

# Flight Procedures Handbook

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## Ascent/Aborts

Flight Design and Dynamics Division  
Flight Analysis Branch

Final, Revision A  
June 1988

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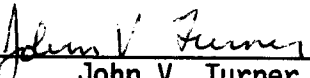
MISSION OPERATIONS DIRECTORATE

ASCENT/ABORTS FLIGHT PROCEDURES HANDBOOK

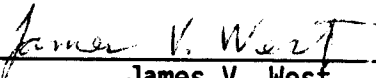
FINAL, REVISION A


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## SECTION 1 INTRODUCTION

### 1.1 PURPOSE

The purpose of the Ascent/Aborts Flight Procedures Handbook (FPH) is to describe and provide rationale for the flight procedures used during Space Transportation System (STS) ascent and aborts. It has been prepared for STS flight crews and ground operations personnel as an ascent flight training supplement and convenient reference source. Upon completion of the Ascent/Aborts FPH, the reader should have a thorough understanding of all aspects of STS ascent flight.

### 1.2 SCOPE

The Ascent/Aborts FPH covers nominal ascent, orbital insertion, and all abort flight phases that can occur during ascent. The entry and landing portions of the aborts are included. The Ascent/Aborts FPH was designed to be general in nature and not flight specific. It represents the latest in STS guidance and procedures as of STS-26. Where specific numbers are required, either generic values or STS-26 values are used.

The Ascent/Aborts FPH includes trajectory and guidance-related flight procedures only. It does not address procedures to be used in the event of systems failures. Systems failures are covered in the Ascent/Orbit/Entry Pocket Checklist and Cue Cards Handbook.

### 1.3 DESCRIPTION

This document covers the following flight phases:

- a. Nominal ascent
- b. Abort to orbit (ATO)
- c. Abort once around (AOA)
- d. Transoceanic abort landing (TAL)
- e. LATE TAL
- f. Return to launch site (RTL)
- g. Contingency abort

Section 2 of this FPH provides a general description of each flight phase, including an explanation of the trajectory and guidance phases. Section 2 also includes an overview of the backup flight system (BFS) for ascent.

Section 3 describes the actual crew operations for ascent/aborts. Section 3.1 covers the crew monitoring and control devices. This includes a discussion of dynamic flight cues and the instruments and cue cards used to monitor them. Abort selection rationale is also included in this section. Section 3.2 describes the orbital maneuvering subsystem (OMS) targeting rationale for standard and direct insertion. Section 3.3 provides the rationale for the procedures used in each of the above flight phases. It follows the procedures line by line as they are presented in the Ascent Checklist.



## SECTION 2 ASCENT FLIGHT PHASE DESCRIPTION

### 2.1 ASCENT FLIGHT PHASE

The ascent flight phase consists of those activities a crew performs to prepare for launch, to monitor ascent performance, and to perform OMS burns required for the ascent flight phase through OMS-2 of a nominal, ATO, or AOA. The ascent flight phase is shown in figure 2.1-1. A due east nominal ascent groundtrack with direct insertion trajectory data and event timeline is shown in figure 2.1-2.

This section provides a general description of each flight phase including an explanation of the trajectory and guidance phases of each. Nominal ascent begins prior to lift-off and ends after OMS-2. The ATO ascent phase begins after abort selection and ends shortly after OMS-2 (ATO-2), inserting the vehicle into a circular orbit of at least 105 n. mi. radius. AOA begins at abort selection or failure identification and continues through landing. The TAL and RTLS abort phases begin at abort selection and continue through landing. The contingency abort begins at second engine failure and continues through crew egress.

This section will also discuss the BFS, its capabilities, and its similarities and differences in comparison to the primary avionics software system (PASS).

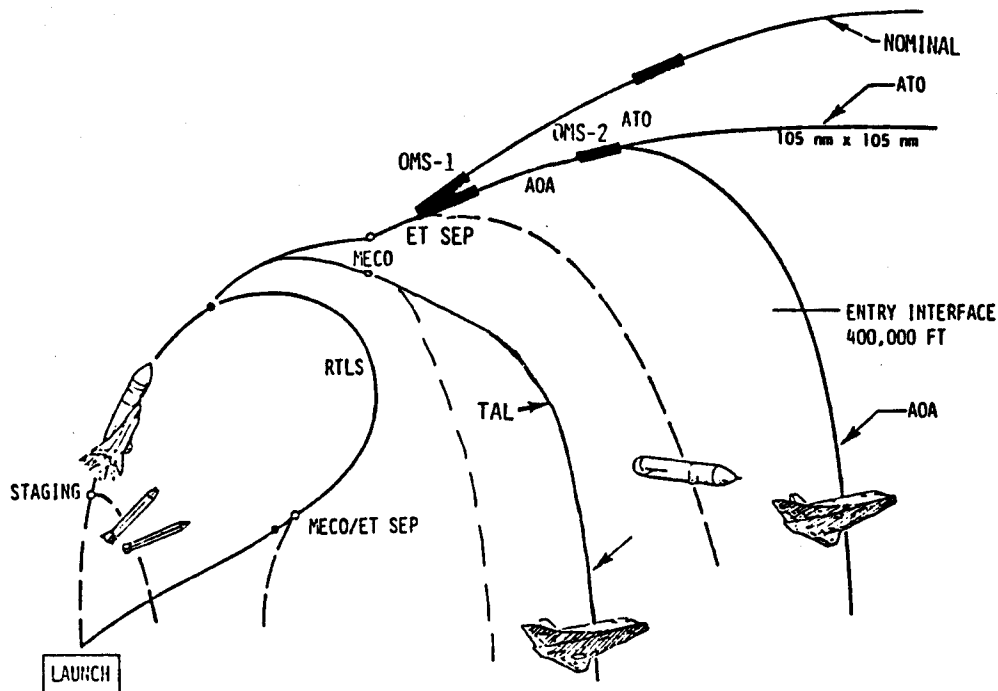


Figure 2.1-1.- Ascent flight phase.

2.1-1

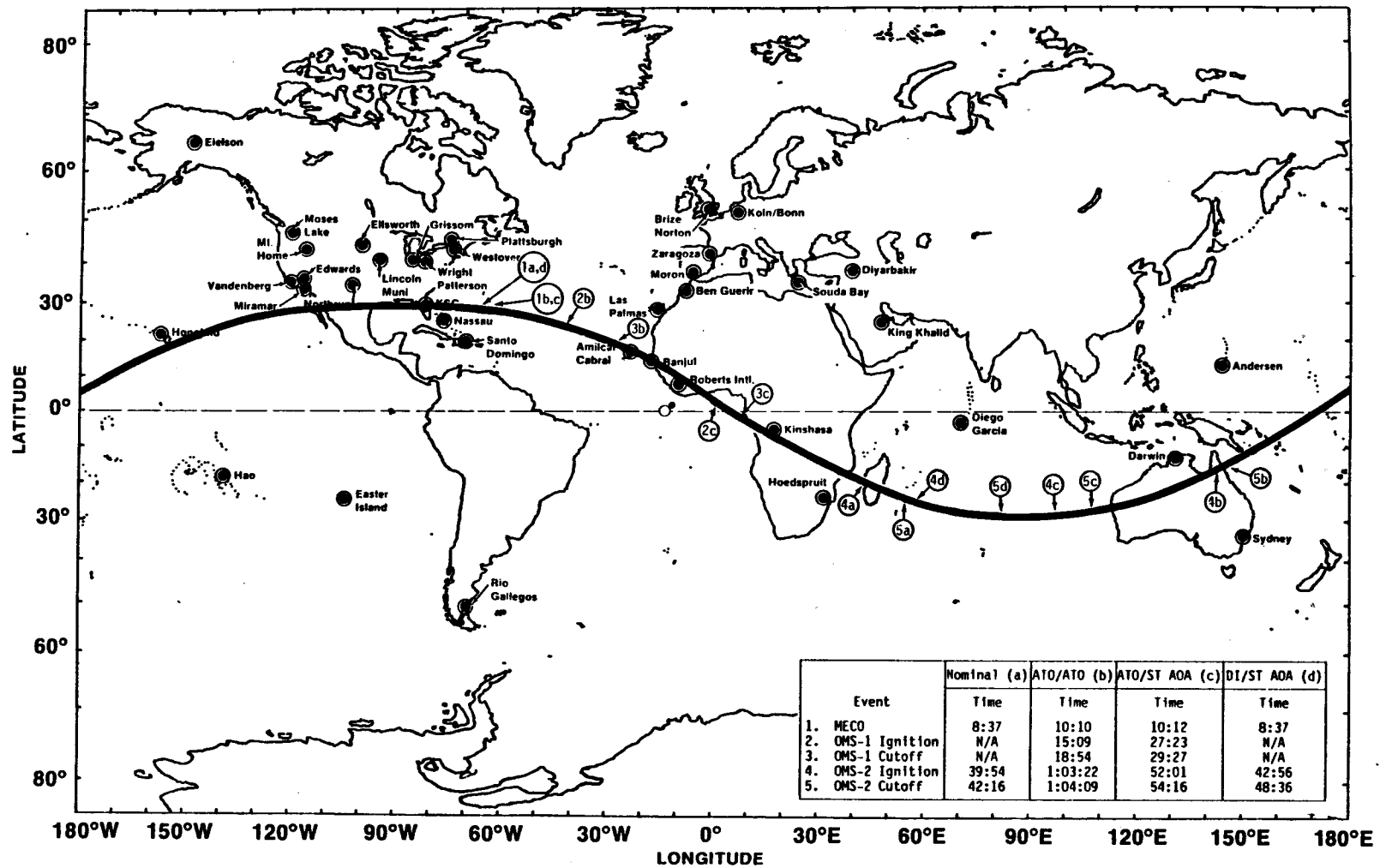


Figure 2.1-2.- Ascent ground track.

## 2.2 NOMINAL SUMMARY

The guidance software for nominal ascent is contained in Operational Sequence 1 (OPS 1). OPS 1 is composed of major modes (MM's) 101, 102, 103, 104, 105, and 106. A summary of the MM is contained in figure 2.2-1.

Twenty minutes prior to launch, the flight software is moded to OPS 1 MM 101 from OPS 9 in preparation for lift-off. At T-6.6 sec, the redundant set launch sequencer (RSLs) commands the Space Shuttle main engine (SSME) start, and all three SSME's are commanded to throttle up to 100 percent. If all three engines are detected to be greater than 90 percent, then the solid rocket booster (SRB) ignition is commanded at T-0, and the flight software changes to MM 102, first stage guidance.

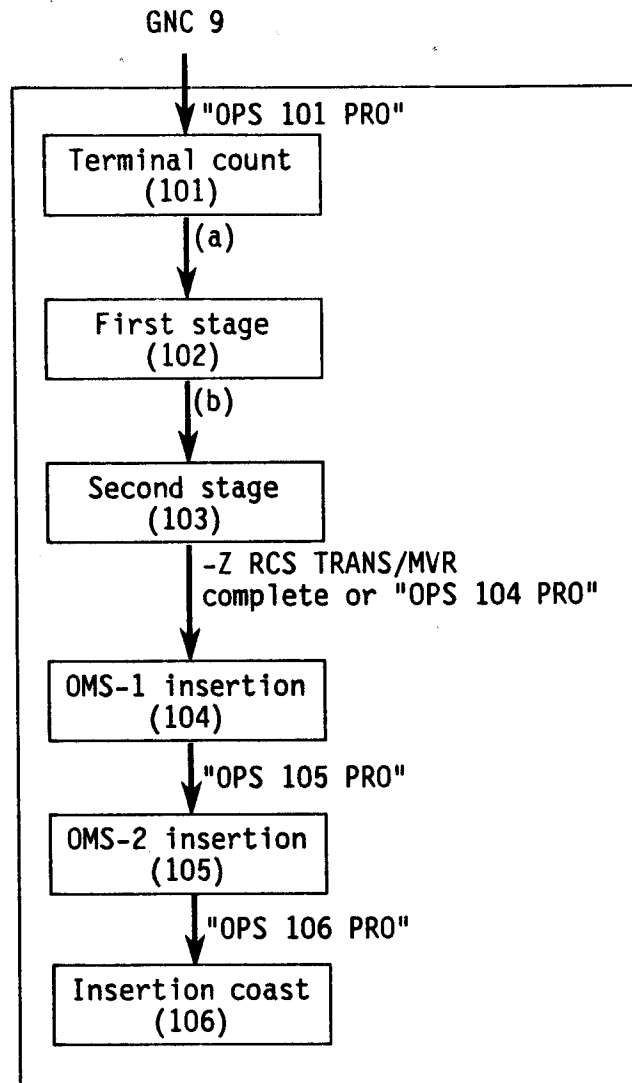
First stage guidance is an open loop scheme. Due to this fact, guidance commands are not a direct function of vehicle performance. Instead, guidance commands a pitch, yaw, and roll attitude profile as a function of Earth relative velocity (VREL). First stage guidance uses an attitude-versus-VREL table to command the appropriate vehicle attitude needed to maximize vehicle performance within system constraints. Table 2.2-1 is a summary of first stage guidance events.

VREL is computed in navigation user parameter processing (UPP) and is derived from the propagation of the equations of motion using sensed velocity deltas from the inertial measurement units (IMU's). This navigation scheme is common throughout OPS 1.

When the first velocity breakpoint is reached (VREL = 60 fps,  $\sim$ T+4.0 sec), SSME's are throttled to 104 percent. Guidance maintains vehicle launch pad orientation until the roll maneuver is commanded (VREL  $\geq$  127 fps,  $\sim$ T+7 sec) at which time a roll, pitch, and yaw rotation places the vehicle in a head-down attitude aligned with the desired launch azimuth. The roll maneuver is completed at  $\sim$ T+18 sec.

During the early part of first stage as the vehicle flies through the densest part of the atmosphere, dynamic pressure ( $\bar{q}$ ) builds up rapidly. The nominal first stage pitch and throttle profile is designed to keep aerodynamic loads within limits. However, winds and SRB burn rate dispersions will additionally stress the vehicle. In order to avoid exceeding aerodynamic load limits, several types of load relief logic are designed into first stage guidance and flight control.

To decrease structural loading, the SSME's are throttled down through a single or multistep throttle profile to an I-loaded minimum throttle setting (normally 65 percent). The throttle bucket breakpoints are based on VREL cues. Throttle down begins at  $\sim$ 00+25 sec. Prior to this phase of load relief, only SRB dispersions will significantly alter the velocity-time history. To account for hot or cold SRB burn rate dispersions, adaptive guidance compares the predicted time that a predetermined velocity is to be reached to the actual time that this velocity was reached. The time difference (T\_DEL\_ADJ) will indicate the magnitude and direction of the SRB



- a All SSME's 90 percent RPL. No countdown holds, +2/5 sec time delay, and no FRF flag (SRB ignition).
- b  $(P_c \leq 50$  or  $MET \leq 129.8$  sec) + -8 sec and attitude rates within limits or manual switch enabled and closed (SRBSEP complete)

(Information in this figure is from COMPUTER PROGRAM DEVELOPMENT SPECIFICATION, Vol. V. Book I. GNC.)

JSC-10559\*001

Figure 2.2-1.- Major mode flow.

TABLE 2.2-I.- FIRST STAGE GUIDANCE EVENTS

| EVENT   | MET   | VREL<br>(fps) | V <sub>I</sub><br>(fps) | K (%) | ALT<br>(ft) | MACH |
|---|-------|---------------|-------------------------|-------|-------------|------|
| First throttle command (VREL ≥ QPOLY(1) = 60 fps)                           | 00:04 | 60            | 1342                    | 104   | 95          | .06  |
| Tower clear/begin SAR (VREL ≥ PPOLY(2) = 127 fps)                           | 00:07 | 127           | 1347                    | 104   | 387         | .11  |
| READ AGT (VREL > VREF_ADJUST = 380 fps)                                     | 00:19 | 380           | 1526                    | 104   | 3162        | .35  |
| Second throttle command (VREL ≥ QPOLY(2) = 400 fps, KCMD = THROT(2) = 104%) | 00:19 | 400           | 1526                    | 104   | 3162        | .35  |
| Engine out switch velocity (V > V_EO_SW)                                    | 00:20 | 450           | 1549                    | 104   | 3963        | .40  |
| Ramp in load relief (V > VREL_GAIN_TAB(2) = 547 fps)                        | 00:23 | 547           | 1619                    | 104   | 5352        | .48  |
| Third throttle CMD (V ≥ QPOLY(3) = 658 fps, KCMD = THROT(3) = 65%)          | 00:27 | 658           | 1708                    | 104   | 8157        | .58  |
| Third throttle attained   | 00:32 | 772           | 1812                    | 65    | 10796       | .70  |
| Begin max. load relief (V > VREL_GAIN_TAB(3) = 900 fps)                     | 00:38 | 900           | 1937                    | 65    | 15275       | .83  |
| Begin load relief termination (V > VREL_GAIN_TAB(4) = 1335 fps)             | 00:58 | 1335          | 2364                    | 65    | 34150       | 1.31 |
| Fourth throttle CMD (V ≥ QPOLY(4) = 1358 fps, KCMD = THROT(4) = 104%)       | 00:59 | 1358          | 2389                    | 65    | 35252       | 1.35 |
| Fourth throttle attained  | 00:64 | 1504          | 2534                    | 104   | 41058       | 1.54 |
| Load relief off (V > VREL_GAIN_TAB(5) = 2628 fps)                           | 01:18 | 2628          | 3713                    | 104   | 79029       | 2.72 |
| SRB staging   | 02:04 | 4139          | 5336                    | 104   | 155315      | 3.93 |

dispersion. Based on this information, guidance then makes trajectory adjustments by varying the throttle profile and the commanded pitch profile. This is done primarily to minimize  $\bar{q}$  dispersions. Figure 2.2-2 shows a typical throttle bucket for nominal, dispersed hot, and dispersed cold SRB's. Adaptive guidance throttling and adaptive guidance pitch biasing are based totally on this single relative velocity check which occurs at ~20 sec, mission elapsed time (MET).

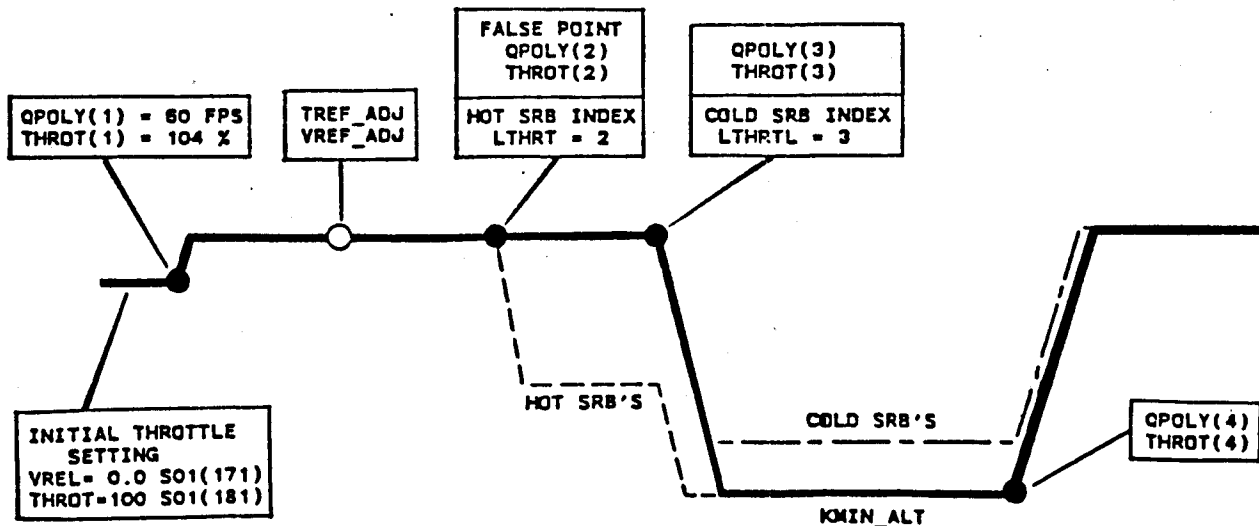


Figure 2.2-2.- Throttle bucket for nominal, dispersed hot, and dispersed cold SRB's.

When a VREL of approximately 550 fps (~T+25 sec) is reached, the normal and lateral acceleration control biases are gradually increased with a ramp function. Throughout the high  $\bar{q}$  region ( $547 < VREL < 2500$  fps), flight control will prioritize lateral acceleration over attitude and fly to the reference normal acceleration profile while attempting to zero lateral accelerations. This phase of load relief is designed to make the vehicle more responsive to acceleration errors induced by wind effects in the high  $\bar{q}$  region. The vehicle will actually steer off course (into the wind), out of the planned trajectory plane, in order to fly out lateral acceleration errors and thus reduce aerodynamic loading. Depending on the severity of the winds, the vehicle could experience a noticeable deviation from the planned trajectory plane.

Also, during the region of maximum  $\bar{q}$ , the elevons may be driven off schedule in order to reduce aerodynamic loading. This phase of load relief is actually closed loop as the elevons respond to a sensed aerodynamic loading.

In the event of an SSME failure during the first stage, guidance will automatically command the remaining two SSME's to throttle to 104 percent,

regardless of where you are in the thrust bucket, to obtain maximum performance. A pitch bias is then added to the nominal pitch attitude history in order to loft the trajectory. This pitch bias is a function of the engine-out velocity. The lofted trajectory is needed to protect for proper completion of the RTLS abort, which is discussed in section 2.7.

SRB separation (event 26) is initiated when SRB chamber pressure ( $P_c$ )  $\leq$  50 psi or  $MET \geq$  SRB\_SEP\_BACKUP\_CUE\_T (=129.8 sec (I-load)), whichever comes first. During the separation (SEP) sequence, the vehicle is in a 3-axis attitude hold. After an I-loaded time delay (4.8 sec), event 28 is reached causing fire commands to be issued to the SRB separation pyro initiator controller (PIC). The flight software then modes to MM 103 (second stage guidance).

Second stage guidance functions much differently from first stage guidance in that it is completely closed loop. Simply stated, second stage guidance computes the control variables and burn time to go (TGO), such that the vehicle flies from the current state to the prescribed target conditions (altitude, velocity, flight path angle, and orbit plane) within trajectory constraints. It solves this two-point boundary value problem each cycle (every 1.92 sec) from initiation through fine countdown mode (MECO-10 sec). At SRB SEP, flight control holds attitude until the second stage guidance solution converges in MM 103. This normally takes only 3 to 5 cycles (6 to 10 sec). Once guidance is converged, active steering and throttle settings are commanded.

The powered explicit guidance (PEG) scheme used by second stage guidance nominally operates in two phases. The first phase computes throttle and attitude commands based on three SSME's and a constant thrust requirement until an acceleration of 3g is reached. At that time, the second phase is entered which uses variable throttle to maintain a constant acceleration. If an engine failure is detected, a third phase of PEG is entered (assuming no RTLS or TAL abort), which will compute the necessary guidance commands using constant thrust to aim for the desired targets using two SSME's.

In most cases, only two phases of PEG are used, constant thrust through 3g, then variable thrust through the main engine cutoff (MECO). However, by taking advantage of the third phase of PEG, second stage trajectories can be lofted or "abort-shaped" by making use of a flag called T\_FAIL. By setting this flag to a nonzero value (e.g., T+4:27 for STS-26), guidance will assume an engine failure at this time and loft the trajectory to compensate for the anticipated failure. Abort shaping allows for earlier press-to-MECO calls but does sacrifice overall performance.

For reasons of flight control stability near MECO, the desired target conditions of altitude and orbital plane are unconstrained at MECO-40 sec. At this time, velocity and flight path angle become the only constraints.

At MECO-10 sec, fine countdown mode is entered, guidance goes "open loop" and commands a safe thrust tailoff for SSME's to achieve the desired velocity. MECO nominally occurs at  $\sim$ T+8:30. Approximately 4 sec after MECO the transition digital autopilot (TRANS\_DAP) issues command to hold altitude

using the reaction control system (RCS). At MECO+10 sec, a liquid hydrogen (LH<sub>2</sub>) venting dump is performed out of the RTLS-dump port for approximately 30 sec. The dump will relieve any high pressure found in the LH<sub>2</sub> feedlines prior to the initiation of the main propulsion system (MPS) dump.

The external tank separation sequencer (ET SEP SEQ) performs several tasks during the coasting period between MECO and ET SEP. This includes driving the main engines to stow position and performing several software tests to determine whether the structural separation should be inhibited. These software tests include checking that the vehicle rates are within the prescribed 0.7 deg/s deadband limits. If these constraints are met, then external tank (ET) separation will be commanded at approximately MECO+18 sec. The TRANS\_DAP automatically initiates a -Z RCS translation burn just prior to structural separation to move the Orbiter away from the ET. Once the -Z translation achieves 4 fps, the software transitions to the insertion MM 104 and the OMS-1 MNVR EXEC display comes up on the cathode-ray tube (CRT) with the I-loaded OMS-1 targets automatically loaded. The crew should verify the burn targets and the OMS-1 burn solution in both the PASS and the BFS, and then maneuver to the burn attitude if the burn is to be performed. If the crew does an auto maneuver using the digital autopilot (DAP), the burn attitude will be maintained within a 3.5° deadband.

The standard insertion mission requires two OMS insertion burns. The first burn (OMS-1) establishes the desired apogee altitude, and the second burn (OMS-2) either circularizes the orbit or raises the perigee to a desired mission altitude.

The OMS-1 burn will not be executed nominally for the direct insertion mission. The direct insertion technique makes use of the main engines to achieve a desired apogee altitude, conserving OMS propellant for on-orbit/entry usage. This technique is used for either heavy payloads or high apogee missions in which the ET disposal constraints are not violated. Only one OMS burn, performed near the MECO apogee, is required for the direct insertion mission to raise the perigee.

During the insertion coast, the Mission Control Center (MCC) will inform the crew if the navigation (NAV) state vector needs to be updated, or if new OMS burn targets are required. If either action is taken, a reload of the OMS-1 targets will be performed to update the burn solution. On nominal standard insertion missions, the OMS-1 ignition time is 1 min 42 sec from ET SEP or approximately MECO+2 min. The MPS liquid oxygen (LOX) and LH<sub>2</sub> dumps start automatically when the OMS-1 burn for ullage is initiated. For direct insertion missions, the MPS LOX and LH<sub>2</sub> dumps are initiated manually by the crew placing the MPS DMP SEQ switch to start. A 5-sec manual 4+X RCS ullage burn will precede the manual dump in order to shift the propellant toward the back of the feedlines. The MPS dumps are terminated after the ~2-min I-loaded dump time has expired.

The OMS cyclic guidance initiates 15 sec prior to OMS ignition, updating the delta-V solution and requesting the crew to enable the burn. Once the burn is enabled, the crew can monitor the status of the burn by checking the OMS-1 MNVR EXEC, the BFS GNC SYS SUMM 2 display, and the dedicated gauges.



Upon completion of the burn, the crew should note any anomalies and null out any burn residuals greater than 2 fps by using the translational hand controller (THC). The OMS cyclic guidance remains active until transition to the OMS-2 insertion mode (MM 105).

After the crew performs the auxiliary power unit (APU) shutdown, a manual transition to MM 105 is performed causing the OMS 2 MNVR EXEC display to come up on the CRT with the I-loaded OMS-2 burn targets. The OMS-2 targets are loaded and the burn solution is verified by the crew. The OMS-2 time of ignition (TIG) time should be checked to center the burn about apogee for the most fuel optimal burn solution. During the maneuver coast, the crew will perform the MPS vacuum inerting procedure and close the ET umbilical doors. The OMS-2 burn attitude can be maneuvered to automatically or the crew can elect to use the rotational hand controller (RHC) for a manual maneuver. If the DAP is used, the burn attitude will be maintained within a 3.5° deadband during the coast. OMS guidance will initiate 15 sec prior to the OMS-2 burn requesting the crew for a burn enable. The crew monitors the OMS-2 burn as they did for OMS-1 with guidance computing the PEG solution actively until the next MM transition. The burns are normally flown automatically; however, the crew can take control with the RHC and fly manually at any time. The crew will note the postburn status, then reconfigure the OMS/RCS for on-orbit usage. A manual transition to the insertion coast (MM 106) is then performed, terminating the ascent phase.

### 2.3 ATO MODE

The ATO mode is designed to achieve a temporary orbit that is lower than the nominal orbit (fig. 2.3-1). This mode requires less OMS propellant than the nominal scenario and allows time for problem evaluation in determining whether an early deorbit burn is required or whether an orbit insertion burn should be performed to raise the orbit and continue the mission. The ATO may be selected due to either a performance problem during powered flight (SSME failure), or due to certain system failures as identified in the Flight Rules. In any case, the MCC is prime for identifying the abort mode.

The ATO may be selected pre-MECO by using either the abort rotary switch and pushbutton on panel F6 or by using the OVERRIDE Display (GNC SPEC 51). The main purpose of the pre-MECO ATO selection is to provide the earliest AOA capability off of the MECO design underspeed (reducing TAL window exposure) by performing either a pre-MECO OMS dump, switching to abort MECO targets, or by employing variable IY steering. The MECO design underspeed is protected for MPS performance and is constrained by either ET disposal safety limits, net positive suction pressure (NPSP) limits on the main engines, maximum delta-V capability for the ATO/AOA steep scenario, or drag constraints measured during the OMS-1 cutoff to OMS-2 ignition coasting period. The pre-MECO OMS dump, abort MECO targets, and variable IY steering options are discussed in the AOA description, section 2.4.

