/o APUs on              | 0.2                             | 362.21           | 485.29             | 408.40             | 7522.00                       |

TABLE A-V.- STS-1 TYPICAL MANUEVERS - PROPELLANTS USED (Continued)

| Event                         | PRPLT used<br>each event,<br>lb | RCS PRPLT        |                    |                    | OMS PRPLT<br>L,R - TOT,<br>lb |
|-------------------------------|---------------------------------|------------------|--------------------|--------------------|-------------------------------|
|                               |                                 | Fwd - TOT,<br>lb | L Aft - TOT,<br>lb | R Aft - TOT,<br>lb |                               |
| FREE DRIFT                    | 0.0                             | 362.21           | 485.29             | 408.40             | 7522.00                       |
| ATT HOLD                      | 0.4                             | 362.33           | 485.44             | 408.56             | 7522.00                       |
| FREE DRIFT                    | 0.0                             | 362.33           | 485.44             | 408.56             | 7522.00                       |
| ATT HOLD                      | 1.0                             | 362.61           | 485.78             | 408.90             | 7522.00                       |
| AUTO MNVR TO PTC ATT          | 21.0                            | 369.61           | 492.78             | 415.90             | 7522.00                       |
| START 0.2 deg/s PTC           | 2.1                             | 370.24           | 493.50             | 416.62             | 7522.00                       |
| PTC 1 deg DB,VERN             | 7.7                             | 373.57           | 496.59             | 417.87             | 7522.00                       |
| STOP 0.2 deg/s PTC            | 2.1                             | 374.20           | 497.31             | 418.59             | 7522.00                       |
| AUTO MNVR TO PLBD CLOSING ATT | 21.0                            | 381.20           | 504.31             | 425.59             | 7522.00                       |
| ATT HOLD (trans DAP)          | 36.7                            | 394.13           | 516.19             | 437.47             | 7522.00                       |
| MAN MNVR TO IMU ALIGN ATT     | 66.8                            | 414.09           | 539.62             | 460.90             | 7522.00                       |
| ATT HOLD (trans DAP)          | 5.2                             | 415.93           | 541.32             | 462.60             | 7522.00                       |
| MAN MNVR TO IMU ALIGN ATT     | 66.8                            | 435.89           | 564.75             | 486.03             | 7522.08                       |
| ATT HOLD (trans DAP)          | 26.2                            | 445.12           | 573.24             | 494.52             | 7522.00                       |
| MAN MNVR TO DEORBIT BURN ATT  | 66.8                            | 465.08           | 596.67             | 517.95             | 7522.00                       |
| ATT HOLD (trans DAP)          | 51.9                            | 483.38           | 613.49             | 534.77             | 7522.00                       |
| MAN MNVR TO OMS-3 BURN ATT    | 66.8                            | 503.34           | 639.92             | 558.20             | 7522.00                       |
| ATT HOLD (trans DAP)          | 5.2                             | 505.18           | 638.62             | 559.89             | 7522.00                       |
| OMS-3 BURN (20 sec)(142-01)   | 400.0                           | 505.18           | 638.62             | 559.89             | 7922.00                       |
| ATT HOLD (trans DAP)          | 8.9                             | 508.32           | 641.50             | 562.78             | 7922.00                       |
| MAN MNVR TO OMS-4 BURN ATT    | 66.8                            | 528.28           | 664.93             | 586.21             | 7922.00                       |
| ATT HOLD (trans DAP)          | 5.1                             | 530.06           | 666.57             | 587.85             | 7922.00                       |
| OMS-4 BURN (30 sec)(142-02)   | 600.0                           | 530.06           | 666.57             | 587.85             | 8522.00                       |
| ATT HOLD (trans DAP)          | 3.8                             | 531.41           | 667.81             | 589.09             | 8522.00                       |

TABLE A-V.- STS-1 TYPICAL MANUEVERS - PROPELLANTS USED (Continued)