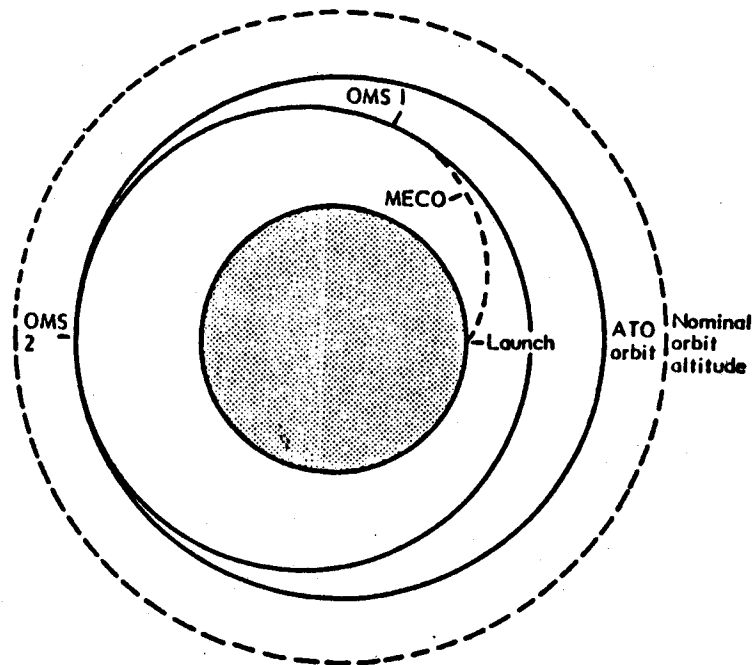


Figure 2.3-1.- ATO versus nominal orbit.

If possible, ATO abort initiation is accomplished after MECO to ensure that RTLS, TAL, and contingency abort capabilities are retained as long as possible and in order to take maximum advantage of observed performance in making the ATO versus AOA abort mode determination. The ATO OMS-1 (I-TGT 1) target set is called up by the ATO AUTO TGT software if the abort rotary switch is used either pre-MECO or pre-OMS-1. The ATO OMS-1 target set is designed to be used as a common target set in which either an AOA deorbit burn or ATO circularization burn can be performed at OMS-2. The final decision for committing to either an ATO or AOA can thereby be delayed until after the OMS-1 burn is completed.

In order to provide a fuel-efficient ATO or AOA scenario, the OMS-1 burn is initiated at 2 min prior to apogee but no earlier than MECO+2 min. A delay in the OMS-1 ignition time (for low underspeed ranges) also provides the advantage of a shallow post-OMS-1 orbit (105 by 80 n. mi.) which can be maintained for three revs. If the MECO apogee is more than 6 min away, a manual dump will be initiated at MECO+2 min using the MPS DMP SEQ switch preceded by a 5-sec 4+X RCS ullage burn. After completion of both ATO OMS burns, the Orbiter is in a 105 n. mi. circular orbit. Once this safe orbit is achieved, the mission may be continued in that orbit for 2 days, additional burns may be made to raise the orbit, or the mission may be ended early.

## 2.4 AOA MODE

The AOA mode is designed to allow the Orbiter to fly once around the Earth and make a nominal entry and landing instead of continuing uphill into orbit. In most cases this mode involves two OMS burns, with the second burn being a retrograde deorbit maneuver.

Edwards Air Force Base (EDW), Northrup Strip (NOR) and Kennedy Space Center (KSC) are AOA landing sites for Eastern Test Range (ETR) launches. Prime site selection is based on several factors which are flight specific, such as crossrange, runway length, runway surface, and lighting. A second site may be loaded as a weather alternate.

There are two types of AOA trajectories; a steep AOA and a shallow AOA. The entry trajectory for the steep AOA is similar to the nominal entry trajectory. The shallow AOA results in a flatter trajectory which is less desirable than that of the steep AOA but requires less OMS propellant. The shallow entry trajectory is less desirable because it exposes the vehicle to a longer period of atmospheric heating and to less predictable aerodynamic drag forces.

An AOA may be required due to performance problems (SSME failure) or due to certain systems failures as identified in the Flight Rules. Systems and performance abort groundrules are defined by the OMS TGTING cards discussed in section 3.2.

### 2.4.1 Pre-MECO Abort Selection

A pre-MECO AOA abort, due to an engine failure, can be selected only indirectly. This is done by selecting ATO using either the abort rotary switch and pushbutton on panel F6 or the OVERRIDE display (GNC SPEC 51). Selecting the AOA-S/TAL position on the abort rotary switch will result in TAL pre-MECO. The main purpose of the pre-MECO ATO selection is to provide the earliest AOA capability with the MECO design underspeed (reducing exposure to TAL) by performing a pre-MECO OMS dump, switching to abort MECO targets, and employing variable IY steering.

The pre-MECO OMS dump will initiate immediately upon ATO abort selection and will terminate based on either a constant or ramp dump timer. The ramp dump is used for long dump timers. The software actually calculates the OMS dump time (OMS\_DT) as a function of the engine-out velocity. This type of dump is used to prevent the waste of OMS propellant in late engine failures cases (just prior to PRESS TO MECO). The AOA OMS dump will normally be performed using both of the OMS engines but may be interconnected with 18 RCS jets in cases where the dump time exceeds the time period between abort selection and MECO.

Depending on the flight, the AOA pre-MECO selection may also invoke variable IY steering and/or abort MECO targets. Depending on the engine failure time, variable IY steering retargets the vehicle to either its current or a specified minimum inclination in order to gain performance to achieve the

MECO design underspeed. This option is used for high inclination missions where performance gains are realized by allowing the vehicle to fly in a more easterly direction, due to the Earth's rotation. The abort MECO target consists of an alternate altitude, velocity, and flight path angle target for MECO. Abort MECO targets are employed for high apogee direct insertion (DI) missions where performance is gained by retargeting to a lower MECO apogee.

The alternative to variable IY steering, abort MECO targets, or a pre-MECO OMS dump is longer exposure to TAL. A disadvantage of pre-MECO abort selection is the possibility of ending up with better than predicted MPS performance in which either an ATO or nominal mission could have been completed if no OMS were dumped or no alternate MECO targets selected.

#### 2.4.2 Post-MECO Abort Selection

AOA may be selected post-MECO by using the abort rotary switch and push-button on panel F6 or by I-TGT selection on the OMS MNVR display. If AOA is selected post-MECO and prior to OMS-1, the AOA automatic targeting software automatically downmodes the OMS-1 to be an AOA shallow (I-TGT 5). The AOA shallow OMS-1 target set is used only for severe MECO underspeed conditions. This target set may be changed by keying in a different I-TGT value such as I-TGT 1 for the ATO OMS-1 targets.

For most flights, ATO and AOA steep use common OMS-1 targets. In this manner, the decision to abort AOA may be delayed until after OMS-1, thus giving more time to assess the failure scenario and select the appropriate abort mode. If AOA is selected after OMS-1, the AOA procedures call for the crew to depress the hydraulics instead of shutting down the APU's. Also, during the coasting period between the ATO OMS-1 burn and the deorbit burn, the crew will work the alpha management procedure to minimize drag effects.

If an OMS-1 is required, there may be a large radial velocity component. The line of apsides is shifted in order to adjust the post-OMS-1 orbit to support entry or uphill.

Once the OMS-1 burn is completed or the software is transitioned to MM 105 and the AOA abort mode is selected, the deorbit targets are called up in OPS 1 and carried across the transition to OPS 3. However, the deorbit targets are not loaded until after the OPS 3 transition due to different guidance targeting logic. In calculating the deorbit OMS-2 TIG, the AOA software takes into account any downrange dispersions at MECO by comparing the angle between the launch site and OMS-1 TIG to an I-loaded reference angle in the software. This TIG-adjust logic is required since the OMS ignition times are based on an I-loaded delta time from ET SEP. Figure 2.4-1 provides a visual description of how the TIG adjust logic works. Figure 2.4-2 shows the approximate orbital position of the AOA OMS burns. The OMS-1 maneuver establishes a temporary orbital trajectory, and the OMS-2 maneuver is a deorbit burn.

The AOA software will also compute the amount of excess OMS that may be burned out of plane during the deorbit maneuver by subtracting from the usable OMS load the amount used during the pre-MECO OMS dump and the OMS-1 burn and the amount reserved for center of gravity (c.g.) control. The crew can change the amount of OMS propellant to be wasted and the direction of the out-of-plane wasting through keyboard entries on the OMS MNVR display.

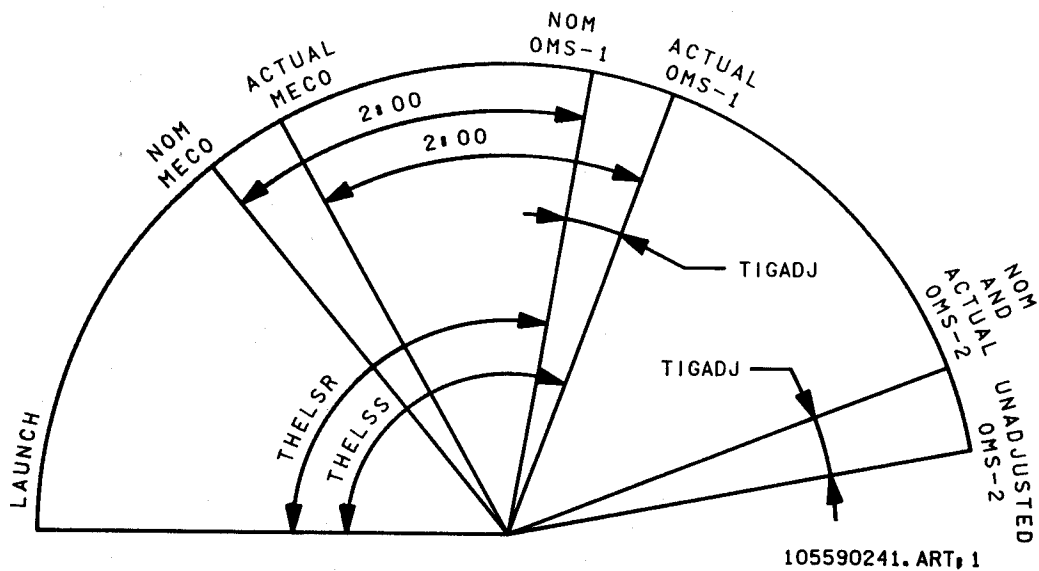


Figure 2.4-1.- TIG adjust logic.

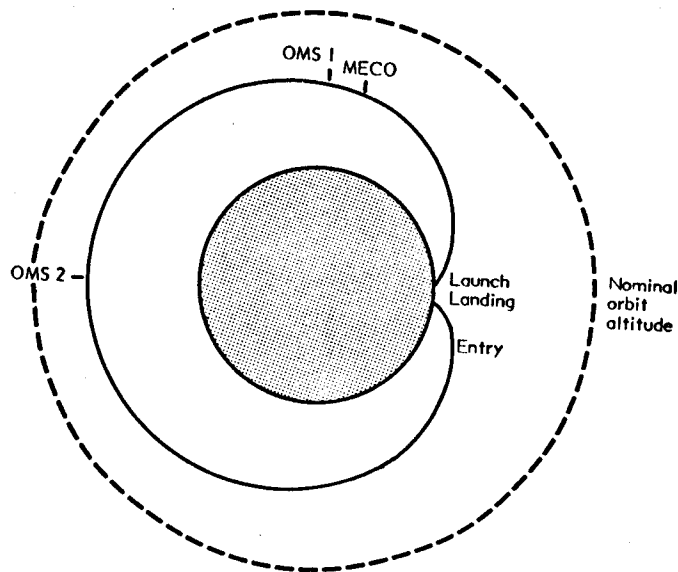


Figure 2.4-2.- AOA trajectory.

2.4-3

AOA targets should not be loaded until OPS 3 because OPS 3 calculates the theta target differently from OPS 1. MM 105 (AOA TRANS) is used to carry parameters from GNC OPS 1 to GNC OPS 3. The transition to OPS 3 is not completed until the targets have been verified. When the reconfiguration is complete, the DEORBIT MNVR display appears on the CRT with the I-loaded deorbit burn setup and targeting parameters displayed. If the AOA has not been selected prior to the crew transitioning from OPS 105 to OPS 301, the AOA deorbit targets may be keyed in on the OMS MNVR display.

After the deorbit targets are loaded on the MNVR display, the deorbit solution should be checked against the OMS target cards for any discrepancies. The TIG of the burn may need to be adjusted such that the range from entry interface (EI) to the targeted landing site is approximately the reference range listed in the OMS target cards. The deorbit burn attitude can then be maneuvered to automatically using the DAP and will be maintained within a 3.5° deadband.

Prior to the burn, MPS vacuum inerting will be terminated, an MPS/H<sub>2</sub> purge will be performed, and the vent doors will be closed. The OMS cyclic guidance will initiate at TIG-15 sec and will remain active calculating a PEG solution until the MM transition to MM 303.

After the burn is completed and the MM 303 transition has occurred, the crew maneuvers to the EI-5 min attitude, which for steep entry trajectories consists of 0° prebank and 40° angle of attack. In the case of a shallow deorbit burn, a prebank of 90° will be required to ensure atmospheric capture. If required, the forward RCS (FRCS) will be dumped to control the c.g. and total Orbiter weight for entry. Procedures for EI to landing are the same as nominal entry except hydraulics are repressed, when the dynamic pressure reaches 1 psf.

## 2.5 TAL ABORT

The TAL is designed to provide for the safe return of the Orbiter cargo and crew to a designated TAL landing site in the event of an engine failure occurring in the region between the last RTLS and first AOA. During a TAL abort, the vehicle will continue in a ballistic trajectory across the ocean to land at a predetermined runway. Landing occurs approximately 45 min after launch. Figure 2.5-1 compares a TAL trajectory with a nominal trajectory.

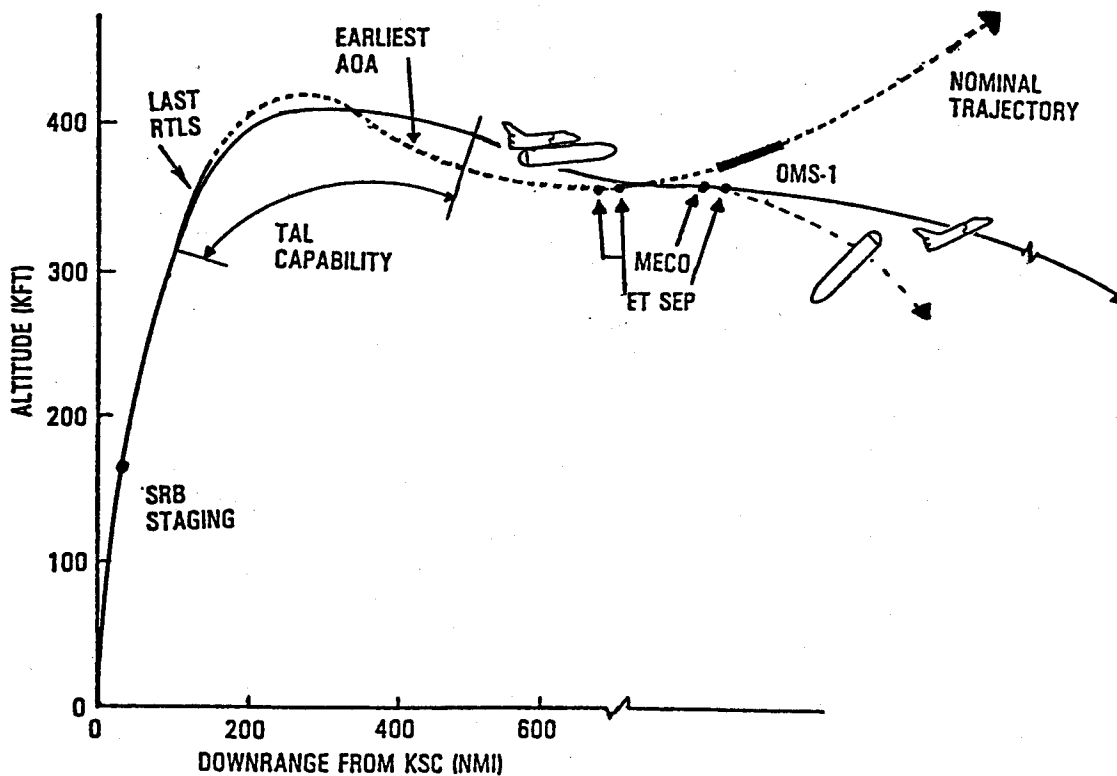


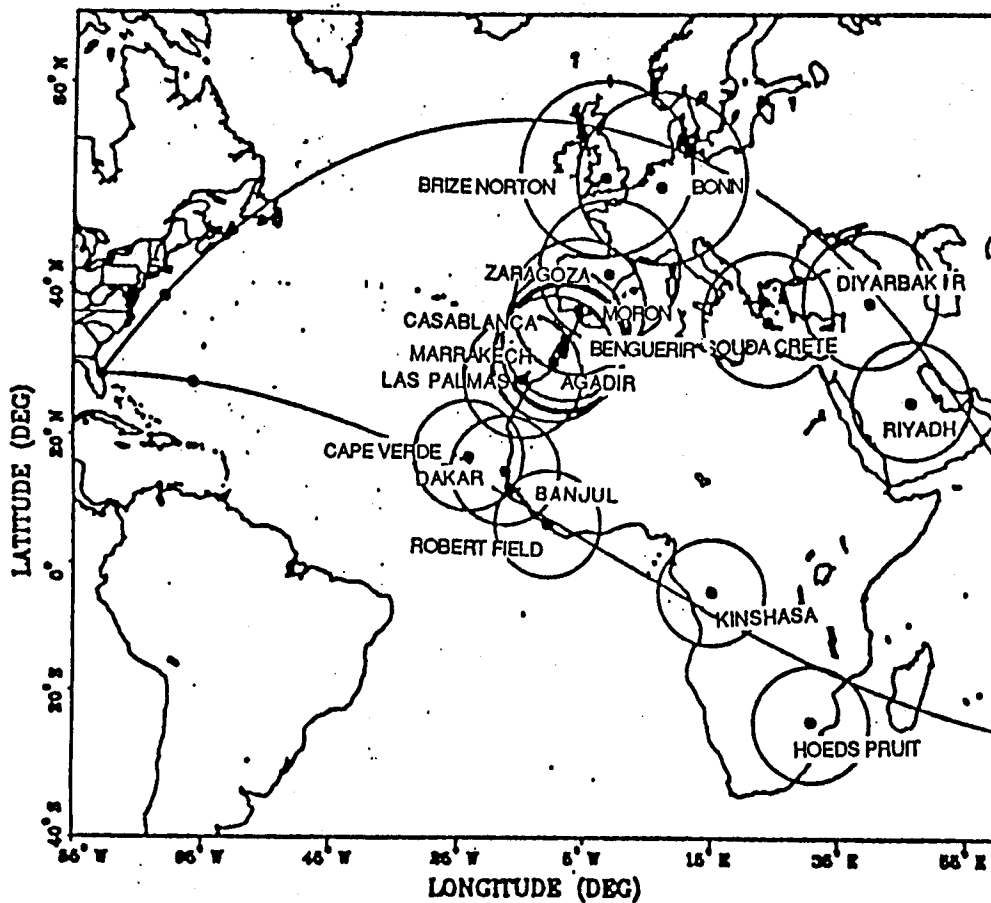
Figure 2.5-1.- TAL versus nominal ascent.

TAL landing sites are selected based on several criteria, including runway dimensions, load bearing capability, weather, security, and surrounding terrain. Powered flight guidance has the capability to target for four different sites. Generally, a prime, weather alternate, and two contingency landing sites are I-loaded for each mission. Ben Guerir and Moron are currently the prime and weather alternate landing sites for 28.5° inclination missions. Figure 2.5-2 is a plot of 28.5° and 57° inclination groundtracks and the surrounding TAL landing sites. Due to reduced crossranging requirements, landing sites near the nominal ascent groundtrack of the Orbiter make the most efficient use of SSME propellant.



# ETR TAL LANDING SITES

28.5 AND 57 DEG INCL



PROJECTION : MERCATOR

Figure 2.5-2.- ETR TAL landing sites.

To select the TAL abort mode, the crew places the abort rotary switch in the TAL/AOA position and depresses the ABORT pushbutton prior to MECO (depressing it post-MECO will select the AOA abort mode). TAL may also be selected via the OVERRIDE display (SPEC 51). Upon abort initiation, the title of the ASCENT TRAJ display will change to TAL TRAJ. This is a fairly obvious cue to the crew that the software has moded properly. An overview of guidance related events occurring during a typical TAL ascent is shown in figure 2.5-3.

At abort selection, an OMS propellant dump will be initiated. OMS propellant may be dumped through the two OMS engines only or through both OMS engines plus 24 aft RCS jets (20 null jets and 4+X jets) interconnected to the OMS propellant tanks. Depending on the flight, the OMS/RCS interconnect

2.5-2

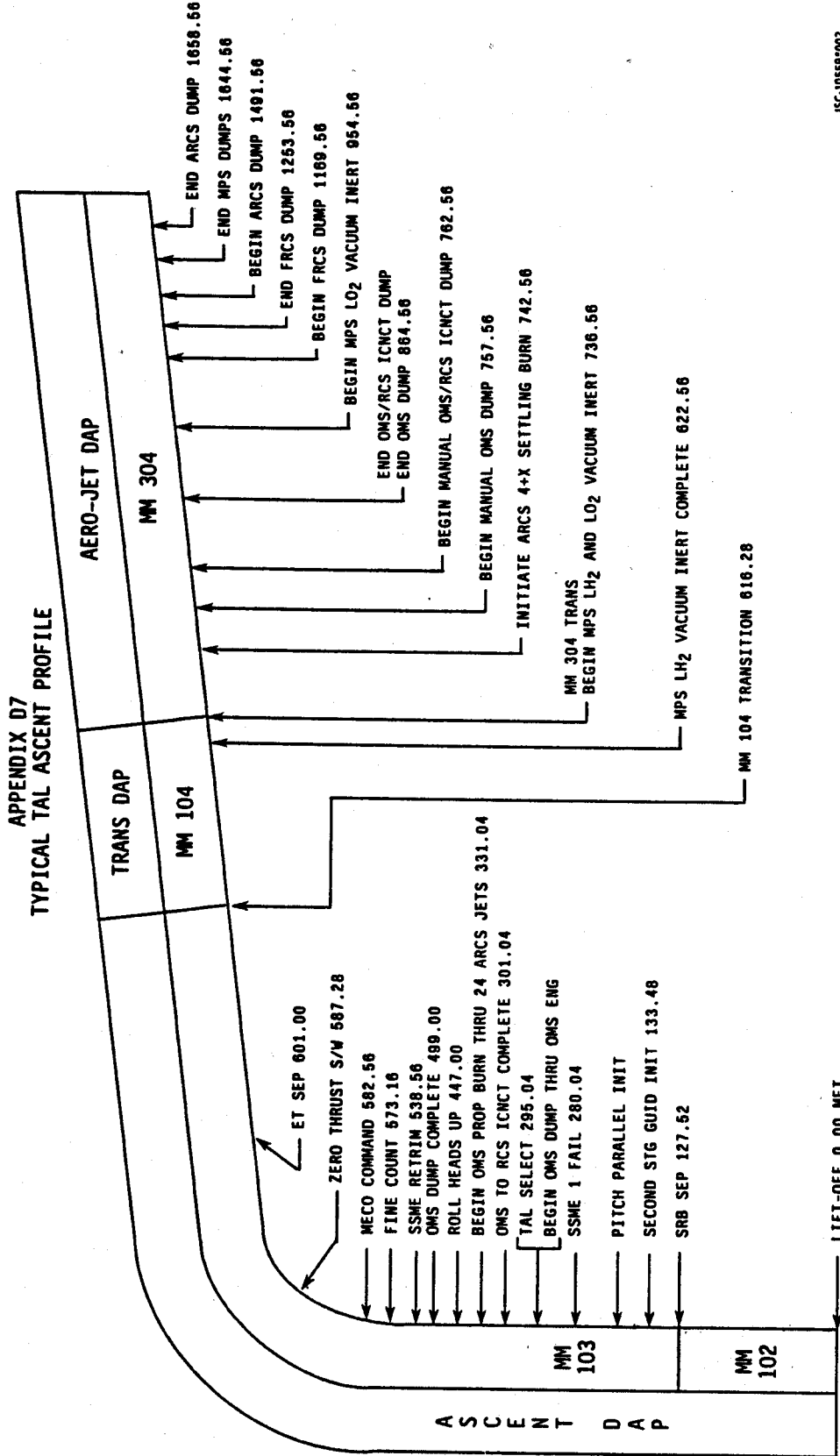


Figure 2.5-3- TAL ascent guidance events.

may be enabled or inhibited prior to liftoff. The dump is set to a pre-determined I-loaded time duration and will terminate automatically at MECO prep (fine countdown), MECO confirmed or the timer, whichever comes first. When the dump is initiated with the interconnect enabled, the dump time is adjusted with an I-load bias to account for the additional flow rate through the RCS jets.

Also, at abort selection, TAL guidance begins steering the vehicle toward the plane of the landing site. After TAL initiation a table lookup is done for the guidance and navigation I-loads associated with the selected landing site. The navigation I-loads (i.e., runway geodetic latitude and longitude) are transformed into an Earth-fixed landing site position vector for guidance targeting. The desired MECO inertial velocity magnitude is computed with a third order polynomial equation. This polynomial is a function of the surface range between the predicted MECO position vector and the aim point vector associated with the TAL Earth-fixed landing site vector at the predicted MECO time.

Variable IY TAL steering is designed to get the crossrange to the TAL site within an acceptable limit at MECO. If the calculated crossrange, based on the current TAL IY and TAL aimpoint, exceeds the I-loaded maximum allowed crossrange (500 n. mi.), the TAL aimpoint is adjusted so that the crossrange will equal the maximum crossrange. A new IY is then defined so that the crossrange will equal the maximum crossrange and a new IY is defined so that the target plane passes through the new aim point vector. In this manner the vehicle will begin to steer closer to the landing site. If the calculated crossrange is less than the maximum allowed crossrange, the targeted orbital plane defined by the IY vector is not changed.

The maximum crossrange I-load is based on a two-engine TAL aimpoint velocity and range. Due to this fact, the maximum crossrange may not be valid for single-engine TAL's. Thus, it is possible to hit the range-velocity (R-V) line at the maximum crossrange and not make the runway.

In addition to the R-V and crossrange limit, a desired flight path angle and radius/altitude target must also be achieved at MECO. Currently, guidance targets for a MECO flight path angle and altitude such that at ET separation the flight path angle will be zero and the altitude 360,000 ft.

The only maneuver done during TAL powered flight is a roll to heads up. This is done in order to put the vehicle in the correct entry attitude at ET SEP. When the Earth relative velocity of the vehicle is greater than the I-loaded reference velocity of 14,000 fps, the vehicle begins rolling to heads up at 5 deg/s. The rollover is done at this time to distribute ET heating evenly and prevent thermal exceedances.

Once all the powered flight guidance targets have been achieved, MECO is commanded. Following MECO confirmed, after a time period of 3.75 sec, SSME OPS declares software zero thrust, which is the signal to the master sequence controller (MSC) to terminate the ascent DAP and initialize the transition DAP. ET structural release is commanded automatically 0.16 sec

after -Z command (MECO command plus approximately 18 sec), beginning the -Z translation, ET SEP phase. When the velocity in the -Z direction exceeds 11 fps, the separation complete signal is given, at which time transition to MM 104 takes place.

2.5-5

## 2.6 LATE TAL ABORT

LATE TAL is a downrange abort to Africa (low inclination) or Europe (high inclination) due to an early MECO. This procedure is used when the resulting low energy MECO state will not support an uphill trajectory. Late TAL can also be used for systems failures that occur during the final minute of powered flight, although this is unlikely (see SYS FLIGHT RULES discussion section 3.1.5). For cases such as these, the crew will manually perform MECO at the inertial velocity (VI) cue designated in the LATE TAL procedures of the Ascent Checklist (STS-26 ~24k fps).

Because a TAL abort cannot be selected post-MECO, OPS 3 end of mission (EOM) guidance and flight control is used for entry. It is necessary to transition to OPS 3 as soon as possible after MECO in order to maximize OMS dump time, since all of the OMS dumps must now occur post-MECO and prior to 0.05g. In order to expedite the OPS transition, the roll to heads up is delayed until OPS 3, the MM 104 pressurized MPS dump is replaced with an OPS 3 unpressurized dump, and the ET doors remain unlatched until OPS 3.

Depending on the MECO energy state, an emergency landing site may be required. For low inclination flights, late TAL sites include Banjul (Gambia), Amilcar Cabral (Cape Verde), Roberts Field (Liberia), Kinshasa (Zaire), and Hoedspruit (South Africa). For high inclination flights late TAL sites include Brize Norton Royal Air Force (RAF) (United Kingdom), Koln/Bohn (West Germany), Diyarbakir (Turkey), and King Khalid (Saudi Arabia).

## 2.7 RTLS ABORT

The RTLS abort is designed to provide intact abort capability for a suborbital return of the Orbiter, crew, and payload directly to the KSC landing field in the event of an engine failure after liftoff and prior to NEGATIVE RETURN. The RTLS abort mode must be initiated approximately within the first 245 sec of ascent (prior to NEGATIVE RETURN), and requires approximately 22 min to return and land after liftoff.

RTLS consists of several flight regimes: powered flight, ET separation, and glide-flight. The RTLS ET SEP maneuver makes the transition from the Orbiter/ET powered flight configuration to the Orbiter gliding flight configuration. A typical RTLS trajectory profile is presented in figure 2.7-1, which indicates the associated flight phases. An overview of guidance related events during the powered flight portion of a typical RTLS is shown in figure 2.7-2.

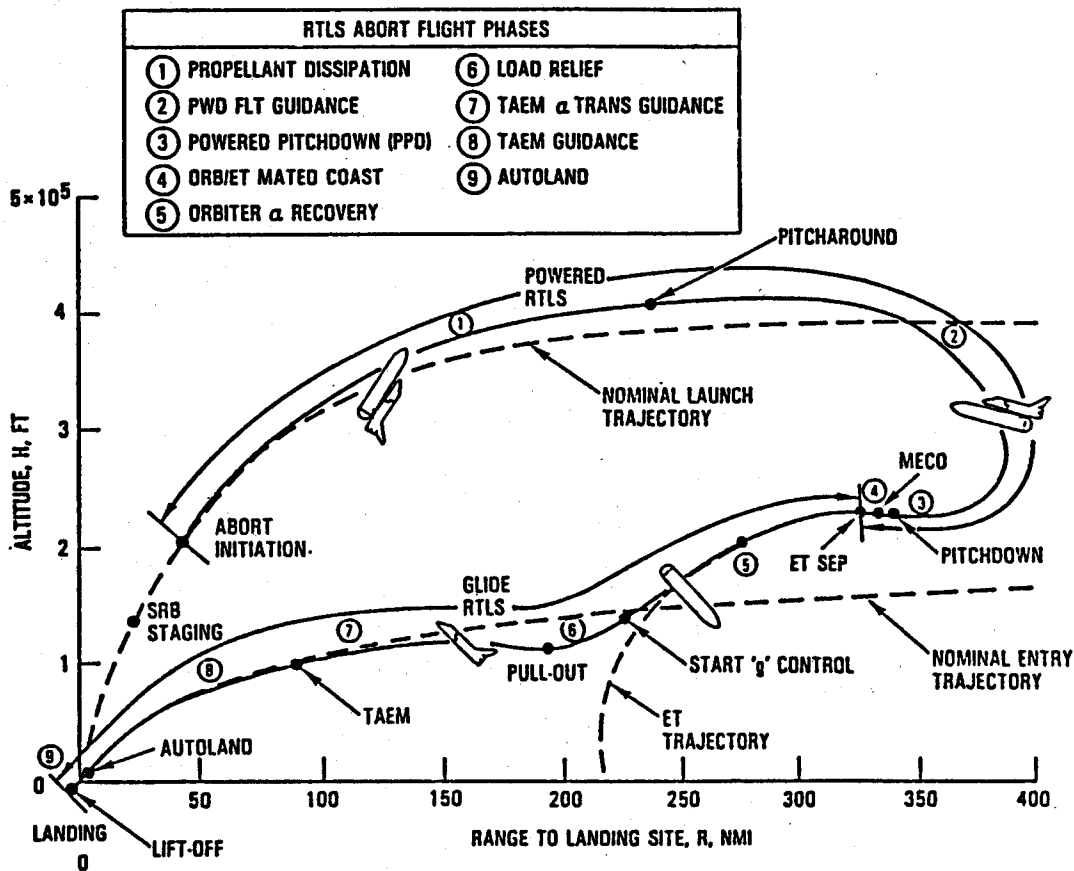


Figure 2.7-1.- RTLS trajectory and flight phases.

APPENDIX D2  
TYPICAL RTLS ASCENT PROFILE

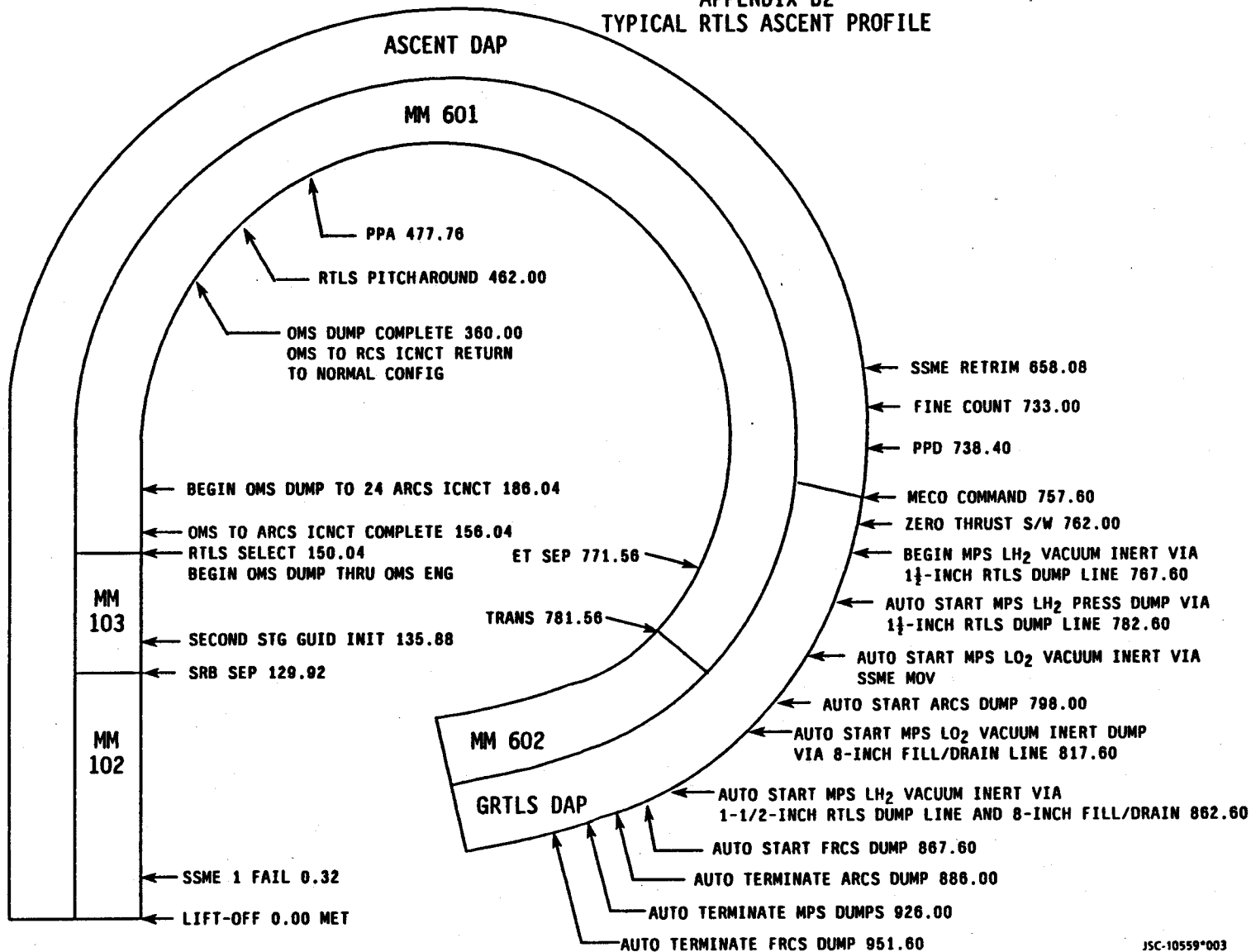


Figure 2.7-2.- RTLS ascent guidance events.

### 2.7.1 Powered RTLS

The decision to return to the launch site can be made during ascent prior to about 245 sec MET. The exact time of last RTLS capability is a function of ascent trajectory shaping and performance. The powered RTLS (PRTLS) phase is that portion of RTLS during which the SSME's are burning. It begins when the abort is initiated and terminates at MECO. If an RTLS is required, it is commanded via the abort mode selector. For engine failures in the first stage (MM 102), RTLS will not be selected until approximately 150 sec MET. If an RTLS is selected during first stage, guidance will not mode to RTLS until after SRB separation. At this time, the title of the TRAJ display changes from ASCENT to RTLS, and the MM indicator changes from MM 103 to MM 601 (OPS 1 to OPS 6).

PRTLS is normally composed of three flight phases: Fuel dissipation, flyback, and powered pitchdown. During the fuel dissipation phase the vehicle continues heading downrange at a fixed inertial thrust direction while cyclical computations are performed to determine the proper time to initiate the turnaround. This phase is not executed in aborts near the limit of RTLS capability since the turnaround begins immediately. The flyback phase, which includes turnaround, guides the vehicle to targets designated at MECO-20 sec. Throttling for fuel depletion control is also performed during the flyback phase. The powered pitchdown phase serves two functions. Each cycle it commands the Orbiter/ET to the angle of attack required for separation and simultaneously computes the SSME cutoff time. The SSME thrust is then terminated at this time by the SSME OPS principle function.

At abort selection an OMS propellant dump will be initiated. The dump can be performed using OMS only or OMS plus 24 aft RCS jets (20 null jets and 4 +X jets). Depending on the flight, the OMS/RCS interconnect may be enabled or inhibited prior to liftoff. The dump is set to a predetermined I-loaded time duration and will terminate automatically at countdown (MECO-26 sec) fine countdown, MECO confirmed or the timer, whichever comes first. When the dump is interconnected, the dump time is adjusted with an I-loaded bias to account for the additional flow rate through the RCS jets.

The first maneuver in the fuel dissipation phase is a pitch attitude change to loft the vehicle out of the atmosphere and to deplete the propellant to the point where the separation requirement of <2 percent MPS propellant remaining at MECO can be achieved. Pitcharound is delayed until the MPS propellant is sufficiently depleted. Fuel dissipation is not initiated for late RTLS aborts (RTLS initiation later than the I-loaded latest RTLS velocity), where pitcharound would be performed immediately.

If the velocity is greater than the I-loaded latest RTLS velocity, the RTLS flyback and pitch command discrettes are set for an immediate turnaround. An immediate turnaround is required to provide adequate propellant to achieve the RTLS pitchdown and MECO targets.



An I-loaded velocity cue (currently the nominal SRB staging velocity) is used to determine whether first stage or second stage fuel dissipation I-loads are used to compute the desired thrust direction. For engine failures in the first stage, the fuel dissipation attitude is calculated as a function of the SRB staging Earth VREL and H. The Earth VREL at engine failure is used to calculate the fuel dissipation attitude for engine failures in second stage.

During fuel dissipation, guidance projects what the powered pitchdown state would be if turnaround was initiated at that instant. The vehicle position, acceleration and time are extrapolated to the estimated end of the turn, and PEG is called to obtain the magnitude of velocity to be gained by thrust to achieve the powered pitchdown (PPD) targets. This velocity is summed with the estimated velocity gained during the turn by thrust and is used in the ideal rocket equation to predict the final mass at PPD. If PEG is converged, the predicted final mass is less than or equal to the I-loaded desired final mass, and the desired flyback attitude satisfies initial flyback attitude constraints (i.e., the flyback thrust attitude is towards the landing site); then turnaround is initiated.

When turnaround is initiated, a powered pitcharound (PPA) maneuver is performed at approximately 10 deg/s to begin the flyback phase. The RTLS pitcharound maneuver is shown in figure 2.7-3.

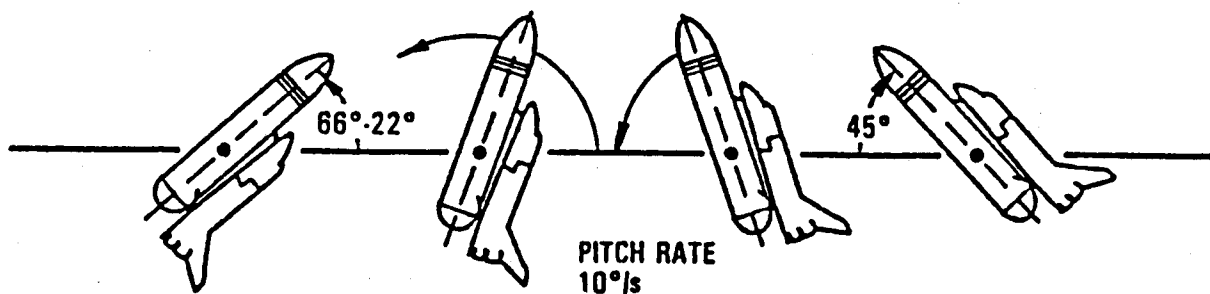


Figure 2.7-3.- RTLS pitcharound maneuver.

Once the pitcharound has occurred, flyback guidance will be initiated to null the downrange velocity and add sufficient uprange velocity for the Orbiter to return. During the flyback phase, the vehicle will be explicitly targeted to the altitude, flight path angle, and R-V line. Also, active SSME throttling will be performed to make final adjustments to the MPS propellant remaining to allow for a satisfactory ET SEP (less than 2 percent excess MPS propellant remaining in the ET) and to remain below the 3g acceleration level. The engines should maintain a throttle setting of approximately 100 percent during flyback for two-engine RTLS aborts. For three-engine RTLS aborts, the engines should maintain a throttle setting of approximately 70 percent. There are separate R-V target lines as well as mass targets at PPD for two-engine and three-engine RTLS aborts. The flight path angle target at PPD is also a function of engine failure. There are

separate flight path angle targets for top and side engine failures as well as three-engine RTLS aborts. The altitude target at PPD is the same for all RTLS aborts.

The final powered RTLS phase is the PPD phase. The PPD phase is initiated approximately 20 sec before MECO. During this phase the main engines are throttled down to 65 percent thrust, and the vehicle pitch attitude is reduced from about 50° to the ET separation pitch attitude of -4 deg/s. MECO will then be performed when the desired cutoff velocity has been achieved based on the MECO range-velocity-flight path angle line.

The mated coast (MC) phase of ET separation begins at the MECO command event, at which time the glide RTLS (GRTLS) DAP is activated. The ascent (ASC) DAP, however, continues to control the MPS gimbals until the software zero thrust event. During the overlap, both DAP's use the same guidance law: attitude hold. The overlap is provided to ensure that, during MPS tailoff, control authority will always be adequate to control the influence of the aerodynamic loads which may be present.

When the separation sequencer has completed all the tasks of the MC phase, the DAP begins to interrogate the state vector for compliance with the structural release inhibit values, which are shown in table 2.7-I. If the inhibit values are satisfied, the ET separation command is issued, the structural release pyros are fired, and the four forward and six aft downfiring RCS jets for -Z translation are fired at separation for 10 sec.

GRTLS begins at the end of the Orbiter -Z translation and terminates at landing. Also, at completion of the translation maneuver, the GPC's will transition to MM 602, or the crew can select OPS 602 via the keyboard.

TABLE 2.7-I.- ORBITER/ET RTLS ABORT DESIGN CONDITIONS

| Event<br>Parameter           | MECO                          | Structure release                     | Separation termination      | AUTO SEP limits                 |
|------------------------------|-------------------------------|---------------------------------------|-----------------------------|---------------------------------|
| Angle of attack - $\alpha$   | $-4 \pm 2^\circ$              | $-4 \pm 2^\circ$                      | $>10^\circ$                 | $-89.0 < \alpha < -2.0^\circ$   |
| Roll angle - $\phi$          | $0 \pm 2^\circ$               | $0 \pm 5^\circ$                       | $0 \pm 30^\circ$            |                                 |
| Sideslip angle - $\beta$     | $0 \pm 2^\circ$               | $0 \pm 2^\circ$                       | $0 \pm 3^\circ$             | $-2.0 < \beta < 2.0^\circ$      |
| Yaw rate - $r$               | $0 \pm 0.5 \text{ deg/s}$     | $0 \pm 0.5 \text{ deg/s}$             | $0 \pm 1 \text{ deg/s}$     | $-0.5 < r < 0.5 \text{ deg/s}$  |
| Roll rate - $p$              | $0 \pm 0.5 \text{ deg/s}$     | $0 \pm 1.25 \text{ deg/s}$            | $0 \pm 2 \text{ deg/s}$     | $-5.0 < p < 5.0 \text{ deg/s}$  |
| Pitch rate - $q$             | $-0.25 \pm 0.5 \text{ deg/s}$ | $-0.25 \pm 0.5 \text{ deg/s}$         | $2.5 \pm 2.5 \text{ deg/s}$ | $-5.0 < q < 0.25 \text{ deg/s}$ |
| Dynamic pressure - $\bar{q}$ |                               | $0 < \bar{q} \leq 10 \text{ lb/ft}^2$ |                             |                                 |

## 2.8 INTRODUCTION TO CONTINGENCY ABORT PROCEDURES RATIONALE

### 2.8.1 Overview

A contingency abort (CA) must be performed whenever the Shuttle thrust to weight ratio is less than that needed for achieving orbit or an intact abort. This can occur if three SSME's fail prior to the late TAL boundary (VI ~24k) or if two SSME's fail prior to single-engine TAL capability (VI ~12k). A CA also may be needed for a single-engine failure if the remaining two engines are not operating at full performance, for example, if a remaining engine throttle is stuck "in the bucket". MCC calls and the NO COMM MODE boundaries cue card indicate when intact abort capability is available.

The purpose of CA is to guide the vehicle to a safe gliding flight condition where bailout or a ditch can be performed. Presently, there is no guidance software for CA's, therefore they must be flown manually. The CA is a very dynamic flight mode that often takes the Orbiter to the limits of its structural and flight control envelopes, and considerable training is required for proper execution of CA procedures. In some cases, the Orbiter is left without thrust at such high altitudes and low velocities that the entry may not be survivable.

The CA procedures are outlined on the contingency abort cues cards. The procedures are shown on an engine out/event timeline and are color-coded for easy reference. Although it appears that there are many different CA procedures, they are all similar. This overview describes the basics of all CA procedures.

CA may be divided into three major phases.

- a. Powered flight - If any thrust is available, the Shuttle is maneuvered to reduce the entry sink rate and rolled to a heads-up attitude.
- b. ET SEP - ET SEP must be performed before the Orbiter enters the atmosphere. For most cases, a 5-sec fast SEP is performed while the Orbiter and ET are pitching down at 4 deg/s. If  $\dot{q}$  is greater than 2 lb/ft<sup>2</sup> and increasing, the Orbiter must maneuver to a negative angle of attack for successful separation from the ET.
- c. Entry - The CA entry is similar to that of an RTLS, but the wide range of initial velocities, high sink rates, and altitudes can result in high normal load factors and heating rates. The entry is divided into four phases:
  - (1) Alpha recovery - The Orbiter is pitched to an angle of attack that gives maximum lift and drag.
  - (2) Nz hold/pullout - As the load factor increases, angle of attack is decreased to maintain the load factor limit. This load factor is

held until the Orbiter has completed a pullout from its dive into the atmosphere.

- (3) Alpha-Mach schedule - When the sink rate has reduced to -250 fps, the Orbiter has achieved pullout, and transitions to flying a wings' level angle of attack (alpha) versus the velocity relative to the speed of sound (Mach) number.
- (4) Bailout or ditch - When Mach is less than one, an attitude hold may be selected and the crew can bail out, or alternatively, an attempt to ditch the Orbiter can be made.

The PASS is taken to OPS 6 (RTLS) during a CA. OPS 6 provides the OMS/RCS dump and entry flight control needed for CA. For some high speed CA's, the OPS 6 flight control may result in some attitude oscillation because the gains were designed for the lower Mach regime of RTLS. Currently, all CA flight procedures are performed in control stick steering (CSS) except for the bailout attitude hold. CR's are in development that could automate much of the CA using modified RTLS guidance.

### 2.8.2 Powered Flight

If two SSME's fail, the remaining thrust is used to reduce the sink rate that will occur during entry. This can be done by directing the thrust vector to lower the altitude and bring the flight path angle to zero before separation. Another way to describe this is that it should minimize the calculated apogee altitude, since apogee altitude combines the effects of current altitude and flight path angle.

If two SSME's fail at an inertial velocity between 7,000 and 12,000 fps, a vertical thrust vector is used. However, if the engine failure occurs earlier in the ascent when the Shuttle has a large positive altitude rate, or if significant thrust is available (i.e., a stuck throttle abort), the thrust vector is pointed toward the horizon to prevent further lofting of the Shuttle trajectory. This lower thrust vector increases velocity and helps reduce the severity of the entry pullout (but may increase heat loads). At an inertial velocity greater than 12,000 fps the Shuttle may have enough energy to continue to a downrange landing site.

Powered flight also extends the time available for dumping OMS propellant which reduces the Orbiter weight and moves the X c.g. forward. Reducing weight decreases the peak  $\dot{q}$  that occurs during pullout. Moving the X c.g. forward reduces the elevon and bodyflap deflections required during pullout, which decreases the probability of aerosurface saturation or actuator stall.

A roll to heads-up is also performed during powered flight. This maneuver orients the bottom of the Orbiter/ET in the direction of the velocity vector, which is the proper attitude to start the ET SEP.

### 2.8.3 ET SEP

As the Shuttle continues to fall during CA powered flight,  $\bar{q}$  increases, and separation from the ET must occur. The Orbiter can separate from the ET at dynamic pressures up to 10 lb/ft<sup>2</sup>. At pressures above 10 lb/ft<sup>2</sup> the ET may recontact the Orbiter after separation. From 2 to 10 psf the Orbiter should be at a small ( $\sim 4^\circ$ ) negative angle of attack to ensure successful separation. This is the separation technique used for normal RTLS. Below 2 lb/ft<sup>2</sup>, the Orbiter can be at positive angles of attack, but the -Z translation should be increased to prevent recontact.

The high sink rate during many CA's result in a very rapid entry into the atmosphere, and thus, a very rapid increase in  $\bar{q}$ . In most cases, there is insufficient time for a pitchdown to a negative angle of attack and a normal 14-sec RTLS ET SEP. Using this procedure would necessitate terminating powered flight at higher altitudes and would increase the severity of the entry.

Instead, a manual fast SEP is performed, which takes only 5 sec. Instead of pitching to a negative angle of attack, which could take as much as 30 sec, the separation is commanded while at a high angle of attack and a -4 deg/s pitch rate. This CA separation procedure offers distinct advantages over normal separation techniques.

First, it allows the separation to be delayed as long as possible and extends the time available for powered flight. It is initiated when equivalent airspeed (EAS) is greater than 7 fps and increasing. This corresponds to a  $\bar{q}$  of approximately 0.62 lb/ft<sup>2</sup>, which allows ET SEP to occur before the 2 psf limit for high angle-of-attack separations. Analysis shows this to be a safe technique.

Second, the Orbiter is already near the angle of attack that will be required for entry, and the -4 deg/s pitch rate needs only be slowed as the proper angle of attack is reached. If the Orbiter were taken to a negative angle of attack for separation, it would require two pitch maneuvers, a negative pitch to the separation angle of attack, followed by a pitch back up to the entry alpha.

The -4 deg/s pitch rate used for the high rate SEP is a compromise between desiring a rapid pitchdown with the need to maintain control and slow the pitch rate after separation. Simulations have shown that pitch rates exceeding -6 deg/s may result in loss of control.

The GPC's will automatically mode to MM 602 10 sec after ET SEP is complete if the angle of attack is greater than 10. At MM 602 the alpha/Mach indicator (AMI) and altitude/vertical velocity indicator (AVVI) become active, and Mach will be displayed.

## 2.8.4 Entry

The goal of CA-powered flight and ET SEP is to deliver the Orbiter to acceptable entry conditions without loss of control. In general, reducing SEP altitude and sink rate improve the entry. Any mistakes made in powered flight or separation will manifest themselves in entry. Entry phases include alpha recovery, Nz hold/pullout, alpha-Mach, and bailout.

### 2.8.4.1 Alpha Recovery

After separation is complete, the Orbiter should be maneuvered to an angle of attack that maximizes lift and drag. This is called alpha recovery. This angle of attack is dependent on Mach and trim and can range from 20 to 60 deg/s. For the simplification of crew procedures, however, discrete angles of attack as a function of Mach are given in the procedures.

| M         | Alpha recovery |
|-----------|----------------|
| < 1.6     | 20°            |
| 1.6 - 4.5 | 50°            |
| > 4.5     | 58°            |

In most cases, the alpha recovery will be reached by continuing the negative pitch rate initiated in the high rate separation. The alpha display tape will only show a maximum of 60 deg/s; so 58 deg/s is the maximum alpha used.

The speedbrake and bodyflap should also be set in the alpha recovery phase before the critical load relief phase begins. Both of these surfaces affect the maximum  $\dot{q}$  and the hinge moment loads on the elevon during the critical load relief phase. The speedbrake can be opened to increase the vehicle drag, slow the Orbiter, and reduce dynamic pressure. Unfortunately, opening the speedbrake also induces a pitching moment that forces the elevon to a lower trim position and may result in elevon saturation or actuator stall during Nz hold. Also, the speedbrake should not be opened above Mach 10 because of thermal constraints. As a result, the procedures recommend manually closing the speedbrake unless the Mach is less than three, when it should be set to 65 percent.

The bodyflap can also be lowered to increase the drag. However, this induces a negative pitching moment that forces the elevon to a higher trim position.

Lateral control problems may occur if the elevons are in an up (negative) position. As a result, the procedures recommend leaving the bodyflap in auto to trim the elevon to its schedule. The bodyflap should be driven manually only if control problems occur.

#### 2.8.4.2 Nz Hold/Pullout

The altitude rate ( $\dot{H}$ ) will continue to increase during alpha recovery until the Orbiter drops low enough in the atmosphere to develop sufficient  $\bar{q}$  and lift for equilibrium flight. As lift increases, the Nz on the Orbiter will increase. When the Nz reaches one, the Orbiter is developing enough lift to support its own weight, and the  $\dot{H}$  will begin to decrease. This is called the point of maximum  $\dot{H}$ . The maximum  $\dot{H}$  is a good indicator of how severe the CA entry will be, and it is used to calculate a maximum (Nz) that will be required for pullout. The equation currently used is

$$Nz \text{ target} = - \dot{H} \text{ max}/1000 + 0.5$$

The Nz target is calculated and displayed on the VERT SIT display. This Nz target has been found to provide a good balance between structural normal load factor limits and  $\bar{q}$  limits. The structural load factor limit is actually a function of Orbiter weight and wing root bending moment, but 3.1g is used as an approximate limit. The  $\bar{q}$  limit is a function of angle of attack, but an approximate limit of 800 psf is usually used.

#### 2.8.4.3 Alpha-Mach

The contingency abort alpha-Mach entry phase is similar to other entry phases of flight.

#### 2.8.4.4 Bailout or Ditching

Analysis has shown that the Orbiter will probably not survive a water ditch. Current recommendations are for the crew to place the Orbiter in an attitude hold and then bail out. For this purpose, an attitude hold mode was added to the MM 603 software. It is available when Mach is less than 1.0 and is activated by moving the abort rotary switch to ATO and pressing the abort pushbutton indicator (PBI). When the crew switches from CSS to AUTO, guidance will snapshot the current airspeed and roll angle and attempt to hold both constant. If a new airspeed or roll is desired, control can be taken back to CSS. When auto is selected again a new snapshot will be taken.

After the attitude hold is established and an altitude of about 20,000 ft is reached, the crew should depressurize the cabin, blow the hatch, and bailout.

## 2.9 BACKUP FLIGHT SYSTEM

The BFS is a unique set of software that is loaded into GPC 5. It provides OPS 1, 3, and 6 capability plus some systems management (SM) functions, all in one resident set. It supports nominal ascent as well as ATO, AOA, RTLS, and TAL aborts. It can be engaged anytime after liftoff. However, once engaged it is an irreversible step until in orbit or back on the ground.

The BFS flight software provides navigation, guidance, flight control, fault detection, displays and controls, SM, and sequencing. It uses the same algorithms and guidance laws as the PASS to deliver the same performance, but with reduced capability. The BFS performs some functions in the preengage phase that the PASS does not. These functions include S-band antenna management, flash evaporator/ammonia boiler activation/deactivation, APU fuel quantity gauging, hydraulic water boiler quantity gauging, fuel cell total and current power calculations, and cabin delta pressure/delta time (dP/dT) calculations. If the BFS is not operating properly, the S-band antenna management and flash evaporator activation must be performed manually for ascent.

The BFS commands over the payload buses, and "listens" to the other PASS buses preengage. Upon engagement, it takes over all buses. It is dependent on the PASS, preengage, for initialization data. Data is received by listening to the PASS buses (DK listen). Postengage, it is totally independent of the PASS. Preengage, the BFS stops listening to the PASS buses (goes standalone) for most OPS transition (OPS 1 to 6 included) and some multiple PASS failures. The BFS state vector degrades quickly while in standalone mode as the state is propagated using the last known  $\Delta V$  from the IMU's. It will degrade very rapidly during powered flight (10 sec), more slowly in gliding flight (45 sec) and much more slowly during on-orbit coast. A standalone condition is indicated by the illumination of the backup flight control (BFC) light on the eyebrow panel and a CRT message. If an I/O RESET EXEC does not fix the problem within the time limits above, the BFS is declared NO-GO.

The BFS is engaged by depressing the pushbutton (pb) on top of either RHC. The criteria for engagement are listed in the Flight Rules and on the data processing and software (DPS) cue cards, but in general require the loss of PASS capability to successfully continue. Upon BFS engagement large X's cover the PASS CRT's and the BFC light will illuminate.

The BFS CRT display assignment is controlled by the BFC/CRT switch on C3. It is normally placed in the 3+1 position pre-liftoff. BFS then has CRT 3 preengaged, and picks up CRT 1 when engaged. The BFS can also be assigned to CRT's via the keyboard general purpose computer (GPC)/CRT pb.



The following BFS CRT displays are available during ascent:

|                |                |
|----------------|----------------|
| XXXXX TRAJ1    | GNC SYS SUMM 1 |
| XXXXX TRAJ2    | GNC SYS SUMM 2 |
| RTLS TRAJ2     | SM SYS SUMM 1  |
| VERT SIT 1     | SM SYS SUMM 2  |
| VERT SIT 2     | THERMAL        |
| HSD            | FAULT          |
| XXXX MNVR XXXX | MEMORY         |
| OVERRIDE       |                |

In a typical ascent, the BFS will receive the PASS/BFS one-shot data transfer (IMU calibration data, primarily) before T-20 minutes. Then, after the PASS is moded to OPS 1 at T-20 minutes, the BFS will be moded to RUN and OPS 1. SPEC 50 display is then checked to verify that the BFS is configured correctly for a possible RTLS abort. BFS SYS SUMM displays are used to monitor prelaunch systems reconfigurations. The BFS nominally has CRT 3 assigned to it. During flight, the crew monitors the TRAJ displays on this CRT for trajectory information and guidance status. TMECO should be the same as PASS, and altitude errors should be near zero. The crew also uses the BFS SYS SUMM displays whenever there are systems problems, since these contain more information than is available on the PASS SYS SUMM display. During the OMS burns, the BFS OMS MNVR EXEC displays are monitored to assure the BFS has the same targets and solutions as the PASS.