| Event                            | PRPLT used<br>each event,<br>lb | RCS PRPLT        |                    |                    | OMS PRPLT<br>L,R - TOT,<br>lb |
|----------------------------------|---------------------------------|------------------|--------------------|--------------------|-------------------------------|
|                                  |                                 | Fwd - TOT,<br>lb | L aft - TOT,<br>lb | R aft - TOT,<br>lb |                               |
| ATT HOLD (orbit DAP)             | 0.8                             | 531.73           | 668.06             | 589.35             | 8522.00                       |
| AUTO MNVR TO -XLV,ZPOP ATT       | 21.0                            | 538.73           | 675.06             | 596.35             | 8522.00                       |
| L OMS TO RCS INTERCONNECT        | 0.0                             | 538.73           | 675.06             | 596.35             | 8522.00                       |
| MAN XLAT ACCEL TEST (174-06)     | 427.4                           | 690.90           | 675.06             | 596.35             | 8797.20                       |
| STOP INTERCONNECT                | 0.0                             | 690.90           | 675.06             | 596.35             | 8797.20                       |
| MAN XLAT PULSE TEST (174-05)     | 14.0                            | 695.66           | 679.69             | 600.99             | 8797.20                       |
| MAN ROT DISC TEST (174-03)       | 17.1                            | 701.39           | 685.28             | 606.78             | 8797.20                       |
| MAN ROT PULSE TEST (174-01)      | 0.8                             | 701.65           | 685.54             | 607.04             | 8797.20                       |
| MAN ROT ACCEL TEST,VERN (174-02) | 4.6                             | 703.49           | 686.92             | 608.43             | 8797.20                       |
| MAN ROT ACCEL TEST (174-02)      | 46.7                            | 719.04           | 702.47             | 623.98             | 8797.20                       |
| MAN ROT PULSE TEST,NORM (174-01) | 14.4                            | 723.66           | 707.47             | 628.73             | 8797.20                       |
| MAN ROT DISC TEST,NORM(174-03)   | 65.5                            | 743.64           | 730.23             | 651.49             | 8797.20                       |
| AUTO MNVR TO -ZLV ATT            | 21.0                            | 750.64           | 737.23             | 658.49             | 8797.20                       |
| -ZLV 1 deg DB, VERN (174-08.6)   | 0.5                             | 751.09           | 737.25             | 658.53             | 8797.20                       |
| -ZLV 0.5 deg DB,VERN(174-08.5)   | 0.7                             | 751.73           | 737.28             | 658.57             | 8797.20                       |
| AUTO MNVR TO IMU ALIGN ATT       | 21.0                            | 758.73           | 744.28             | 665.57             | 8797.20                       |
| ATT HOLD                         | 1.0                             | 759.08           | 744.59             | 665.86             | 8797.20                       |
| OAS CALIBRATION                  | 9.0                             | 762.08           | 747.59             | 668.89             | 8797.20                       |
| ATT HOLD                         | 0.8                             | 762.37           | 747.84             | 669.15             | 8797.20                       |
| AUTO MNVR TO PTC ATT             | 21.0                            | 769.37           | 754.84             | 676.15             | 8797.20                       |
| START 0.2 deg/s PTC              | 2.1                             | 770.00           | 755.56             | 676.87             | 8797.20                       |
| PTC 1 deg DB VERN                | 37.3                            | 786.18           | 770.59             | 682.93             | 8797.20                       |
| STOP PTC                         | 2.1                             | 786.81           | 771.31             | 683.65             | 8797.20                       |
| AUTO MNVR TO IMU ALIGN ATT       | 21.0                            | 793.81           | 778.31             | 690.65             | 8797.20                       |



TABLE A-V.- STS-1 TYPICAL MANUEVERS - PROPELLANTS USED (Continued)