During all OPS, the crew communicates with the BFS either directly through the keyboard, or via DK listen.

The BFS DK listens to the following PASS inputs:

HSD - items 3 through 9, 40, 41  
 MNVR - items 1 through 4, 6-26, 28-33, 35, EXEC  
 OPS 104, 105, 106, 302, 303, 304, 305, 601, 602 PRO  
 GPC/CRT 5X EXEC  
 OVERRIDE - items 1-24

The Flight Rules call for an engagement of the BFS for many different reasons, including the following:

- a. Loss of a redundant set: During ascent or entry a redundant set failure is defined as all GPC's QUIT or HALT, or the redundant set to all simplex.
- b. Loss of the PASS capability to control the vehicle due to GPC/multiplexer/demultiplexer (MDM)/line replaceable unit (LRU) failures.
- c. Loss of control due to divergent trajectory: after 1:30 MET, CSS may be attempted before BFS engage.
- d. Roll maneuver not initiated as scheduled.

If the BFS is engaged in flight, many differences with the PASS exist. Most of these differences are the result of one of the following six functional differences between the two systems:

- a. Guidance - the BFS is not required to support manual guidance (CSS) during powered flight or auto guidance (AUTO) during entry.
- b. Manual throttling - the BFS is not required to support manual throttling.
- c. Contingency aborts - the BFS is not required to support contingency aborts (i.e., multiple SSME failures). Therefore, there is no single engine roll control (SERC) in the BFS.
- d. Preengage mode - the BFS must run preengage, in parallel with the primary flight system (PFS), and although not in control of the vehicle, must replicate the PFS commands in such a fashion as to enable the BFS to take over control of the vehicle at any time and ensure safe operation of the Shuttle. This preengage mode of operation results in some unique BFS software requirements that are not applicable to the PFS.
- e. Operating system - the BFS's backup operating system (BOS) is different from the PFS's flight control operating system (FCOS). This may result in some detailed requirements differences, but should not result in any functional differences.
- f. Computer memory load - the BFS has only one computer memory load and does not support OPS 2. Unique OPS 1, OPS 3, and OPS 6 requirements are merged into one common set of guidance requirements.

### 2.9.1 PFS/BFS Differences

#### a. Measures SSME throttle setting

During the pre-MECO major modes (102, 103, and 601), various guidance calculations (mass, thrust, acceleration, etc.) are a function of the SSME throttle setting. The PFS uses its commanded throttle setting for most of these calculations. The BFS, on the other hand, does not use the commanded throttle setting for these calculations because the BFS throttle command could be different from the PFS command when the BFS is not engaged. Instead, the BFS estimates actual throttle setting from measured chamber pressure. It does a MIDVAL select on the three SSME chamber pressures. This protects against a single point failure of one of the chamber pressure sensors. If the BFS becomes engaged, it continues to use measured throttle setting for mass estimation, but switches to commanded throttle setting for all other calculations.

## b. MPS guidance cutoff task

- (1) This task executes at a rate of 3-1/8 Hz in the PFS and 6-1/4 Hz in the BFS during ascent second stage (MM 103); during powered RTLS (MM 601), it executes at 6-1/4 Hz for both the PFS and BFS systems.
- (2) During powered RTLS this task requires flight path angle, as an input, from the UPP principle function. In the PFS, flight path angle is only updated at a rate of 2.08 Hz; in the BFS, it is updated at 6.25 Hz. As a result, the PFS has unique guidance requirements to estimate flight path angle in between UPP updates.

The original design of this task did not require flight path angle as an input. Hence, there was no requirement for UPP to update this variable at 6.25 Hz. When the design of the MPS guidance cutoff task changed making flight path angle a required input, it was decided not to change the processing requirements of UPP, but rather to add code to guidance to estimate this variable locally in between UPP updates.

## c. G-limiting

- (1) If either the crew manually or the PFS erroneously throttles the SSME's down during g-limiting, and prior to or during a PFS system failure, the BFS will throttle up as required to maintain 3g, upon engagement.

The primary reason for this design is to maximize performance while the BFS is engaged. A lower throttle setting during g-limiting would result in excess fuel consumption.

- (2) When the BFS is not engaged, the g-limiting algorithm is active, but the "proportional + integral" acceleration filter is bypassed.

If the acceleration filter were active when not engaged, the integral error term could become saturated if a manual throttledown were commanded by the crew.

## d. Powered Explicit Guidance

- (1) The BFS uses 12 precise/predict integration steps to predict the final state in PEG, while the PFS uses 10 steps.

The reason for this is to provide CPU load balancing and to minimize the BFS core. The final state prediction in PEG is performed in four minor cycles in the BFS. On each of the four minor cycles three integration steps are performed. Hence, the 12 steps.

- (2) The PFS has logic that causes the error needles to be stowed if guidance is unconverged for several consecutive guidance cycles during second stage ascent and RTLS. The BFS does not have comparable logic.

The reason that the PFS has this logic is to tell the crew that PEG is experiencing convergence problems. If PEG remains unconverged for any significant length of time, it may be necessary for the crew to engage manual guidance. Since the BFS does not support manual guidance, there is no point in telling the crew that PEG is experiencing convergence problems.

- (3) The criterion for outputting steering commands (EPS\_TGO) when the BFS is not engaged is double the value of what is used when it is engaged.

The reason for this difference is that, if the BFS is not controlling the vehicle, its guidance solution, while it is good, may be diverging somewhat and might not pass the standard criterion for issuing steering commands. So this criterion is relaxed when the BFS is not engaged to ensure that the BFS attitude errors are being cyclically updated for "reasonable" guidance solutions.

e. Range to landing site task

In MM 303, the PFS executes this task only once (upon entry into the MM), while the BFS executes this task cyclically at a rate of 1/8 Hz.

The original requirement was to execute this task cyclically for both the PFS and BFS. However, on early PFS software releases (pre-STS-1), the PFS was exhibiting cycle rap problems with this task. As a result, the PFS requirements were changed such that this task is now executed only once at the start of MM 303.

f. Maneuver execute display interface processing (DIP)

- (1) For multiple inputs to the MNVR EXEC display via a single item enter, the PFS accepts all data until a bad entry is made (i.e., improper format); it then rejects the bad entry and all subsequent good entries. The BFS rejects all entries of a multiple item enter if a bad input is encountered.
- (2) If cyclic guidance becomes unconverged such that guidance outputs cannot be fully displayed on the CRT (ex.  $\Delta VTOT$ ), the BFS blanks the CRT item, while the PFS truncates the leftmost digits.
- (3) If guidance does not converge during the execution of a LOAD solution, the BFS will not initiate cyclic guidance, while the PFS will initiate cyclic guidance.

g. Restart

The BFS has restart capability, while the PFS does not. The primary purpose for restart capability is to allow the BFS to recover from momentary GPC errors due to divide-by-zero interrupts, power transients

due to lightning, cycle rap, etc. The PFS does not require this protection because of its redundant GPC set and, also, because of the existence of the BFS, itself.

#### h. I-loads

In the PFS, I-load values are assigned directly to the program variables and their values may be changed to satisfy mission requirements. For example, the MECO constraint I-load variable, RDMAG, is initially I-loaded to the nominal second stage value; if an RTLS abort is selected, this variable is reset internally by guidance to the required RTLS value.

The BFS, on the other hand, adheres to a philosophy that I-load variables should retain their original value and never be changed internally by the flight software. As a result, all I-loads are buffered in the BFS. When guidance is first activated, the local program variables are set to their buffered values. The local program variables may be changed to satisfy mission requirements, but the set of I-load buffer variables is never changed.

#### i. RTLS manual turnaround

The PFS has logic to monitor for manual turnaround by the crew. When a manual turnaround is sensed, the PFS automatically modes to the flyback phase. The BFS does not have comparable logic. Instead, the BFS modes to flyback (preengage, only) after a manual turnaround when either the PFS's flyback discrete is received over the transfer data bus, or (pre- and postengage) when the crew issues a flyback moding command to the BFS via an RTLS TRAJ display item enter.

If the crew commands the BFS to mode to flyback when not engaged, the BFS will inhibit throttling for mass control if either PEG is unconverged, or if the difference between the predicted and desired final masses, MF and MBO, respectively, is larger than a specified I-load value (currently, 800 slugs). Under these conditions, the BFS commanded throttle is frozen at the current PEG desired value (K).

#### j. Transfer data

When the BFS is not engaged, it receives the following transfer data from the PFS:

- (1) Engine-out velocity (V\_ME\_OUT).
- (2) RTLS flyback discrete (S\_RTLS\_FB).
- (3) AOA excess velocity (DV\_EXCESS).

The engine out velocity is required to ensure that the BFS selects the same target set in the event of an AOA or ATO abort. The RTLS flyback discrete is required to ensure that the PFS and BFS mode

to the flyback phase at the same time. This is primarily for early, manual turnarounds. The AOA excess velocity ensures that the BFS selects the same AOA target set as the PFS, in the event that the PFS downmodes due to a negative excess velocity ( $DV\_EXCESS < 0$ ).

k. AOA/ATO targeting

For variable-IY targeted missions, the BFS cyclically updates the desired plane (IY), when it is not engaged and an AOA or ATO has been declared. If the BFS is engaged when the abort is declared, the desired plane is calculated only once.

This is a recent change required for Western Test Range (WTR) launches which require a significant amount of yaw steering. Typically, the PFS and BFS do not compute the variable-IY at the same time; hence the state vectors used to compute the plane are different. If the desired plane is not recomputed each guidance cycle, the yaw error needle would diverge and eventually could become "pegged".

l. Single engine roll control

This capability is not supported by the BFS.

m. MPS dump

Presently there is no manual MPS dump stop capability in the BFS. However, the dump may be initiated manually.

n. CRT's

There are only two CRT's available unless a third is assigned via keyboard input. The BFS can drive all four CRT's simultaneously if desired, while the PASS can only drive three.

o. Dedicated flight instruments

The attitude direction indicator (ADI) and the horizontal situation indicator (HSI) are the only dedicated displays supported in powered flight. There is no altitude or velocity data displayed during powered flight in the BFS.

p. Entry guidance

No autoland guidance available. Guidance stops at preflare (~2000 ft). Bodyflap retracts at 10k (auto).

q. Entry navigation

Microwave landing system (MLS) data is not used by the BFS.

- r. Fast SEP  
Available in MM 102 only.
- s. SRB SEP  
BFS does not do the 50-psi reasonableness test.
- t. ET SEP  
No manual -Z.
- u. Caution and warning (C&W)  
Only half supported by BFS.
- v. TRANS-DAP  
No auto maneuver capability or pulse mode.
- w. Redundancy Management  
Limited fault detection and isolation capability. Generally different redundancy management (RM) schemes.

Many switches are not supported by the BFS:

Panel C3  
ORB DAP pb

Panel F8  
AIR DATA sw  
ADI ATT sw  
ADI ERROR sw

ATT REF pb (ADI)

HSI SEL MODE sw  
HSI SEL SOURCE TACAN/NAV/MLS sw  
HSI SEL SOURCE 1/2/3 sw  
RADAR ALTM 1/2 sw

Panel F6  
ADI ERROR sw  
ADI RATE sw

HSI SEL MODE sw  
HSI SEL SOURCE 1/2/3 sw  
RADAR ALTM 1/2 sw

Panel R4  
LG RET/CIR VLV sw

Panel O7  
AFT LEFT RCS He PRESS sw  
AFT RIGHT RCS He PRESS sw  
AFT LEFT RCS MANIFOLD ISOLATION sw  
(No corresponding PASS GPC support)  
AFT RIGHT RCS MANIFOLD ISOLATION sw  
(No corresponding PASS GPC support)  
MASTER CROSSFEED sw  
LEFT, RIGHT CROSSFEED sw

Panel O8  
FWD RCS He PRESS sw  
FWD RCS MANIFOLD ISOLATION sw  
(No corresponding PASS GPC support)  
OMS KIT TANK ISOLATION sw  
LEFT OMS TANK ISOLATION sw  
RIGHT OMS TANK ISOLATION sw

Panel L1

H2O PUMP LOOP 1 GPC/OFF/ON sw  
H2O PUMP LOOP 2 GPC/OFF/ON sw

Panel L2

NOSEWHEEL STEERING sw

Panel R2

Backup LH2 VLV sw  
He ISOLATION A sw  
HE ISOLATION B sw  
HYD CIRC PUMP sw

Panel R12

FUEL CELL GPC PURGE SEQ START sw

MISCELLANEOUS

Right RHC TRIM sw



### SECTION 3 CREW OPERATIONS

#### 3.1 ASCENT CREW MONITORING AND CONTROL DEVICES

The primary role of the crew during ascent is to monitor the performance of the automatic sequencing, guidance, navigation, flight control, propulsion, and other critical systems. If performance is not acceptable, the crew will intervene as required to promote mission success and personnel and vehicle safety. Cockpit-dedicated instruments and CRT displays that present critical ascent parameters for determining vehicle performance and trajectory state are available. Uplinked advisory data and onboard cue cards will also be available to assist the crew in the monitoring and control task.

The purpose of this section is to present data on the crew use of the cockpit flight displays, controls, and cue cards during ascent and aborts.

##### 3.1.1 Onboard Ascent Event Reference

During ascent, the events in the checklist are keyed to either MET or the TIG of the OMS burns. The following explains the reference notation and when each reference is used:

- a. The MET is the primary event reference throughout ascent. The MET is set to zero at SRB ignition and is shown on the mission timer on the first line of all CRT's and on panel 03, and on the event timer on panel F7. Prelaunch, the MET on the CRT and panel 03 shows Greenwich mean time (GMT).
- b. The TIG of the OMS burns is used at times close to the OMS burns. This time is displayed on the CRT timer (second line on the CRT). It counts down to the ignition of the OMS, then counts up. See the XXXXX MNVR XXXXX display description for more details. Prelaunch and during powered flight, this timer will be zeroed.
- c. The EVENT TIME on panel F7 can be controlled by the crew. It is set to count down to launch from T-9 minutes. The EVENT TIMER resets at SRB ignition and then shows MET.

Before launch (while in OPS 9), the crew can set the CRT timer; however, after transition to OPS 1, a launch hold or recycle would invalidate the time because the CRT timer cannot be reset in MM 101. The CRT timer is not reset at lift-off, but the EVENT TIME and MET are reset. Therefore, the CRT timer is not used prelaunch or during powered flight.

The event references for AOA entry are the same as in nominal entry. For further information, see the Entry Procedures Handbook, JSC-11542.

### 3.1.2 Cockpit CRT Displays

The displays available to the crew for ascent and aborts are shown in table 3.1-I. Since the displays available depend on the MM, the MM flow is shown in figure 3.1-1. The three CRT displays on the forward panels are managed by the crew to maximize crew insight into the status of Orbiter operations. CRT displays will be called as necessary to monitor, check status, or reconfigure systems; but, the basic configuration assumed for normal operations is:

- a. CRT 1 (left) - XXXXX TRAJ or XXXXXX MNVR XXXXX
- b. CRT 2 (right) - GNC SYS SUMM 1 or XXXXXX MNVR XXXXX
- c. CRT 3 (center) - [BFS] XXXXX TRAJ X or XXXXXX MNVR XXXXX  
(SM or GNC SYS SUMM as required)

The configuration for an ATO is the same as for normal ascent. For an AOA, the configuration through the first OMS burn is the same as normal ascent and then is the same as normal entry. For an RTLS, the configuration during the powered phase corresponds to ascent, and during the glide phase the configuration corresponds to entry.

When the BFS is engaged, there are only two CRT's available automatically. Preengage, no more than one CRT is normally driven by the BFS. Any CRT can be driven by the BFS if the GPC/CRT function on the keyboard is used. The BFC DISP SEL switch is set in 3 + 1 so that CRT 3 can be driven by BFS preengage, and CRT 3 and CRT 1 are driven automatically postengage. The configuration for the displays with the BFS engaged is:

- a. CRT 1 (left) - XXXXX TRAJ X or XXXXX MNVR XXXXXX
- b. CRT 2 (right) - Assigned to BFS when time permits; then the CRT is used as needed to monitor systems.
- c. CRT 3 (center) - As required to check the status of systems, any reconfiguration change required, or XXXXX TRAJ or XXXXX MNVR XXXXXX.

TABLE 3.1-I.- COCKPIT CRT DISPLAYS

| Display number | CRT display title     | OPS 0 | OPS 9 (GNC) | OPS 1 | OPS 6 (RTLS) | OPS 3 (AOA) | BFS |
|----------------|-----------------------|-------|-------------|-------|--------------|-------------|-----|
| 0001           | GPC MEMORY            | X     |             |       |              |             |     |
| 1011a          | (LAUNCH) TRAJ         |       |             | X     |              |             |     |
| 1021a          | (ASCENT) TRAJb        |       |             | X     |              |             |     |
| 1031a          | (ASCENT) TRAJb        |       |             | X     |              |             |     |
| 1041a          | (OMS 1) MNVR (EXEC)c  |       |             | X     |              |             | X   |
| 1051           | (OMS 2) MNVR (EXEC)d  |       |             | X     |              |             | X   |
| 1061           | (OMS 2) MNVR (COAST)e |       |             | X     |              |             | X   |
| 3011           | (DEORB) MNVR (COAST)  |       |             |       |              | X           | X   |
| 3021           | (DEORB) MNVR (EXEC)   |       |             |       |              | X           | X   |
| 3031           | (DEORB) MNVR (COAST)  |       |             |       |              | X           | X   |
| 3041f          | ENTRY TRAJ 1          |       |             |       |              | X           | X   |
|                | ENTRY TRAJ 2          |       |             |       |              | X           | X   |
|                | ENTRY TRAJ 3          |       |             |       |              | X           | X   |
|                | ENTRY TRAJ 4          |       |             |       |              | X           | X   |
|                | ENTRY TRAJ 5          |       |             |       |              | X           | X   |
| 3051a,f        | VERT SIT 1            |       |             |       |              | X           | X   |
|                | VERT SIT 2            |       |             |       |              | X           | X   |
| 6011           | (RTLS) TRAJ           |       |             |       | X            |             |     |
| 6021a,f        | VERT SIT 1            |       |             |       | X            |             | X   |
| 6031a,f        | VERT SIT 1            |       |             |       | X            |             | X   |
|                | VERT SIT 2            |       |             |       | X            |             | X   |
| 9011           | GPC MEMORY            |       | X           |       |              |             |     |

aDisplays described in this section.

bIn MM's 102 and 103, the nominal display is ASCENT; with RTLS, AOA, or ATO selected, it is RTLS, AOA, or ATO, respectively.

cIn MM 104, the nominal display is OMS-1; with an ATO selected, it is ATO 1; with an AOA selected, it is AOA 1.

dIn MM 105, the nominal display is OMS-2. With an ATO selected, the display will be ATO 2. With an AOA selected, the display will be AOA MNVR TRANS. The crew will transfer to OPS 3 to perform the AOA OMS-2 burn (as the deorbit maneuver) upon being informed that AOA 2 targeting is complete by a flashing 'OPS 301'. The targets for the burn will be computed in OPS 1 and carried across to OPS 3. However, an AOA can also be performed by manually transitioning to OPS 3 and inputting the AOA targets without selecting AOA.

eIn MM 106, the nominal display is OMS-2. With an ATO selected, the display will be ATO 2.

fDisplays described in the Entry Flight Procedures Handbook.

TABLE 3.1-I.- Concluded

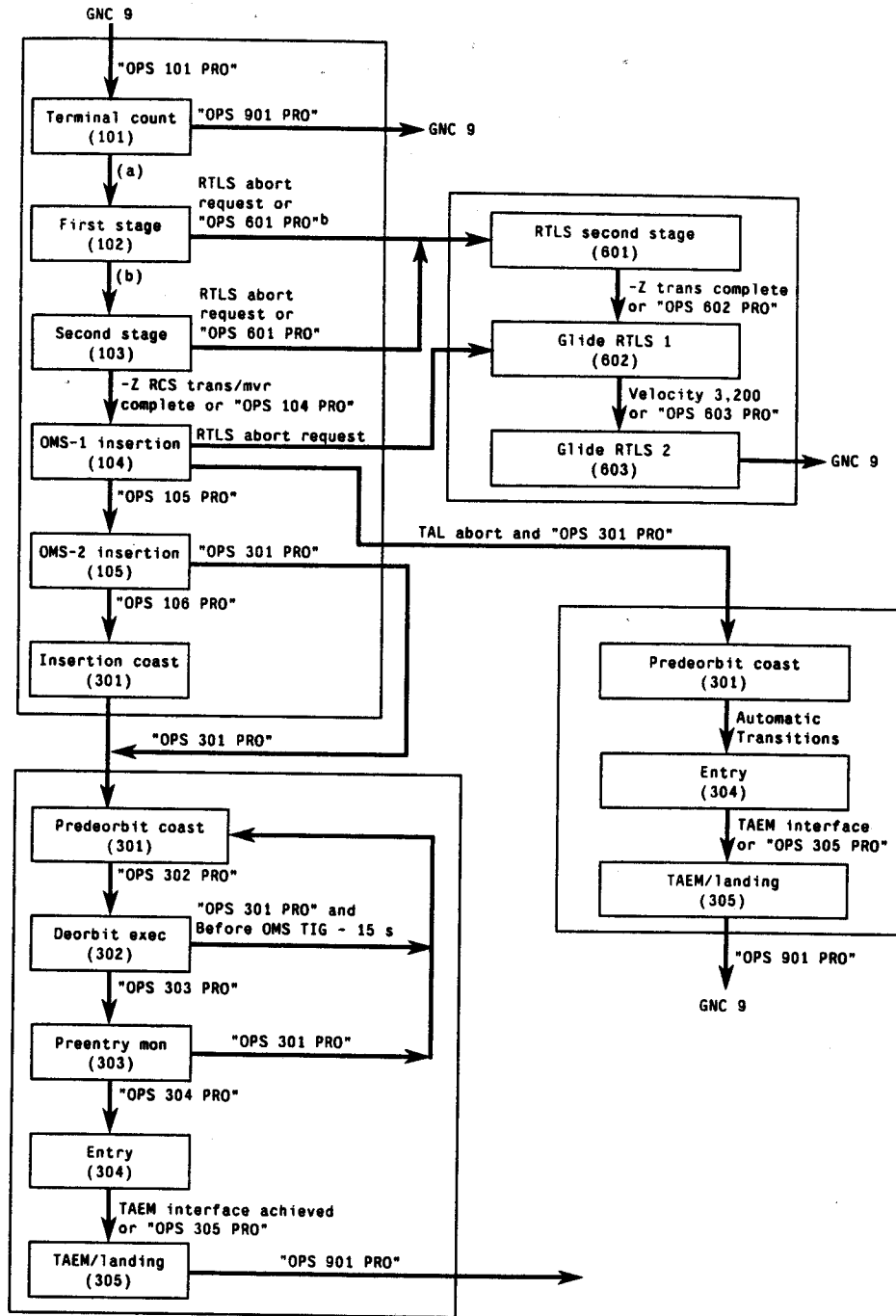
| Display number    | CRT display title | OPS 0 | OPS 9 (GNC) | OPS 1 | OPS 6 (RTLS) | OPS 3 (AOA) | BFS            |
|-------------------|-------------------|-------|-------------|-------|--------------|-------------|----------------|
| 0                 | GPC MEMORY        | X     | X           | X     | X            | X           |                |
| 1                 | DPS UTILITY       |       | X           |       |              |             |                |
| 2                 | TIME              |       | X           |       |              |             |                |
| 6                 | GPC/BUS STATUS    |       | X           |       |              |             |                |
| 18 <sup>g</sup>   | GNC SYS SUMM 1    |       |             | X     | X            | X           | X <sup>h</sup> |
| 19 <sup>g</sup>   | GNC SYS SUMM 2    |       |             |       |              |             | X              |
| 20 <sup>i</sup>   | DAP CONFIG        |       |             |       |              |             |                |
| 50 <sup>i</sup>   | HORIZ SIT         |       |             | X     | X            | X           | X              |
| 51 <sup>g</sup>   | OVERRIDE          |       |             | X     | X            | X           |                |
| 99                | FAULT             | X     | X           | X     | X            | X           | X              |
| 100               | GTS DISPLAY       |       | X           |       |              |             |                |
| 101               | SENSOR SELF-TEST  |       | X           |       |              |             |                |
| 102               | RCS/RGA/ADTA      |       | X           |       |              |             |                |
| 104               | GND IMU CNTL/MON  |       | X           |       |              |             |                |
| 105               | TCS CONTROL       |       | X           |       |              |             |                |
| 110               | BUS/BTU STATUS    |       | X           |       |              |             |                |
| 1011 <sup>g</sup> | LAUNCH TRAJ 1     |       |             |       |              |             | X              |
| 1021 <sup>g</sup> | (ASCENT) TRAJ 1   |       |             |       |              |             | X              |
| 1031 <sup>g</sup> | (ASCENT) TRAJ 2   |       |             |       |              |             | X              |
| 6011 <sup>g</sup> | RTLS TRAJ 2       |       |             |       |              |             | X              |
| 0001              | BFS MEMORY        |       |             |       |              |             | X              |
| 0001 <sup>g</sup> | THERMAL           |       |             |       |              |             | X <sup>j</sup> |
| 78 <sup>g</sup>   | SM SYS SUMM 1     |       |             |       |              |             | X <sup>j</sup> |
| 79 <sup>g</sup>   | SM SYS SUMM 2     |       |             |       |              |             | X <sup>j</sup> |

<sup>g</sup>Displays described in this section.

<sup>h</sup>GNC SYS SUMM displays in the backup system are not the same displays as in the primary systems.

<sup>i</sup>Displays described in the Entry Flight Procedures Handbook.

<sup>j</sup>THERMAL, SM SYS SUMM 1, and SM SYS SUMM 2 are SM displays.



a All SSME's 90 percent RPL, no countdown holds, +2/5 sec time delay, and no FRF flag (SRB ignition).

b  $P_c \leq 50$  or  $MET \leq 129.8 + -8$  sec and attitude rates within limits or manual switch enabled and closed (SRBSEP complete)

(Information in this figure is from COMPUTER PROGRAM DEVELOPMENT SPECIFICATION, Vol. V, Book I, GNC.)

JSC-10559\*004

Figure 3.1-1.- Major mode flow.

3.1.2.1 XXXXX TRAJ (Primary System)

a. Description

This display is called up in MM 101 and is also available in MM's 102, 103, and 601 (fig. 3.1-2). The title is dynamic and reads LAUNCH in MM 101, ASCENT in MM's 102, and 103 (ATO, or TAL if one of these aborts is selected), and RTLS in MM 601.

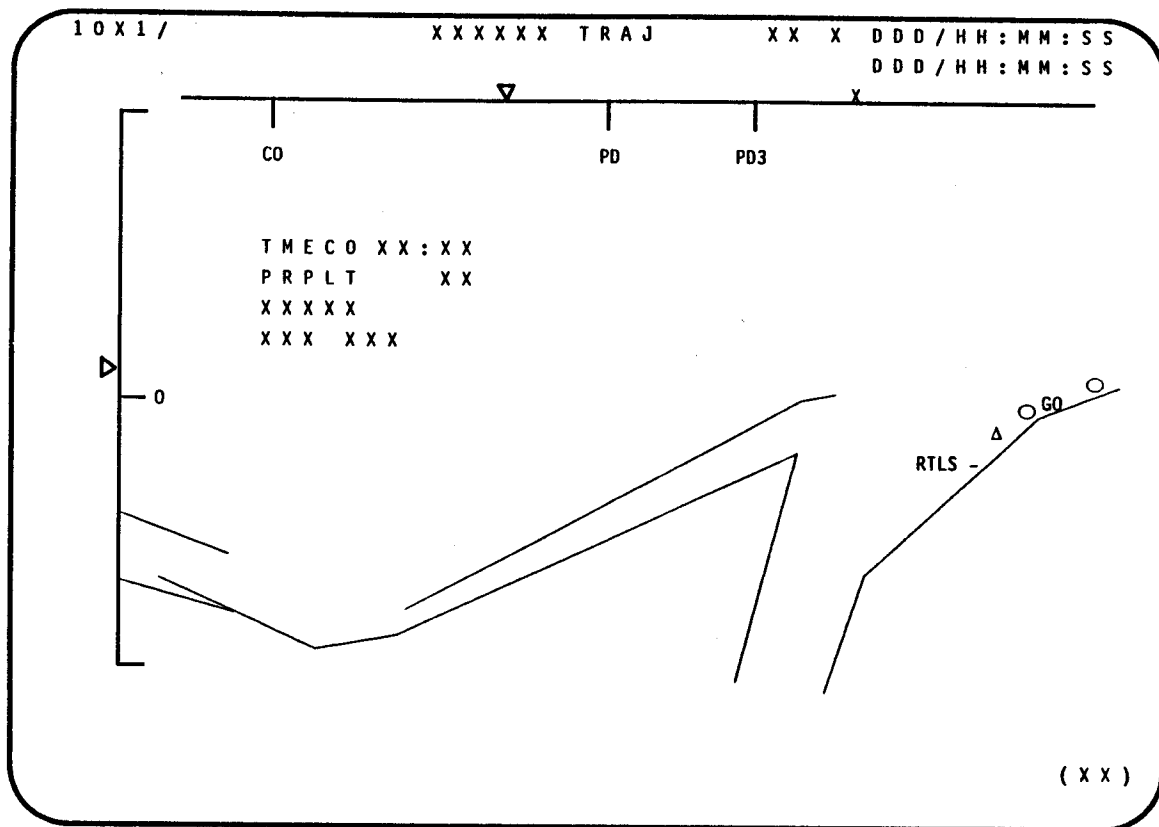


Figure 3.1-2.- XXXXX TRAJ display.

There are two different second-stage profile scales in use on this display. The rightmost profile is a nominal ascent profile plotted as a function of altitude above the Fisher ellipsoid (ft) versus magnitude of VREL fps. The other profiles are plotted as a function of altitude above the Fisher ellipsoid (ft) versus horizontal component of downrange VREL (VH) in fps. These curves represent the  $3\sigma$ -dispersed PRTLs flight envelope. The top curve depicts the highest lofting expected in any dispersed RTLS case. Highest loft usually occurs with an engine out at approximately 2 min. The lower line segments represent the lowest lofted PRTLs trajectories. Since this is a dispersed range, utilizing a limited number of data points, it is possible to fly outside the range for short periods of time.

The current vehicle state is indicated by a moving triangle with the 30- and 60-sec predictors represented by circles. The triangle and circles are plotted as a function of altitude above the Fisher ellipsoid versus magnitude of VREL for a nominal ascent, but change to functions of altitude above the Fisher ellipsoid versus V\_HORIZ\_DNRNG when RTLS is selected. Both the altitude and velocity come from NAV (either the ascent or RTLS UPP).

The RTLS tick mark represents the latest time the vehicle can sustain a single SSME failure and still perform an RTLS (4:05 sec for STS-26, cycle 1) assuming

- (1)  $3\sigma$  ascent propulsion performance dispersions
- (2) 15-second crew delay in selecting RTLS
- (3) 104 percent throttle

The scale across the top represents delta range ( $\Delta R$ ) where  $\Delta R$  is defined as the glide range potential based on the energy state (function of the horizontal component of downrange VREL and flightpath angle from the RTLS UPP) minus the range to the runway threshold (from RTLS UPP) in nautical miles. The pitchdown (PD) and PD3 tick marks represent the  $\Delta R$  at which PPD is initiated for a two-SSME and three-SSME RTLS, respectively. In both cases, PPD occurs 20 sec before MECO. The cutoff (CO) tick is the  $\Delta R$  where MECO should occur and is biased by -3 n. mi. so that zero thrust and zero  $\Delta R$  will occur simultaneously. The  $\Delta R$  scale starts at -143 n. mi. on the right and goes to +17 n. mi. on the left. The  $\Delta R$  symbol (triangle) is only driven during RTLS.

The scale on the left is delta  $\dot{H}$  ( $\Delta \dot{H}$ ) where  $\Delta \dot{H}$  is defined as the  $\dot{H}$  from NAV (RTLS UPP) minus a reference  $\dot{H}$  from a table of average  $\dot{H}$  versus VREL for all RTLS's. The limits on the scale are 200 fps (top) to -200 fps (bottom). The  $\Delta \dot{H}$  symbol is displayed only for an RTLS, for V\_HORIZ\_DNRNG < 0, and if  $-550 < \Delta R < -50$ . The symbol will flash if off-scale and is "fly to."

The digital readouts follow:

- (1) Time of main engine cutoff (TMECO) is the predicted time of MECO in minutes and seconds. The time comes from guidance and is displayed after SRB SEP.
- (2) 'PRPLT' is the propellant remaining in the ET (in percent) and is calculated in the XXXXX TRAJ DIP in MM's 103 and 601.
- (3) 'Pc < 50' will be displayed when the chamber pressure on both SRB's falls below 50 psi within 5.9 sec of each other. This is displayed when a discrete from the SRB SEP sequencer is set.
- (4) 'SEP INH' will be displayed flashing if the SRB or ET SEP constraints, as determined by the SRB or ET SEP sequencer are violated. For ET SEP, the crew also gets a class 3 alert and ET SEP INH message at the bottom of the CRT.
- (5) A flashing overbright 'F' will be displayed when the RTLS fine-countdown mode is entered (6 sec before powered pitchdown).

The two lines which bracket the end of the last-time two-SSME RTLS abort profile (lower left of the CRT) represent the ET SEP  $\bar{q}$  constraints. The top line represents  $\bar{q} = 2 \text{ lb/ft}^2$  and the bottom lines represents  $q = 10 \text{ lb/ft}^2$ . Although the display limit is  $2 \text{ lb/ft}^2$ , the actual limit is 0 to  $10 \text{ lb/ft}^2$ .

b. Use

The XXXXX TRAJ display is used primarily to monitor or manually fly the Shuttle trajectory on a velocity-versus-altitude plot.

c. Nominal, AOA, or ATO

The Shuttle symbol and predictors should remain on the rightmost profile and will appear immediately after SRB SEP. The crew should vary the pitch angle ( $\theta$ ) to stay on the profile if they are flying in CSS. If the Shuttle symbol is past the RTLS tick and a single SSME fails, the crew will press uphill or select TAL with MCC concurrence. If the Shuttle symbol is past the RTLS tick, an RTLS can no longer be successfully performed.

The TMECO readout will become active in MM 103 and will indicate to the crew that second stage guidance has converged when the time is stable. The propellant, Pc < 50, and SEP INH readouts perform as discussed earlier. If Pc < 50 has not occurred, it will not be displayed and the SRB SEP cannot be performed either automatically or manually until the backup cue is issued at a MET of 2:16.

The  $\Delta H$  and  $\Delta R$  scales are not driven for nominal, AOA, or ATO missions.



## d. RTLS

The Shuttle symbol and predictors will appear immediately after SRB SEP either on the nominal profile line or slightly to the left and below the nominal line if an SSME failed in the first stage. Once an RTLS abort is selected (>2:30 for a two-SSME RTLS, 3:40 for a three-SSME RTLS) the Shuttle symbol and predictors will immediately jump to the left (now plotting V\_HORIZ\_DNRNG instead of VREL magnitude) and, depending on the SSME out time, reappear somewhere inside the implied flight envelope. If the crew is flying in CSS they will vary the pitch angle ( $\theta$ ) to stay on the appropriate profile.

The  $\Delta H$  scale is provided as an aid to the crew in maintaining the optimum flyback profile. During flyback the crew will fly the altitude-versus-velocity profiles using the 30- and 60-sec predictors. The vehicle should then be close to following the optimum H versus R profile. The  $\Delta H$  scale which represents  $\Delta H$  error will become active when V\_HORIZ\_DNRNG = 0 if  $-550 \leq \Delta R \leq -50$ . The crew will vary  $\theta$  to null out any errors on the  $\Delta H$  scale to keep  $\Delta H = 0$  to stay on the desired profile and to assure an acceptable gamma at MECO. This assumes that the crew is flying the vehicle in CSS. If AUTO or BFS control is active, the crew will use the  $\Delta H$  scale as a monitoring device.  $\Delta H$  is no longer valid after the start of PPD.

The  $\Delta R$  scale will indicate when PPD should be initiated for a two- or three-SSME RTLS (PD or PD3 tick), and when MECO should be initiated (CO tick). The  $\Delta R$  indicator (triangle) will appear at the far right of the scale when an RTLS is initiated and remain there until  $\Delta R$  is greater than -143 n. mi.

The propellant readout will be used by the crew to monitor the initiation or as a manual backup to initiate the PPA. The PPA maneuver is automatically initiated based on vehicle mass or manually initiated based on a PPA time from MCC or on predicted mass versus PPA TGT mass on SPEC 0.

The rest of the digital readouts have the same use and function as for nominal ascent.

3.1.2.2 XXXXX TRAJ 1 (BFS)

a. Description

This display is available in MM 101 and in MM 102 (fig. 3.1-3). The title is dynamic and reads LAUNCH in MM 101 and ASCENT in MM 102.

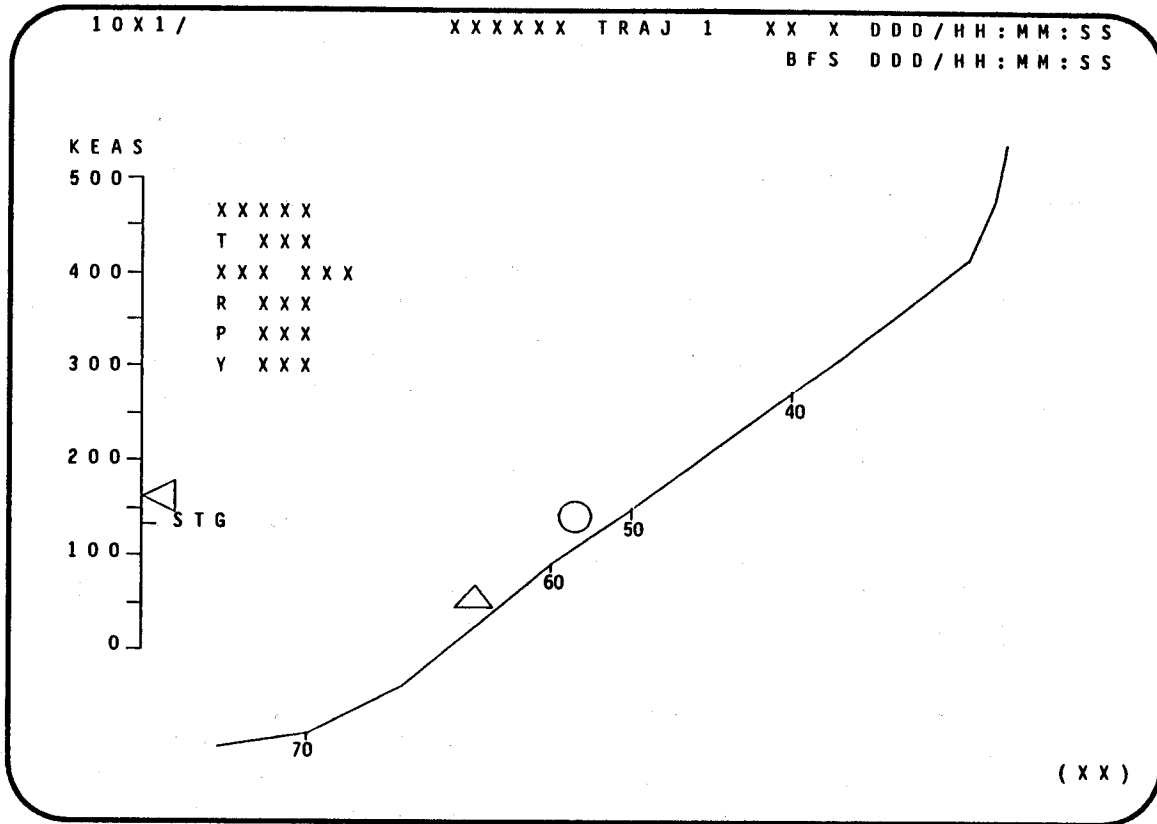


Figure 3.1-3.- XXXXX TRAJ 1 (BFS) display.

The central plot represents a nominal first stage ascent plotted as a function of altitude above the Fisher ellipsoid versus the magnitude of VREL. The altitude scale is from 0 to 170,000 ft and the velocity from 0 to 5000 fps. Tick marks on the profile show the local vertical inertial yaw (LVIY) ADI pitch angles which should be flown at the point on the nominal profile.

The current vehicle state is shown by a moving triangle with a 20-sec predictor represented by a circle. The altitude and velocity used to plot the current vehicle state comes from NAV (ascent UPP).

The scale on the left displays knots equivalent airspeed (KEAS) with the current KEAS shown by a triangle. The triangle will flash at maximum

scale. The staging tick corresponds to the maximum SRB\_SEP  $\bar{q}$  constraint. The onboard-computed  $\bar{q}$  is inhibited to a maximum value of 63 lb/ft<sup>2</sup>, because of uncertainties in its computation, to protect the real  $\bar{q}$  limit of 75 lb/ft<sup>2</sup>. Therefore, the current display puts the stage (STG) tick at 63 lb/ft<sup>2</sup>, 139 KEAS.

The digital readouts are as follows:

- (1) 'Pc < 50' will be displayed flashing whenever two of the three Pc sensors on each SRB fall below 50 psi. This is displayed when a discrete from the BFS SRB SEP sequencer is set.
- (2) 'T' is a digital readout of the throttle command from guidance in percent. The range is from 65 to 109 percent.
- (3) 'SEP INH' will be displayed flashing if the SRB SEP constraints are violated. The SEP INH discrete is set by the SRB SEP sequencer.
- (4) R, P, and Y are the BFS-computed roll, pitch, and yaw errors and are displayed before BFS engages for comparison with the PASS ADI error needles. Signs of the error values will be U (pitchup), D (pitchdown), L (roll or yaw left), and R (roll or yaw right) to indicate fly-to errors.

b. Use

Prior to BFS engage, the XXXXX TRAJ 1 display is used as a supplement to cue cards to monitor or manually fly the first stage TRAJ. Whether BFS is engaged or not this display is the only CRT display available to monitor the first stage trajectory.

c. Nominal, AOA, ATO

The Shuttle symbol and predictors should track the profile through SRB SEP. If the vehicle is being flown in CSS (PASS only), the crew can vary the pitch angle ( $\theta$ ) to fly the TRAJ while using the LVIY pitch attitude tick marks as references. After the BFS is engaged in OPS 1, CSS is not operational.

The KEAS scale provides the current KEAS ( $\bar{q}$ ) as calculated in the BFS. If the KEAS indicator is above the STG tick during SRB SEP there will be a SEP INH due to  $\bar{q}$  and the SEP INH readout will flash.

The Pc < 50, SEP INH, and T digital readouts are active and perform as discussed earlier (description section). If Pc < 50 is not displayed, the SRB SEP cannot be performed automatically or manually until a backup cue is set at a MET of 2:16.

The BFS-computed roll, pitch, and yaw errors can be compared to the PFS ADI errors before the BFS engages to obtain an indication of the health of the BFS system and the validity of its displays, assuming the PFS is

working properly. The BFS-displayed errors will also tell the crew what attitude changes to expect when the BFS is engaged. After the BFS is engaged the errors are displayed on the ADI and not on the CRT display.

d. RTLS

Procedurally an RTLS will not be selected in the first stage because the TRAJ's and Guidance, Navigation, and Control (GN&C) operations are identical whether or not an RTLS is selected. The TRAJ and GN&C operations change based on an engine out.

If an SSME fails in the first stage, guidance will automatically loft the trajectory ( $\theta$  will increase  $1^\circ$  to  $2^\circ$ ) whether or not an RTLS is selected.

3.1.2.3 XXXXX TRAJ 2 (BFS)

a. Description

This display comes up at the transition to MM 103 and is only available in MM 103 (fig. 3.1-4). The title is dynamic and will read ASCENT, ATO, or TAL.

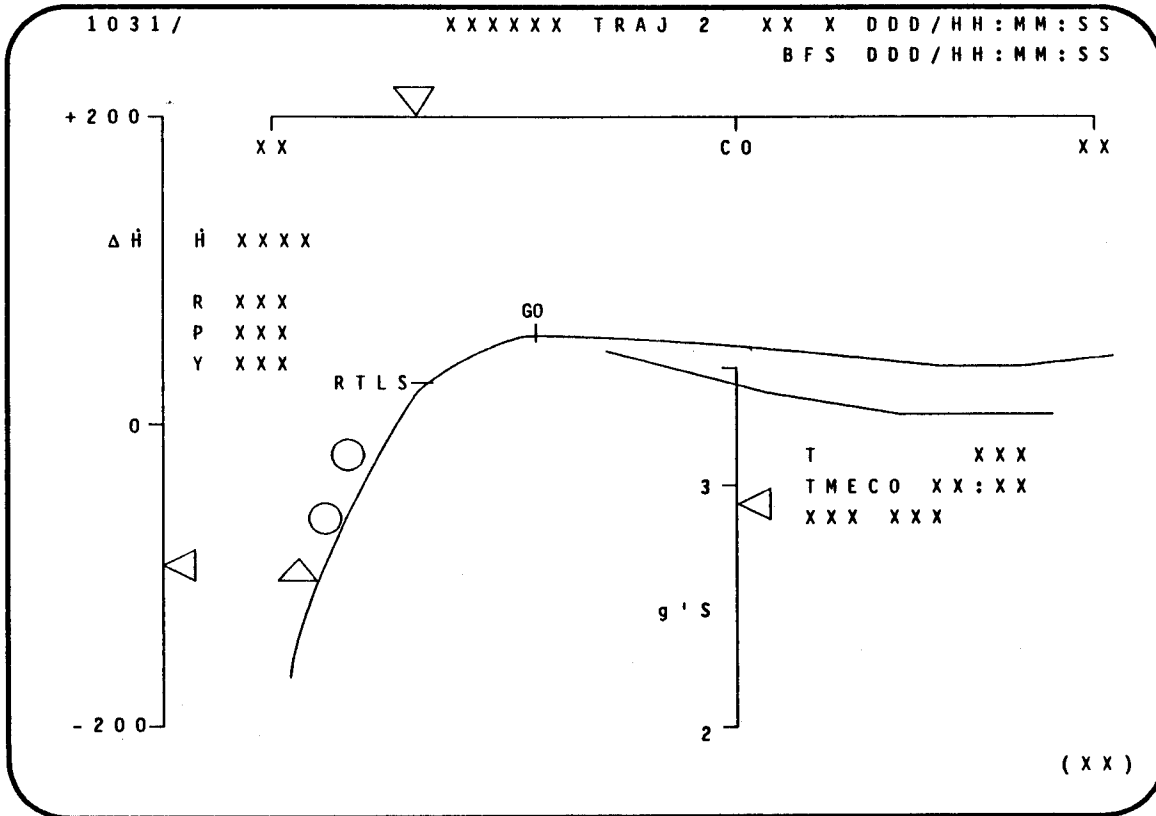


Figure 3.1-4.- XXXXX TRAJ 2 (BFS) display.

The solid line profile represents a nominal second stage ascent plotted as a function of altitude above the Fisher ellipsoid versus  $V_I$ . The altitude scale goes from 140,000 to 525,000 ft and the velocity scale from 5000 to 26,000 fps. The RTLS tick mark has the same definition and application as on the XXXXX TRAJ (primary system). The GO tick represents the point where no pre-MECO abort and no manual throttle-up would be required if one engine failed assuming 104 percent throttle,  $-2\sigma$  performance and no pre-MECO OMS dumps. The short solid line represents a TAL TRAJ for an engine out at the time of the earliest TAL opportunity and abort selection at 15 seconds later with 104 percent throttle.

The scale across the top is  $V_I$  from 25,000 to 26,000 fps with a CO tick at approximately 25,560 fps (due east SI missions). CO represents the nominal MECO point biased by 110 fps for thrust tail-off and manual MECO. In the case of a TAL the CO tick would again represent the appropriate velocity for MECO. In this case, the MECO point is biased by 74 fps for thrust tail-off and manual MECO. The current  $V_I$  is indicated by a triangle and comes from NAV. The triangle is initialized at 25,000 fps and remains there until  $V_I > 25,000$  fps.

The vertical scale near the center of the display shows the total load factor in g. The scale goes from 2 to 3.5g with the current value indicated by a triangle. The triangle will flash if 3g is exceeded.

The digital readouts follow:

- (1)  $\dot{H}$  is a readout of the present radius (altitude) rate from NAV.
- (2) R, P, and Y are the BFS-computed roll, pitch, and yaw errors and are displayed before BFS engage for comparison with the PASS ADI error needles. The signs of the error values will be U (pitch up), D (pitch down), L (roll or yaw left), and R (roll or yaw right) to indicate fly-to errors.
- (3) 'T' is the throttle command in percent. The range is from 65 to 109 percent and the value comes from guidance.
- (4) 'TMECO' is the predicted time of MECO in minutes and seconds. The time comes from BFS guidance and the stability of the time indicates whether or not BFS guidance is converged.
- (5) 'SEP INH' will be displayed flashing if the ET SEP constraints are violated and the ET SEP inhibit is set by the ET SEP sequencer.

b. Use

The XXXXX TRAJ 2 display is used as a supplement to the XXXXX TRAJ PFS and cue cards to monitor or manually fly the second stage TRAJ. After the BFS is engaged this display becomes the only CRT display for monitoring the second stage TRAJ.

c. Nominal, TAL, ATO

The Shuttle symbol and predictors should track the appropriate profile all the way through MECO. If the crew is flying in CSS and before the BFS engages, they can use pitch ( $\theta$ ) to stay on the trajectory. The CSS is not available after the BFS is engaged. If the triangle is past the GO tick and a single SSME fails, the crew will press uphill with MCC concurrence. An RTLS can no longer be successfully performed if the triangle is past the RTLS tick.

The  $\Delta H$  scale is used as an indicator to help get the proper  $\dot{H}$  at MECO.

The  $V_I$  scale across the top can be used to monitor or manually back up the proper engine cutoff (MECO) point.

The g scale can be used to monitor or manually perform 3g throttling.

The  $\dot{H}$ , T, SEP INH, and TMECO readouts perform as discussed earlier (description section).

The R, P, and Y digitals are used as described for XXXXX TRAJ 1 (BFS) display.

d. RTLS

This display is not available in MM 601.

e. TAL

This display can also be used to help fly the powered portion of the TAL TRAJ.

3.1.2.4 RTLS TRAJ 2 (BFS)

a. Description

This display comes up when an RTLS abort is selected in the second stage and is only available in MM 601 (fig. 3.1-5).

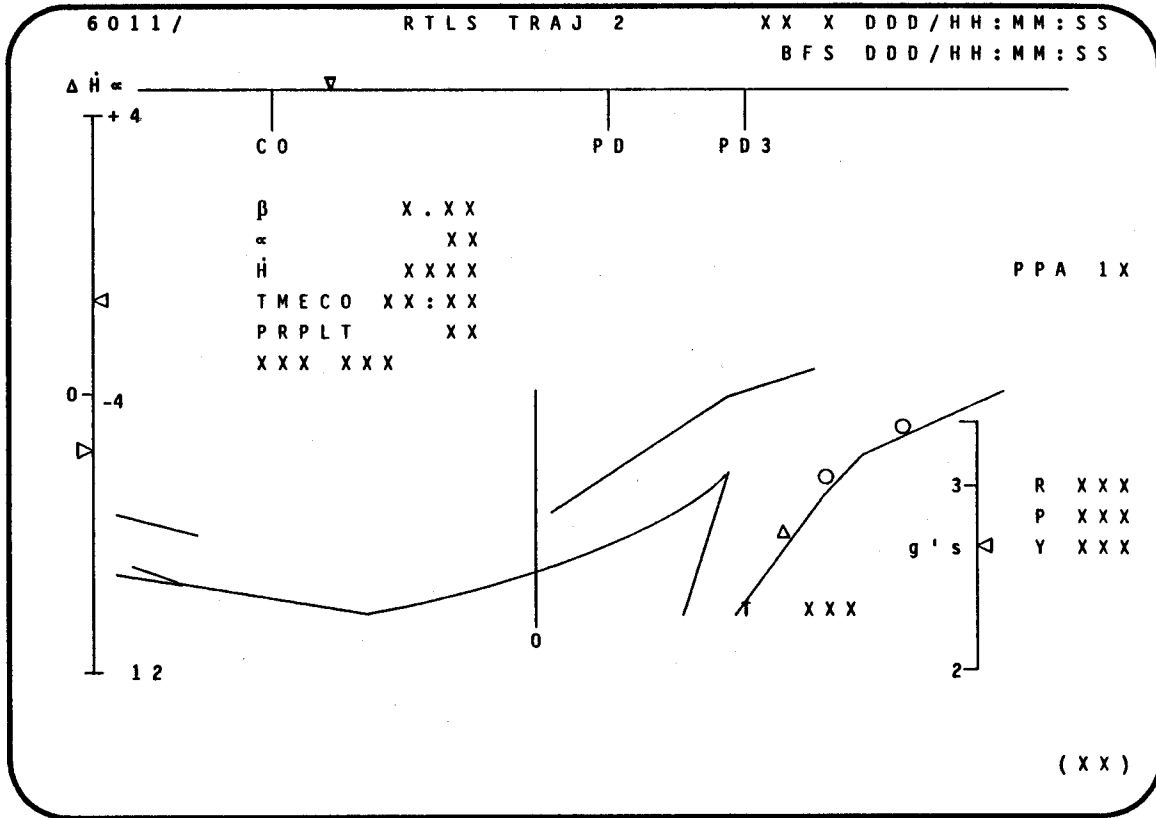


Figure 3.1-5.- RTLS TRAJ 2 (BFS) display.

The central plots represent the same second stage RTLS flight corridor as on the XXXXX TRAJ (primary system) display. However, unlike the XXXXX TRAJ display, all the profiles are plotted as a function of altitude above the Fisher ellipsoid versus the horizontal component of downrange  $V_{REL}$  ( $V\_HORIZ\_DNRNG$ ). The altitude scale goes from 140,000 to 525,000 ft while the velocity scale goes from -7000 to 10,000 fps.

The current vehicle state is shown by a moving triangle with 30- and 60-sec predictors represented by circles. The altitude and  $V\_HORIZ\_DNRNG$  used to plot the current vehicle state comes from NAV (RTLS UPP).



The two lines which bracket the end of the last-time two-SSME RTLS abort profile (lower left of the CRT) represent the ET SEP  $\bar{q}$  constraints. The top line represents  $\bar{q} = 2 \text{ lb/ft}^2$  and the bottom  $\bar{q} = 10 \text{ lb/ft}^2$ .

Also associated with the central plot is a vertical line labeled zero which intersects the plots and represents the point where  $V\_HORIZ\_DNRNG$  equal zero. The sign attached to the velocity changes from plus to a minus at this point to prevent doubling back.

The scale on the left represents  $\Delta\dot{H}$  and alpha. The  $\Delta\dot{H}$  is defined as the  $\dot{H}$  from NAV minus a reference  $\dot{H}$  from a table of average  $\dot{H}$  versus  $\Delta R$  for all RTLS's (same as XXXXX TRAJ). The limits on the scale are 200  $\text{fps}^2$  (top) to -200  $\text{fps}^2$  (bottom). The  $\Delta\dot{H}$  symbol, a triangle, is only displayed for  $V\_HORIZ\_DNRNG < 0$  and if  $-550 < \Delta R < -50$ . The symbol will flash if off-scale and is "fly to."

The alpha scale uses a triangle to indicate the current NAV-derived alpha. The indicator will not flash if off-scale. The scale limits are from  $+4^\circ$  (top) to  $-12^\circ$  (bottom).

The scale across the top is delta range ( $\Delta R$ ). This scale is identical to the  $\Delta R$  scale on the XXXXX TRAJ display.

The g-scale is the total load factor in g's with a triangle indicating total load factor. The triangle will flash if the load factor exceeds 3g's.

The digital readout follows:

- (1)  $\beta$  is the sideslip angle from NAV in degrees.
- (2)  $\alpha$  is the angle of attack from NAV in degrees.
- (3)  $\dot{H}$  is the altitude (radius) rate from NAV in feet per second.
- (4) 'TMECO' is the predicted time of MECO from guidance. It reads in minutes and seconds.
- (5) 'PRPLT' is the percentage of propellant remaining in the ET. This value is calculated in the RTLS TRAJ 2 DIP.
- (6) 'SEP INH' is displayed flashing just below the TMECO readout if the ET SEP inhibit discrete is set by the ET SEP sequence.
- (7) T is the commanded throttle setting in percent. The value comes from guidance.
- (8) R, P, Y are the ADI errors in roll, pitch, and yaw computed by the BFS. They are displayed before the BFS engages for comparison with the PASS ADI error needles. The signs of the error values will be U (pitchup), D (pitchdown), L (roll or yaw left), and R (roll or yaw right) to indicate fly-to errors.

- (9) PPA 1 selection (ITEM 1 EXEC) forces BFS into the PPA phase. An asterisk indicates BFS has started PPA.

The RTLS TRAJ 2 display is used as a supplement to the XXXXX TRAJ to monitor or manually fly the PRTLS TRAJ. After the BFS is engaged this display becomes the only CRT display for monitoring the PRTLS TRAJ.

b. Nominal, AOA, ATO

Not applicable; this display is only up for an RTLS abort, MM 601.

c. RTLS

This display will appear on the BFS CRT immediately after an RTLS (MM 601) is selected. Depending on the engine-out time, the Shuttle symbol and predictors will track the engine out at lift-off profile, the last-time two-SSME RTLS profile, the highest loft profile, or somewhere inside the implied flight envelope. For a three-SSME RTLS, the symbol and predictors should track very close to the last time two-SSME RTLS profile. If in CSS and before BFS engage, the crew will vary pitch ( $\theta$ ) to stay on the appropriate profile. CSS is not available after the BFS is engaged.

The  $\Delta H$  scale is used as described for the XXXXX TRAJ (primary system) display.

The alpha scale will be used primarily after PPD to monitor alpha during the mated coast and the ET SEP sequence.

The  $\Delta R$  scale will indicate when PPD should be initiated for a two- or three-SSME RTLS (PD or PD3 tick), and when MECO should be initiated (CO tick).

The g-scale will be used to monitor the total load on the vehicle. Three-g throttling is not needed for an RTLS.

The  $\alpha$ ,  $\beta$ ,  $\dot{H}$ , T, and SEP INH readouts perform as discussed earlier.

The TMECO readout will provide the MECO time as calculated by guidance.

The propellant readout will be used to monitor the initiation or as a manual backup (before the BFS engages) to initiate the PPA. The PPA maneuver is automatically initiated based on vehicle mass and manually initiated based on a PPA time from MCC or on the percentage of propellant remaining as a backup cue.