| Event                         | PRPLT used<br>each event,<br>lb | RCS PRPLT        |                    |                    | OMS PRPLT<br>L,R - TOT,<br>lb |
|-------------------------------|---------------------------------|------------------|--------------------|--------------------|-------------------------------|
|                               |                                 | Fwd - TOT,<br>lb | L Aft - TOT,<br>lb | R Aft - TOT,<br>lb |                               |
| ATT HOLD                      | 1.6                             | 794.39           | 778.83             | 691.19             | 8797.20                       |
| AUTO MNVR TO PTC ATT          | 21.0                            | 801.39           | 785.83             | 698.19             | 8797.20                       |
| START 0.2 deg/s PTC           | 2.1                             | 802.02           | 786.55             | 698.91             | 8797.20                       |
| PTC 1 deg DB VERN             | 2.1                             | 802.95           | 787.41             | 699.25             | 8797.20                       |
| STOP 0.2 deg/s PTC            | 2.1                             | 803.58           | 788.13             | 699.97             | 8797.20                       |
| AUTO MNVR TO FCS C/O ATT      | 21.0                            | 810.58           | 795.13             | 706.97             | 8797.20                       |
| FCS C/O ATT w/o APU's on,NORM | 1.6                             | 811.05           | 795.70             | 707.55             | 8797.20                       |
| FCS C/O ATT w/o APU's on,VERN | 0.2                             | 811.12           | 795.78             | 707.63             | 8797.20                       |
| FREE DRIFT                    | 0.0                             | 811.12           | 795.78             | 707.63             | 8797.20                       |
| ATT HOLD                      | 0.4                             | 811.24           | 795.93             | 707.78             | 8797.20                       |
| FREE DRIFT                    | 0.0                             | 811.24           | 795.93             | 707.78             | 8797.20                       |
| ATT HOLD                      | 1.0                             | 811.52           | 796.27             | 708.12             | 8797.20                       |
| AUTO MNVR TO PTC ATT          | 21.0                            | 818.52           | 803.27             | 715.12             | 8797.20                       |
| START 0.2 deg/s PTC           | 2.1                             | 819.15           | 803.99             | 715.84             | 8797.20                       |
| PTC 1 deg DB VERN             | 7.3                             | 822.32           | 806.93             | 717.03             | 8797.20                       |
| STOP PTC                      | 2.1                             | 822.95           | 807.65             | 717.75             | 8797.20                       |
| AUTO MNVR TO PLBD CLOSING ATT | 21.0                            | 829.95           | 814.65             | 724.75             | 8797.20                       |
| ATT HOLD (trans DAP)          | 36.7                            | 842.87           | 826.53             | 736.63             | 8797.20                       |
| MAN MNVR TO IMU ALIGN ATT     | 66.8                            | 862.83           | 849.96             | 760.06             | 8797.20                       |
| ATT HOLD (trans DAP)          | 5.2                             | 864.67           | 851.66             | 761.76             | 8797.20                       |
| MAN MNVR TO IMU ALIGN ATT     | 66.8                            | 884.63           | 875.09             | 785.19             | 8797.20                       |
| ATT HOLD (trans DAP)          | 26.2                            | 893.87           | 883.58             | 793.68             | 8797.20                       |
| MAN MNVR TO DEORBIT BURN ATT  | 66.8                            | 913.83           | 907.01             | 817.11             | 8797.20                       |
| ATT HOLD (trans DAP)          | 12.0                            | 918.05           | 910.89             | 820.99             | 8797.20                       |

TABLE A-V.- STS-1 TYPICAL MANUEVERS - PROPELLANTS USED (Concluded)

| Event                           | PRPLT used<br>each event,<br>lb | RCS PRPLT        |                    |                    | OMS PRPLT<br>L,R - TOT,<br>lb |
|---------------------------------|---------------------------------|------------------|--------------------|--------------------|-------------------------------|
|                                 |                                 | Fwd - TOT,<br>lb | L Aft - TOT,<br>lb | R Aft - TOT,<br>lb |                               |
| ATT HOLD with APU's             | 19.0                            | 921.50           | 918.65             | 828.75             | 8797.20                       |
| DEORBIT BURN (152.1 sec)        | 5827.0                          | 921.50           | 918.65             | 828.75             | 14624.20                      |
| ATT HOLD with APU's             | 24.3                            | 925.92           | 928.58             | 838.68             | 14624.20                      |
| MAN MNVR to EI-5 ATT            | 66.8                            | 945.88           | 952.01             | 862.11             | 14624.20                      |
| ATT HOLD with APU's (trans DAP) | 56.9                            | 956.23           | 975.28             | 885.39             | 14624.20                      |
| CONSTANT ALPHA ATT HOLD         | 16.7                            | 956.23           | 983.62             | 893.72             | 14624.20                      |
| ENTRY INTERFACE                 | 0.0                             | 956.23           | 983.62             | 893.72             | 14624.20                      |
| EI TO LANDING                   | 546.0                           | 956.23           | 1256.62            | 1166.72            | 14624.20                      |
| LANDING                         | 0.0                             | 956.23           | 1256.62            | 1166.72            | 14624.20                      |

| Event              | Start Date | End Date | Start Time | End Time | Duration |
|--------------------|------------|----------|------------|----------|----------|
| ATTN: HOLD WITH... | 11/18/80   | 11/18/80 | 08:00      | 09:00    | 1:00     |
| REGISTRATION...    | 11/18/80   | 11/18/80 | 09:00      | 10:00    | 1:00     |
| ATTN: HOLD WITH... | 11/18/80   | 11/18/80 | 10:00      | 11:00    | 1:00     |
| MAIN MEETING...    | 11/18/80   | 11/18/80 | 11:00      | 12:00    | 1:00     |
| ATTN: HOLD WITH... | 11/18/80   | 11/18/80 | 12:00      | 13:00    | 1:00     |
| CONSTANT ALPHA...  | 11/18/80   | 11/18/80 | 13:00      | 14:00    | 1:00     |
| TRAY INTERVIEW...  | 11/18/80   | 11/18/80 | 14:00      | 15:00    | 1:00     |
| END OF MEETING     | 11/18/80   | 11/18/80 | 15:00      | 16:00    | 1:00     |

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