The R, P, and Y digitals are used as described for the XXXXX TRAJ (BFS) display.

### 3.1.2.5 VERT SIT 1 (PASS and BFS)

#### a. Description

This display comes up at MM 602 transition for GRTLS or MM 305 transition for a nominal entry (fig. 3.1-6). The only portion of the display that will be described in this writeup is the Mach-alpha profile in the upper left corner of the display. The remainder of the display is described in the Entry Flight Procedures Handbook. The profile described below is for cycle 2 data.

The Mach-alpha profile (dashed line) is used during the alpha transition phase of GRTLS guidance and represents the Mach-alpha profile that guidance is attempting to fly (fig. 3.1-7). The dashed Mach-alpha profile line moves from Mach 6 and alpha = 20° (upper-right of dashed line) to an alpha of 16° at Mach 4 (bend in line) where alpha is held constant down to Mach 3 (lower left of dashed line). The current vehicle state is indicated by a symbol in the shape of an Orbiter at a fixed orientation. The symbol can represent a vehicle state anywhere between alphas of 8° to 24° and Mach 3 to 6.

Below the dashed line is a solid line representing a lateral/directional trip boundary defined for  $3\sigma$  aero with two RCS jets available for trim. The solid line moves from alpha = 10° at Mach 6 down to alpha = 8° at Mach 3.

#### b. Use

This display is used primarily to monitor or fly the alpha transition phase of GRTLS and to monitor the energy state of the Orbiter, whether it is flying in AUTO or CSS during and after the alpha transition phase.

#### c. Nominal, ATO, AOA

This display is not available for nominal ascent, or the ascent portion of aborts.

#### d. RTLS

The VERT SIT 1 comes up at MM 602 transition (end of -Z translation) with the energy-to-weight ratio (E/W) scale and digital data being active, and the Orbiter symbol pegged above the upper-right portion of the Mach-alpha dashed line at Mach 6 and alpha = 24°. Only the E/W scale and digital data will be active during the first two phases of GRTLS ( $\alpha$ -recovery and Nz hold). Since a constant alpha (50°) is flown during  $\alpha$ -recovery and Nz is held at 64.4 fps<sup>2</sup> (2g) during Nz hold, the VERT SIT 1 is not used until the alpha transition phase. The E/W is not valid until after the Nz hold phase is complete.

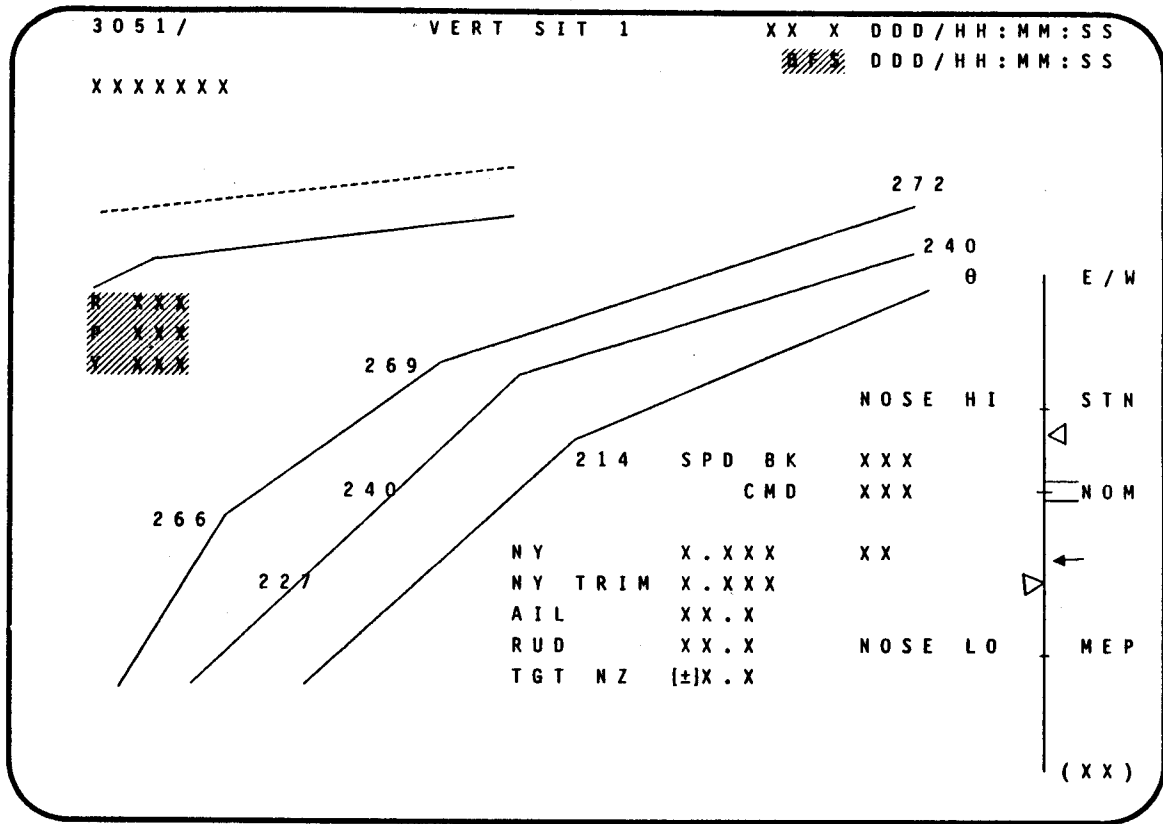


Figure 3.1-6.- VERT SIT 1 (PASS and BFS) display.

The Shuttle symbol will start moving once the vehicle state falls within the scaling of the Mach-alpha plot on the display ( $\alpha \leq 24^\circ$ , Mach  $\leq 6$ ); however, the Mach-alpha profile (dashed line) is not allowed until the descent rate is less than 250 fps. If the E/W symbol is at S-turn (STN) and flashing, an S-turn will be performed while flying the Mach-alpha profile until E/W falls below STN.

The Mach-alpha profile is followed until the Orbiter symbol switches to the altitude/range lines. This occurs at Mach 3.2, the MM 603 transition point. The  $\theta$  scale becomes active at the same time.

After the Shuttle symbol switches to the altitude/range lines (Mach 3.2), the E/W scale becomes the prime readout since kinetic energy is the most important parameter to control. Whether in AUTO or CSS, if the E/W symbol is below nominal (Orbiter low on energy) fly 200 KEAS (maximum L/D) and hold until energy is nominal. If the E/W symbol is above nominal (Orbiter high on energy), fly 300 KEAS and hold until energy is nominal. Once the E/W scale is at nominal, altitude control can be used to fly towards the altitude/range reference line (middle line).

The  $\theta$  scale, displaying current vehicle pitch attitude, is used when default air data transducer assembly (ADTA) is in use and  $V_{REL} < 1500$  fps. The NOSE HI and NOSE LOW scale may be flown in order to correct situations in which AUTO control commands  $\theta$  out of limits and exceed the  $\bar{q}$  limits ( $140 \leq \bar{q} \leq 300$ ).

3.1.2.6 XXXXX MNVR YYYYY (Primary System and BFS)

a. Description

This display is available in MM's 104, 105, 202, 301, 302, and 303 (fig. 3.1-7). The title is dynamic and reads the appropriate I-loaded maneuver to be performed. The purpose of the display is to provide a means of inputting maneuvers, evaluating their effects on the TRAJ, and adjusting parameters as required.

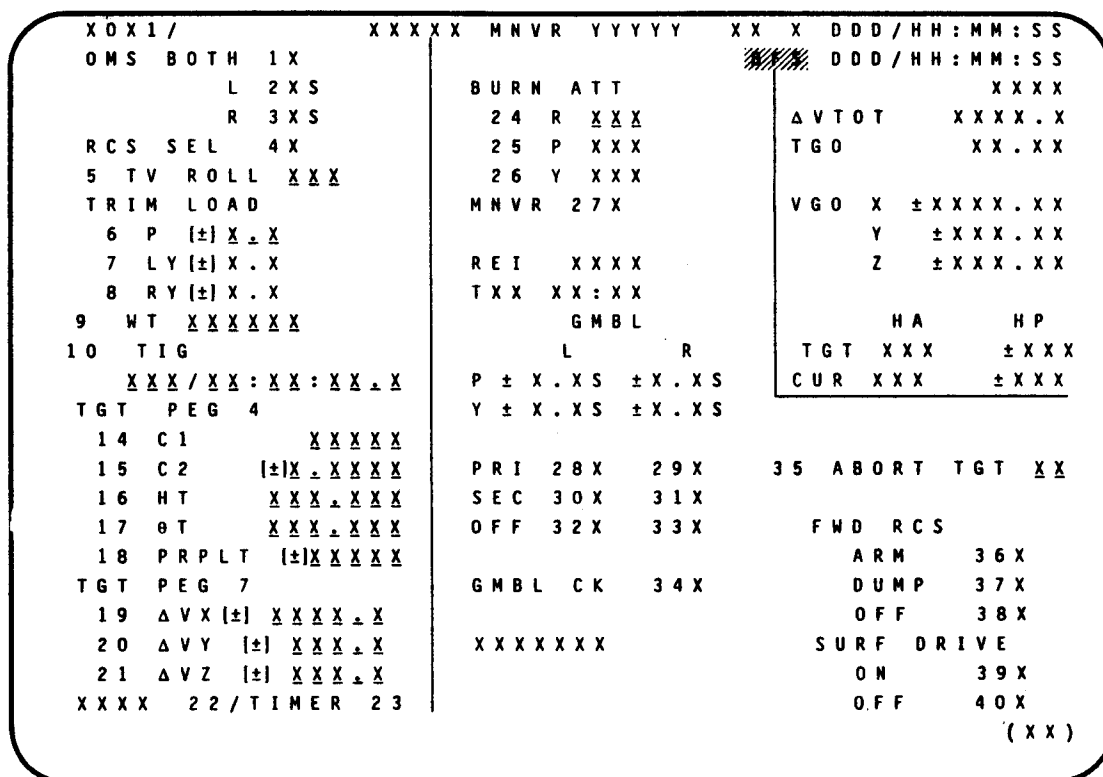


Figure 3.1-7. XXXX MNVR YYYYY display.

The display parameters and their functions are

- (1) Item entries are provided to select both OMS, left OMS, right OMS, or +X RCS. Guidance will use the selected engine in computing its calculations for the burn when LOAD is executed. The 'OMS BOTH' selection is initialized for the OMS-1 burn in OPS 104. Subsequent use of the display will reflect the last selected engine option. A down arrow (+) will be displayed after L and R when predefined chamber pressure and delta velocity limits are exceeded. When OMS RM is running (RM is set by selecting OMS BOTH), it will remove the (+) during initialization. The down arrow (+) will remain until OMS RM is running.

Item 5 (TV ROLL) defines the desired local roll angle at ignition ( $0^\circ$  is heads up). The TV roll angle to be displayed shall come from crew item entry, uplink or I-load. Item 5 is only legal in OPS 2.

- (2) TRIM angles in degrees are displayed and can be changed by item entry. For the OMS-1 burn in ascent these trim values are I-loaded and should appear when in OPS 104. Burns after OMS-1 will be automatically trimmed to the last burn's gimbals unless manually changed or changed by uplink. Modification of the trim angles requires execution of the LOAD (item 22) for recognition by the DAP and guidance. The BFS does not track PASS gimbals during the burn pre-engaged. Thus I-loaded values will remain on the display and need changing. If BFS is engaged, the trims will change just like the PASS.
- (3) The capability to display and change the total Orbiter weight (WT) in pounds is available via Item 9. The WT is calculated by the MNVR DIP the first time this display is called, and it will be updated cyclically as current mass is updated unless LOAD is flashing. The value of WT can be updated by ground uplink, or crew entry to account for changes in total Orbiter mass and is recognized when the LOAD item is executed.
- (4) Targeting information is displayed in the lower-left section for various PEG modes. Specific PEG 4 I-loaded targets are automatically entered depending on MM and abort mode selected.
  - (a) TIG is the desired mission elapsed time of ignition in days:hr:min:sec. TIG will be checked by the MNVR DIP upon performing a LOAD to verify that the TIG is within 5 min in the past and 12 hours in the future. If the TIG is not within this envelope (for an AUTO LOAD in MM 104 or crew manual LOAD in all other applicable MM's), an ILLEGAL ENTRY message will be generated.
  - (b) C1 and C2 are coefficients of the linear equation ( $V_{REL} = C1 + C2 V_{HOR}$ ) which defines the desired flightpath angle at the end of the coast phase for PEG 4. C1 is in FPS and C2 is a scalar.  $V_{HOR}$  is the horizontal velocity component. For all burns targeted to apogee or perigee both C1 and C2 are zero.
  - (c) HT is the PEG 4 targeted radius (height) in nautical miles. In OPS 1 this is the targeted height (HA or HP) required for the burn. In OPS 3 it is the targeted EI height - 400,000 ft or 66 n. mi.
  - (d)  $\theta T$  is a PEG 4 parameter. In OPS 1, it is the angle between the launch site and the post OMS-1 apogee point. In OPS 3 it is the angle between the deorbit burn TIG and EI.
  - (e) PRPLT is the total OMS propellant in pounds to be used in OPS 3 by the deorbit burn. It includes the propellant required

for the in-plane target plus the propellant to be wasted in order to achieve a planned c.g. and mass. During the burn PRPLT shall be updated cyclically as the current mass is updated. The sign of this quantity defines the side of the orbital plane where wasting will occur. If PRPLT needs to be changed after LOAD is entered, a flashing LOAD must be present to update the display with the new number. This can be accomplished by temporarily selecting an alternate engine configuration, then reselecting the desired configuration. Wasting can be canceled during the burn by entering zero. This item is honored in OPS 3 only.

- (f) An external delta velocity targeting (PEG 7) option can be exercised by inputting the desired delta velocities needed in the local vertical reference system at ignition.
- (5) LOAD flashing occurs anytime any of the above targeting parameters (including engine selection, trim, and vehicle weight) is changed, with the exception of a PRPLT input of zero. An item 22 entry must be made to send the loaded targets to guidance for a solution (with the exception of the OPS 104 OMS-1 burn which is automatically loaded).
- (6) TIMER initiates the CRT event timer to count down to the loaded TIG. An ITEM 23 EXEC is required to start this function. (For the OPS 104 OMS-1 burn this is automatically started.) The timer should not be initiated until after the guidance target has been loaded (ITEM 22 EXEC).
- (7) BURN ATT provides the guidance-computed ADI inertial burn attitude in roll, pitch, and yaw for MM's 104, 105, 301, and 302. Attitude errors are also displayed by the ADI error needles. In MM 303 it displays a premission I-loaded desired attitude which can be changed by item entry. On AOA the item entry may be used in MM 303 to enter the appropriate EI - 5-min attitude required for entry.

BURN ATT R, P, Y will display the desired burn attitude computed by guidance once LOAD is executed in MM 301 and 302. The crew may enter a desired attitude via ITEMS 24, 25, 26 prior to the execution of LOAD, or override the guidance-computed values after the execution of LOAD. If the crew overrides the burn attitude, LOAD must be executed again to display the new burn attitude. For MM 303 BURN ATT, R, P, and Y will display a preflight I-load desired attitude; a ground-uplinked attitude or a crew-entered attitude. This attitude will be used to generate ADI attitude errors such that the crew can maneuver manually or automatically to desired attitude (normally entry interface attitude). BURN ATT R, P, and Y are only enabled for data loading in MM's 301, 302, and 303. Execution of the corresponding item numbers in any other MM will result in an illegal entry message.



- (8) MNVR provides control for the automatic maneuver to the desired burn attitude. When executed, an asterisk (\*) shall be displayed next to the item number while the maneuver is in progress. If the current attitude is within 8° of the desired attitude when the item 27 is executed, no "\*" will appear even with DAP AUTO selected; however, the Orbiter will move slowly to the desired attitude.
- (9) Below the burn attitude section, data shall be displayed to inform the crew of projected mission milestones.
- (a) During OPS 3, a display of the Orbiter range at entry interface (REI) from 400,000 feet to the target landing site is available to the crew in nautical miles. In OPS 1 and 2 the data field is blanked.
- (b) A time display (TXX) shall be provided which is either time-to-next-apsis for OPS 1 and 2, or time-to-400,000 feet (above a spherical Earth) for OPS 3, in minutes and seconds. In MM 303, REI and time to free fall (TFF) are recomputed whenever the state vector is updated by either uplink or horizontal situation display (HSD) entry.
- During OPS 1 and 2 the dynamic title field TXX displays either time to apogee (TTA) or time to perigee (TTP) and the time field displays the time to apogee or perigee, whichever is closer. For orbits where the difference between apogee and perigee altitude is less than 5 n. mi., the dynamic characters become time to circularize (TTC) and the time field is blanked.
  - During OPS 3 the dynamic title field TXX displays TFF and the time field displays the time-to-400,000 feet.
- (10) The gimbal (GMBL) data provides the crew with a monitoring capability of the pitch and yaw engine gimbal positions for the left and right OMS actuators. These gimbal positions (in degrees) are from the position transducers located on the gimbal drive actuators for the selection drive systems.

A down arrow (+) will be driven adjacent to the failed actuator upon detection of a gimbal actuator failure by fault detection and identification (FDI). A data missing indicator (M) shall be displayed in the status column and the parameter data field blanked when a comm fault exists. The M has priority over the down arrow (+).

- (a) GMBL PRI/SEC provide the capability for the crew to select the active gimbal drive system (primary (PRI) or secondary (SEC)) on the left or right engine. Selection of either gimbal drive system (PRI or SEC) causes both the pitch and yaw actuators to

be driven by the designated controller system. Whenever any one of Items 28 through 31 is executed, a flag is sent to OMSTVC Command Subsystem Operating Program (CMDSOP) which initiates a command sequence intended to free the OMS actuators. The sequence is performed for all actuators. Gimbal OFF L/R provide the capability to power down the respective left and right gimbal drive systems. An asterisk (\*) will be displayed next to the selected gimbal drive system item number. When the display is first called, the PRI GMBL drive systems on both engines are selected unless a previous selection has been made automatically during ascent. The gimbal drive system selected last shall be initialized upon transitioning to another OPS.

- (b) Gimbal check provides the capability for the crew to initiate an automatic thrust vector control (TVC) check of the active gimbal drive systems in all MM's in which the display is available. An asterisk (\*) is displayed next to the item number while the check is in progress. At the completion of the drive check the gimbals are returned to their initial positions and the asterisk (\*) blanked.
- (11) ABORT target provides the capability to select AOA or ATO via the target set. All outputs from the dedicated abort switch or the backup AOA or ATO abort select items on the OVERRIDE display shall be ignored once this item entry control has been exercised. The item allows the crew to either upmode or downmode the type of abort as desired. It is only legal in MM 104 or 105.

The automatically selected abort target set identification (ID) (from the stored matrix of nominal or ATO) will be displayed if an ATO abort is selected via the dedicated abort switch. Any automatically selected target set ID may be overridden via the item entry control. The item entry control also allows the crew to select an AOA or ATO abort and the respective target sets desired by entering the appropriate target ID. (If the crew selects a particular OMS-1 target set in MM 104, the associated OMS-2 target is automatically selected and the ID displayed upon transitioning to MM 105. The crew may override this automatic OMS-2 target selection by entry of a new target set ID in MM 105 prior to the OMS-2 burn for ATO or prior to OPS-3 transition for AOA.) The abort target set ID shall be initially set equal to zero and displayed upon entering MM 104 and thereafter may be set equal to 1 through 12 (by crew entry or automatically by AOA/ATO targeting when an abort is declared). The STS 61-C standard insertion hierarchy of target is shown in figure 3.1-8.

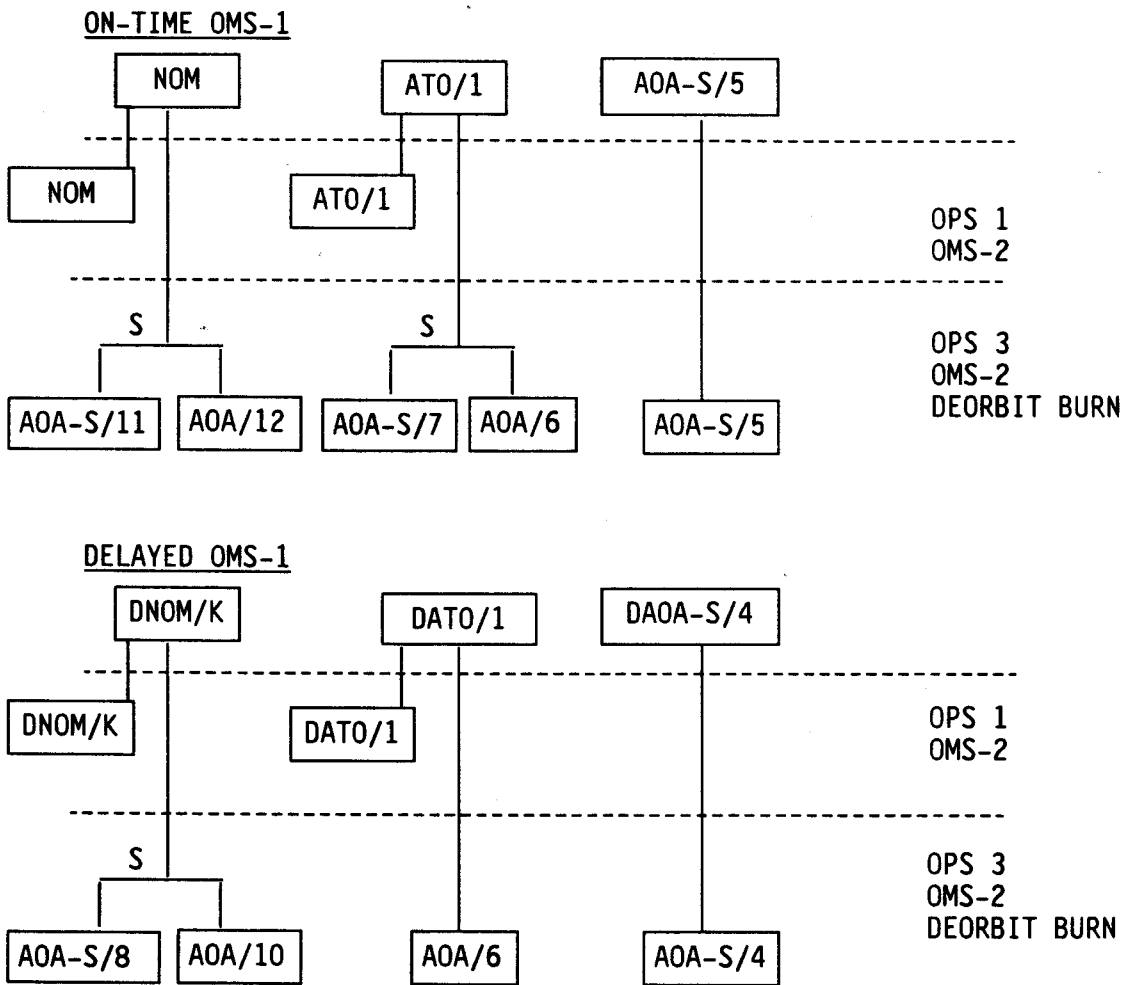


Figure 3.1-8.- STS 61-C OMS targets (SI).

If an AOA abort is selected in MM 105 via the abort pb or I-TGT selection, the text words OPS 301 will flash on the display indicating that the targeting for the AOA OMS-2 burn is completed. The crew can then execute OPS 301 PRO. The AOA targets will be displayed in MM 105.

- (12) The upper right section of the display contains various burn data information as follows:
- (a) A dynamic character field EXEC shall appear flashing at TIG-15 sec and flash until keyboard (KYBD) EXEC is performed, at which time the characters disappear. Ignition is inhibited until this entry is made. A KYBD EXEC prior to TIG-15 sec does not constitute an enable for the maneuver. KYBD EXEC after TIG enables the maneuver to start immediately after the EXEC is entered.
 

If a MM transition is made out of a maneuver execute MM (i.e., MM's 104, 105, 202, 302) while a burn is loaded, enabled or in progress, the burn will be canceled or terminated as applicable.
  - (b) The total delta velocity ( $\Delta VTOT$ ) in fps predicted for the burn of the targeted maneuver as computed by guidance.
  - (c) TGO reflects the predicted burn time (min:sec) prior to TIG and the actual burn time remaining during the burn.
  - (d) The velocity-to-be-gained by the maneuver, expressed in vehicle body axis components (VGO X, VGO Y, VGO Z), is displayed in fps.
  - (e) The apogee altitude (HA) and perigee altitude (HP) values measured in nautical miles above a spherical Earth for two conditions.
    - TGT (target) - predicted postburn values of apogee and perigee
    - CUR (current) - the current orbit apogee and perigee values
- (13) FWD RCS ARM,DUMP,OFF provide the capability to arm, dump, and turn off a forward RCS propellant burnoff only during OPS 3. A burnoff is initiated by executing the RCS ARM item and then the DUMP item. The selection of these items will be indicated by an asterisk (\*) displayed after the item numbers. The execution of FWD RCS OFF terminates the burnoff, displays an asterisk (\*) after its item number and blanks the asterisks (\*'s) after the ARM and DUMP item numbers. If the burnoff is still enabled at the transition to MM 304, it will be automatically terminated.

- (14) A capability to initiate and terminate a flight control surface drive function (SURF DRIVE) is provided. The SURF DRIVE function provides simultaneous motion of all aerosurfaces for hydraulics fluid thermal conditioning in OPS 3 only.

b. Use

- (1) Nominal, ATO, and AOA-S OMS-1 - At MM 104 transition (at the end of the automatic 4 fps -Z translation following ET SEP), the display automatically loads and computes the OMS-1 target. The crew checks to see if the nominal target is the desired target by referring to the OMS-1 targeting cue card. Further explanation of targeting than is given here is in section 3.2. The two parameters on the display used to make this determination are HA and HP. If an abort target is desired, selection of the abort will be made by keying in the I-target desired. The display title will change to indicate the selected abort and also show the abort target. After a short delay for guidance calculations, the targeted burn data will be displayed automatically. If a delayed TIG is required, it must manually be entered by the crew.

After the appropriate target is selected, the crew compares the burn attitude displayed with the inertial ADI and initiates the automatic maneuver via item 27 to that attitude. (DAP must be in 'AUTO'.)

A check of the targets in the BFS is made to compare them with the PASS.

If there is an engine failure before the burn, no attempt will be made to retrim the gimbals or reselect the proper engine. Instead the burn will be started with both engines selected, allowing the software to downmode to the appropriate selection. Nominally, the burn will be done using both OMS engines (item 1). However, in certain delayed burn cases where +X RCS is planned, the crew may select the RCS burn. After an OMS failure is annunciated, the crew must turn the affected OMS engine off and crossfeed at 1/2  $\Delta$ VTOT remaining at the failure time. This makes guidance aware of the failure so that it can accurately display the correct information. After the burn, residuals in any axis greater than 2 fps will be nulled with the THC.

- (2) Nominal or ATO OMS-2 - MM 105 will be manually called up by the crew after the completion of OMS-1. An I-loaded OMS-2 target will appear on the display, but will not be loaded. The crew will verify the target selection. OMS trim values will be entered on the display along with the desired OMS-2 engine selection and targets if different from what is already there. Targets are then loaded and the CRT timer started. The BFS target and its solutions are compared with the PASS. The crew again compares the CRT burn

attitude displayed with the ADI and then maneuvers to that attitude. The crew's interface with the display is similar to OMS-1. There are no residual requirements after the burn as long as an 80-n. mi. perigee is reached.

- (3) AOA deorbit - If an AOA is decided on, then the deorbit burn replaces the OMS-2 burn. The procedures stay the same going into MM 105. The crew will enter the desired AOA target set ID or manually enter the targets as required. After the ET umbilical doors are closed, the crew will transition to OPS 3. The burn targets selected in OPS 1 will automatically be carried over to OPS 3 in the PASS. However, they will have to be manually entered into the BFS in OPS 3 (until CR 79782, OI12).

Since this is a deorbit burn, a propellant value will be entered for c.g. and weight management.

After the deorbit target is loaded, the REI is checked to verify that it is the desired range. If not, the range is corrected by a checklist chart which allows the crewman to adjust TIG. Changing TIG causes LOAD to flash which requires the crew to reload. After loading, a maneuver to burn attitude is as before.

Interface with the display during the burn is similar to that during other burns. If it is necessary to stop fuel wasting during the burn, it can be done simply by entering a zero value for propellant on the display. After the burn, any residuals greater than 2 fps will be nulled using the THC.

The crew will then mode into MM 303. The display will blank all computed values and display only burn attitude. This attitude is an I-loaded value and represents the EI-5 attitude for a nominal AOA entry after an ATO (AOA) OMS-1 burn.

Since AOA deorbits may be performed under different conditions (e.g., shallow entry) the attitude required at EI-5 will vary. If the attitude required is different from the I-loaded value, the crew will enter the required value from the deorbit, entry, and landing (DEL) preliminary advisory data (PAD) and then maneuver to this attitude.

### 3.1.2.7 SYS SUMM DISPLAYS

The SYS SUMM displays are the principal means of monitoring the performance of Orbiter flight-critical systems. The parameters displayed were chosen to support the C&W function by aiding the crew in determining the proper response to alarms. These displays can be called by SYS SUMM or specialists function (SPEC) key sequence with the CRT major function switch in proper position (GNC or SM).

#### a. GNC SYS SUMM 1 (Primary System SPEC 18) (fig. 3.1-9)

The RCS jet manifold status indicators are displayed for each of the three RCS modules and each manifold (except number 5 for ascent and entry). The isolation valve (ISOL VLV) positions are the initialized positions in MM 102 and may not be the true valve positions. Computed aerosurface positions and loading status are displayed during OPS 3 and 6. The DPS indicates when GPC's are voted failed or fail-to-sync. The DPS also provides a summary status of flight-critical data paths.

The flight control system (FCS) channel I/O error and failure indicators are displayed in OPS 1 for SRB, MPS, and aerosurface actuators, but in OPS 3, the I/O error and failure indicators are displayed only for the aerosurface actuators. NAV sensor status is displayed in the following situations:

| <u>Sensor</u>  | <u>OPS</u>        |
|----------------|-------------------|
| IMU            | 1, 2, 3, 6, and 8 |
| ACC and RGA    | 1, 3, and 6       |
| TAC, MLS, ADTA | 3 and 6           |

CNTRLR status is displayed as follows (PASS only):

| <u>Controller</u> | <u>OPS</u>     |
|-------------------|----------------|
| None              | 1              |
| RHC*, THC*, SBTC  | 3, 6, 2, and 8 |

\*Aft CNTRLR's are active in OPS 2 and 8 only.

#### b. GNC SYS SUMM 1 (SPEC 18, BFS) (fig. 3.1-9)

The aerosurface positions and loading status are only supported in OPS 3. The DPS provides failure indication for each data path. The FCS channel status indicates actuator bypass manual deselection, or comm faults. NAV status is supported as follows: IMU in OPS 1, 3, and 6; tactical air navigation (tacan) and ADTA in OPS 3 and MM's 602 and 603.

```

XXXXXXXX/XXX/018      GNC SYS SUMM 1      XX X DDD/HH:MM:SS
                                                                DDD/HH:MM:SS
RCS | JET | ISOL
MANF| FAIL| LVLV | SURF      POS      MOM      DPS      1 2 3 4 5
F1XXX|XXX|XXX|L OB      XXX.XS  XXS      GPC S S S S S
2XXX|XXX|XXX|IB      XXX.XS  XXS      MDM FF S S S S
3XXX|XXX|XXX|R IB      XXX.XS  XXS      FA S S S S
4XXX|XXX|XXX|OB      XXX.XS  XXS
5XXX|XXX|XXX|AIL      XXX.X
L1XXX|XXX|XXX|RUD      XXX.X
2XXX|XXX|XXX|SPD BRK XXX.X
3XXX|XXX|XXX|BDY FLP XXX.X
4XXX|XXX|XXX|XXXXXX
5XXX|XXX|XXX|
R1XXX|XXX|XXX|
2XXX|XXX|XXX|CNTLR  1 2 3
3XXX|XXX|XXX|RHC   L S S S
4XXX|XXX|XXX|      R S S S
5XXX|XXX|XXX|      A S S S
THC   L S S S
      A S S S
SBTC  L S S S
      R S S S
                                                                NAV      1 2 3 4
                                                                IMU   S S S
                                                                ACC   S S S S
                                                                RGA   S S S S
                                                                TAC   S S S
                                                                MLS   S S S
                                                                ADTA  S S S S
                                                                (XX)
    
```

```

XXXXXXXX/XXX/018      GNC SYS SUMM 1      XX X DDD/HH:MM:SS
                                                                BFS DDD/HH:MM:SS
SURF      POS      MOM      DPS      1 2 3 4
L OB      XXX.XS  XXS      MDM FF S S S S
      IB      XXX.XS  XXS      FA S S S S
R IB      XXX.XS  XXS      PL S S
      OB      XXX.XS  XXS
AIL      XXX.X
RUD      XXX.X
SPD BRK XXX.X
BDY FLP XXX.X
                                                                FCS CH 1 2 3 4
                                                                S S S S
MPS      L      C      R      NAV 1 2 3 4
HE TK P   XXXXS XXXXS XXXXS IMU S S S
REG P A   XXXXS XXXXS XXXXS TAC S S S
      B   XXXXS XXXXS XXXXS ADTA S S S S
dP/dT    XXXS  XXXS  XXXS
ULL P LH2 XX.XS XX.XS XX.XS
      LO2  XX.XS XX.XS XX.XS
MANF P LH2 XXXS
      LO2 XXXS
                                                                (XX)
    
```

Figure 3.1-9.- GNC SYS SUMM displays.



| XXXX/XXX/019 GNC SYS SUMM 2     |  |  |  |  |                    |  |  |  |  | XXX DDD/HH:MM:SS |  |  |  |  |
|---------------------------------|--|--|--|--|--------------------|--|--|--|--|------------------|--|--|--|--|
|                                 |  |  |  |  |                    |  |  |  |  | DDD/HH:MM:SS     |  |  |  |  |
| OMS AFT QTY L R                 |  |  |  |  | OMS L R            |  |  |  |  |                  |  |  |  |  |
| OXID XX.XS XX.XS                |  |  |  |  | TK P HE XXXS XXXS  |  |  |  |  |                  |  |  |  |  |
| FU XX.XS XX.XS                  |  |  |  |  | OXID XXXS XXXS     |  |  |  |  |                  |  |  |  |  |
| <del>XXXXXXXXXXXXXXXXXXXX</del> |  |  |  |  |                    |  |  |  |  | FU XXXS XXXS     |  |  |  |  |
|                                 |  |  |  |  | N2 TK P XXXS XXXS  |  |  |  |  |                  |  |  |  |  |
| RCS OXID FU JET ISOL            |  |  |  |  | REG P XXXS XXXS    |  |  |  |  |                  |  |  |  |  |
| FWD HE P XXXS XXXS              |  |  |  |  | P VLV XXXS XXXS    |  |  |  |  |                  |  |  |  |  |
| TK P XXXS XXXS                  |  |  |  |  | ENG IN P           |  |  |  |  |                  |  |  |  |  |
| QTY XXXS XXXS                   |  |  |  |  | OXID XXXS XXXS     |  |  |  |  |                  |  |  |  |  |
| MANF 1 P XXXS XXXS XXXS         |  |  |  |  | FU XXXS XXXS       |  |  |  |  |                  |  |  |  |  |
| 2 P XXXS XXXS XXXS              |  |  |  |  | VLV 1 XXXS XXXS    |  |  |  |  |                  |  |  |  |  |
| 3 P XXXS XXXS XXXS              |  |  |  |  | 2 XXXS XXXS        |  |  |  |  |                  |  |  |  |  |
| 4 P XXXS XXXS XXXS              |  |  |  |  |                    |  |  |  |  |                  |  |  |  |  |
| 5 XXXS XXXS XXXS                |  |  |  |  |                    |  |  |  |  |                  |  |  |  |  |
|                                 |  |  |  |  | OXID FU JET ISOL   |  |  |  |  |                  |  |  |  |  |
| AFT HE P XXXS XXXS              |  |  |  |  | HE P XXXS XXXS     |  |  |  |  |                  |  |  |  |  |
| L TK P XXXS XXXS                |  |  |  |  | R TK P XXXS XXXS   |  |  |  |  |                  |  |  |  |  |
| QTY XXXS XXXS                   |  |  |  |  | QTY XXXS XXXS      |  |  |  |  |                  |  |  |  |  |
| MANF 1 P XXXS XXXS XXXS         |  |  |  |  | 1 P XXXS XXXS XXXS |  |  |  |  |                  |  |  |  |  |
| 2 P XXXS XXXS XXXS              |  |  |  |  | 2 P XXXS XXXS XXXS |  |  |  |  |                  |  |  |  |  |
| 3 P XXXS XXXS XXXS              |  |  |  |  | 3 P XXXS XXXS XXXS |  |  |  |  |                  |  |  |  |  |
| 4 P XXXS XXXS XXXS              |  |  |  |  | 4 P XXXS XXXS XXXS |  |  |  |  |                  |  |  |  |  |
| 5 XXXS XXXS XXXS                |  |  |  |  | 5 XXXS XXXS XXXS   |  |  |  |  |                  |  |  |  |  |

Figure 3.1.9.- Concluded.

For the MPS, the helium tank, regulator, and helium system pressures in psia are displayed for each engine. ET ullage pressure and manifold pressure for LH2 and LO2 are displayed; this is only supported in MM's 101, 102, 103, and 601.

c. GNC SYS SUMM 2 (SPEC 19, BFS only) (fig. 3.1-9)

This display is available only in BFS for ascent and aborts and is used for monitoring Orbiter RCS and OMS system performance. The RCS helium pressure, tank pressure, and manifold pressure in psia and propellant quantity in percent are displayed for oxidizer and fuel in each pod. RCS jet manifold status indicates the position of the RCS manifold isolation valves. Jet fail and manifold 5 status are not driven in the BFS. The OMS helium, oxidizer and fuel tank pressures; nitrogen regulator and tank pressures; and engine oxidizer and fuel inlet pressures are displayed in psia for the left and right pods. The position of the left and right engine nitrogen pressure valves are displayed as open or closed. The left and right one- and two-engine bipropellant valves positions are displayed in percentage open.

d. THERMAL (BFS) (fig. 3.1-10)

SM is available only in the BFS for ascent and aborts. The THERMAL display is the BFS SM OPS display. The (HYD) SYS TEMP section displays

the temperature (° F) of the hydraulic fluid in the actuator/pressurization system of the aerosurface control system. The HTR TEMP system denotes only out-of-limits conditions. This section of the display is presented in such a way as to direct the crew to a specific switch (or set of switches) to correct the malfunction. It should be noted that some heaters are off at launch to save electrical power in main stage and this display will allow the crew to check for out-of-limit conditions. The FREON LOOP and H2O section displays parameter values necessary to support flash evaporator thermal monitoring. The hydraulic brake pressure section displays 16 brake pressure measurements (psia). The hardware consists of two brake skid/control modules for each of the four main gear tires (left outboard, left inboard, right outboard, and right inboard).

e. SM SYS SUMM 1 (BFS SPEC 78) (fig. 3.1-10)

SM is only available in the BFS for ascent and aborts. The emergency parameters, fire and decompression (dP/dT), are displayed. Electrical power (ac and dc) distribution parameters and fuel cell characteristics are displayed. Significant STS life support parameters are also displayed.

f. SM SYS SUMM 2 (BFS SPEC 79) (fig. 3.1-10)

The CRYO parameters for O2 and H2 tank pressure and O2 heater TEMP are displayed. The APU system, arranged according to SYS flow path and avionics bay parameters, is displayed. Hydraulic system, hydraulic water boilers and thermal control parameters are also displayed.

| 0001/ / THERMAL |          | XX X DDD/HH:MM:SS |                        |
|-----------------|----------|-------------------|------------------------|
|                 |          | BFS DDD/HH:MM:SS  |                        |
| HYD             | SYS TEMP | BDYFLP            | RD/SB                  |
|                 | PRIME    | ±XXXX             | ±XXXX                  |
|                 | STBY 1   | ±XXXX             | ±XXXX                  |
| BRAKE           | P L OB   | L IB              | R IB                   |
| 1/3             | XXXXX    | XXXXX             | XXXXX                  |
| 2/3             | XXXXX    | XXXXX             | XXXXX                  |
| HTR TEMP        | L/A      | R/B               | FREON LOOP 1 2         |
| PRPLT           | SSSSSSS  | SSSSSSS           | ACCUM QTY XXXS XXXS    |
| POD             | SSSSSSS  |                   | RAD IN T XXXS XXXS     |
| OMS             | CRSFD    | SSSSSS            | H2O SUP P XXXS         |
| EVAP            |          |                   | TIRE PRESS             |
| HI              | LOAD     | SSS               | MG LEFT RIGHT          |
| TOP             | DUCT     | SS                | IB XXXS XXXS XXXS XXXS |
|                 | NOZ      | S                 | OB XXXS XXXS XXXS XXXS |
| FDLN            | SSSS     | SSSS              | NG XXXS XXXS XXXS XXXS |
|                 |          | 1                 | 2                      |
| HYD BLR/HTR     | S        | S                 | S                      |
| APU             |          |                   |                        |
| GG/FU           | PMP HTR  | SSSS              | SSSS                   |
| TK/FU           | LN HTR   | SSSSSSSSS         | SSSSSSSSS              |
| PUMP/VLV        | COOL     | SS                | SS                     |
| FC END          | HTR A/B  | XXXX/XXXXX        | XXXX/XXXXX             |

Figure 3.1-10.- SM systems displays (BFS).

| XXXX/XXX/078 |       |       |      | SM SYS SUMM 1 |                      |       |       | XX X DDD/HH:MM:SS |  |  |  |
|--------------|-------|-------|------|---------------|----------------------|-------|-------|-------------------|--|--|--|
|              |       |       |      |               |                      |       |       | DDD/HH:MM:SS      |  |  |  |
| SMOKE        | 1/A   | 2/B   |      | DC VOLTS      | 1/A                  | 2/B   | 3/C   |                   |  |  |  |
| CABIN        | XX.XS |       |      | FC            | XX.XS                | XX.XS | XX.XS |                   |  |  |  |
| L/R FD       | XX.XS | XX.XS |      | MAIN          | XX.XS                | XX.XS | XX.XS |                   |  |  |  |
| AV BAY 1     | XX.XS | XX.XS |      | CNTL AB       | XX.XS                | XX.XS | XX.XS |                   |  |  |  |
|              | 2     | XX.XS |      | BC            | XX.XS                | XX.XS | XX.XS |                   |  |  |  |
|              | 3     | XX.XS |      | CA            | XX.XS                | XX.XS | XX.XS |                   |  |  |  |
| CABIN        |       |       |      | ESS           | XX.XS                | XX.XS | XX.XS |                   |  |  |  |
| PRESS        | XX.XS |       |      | AC            |                      |       |       |                   |  |  |  |
| dP/dT        | ±.XXS |       |      | VOLT ΦA       | XXXX                 | XXXX  | XXXX  |                   |  |  |  |
| PPO2         |       |       |      | ΦB            | XXXX                 | XXXX  | XXXX  |                   |  |  |  |
| FAN ΔP       | X.XXS |       |      | ΦC            | XXXX                 | XXXX  | XXXX  |                   |  |  |  |
| HX OUT T     | XXXX  |       |      | AMPS ΦA       | XX.XS                | XX.XS | XX.XS |                   |  |  |  |
| O2 FLOW      | XX.XS | XX.XS |      | ΦB            | XX.XS                | XX.XS | XX.XS |                   |  |  |  |
| N2 FLOW      | XX.XS | XX.XS |      | ΦC            | XX.XS                | XX.XS | XX.XS |                   |  |  |  |
| IMU FAN      | AXS   | BXS   | CXS  | FUEL CELL     | XXXXXXXXXXXXXXXXXXXX |       |       |                   |  |  |  |
| ΔV FC1       | FC2   | FC3   |      | AMPS          | XXXX                 | XXXX  | XXXX  |                   |  |  |  |
| SS1          | XXXX  | XXXX  | XXXX | REAC VLV      | XXS                  | XXS   | XXS   |                   |  |  |  |
| SS2          | XXXX  | XXXX  | XXXX | STACK T       | ±XXXX                | ±XXXX | ±XXXX |                   |  |  |  |
| SS3          | XXXX  | XXXX  | XXXX | EXIT T        | XXXX                 | XXXX  | XXXX  |                   |  |  |  |
| TOTAL AMPS   | XXXXS |       |      | COOL P        | XXXX                 | XXXX  | XXXX  |                   |  |  |  |
|              | KW    | XXS   |      | PUMP          | XXS                  | XXS   | XXS   |                   |  |  |  |
| (XX)         |       |       |      |               |                      |       |       |                   |  |  |  |

| XXXX/XXX/079 |       |       |       | SM SYS SUMM 2 |       |       |       | XX X DDD/HH:MM:SS |   |  |  |
|--------------|-------|-------|-------|---------------|-------|-------|-------|-------------------|---|--|--|
|              |       |       |       |               |       |       |       | BFS DDD/HH:MM:SS  |   |  |  |
| CRYO TK      |       | 1     | 2     | 3             | 4     | 5     |       |                   |   |  |  |
| H2 PRESS     | XXXX  | XXXX  | XXXX  | XXXX          | XXXX  |       |       |                   |   |  |  |
| O2 PRESS     | XXXXX | XXXXX | XXXXX | XXXXX         | XXXXX |       |       |                   |   |  |  |
| HTR T1       | ±XXXX | ±XXXX | ±XXXX | ±XXXX         | ±XXXX | ±XXXX |       |                   |   |  |  |
| T2           | ±XXXX | ±XXXX | ±XXXX | ±XXXX         | ±XXXX | ±XXXX |       |                   |   |  |  |
| APU          | 1     | 2     | 3     | HYD           | 1     | 2     | 3     |                   |   |  |  |
| TEMP EGT     | XXXXX | XXXXX | XXXXX | PRESS         | XXXXX | XXXXX | XXXXX |                   |   |  |  |
| B/U EGT      | XXXXX | XXXXX | XXXXX | ACUM P        | XXXXX | XXXXX | XXXXX |                   |   |  |  |
| OIL IN       | XXXX  | XXXX  | XXXX  | RSVR T        | XXXX  | XXXX  | XXXX  |                   |   |  |  |
| OUT          | XXXX  | XXXX  | XXXX  | QTY           | XXXX  | XXXX  | XXXX  |                   |   |  |  |
| GG BED       | XXXX  | XXXX  | XXXX  | W/B           |       |       |       |                   |   |  |  |
| INJ          | XXXXX | XXXXX | XXXXX | H2O QTY       | XXXX  | XXXX  | XXXX  |                   |   |  |  |
| SPEED %      | XXXX  | XXXX  | XXXX  | BYP VLV       | XXXX  | XXXX  | XXXX  |                   |   |  |  |
| FUEL QTY     | XXXX  | XXXX  | XXXX  | THERM CNTL    |       |       |       | 1                 | 2 |  |  |
| PMP LK P     | XXS   | XXS   | XXS   | H2O PUMP P    |       | XXXX  | XXXX  |                   |   |  |  |
| OIL OUT P    | XXXX  | XXXX  | XXXX  | FREON FLOW    |       | XXXXX | XXXXX |                   |   |  |  |
| FU TK VLV    |       |       |       | EVAP OUT T    |       | XXXX  | XXXX  |                   |   |  |  |
| A T          | XXXX  | XXXX  | XXXX  |               |       |       |       |                   |   |  |  |
| B T          | XXXX  | XXXX  | XXXX  |               |       |       |       |                   |   |  |  |
| AV BAY       |       |       |       |               |       |       |       |                   |   |  |  |
| TEMP         | XXXX  | XXXX  | XXXX  |               |       |       |       |                   |   |  |  |
| FAN ΔP       | X.XXS | X.XXS | X.XXS |               |       |       |       |                   |   |  |  |
| (XX)         |       |       |       |               |       |       |       |                   |   |  |  |

Figure 3.1-10.- Concluded.

3.1.2.8 OVERRIDE (Primary System, SPEC 51)

a. Description

This display, figure 3.1-11, is used during OPS 1, 3, and 6 to allow the crew the capability to deselect or reselect an ADTA, IMU LRU, or hydraulic system to solve an RM dilemma or to force RM to consider a previously deselected LRU. The display also provides the crew the capability to open or close the vent doors during OPS 3 and 6; to select the desired SW mode for the following dedicated switch failures: ABORT SW, ET SEP SW, ET UMB DR SW, and ENTRY roll mode SW; to override any RCS MANF LVL MICRO SW DILEMMA which causes RM to set the MANF VLV STATUS to CLOSED; to enable/inhibit the OMS/RCS interconnect function, the AFT RCS dump, the forward RCS dump, and the OMS dump; to select the nominal or alternate elevon schedule and body bending filter in OPS 3 and to select the entry atmosphere model.

|                    |    |                  |              |                       |  |
|--------------------|----|------------------|--------------|-----------------------|--|
| XXXX/051/          |    | OVERRIDE         |              | XX X DDD/HH:MM:SS     |  |
|                    |    |                  |              | DDD/HH:MM:SS          |  |
| ABORT MODE         |    | ENTRY FCS        |              |                       |  |
| TAL/AOA            | 1X | ELEVON           | FILTER       | ATMOSPHERE            |  |
| ATO                | 2X | NOM 17X          | NOM 20X      | NOM 22X               |  |
| ABORT              | 3X | ALT 18X          | ALT 21X      | N POLE 23X            |  |
| MAX THROT          | 4X |                  |              | S POLE 24X            |  |
| PROPLT DUMP        |    | IMU STAT ATT DES |              | PRL                   |  |
|                    |    | 15               | XXXX X 25X   | SYS AUT DES           |  |
|                    |    | 25               | XXXX XXX 26X | 15 28X 31X            |  |
|                    |    | 35               | XXXX 27X     | 25 29X 32X            |  |
|                    |    |                  |              | 35 30X 33X            |  |
| OMS DUMP TTG XXX   |    | ADTA             |              | H                     |  |
| XXXXXXXXXXXXXXXXXX |    | L 15             |              | XXXXXX ±XX.X X.XX 34X |  |
| XXXX DUMP          |    | 35               |              | XXXXXX ±XX.X X.XX 35X |  |
|                    |    | R 25             |              | XXXXXX ±XX.X X.XX 36X |  |
|                    |    | 45               |              | XXXXXX ±XX.X X.XX 37X |  |
| ARM 6X             |    | ET SEP           |              | ROLL MODE XXXXXX      |  |
| START 7X           |    | AUTO 38X         |              | AUTO SEL 42X          |  |
| STOP 8X            |    | SEP 39X          |              |                       |  |
| AFT RCS 13 XXX     |    | ET UMB DR        |              | VENT DOOR CNTL        |  |
| 14 TIME XXX        |    | CLOSE 40X        |              | OPEN 43X              |  |
| FWD RCS 15 XXX     |    | RCS RM MANF      |              | CLOSE 44X             |  |
| 16 TIME XXX        |    | CL OVRD 41X      |              |                       |  |
| (XX)               |    |                  |              |                       |  |

Figure 3.1-11.- OVERRIDE (primary system, SPEC 51).

## b. Use

Items 1 and 2 allow the crew to select either a TAL/AOA or ATO abort in MM 102 and MM 103. These items are mutually exclusive and the selected abort will be indicated by an asterisk (\*). Item 3 allows the crew to initiate the abort selected. An asterisk (\*) will be displayed whenever an abort has been initiated via this item. The display will be initialized the first time with these items deselected; i.e., no asterisks. If any of these three items are executed in any major mode other than MM 102 and MM 103, an ILLEGAL ENTRY CRT message will be displayed. Also, execution of item 3 without having first selected the type of abort (AOA or ATO) shall result in an ILLEGAL ENTRY message.

Item 4 (MAX THROT) allows the crew to change the maximum SSME throttle level and to rescale the SBTC to the new throttle level. Execution of item 4 in MM 102 will cause the throttle setting to change from 104 to 109 percent upon an engine failure in first stage or upon transition to MM 103. Item 4 EXEC in MM 103 will immediately command engine throttles to 109 percent up to 3g-limiting. Before powered pitcharound in MM 601, an item 4 EXEC will only cause engines to throttle to 109 percent if less than 3 engines are running. After powered pitcharound in MM 601, regardless of the number of engines running, an item 4 EXEC will allow the engines throttles to be set between 65 to 109 percent as required to meet guidance PPD targets. Execution of this item in any major mode other than MM 102, MM 103, or MM 601 will cause an ILLEGAL ENTRY message to be issued to the crew.

## MAX THROTTLE SELECTION MATRIX

| Selection<br>MM | MM 102    |  | MM 103  |
|-----------------|-----------|--|---|
|                 | No. SSME  | 3 engines                                | < 3 engines   |
| Result          | 3 engines | THROTTLE TO<br>K-MAX-SECONDARY<br>(109%) | Any engine configuration<br><br>THROTTLE TO K-MAX<br>SECONDARY<br>(109%) UNTIL 3G<br>THROTTLING |

| MM 601                      |   |  |   |
|-----------------------------|---|--|---|
| 3 engines                   |   | < 3 engines                                  |   |
| Before PPA                  | After PPA   | Before PPA                                   | After PPA   |
| MAINTAIN<br>K-MAX<br>(104%) | THROTTLE UP<br>TO<br>K-MAX-<br>SECONDARY<br>(109%) AS<br>REQUIRED | THROTTLE TO<br>K-MAX-<br>SECONDARY<br>(109%) | THROTTLE UP<br>TO<br>K-MAX-<br>SECONDARY<br>(109%) AS<br>REQUIRED |

The controls and displays in the PROPLT DUMP section of the display give the crew control of OMS and RCS dumps in OPS 1, 3, and 6.

The amount of time required to dump OMS propellant is displayed in seconds. Pre-MECO, this item will be blank when the ABT CNTL SEQ is not active (the sequencer is currently activated under the following conditions: Abort declaration, manual initiation of a contingency dump, or a confirmed second SSME failure). The displayed time will represent the time to dump the OMS propellant based on the type of abort selected. The accumulated dump time is carried across the OPS 3 transition and represents the time to burn available OMS fuel at a pre-MECO two OMS engine flow rate.

Item 5 provides the capability to enable or inhibit the OMS/RCS interconnect function. The display is initialized with the function enabled in OPS 1, and inhibited in OPS 3. Execution of item 5 will alternately inhibit and enable the OMS/RCS interconnect function displaying INH or ENA as appropriate. Whenever the ABT CNTL SEQ terminates the OMS/RCS interconnect, item 5 will be reset (INH).

Item 5 does not operate during a contingency dump or when SECOND\_SSME\_FAIL\_CONFIRM is set in OPS 1/6. In these cases the OMS/RCS interconnect is automatically enabled by the abort control sequencer. The text on the display which normally reads XXX ICNCT 5 will change to read CONT ICNCT ENA, indicating that the interconnect is enabled and that item 5 no longer controls the interconnect function. Execution of item 5 during this time will result in an ILLEGAL ENTRY message.

Items 6, 7, and 8 (PROPLT DUMP:ARM,START,STOP) provide the capability to start and stop the ABORT OMS/RCS propellant dump sequence. The display is initialized with items 6 and 7 (ARM and START) reset (no \* displayed), and item 8 (STOP) set (\* displayed). The display will respond to items 6, 7, and 8 as follows:

- a. Execution of item 6 (ARM) will display an \* beside item 6 and blank the STOP \*.

- b. Execution of item 7 (START) when item 6 is set (ARM \* displayed) will enable the dump, and display an \* next to item 7. Execution of item 7 when item 6 is reset (no ARM \*) will cause an ILLEGAL ENTRY message to be displayed and the input to be rejected.
- c. Execution of item 8 (STOP) when item 6 (ARM) is set will blank the ARM \* and display the STOP \*. Execution of item 8 when items 6 and 7 are both set (dump in progress) will stop the dump, blank the ARM and START \*'s and display the STOP \*.
- d. Whenever a pre-MECO OMS dump, other than the contingency dump, is in progress in OPS 1 or 6, the STOP \* will be blanked. Execution of item 8 in this case (ARM and START reset) will display the STOP \* and cause the ABT CNTL SEQ to stop the dump in progress.
- e. The text identifying the dump control items (6, 7, and 8) will read CONT DUMP In OPS 1 and 6 and will read OMS DUMP in OPS 3.

Items 9, 10, 11, and 12 are nonfunctioning items. Any attempt to execute them will result in an ILLEGAL ENTRY message.

Items 13 (AFT RCS) and 14 (TIME) provide the capability to control the aft RCS propellant dump in OPS 3 and 6. In OPS 6, this item is initialized to the last value from OPS 1. Item 13 is initialized to ENA in OPS 1 allowing a dump to start automatically when other criteria are met. Subsequent execution of item 13 inhibits the dump if it is not in progress and stops the dump if it is in progress. The state of item 13 is indicated by ENA or INH displayed next to item 13. Execution of item 13 will change ENA to INH or vice versa. In OPS 3 with the TAL flag not set, item 13 is initialized to INH, inhibiting the aft RCS dump. In OPS 3 with the TAL flag set, item 13 is initialized to the last value from OPS-1. Execution of item 13 is required to ENABLE the dump.

Item 14 (TIME) is initialized with an I-loaded dump time value in seconds in OPS 1, and OPS 3 if the TAL flag is set. In OPS 6, this item is initialized to the last value from OPS 1. The crew can input a different value of dump time using item 14 during OPS 1, 6, and 3. The dump time displayed next to item 14 will decrement at the appropriate rate, depending upon the number of jets involved, whenever the dump is in progress. In OPS 3, with the TAL flag not set, item 14 is initialized with a dump time of 0 sec; however at MM 304 aft RCS dump may be enabled by inputting a non-zero dump time via item 14 and enabling the dump via item 13.

Items 15 (FWD RCS) and 16 (TIME) control the forward RCS dump in the same manner that items 13 and 14 control the aft RCS dump. The initialization criteria and operation are the same.

The display fields associated with items 13, 14, 15, and 16 will be blanked while a contingency dump is in progress (OPS 1 and 6). Execution of any of these items at this time will cause an ILLEGAL ENTRY message.

Items 17 and 18 allow the crew to command the Aerojet DAP to use a nominal (NOM) or alternate (ALT) elevon schedule. The selected schedule is indicated by an asterisk displayed next to the appropriate item.

The display is initialized with the NOM schedule selected. If OPS 3 is entered from OPS 1 the ALT schedule is selected. Once initialized, the display will reflect the last crew input. Items 17 and 18 are mutually exclusive; execution of one automatically deselects the one selected and displays the asterisk appropriately. These items are legal in OPS 3 only, execution in any other OPS will result in an ILLEGAL ENTRY message.

Items 20 and 21 allow the crew to command the Aerojet DAP to use NOM or ALT body bending filters. The selected filters are indicated by an asterisk displayed next to the appropriate item. The display is initialized with the nominal filters selected. If OPS 3 is entered from OPS 1, the alternate filter is selected. Once initialized, the display will reflect the last crew input. Items 20 and 21 are mutually exclusive: execution of one automatically deselects the other and displays the asterisk appropriately. These items are legal in OPS 3 only, execution in any other OPS will result in an ILLEGAL ENTRY message.

Items 22, 23 and 24 allow the crew to select one of three atmospheric models for use by entry navigation. The display is initialized with the NOM atmospheric model selected. Item 23 selects a North polar model while item 24 selects a South polar model. Items 22, 23, and 24 are mutually exclusive: execution of one of these items deselects the currently active model and selects the one corresponding to the executed item. The selected item is indicated by an asterisk displayed next to the appropriate item. Items 22, 23, and 24 are active in OPS 3 only, execution in any other OPS will result in an ILLEGAL ENTRY message.

For each of the IMU LRU's the following data is displayed cyclically to the crew to aid in solving RM dilemmas. A parameter status column is provided after each LRU ID number that shall be blank for normal operation, display a down arrow (v) for an RM declared failure or crew deselection, display a question mark (?) for an RM dilemma, or an "M" for missing data. The STAT column allows display of the output of built-in-test equipment (BITE) status (hardware and software). The STAT column will either be blank for normal operation or display BITE to indicate a problem detected in the LRU. The ATT column has two parameters displayed, which IMU is selected for use and whether the IMU data is good or not. RGA is displayed when IMU data is not good. There are three item numbers (25, 26, 27) which allow the crew to reselect an LRU that has been declared failed by RM or to deselect an LRU for use by the IMU selection filter.



For each of the three hydraulic systems, two item numbers are provided to allow the crew to manually override automatic system management and to reselect the automatic system management after selecting the manual mode of operation. An asterisk (\*) is displayed after the item numbers indicating the selected mode. The items are mutually exclusive and initialized in the auto mode. A status column is provided for each hydraulic system to display a blank for normal operation or upmoded manual system operation, a question mark (?) for an RM dilemma, and a down arrow (+) for a failure or downmoded system.

For each of the four ADTA LRU's the following data is displayed to the crew cyclically to allow them to determine whether an LRU failed by RM is in agreement with the other LRU's and should be reselected or to aid in solving RM dilemmas; ADTA derived altitude in feet, ADTA derived angle of attack in degrees, and ADTA derived Mach number. A parameter status column after the LRU ID number shall be blank for normal operation, display a down arrow (+) for an RM declared failure or crew deselection, display a question (?) for an RM dilemma, or an "M" for missing data. There are four item numbers (34, 35, 36, 37) which allow the crew to reselect an LRU for use by the ADTA selection filter. These items are legal in MM 304, MM 305, MM 602, and MM 603. Execution of these items in OPS 1, MM 301, MM 302, MM 303, or MM 601 will result in an ILLEGAL ENTRY message.

When an LRU has been declared failed by RM, a down arrow (+) will be displayed in the PSI column and an asterisk (\*) will be driven after the deselect/select item number to indicate that the LRU is failed and deselected. If the deselect/select item number is then executed, the LRU will reselect; the down arrow (+) and asterisk (\*) will be removed; and the fail bit in RM is reset such that this LRU is used by the selection filter until such time that RM declares it failed again. If an LRU is deselected that is in a normal state or in a dilemma, a down arrow (+) will be displayed in the PSI column and an asterisk (\*) driven after the deselect/select item number.

The display will be initialized each time it is called with the current state of the LRU's that are deselected or selected. If no previous failure had occurred prior to calling this display in OPS 1 or 6, the display would show all LRU's selected. If an LRU was deselected during OPS 2 or 8, when this display is called in OPS 3, this LRU would still be deselected. During OPS 1, the ADTA data will be blanked.

Two items (38, 39) allow the crew to select the ET SEP AUTO mode or initiate ET SEPARATION. An asterisk (\*) will be displayed when these items are selected. Item 39 sets the separation discrete and MECO confirmed flag in the same manner that pushing the ET SEP pb does. When the display is first called, it will be initialized with these items deselected; i.e., no asterisks. These items are provided as a backup means of initiating separation based on failures of the dedicated switches. These items are legal only in MM's 102, 103, 104, 105, 106, and 601.

One item (40) is provided which allows the crew to backup the dedicated switch for closing the ET umbilical doors. When the display is first called, this item will be deselected; i.e., no asterisk. This item is legal only in MM's 104, 105, and 106.

One item (41) is provided which allows the crew to override an RCS MANF VLV Micro SW dilemma which has forced RCS RM to set the valve status to closed. Execution of this item causes RCS RM to set the valve status to OPEN on any valve in dilemma and puts the RCS JETS (ones without previous OFF or LK failures that have not been failure overridden) back into the jet availability table.

A status of where GNC SW RM feels the position of the Entry Roll Mode SW is provided to the crew. In addition, an item (42) is provided that allows the crew to select the AUTO position in case this switch fails. When this item is executed, an asterisk (\*) will be displayed and the status from GNC SW RM will also read AUTO. The display will be initialized the first time with this item deselected (i.e., no asterisk) and thereafter will reflect crew inputs. Item 42 is legal only in MM's 304, 305, 602, and 603. Execution in any other major mode will result in an ILLEGAL ENTRY CRT message being displayed.

Two items (43, 44) allow the crew to issue commands to either open or close all of the vent doors. These items are mutually exclusive. An asterisk (\*) shall be driven next to the item currently selected. When the display is initialized, this signal will be set to its last commanded state either by crew entry or via the VENT DOOR SEQ. These items will be legal only in OPS 3 and MM 602 and MM 603 and execution of these items in any other MM will result in an operator error and the ILLEGAL ENTRY CRT message being displayed.

Items 9, 10, 11, 12, and 19 are nonfunctioning items. Any attempt to execute this item will result in an ILLEGAL ENTRY message.

### 3.1.3 Dedicated Displays

In addition to the CRT displays, dedicated displays are used in ascent to monitor the Orbiter performance or to fly the Orbiter. In this section, the displays normally used during ascent and aborts are described. A description of displays for glide RTLS (MM's 602 and 603) is not included because it is basically the same as entry (MM's 304 and 305); any exceptions will be noted. The ascent guidance and navigation computer (GNC) dedicated displays are shown in figure 3.1-12. A summary of the dedicated displays and lights is given in table 3.1-II.

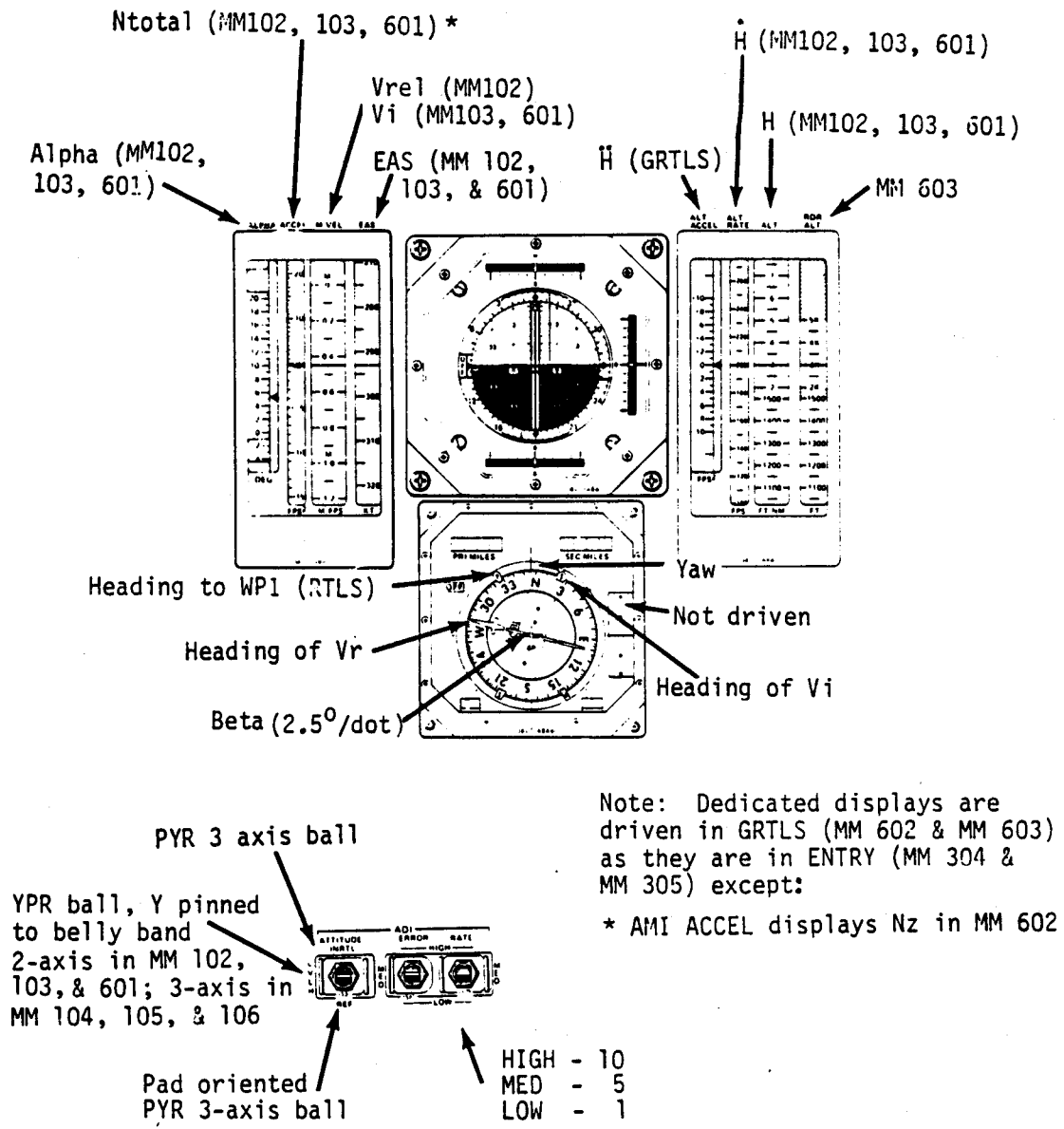


Figure 3.1-12.- Ascent GNC dedicated display.

3.1-43

TABLE 3.1-II.- ASCENT DEDICATED DISPLAYS SUMMARY

| Name                                     | Location | Use   |
|--|----------|---|
| ADIA <sup>a</sup>                        | F6 ,F8   | Trajectory monitoring of roll, pitch, and yaw; attitude, attitude rate, and errors.   |
| ADI ATTITUDE switch <sup>a</sup>         | F6, F8   | INRTL - PYR three-axis ball referenced to arbitrary RELMAT<br>LVLH - YPR two-axis ball with Y pinned to belly band. Active during MM's 102, 103, and 601. In MM's 104, 105, and 106, PYR three-axis ball.<br>REF - PYR three-axis ball referenced to pad-oriented inertial relmat, or to Orbiter attitude when ATT REF pb is pushed.  |
| ADI ERROR and RATE <sup>a</sup> switches | F6, F8   | Full-scale selection for the ADI HIGH is 10, MED is 5, and LOW is 1.  |
| HSI <sup>a</sup>                         | F6, F8   | Ascent - MM's 101 to 103:<br>Primary bearing - constant except in MM 601 - bearing to WP1<br>Secondary bearing - bearing of VI-vector<br>Course pointer - heading of Vr<br>Course dev scale - $\beta$ (2.5°/dot)<br>Heading - yaw<br><br>GRTLS: Displays pictorial view of vehicle wrt various navigation points. Provides magnetic heading, course pointer, displacement of vehicle to left or right of course, displacement above or below glide slope, primary and secondary bearings, and miles to selected nav points. |
| HSI SOURCE switches                      | F6, F8   | Determines source of vehicle position data and which of three TACAN or MLS receivers to use (GRTLS).  |
| HSI MODE switch                          | F6, F8   | Determines display mode - ENTRY, TAEM, APPROACH (GRTLS).  |

<sup>a</sup>Described in this section.

TABLE 3.1-II.- Continued

| Name   | Location | Use  |
|--|----------|--|
| ALPHA/MACH Ind (AMI) <sup>a</sup>                  | F6, F8   | Shows:<br>ALPHA ( $\alpha$ in MM's 102, 103, and 601)<br>ACCEL (total load in MM's 102, 103, and 601) and (Nz in MM 602)<br>M/VEL (inertial vel) (VREL in MMU's)<br>EAS (MM's 102, 103, and 601)                             |
| ALTITUDE/VERTICAL VELOCITY Ind (AVVI) <sup>a</sup> | F6, F8   | Shows:<br>ALT ACCEL (GRTLS)<br>ALT RATE (H) (MM's 102, 103, and 601)<br>ALT (H) (MM'S 102, 103, and 601)<br>RDR ALT (MM 603)   |
| AIR DATA switch                                    | F6, F8   | Selects data from NAV or ADS for use on the AMI or AVVI for (GRTLS).   |
| RADAR ALTM switch                                  | F6, F8   | MM 603 selects data from radar altimeter 1 or 2 and displays it on RDR ALT on AVVI.  |
| ABORT light  | F6       | Indication to abort. Only the control center can illuminate this light.  |
| RCS COMMAND light                                  | F6       | Indication of the RCS activity during GRTLS  |
| MPS PRESS gauges                                   | F7       | Engine status/throttling.  |
| MAIN ENGINE STATUS lts                             | F7       | Amber lights indicate engine status - hydraulic or electronic lockup or commanded or data path failure. Red lights indicate MECO or shutdown limit exceeded when they illuminate, and ET SEP commanded when they extinguish. |
| OMS PRESS gauges                                   | F7       | OMS burn or OMS dump status.   |
| RANGE SAFE ARM light                               | F7       | Warning of range safety system (RSS) being armed.  |
| Surface position indicator (SPI)                   | F7       | Not driven in ascent, but for GRTLS it provides position indication of aerosurfaces.   |

<sup>a</sup>Described in this section.

TABLE 3.1-II.- Concluded

| Name                        | Location | Use  |
|-----------------------------|----------|--|
| HYDRAULIC gauges            | F8       | Hydraulic pressure and quantity.   |
| APU gauges                  | F8       | APU fuel and water quantity, exhaust gas temperature, fuel pressure, and oil temperature.  |
| FREON EVAP OUT TEMP gauge   | 01       | Flash evaporator activation indication.  |
| FCS MODE light <sup>a</sup> | F2, F4   | Indicates the mode (AUTO/CSS) for pitch and roll/yaw. Indicates the mode (AUTO/MAN) for bodyflap and speedbrake/thrust control. BFC light indicates when BFS is engaged. The BODYFLAP light extinguishes when the engines are stowed in OPS 1. |
| ACCEL (g meter)             | F7       | Normal (Z-body) acceleration.  |

<sup>a</sup>Described in this section.

a. ADI

The ADI's on panels F6 and F8 are used during ascent and aborts. The ADI's provide Orbiter attitude, attitude rate, and attitude error information. Each ADI has dedicated controls which affect only the ADI with which the control is associated except the attitude reference (ATT REF) pushbutton. The ATT REF pushbutton affects all ADI's.

The ADI ATTITUDE switch selects the frame of reference for the attitude display of the corresponding ADI.

b. Inertial (INRTL)

The INRTL reference frame is based on the nominal OMS-2 ignition point in the trajectory during ascent. This frame provides an ADI reading at nominal OMS-2 ignition of pitch = 0°, yaw = 0°, and roll = 180°.

c. Local vertical/local horizontal (LVLH)

During powered ascent (MM's 102, 103, and 601), the LVLH position is called LVIY and is a rotating reference frame defined by Z = down (along negative of M50 position vector) and X = downrange (normal to plane formed by the M50 position vector and a unit vector normal to the

desired insertion plane), and Y completing the right-hand system. For LVIY, the attitude is processed in a yaw/pitch/roll sequence; however, the ADI is driven to zero in yaw so that the ball becomes simply a pitch/roll display. The yaw angle is shown on the HSI display and represents yaw with respect to the desired insertion plane. Therefore, the LVIY shows a simple Earth-referenced pitch/roll display on the ADI.

During MM's 104 through 106, the LVLH ADI display reverts to three-axis drive and a pitch/yaw/roll sequence. The reference frame is defined as +Z toward the Earth center, +Y in the opposite direction of the Orbiter momentum vector, and +X completing the right-hand system. The LVLH frame is not a fixed system; it is computed based on the state vector and time.

d. Reference (REF)

REF position causes the ADI attitude to be based on an INRTL reference frame. The REF frame at lift-off is a system based on the nominal launch azimuth: Z = down, X = along the desired Orbiter azimuth at insertion, and Y completes the system. The REF frame can be redefined by depressing the ATT REF pushbutton.

Depressing the ATT REF pushbutton updates the REF frame to the current Orbiter body axis orientation. The update is independent of ADI ATTITUDE switch position and affects the REF frame for all ADI's. An ADI whose ATTITUDE switch is the REF position when an attitude REF pushbutton is depressed will jump to 0° in all axes.

During ascent, the ADI ATTITUDE switch is manipulated as necessary to give the crew an easy way to monitor Orbiter attitude and performance. At lift-off in the LVLH position (LVIY frame), the ADI is at the +90° pitch singularity for an extended period. Therefore, a deadband of ±2° is employed to cause the ADI to remain frozen in roll until after pitch maneuver initiate (yaw is pinned to zero). The frozen roll is 55.3° which is the LVIY roll angle anticipated when the Orbiter breaks out of the 2° deadband in pitch.

Because of this, the LVLH position is not selected at lift-off; instead, the inertial REF frame with respect to launch is selected until after tower clear and the pitch and roll maneuver is completed. At that time, the LVLH position is selected on at least one ADI for the rest of powered ascent. Prior to the OMS-1 burn, INRTL is used so that the attitude can be checked against the OMS-1 attitude on the OMS-1 MNVR EXEC display. The REF frame can be redefined at the OMS-1 ignition attitude to give the crew an easy means of monitoring the burn.

The ADI RATES are RM-selected roll, pitch, and yaw body rates from the rate gyro assemblies (RGA's). The full-scale values for ADI RATES are HIGH = 10 deg/s, MED = 5 deg/s, and LOW = 1 deg/s.

The ADI ERRORS represent total attitude error in body axes (the difference between the actual body attitude and the desired or commanded body

attitude). The first stage ADI errors include load relief effects ( $N_y$ ,  $N_z$  feedback); i.e., the needle deflection can be nulled without having to distinguish load relief from actual TRAJ errors. The full-scale values for ADI ERRORS are HIGH = 10°, MED = 5°, and LOW = 1°. The ADI attitude errors from the primary system can be compared with the attitude errors from the BFS on the XXXXXX TRAJ X display to indicate how closely the primary and backup systems agree. If guidance is unconverged, the error needles stow until guidance reconverges.

For invalid or missing data in any or all axes, the ADI will continue to be driven, but the OFF flag will appear. If any rate or error parameter is considered invalid, the indicator will be driven out of sight; should the parameter later become valid, that indicator will be driven again.

During BFS operations, only the left-side ATTITUDE switch and attitude REF pushbutton are processed. The attitude OFF flag cannot be driven in BFS. The source of attitude knowledge is one of the IMU's selected by an algorithm based on IMU-to-IMU misalignment.

For RTLS aborts, the ADI attitudes will be in accordance with the ADI ATTITUDE switches (INRTL, LVLH, or REF) until MM 602, and topodetic pitch/roll, yaw = 0 after that. For RTLS errors, the roll needle will always be the total body roll attitude error (like the nominal case: body roll attitude differenced with the guidance-limited roll command). As in MM 304, pitch error in MM 602 will be alpha error with the exception of  $N_z$  hold phase, when it will be  $N_z$  error. Pitch error will be the same before and after touchdown in MM 603 as in MM 305;  $N_z$  error before touchdown and splatdown pitch rate after touchdown. The yaw error is the same throughout MM's 602 and 603 as in the nominal case (estimated sideslip, from attitude PROC for  $\bar{q} < 20$ , then from aerojet DAP for  $\bar{q} \geq 20$ ).

In the BFS, during MM's 304 and 305 and MM's 602 and 603, the attitude becomes LVLH in pitch/roll, with yaw zero as in the primary system.

#### e. HSI

The HSI's on panels F6 and F8 are used to monitor AUTO guidance and provide information needed by the crew to fly manually. The HSI provides a geometric view of vehicle location with respect to various NAV points. The left and right HSI displays and controls are identical.

During powered ascent MM's 102, 103, and 601, the HSI provides information relative to the target insertion orbit. The glide slope deviation, primary range, and secondary range are not driven.

The heading represents yaw. North on the compass card points along the target insertion plane. The heading of the body +X axis with respect to the target insertion plane is read at the lubber line.

The course pointer provides the heading of the Earth-VREL vector with respect to the target insertion orbit plane.



The course deviation indicator deflection indicates the estimated side-slip angle; i.e., the angle between the body X-axis and the VREL vector.

The primary bearing pointer is not driven in MM's 101 or 102. During MM 601 (RTL) and MM 103 (TAL), the pointer indicates the heading to the selected runway.

The secondary bearing provides the heading of the  $V_I$  vector with respect to the target insertion orbit plane.

Depending on the position of the source sw (TACAN, NAV, or MLS), different HSI flags may be active.

In GRTL, MM's 602 and 603, the HSI works as it does in entry, MM's 304 and 305.

f. AMI

The AMI's are driven with NAV-derived parameters during powered ascent MM's 102, 103, and 601.

ALPHA displays the angle of attack in MM's 103 and 601. The scale is from  $-18^\circ$  to  $60^\circ$ . During MM 102, the ALPHA flag is displayed. ACCEL displays the total load factor (computed lift/weight) in MM's 103 and 601. The scale is  $-50$  to  $+100$   $\text{fps}^2$ . During MM 102, the ACCEL flag is displayed.

M/VEL displays the magnitude of the  $V_I$  vector during MM's 102, 103, and 601. The scale is from Mach 0 to Mach 4 and 4000 to 24,000  $\text{fps}$ .

EAS displays equivalent airspeed in MM's 102, 103, and 601. The scale is from 0 to 500 knots. EAS is used as an indication of the dynamic pressure.

The AMI is not processed by the BFS during ascent since the BFS ascent TRAJ displays provide the data. In MM's 602 and 603, the AMI works as it does in MM's 304 and 305, except ACCEL displays  $N_z$  times 10 in MM 602.

g. AVVI

The AVVI's are driven with NAV-derived parameters during powered flight. The AVVI is not driven in MM 102, and altitude acceleration and radar altitude are not driven during ascent.

Altitude displays the altitude with respect to the prime selected runway (KSC) in MM's 103 and 601. The scale is from 1100 to 400,000 feet and 40 to 165 n. mi. The foot and nautical mile scales overlap between 40 and 61 n. mi.

ALT RATE displays the radial component of the  $V_I$  in MM 103 and H ellipsoid in MM 601. The scale is from -2940 to 2940 fps.

h. FCS mode PBI's

For AOA entry and GRTLS, these PBI's work as they do in normal entry, except in GRTLS they are initialized in AUTO instead of manual/CSS.

For ascent, the pitch and roll/yaw axes are both in AUTO or CSS, but AUTO and CSS are mutually exclusive of each other. These are initialized in AUTO and can be downmoded for manual steering in all axes by pushing any CSS PBI. The RHC is not hot stick. The control can be returned to the AUTO system by pushing an AUTO PBI. The lights on the PBI's correspond to the control modes.

The speedbrake/throttle (SPD BK/THROT) PBI indicates the mode of the MPS throttle during ascent. The manual throttle is selected by the pilot pushing the takeover pushbutton on the speed brake thrust controller (SBTC) (the SPD BK/THROT light will go out) and moving the SBTC until the throttle command (CMD) matches the AUTO CMD (the SPD BK/THROT MAN light will illuminate). The takeover pushbutton is then released and the crew has manual throttle. The commander's (CDR's) SBTC does not work during ascent. The crew must perform MECO if the manual throttle is selected. To return throttle to automatic, the SPD BK/THROT PBI is pushed. When the pilot has manual control of the throttle, the MAN light is illuminated, but the CDR's SPD BK/THROT light is not illuminated.

The bodyflap (BDYFLP) PBI is only used to indicate when the MPS dump sequence is finished; therefore, the SSME's are stowed and the APU's can be shut down. The other PBI's extinguish at SSME zero thrust (MECO confirmed +3.75 sec), but the BDYFLP PBI extinguishes when SSME stow is complete.

The BFC light is illuminated when the BFS is engaged via the pushbutton on the RHC, or when the BFS goes standalone.

### 3.1.4 Summary of Ascent Monitoring and Manual Control

The nominal crew task from SSME start until MM 104 is one of monitoring, with the exception of possible systems activation after SRB staging. However, the crew should be prepared to take whatever action is necessary in off-nominal situations, as defined by the flight rules built into the Flight Data File cue cards and checklists.

At lift-off the ADI attitude switch (ADI ATT) should be positioned in REF and the error and rate switches in MED (= 5 for ascent and entry). If the LVLH frame of reference is selected and the vehicle is pitched up at near 90°, the ADI will oscillate wildly in roll due to a mathematical singularity in the ADI software. This singularity does not exist in the REF frame of reference.

The crew will monitor the sequential SSME start on the Pc gauges. About 7 seconds after SSME start, SRB ignition and lift-off occur. The crew will observe a vertical rise for about 8 seconds followed by a combination roll, pitch, and yaw maneuver (primarily roll) onto the launch azimuth. Roll attitude is 180° when the launch azimuth is attained. If the maneuver does not begin within 2 seconds following the expected time, the crew should verify that the BFS is calling for the maneuver by observing the attitude errors on the BFS TRAJ display. If it is, the crew should engage the BFS. BFS engagement is preferred over CSS since it has been concluded that flying CSS in first stage before the load relief phase is completed (T+90 seconds) is not possible. After the roll to launch azimuth is completed (180° roll), ADI ATT should be moded to LVLH. An accurate roll attitude is displayed in this frame of reference if pitch attitude is less than 90°. LVLH also pins the ADI yaw to zero. In this manner the ADI really becomes a pitch-roll device. Yaw is displayed on the HSI as a delta from north.

Throughout first stage flight, the crew should monitor vehicle attitude versus cue card numbers and vehicle rates. Attitude errors are not a good indicator of flight dynamics because of load relief (load relief actually produces attitude errors with respect to guidance), engine thrust, etc., and should not be closely monitored. Rates are the only parameter requiring crew action. Prior to 90 sec MET, if pitch or yaw rates exceed 5 deg/s (full scale value medium), the crew should engage BFS. If this occurs after 90 sec MET, the crew should select CSS. If control cannot be regained with CSS, the BFS should be engaged.

Load relief begins at approximately 20 to 30 sec MET. As part of load relief, guidance will fly to the reference lateral acceleration profile in order to reduce aerodynamic loading resulting from winds and wind shears. Guidance will actually turn the vehicle into unexpected winds. A tail wind which is less than expected nominally appears to guidance as a head wind. If the vehicle yaws into a crosswind, it also rolls to keep the thrust vector in the desired plane. Since the crew is briefed prelaunch on winds, the expected dynamic response load relief should not present any surprises.

The first stage SSME throttle bucket is designed to limit dynamic pressure and should be monitored. The SSME's are throttled down at approximately 20

to 30 sec to a minimum throttle setting via a single or multistep bucket. Throttle up occurs at approximately 60 sec. If throttling does not occur, the crew should manually perform the throttling task.

While an SRB throttle bucket is built into the SRB's, active SRB throttling is not possible. Adaptive guidance will measure the direction and level of the SRB performance dispersions in the first 15 sec (approximately) of ascent and adjust the nominal design throttle and pitch profiles accordingly. This optimizes the trajectory for a given SRB burn dispersion by yielding the maximum performance allowable while remaining within acceptable loading limits. Adaptive guidance also makes it difficult for the crew to assess the correctness of the throttling task with great accuracy.

At about 2 min MET, the 'PC < 50' message will flash on the TRAJ displays, followed 6 sec later by SRB separation. This sequence is discussed in section 3. At separation a flash should be visible through the cockpit window. Separation should also be visible in the change to MM 103 on the CRT displays and by AMI and AVVI tape activation.

After staging, the crew should monitor closed loop guidance convergence by noting TMECO convergence within a couple of seconds of the expected MECO time. TMECO can be monitored on the TRAJ displays. If TMECO has not stabilized within 10 sec, the MCC should be consulted. If a no COMM situation exists, CSS and manual throttle should be selected.

Shortly after staging, the crew should monitor the activation of the flash evaporator cooling system.

Throughout second stage flight, the crew should monitor vehicle trajectory data on the BFS ASCENT TRAJ 2 display, or with the flight instruments and ADI cue card if the display is not available. They should also be aware of which abort modes are currently available as defined on the NO COMM MODE BOUNDARY and CONTINGENCY ABORT cue cards, and as called from the ground. 3g-throttling should commence about 60 sec before MECO. If 3g-throttling is not observed, manual throttling must be done using the RH SBTC to avoid exceeding 3g. MECO should be observed at the guidance predicted time TMECO or at the design MECO velocity.

If, at any time during powered flight, conditions call for CSS and/or manual throttle (MAN THROT), as defined in the Flight Rules, the crew should take the appropriate action. Any time CSS is selected, manual throttles should also be selected. The pilot (PLT) can select manual throttle by depressing the red button on the SBTC and moving the lever to match the current commanded throttle setting. As the throttle level is matched the AUTO SPD BK/THROT light on the eyebrow panel will extinguish. Upon release of the button the throttle is completely controlled by the PLT's SBTC. The CDR's SPD BK/THROT light will not be illuminated. The PLT must manually throttle to maintain 3g, and must manually shut down the engines at MECO via the shutdown pb's. Pushing the SPD BK/THROT PBI on the eyebrow panel will return control to AUTO throttle. The throttle setting will remain at the last manually commanded value, but an AUTO shutdown at MECO will occur.

CSS can be selected by either CDR or PLT by depressing any one of the CSS PBI's on the eyebrow panel. Any PBI gives CSS in all axis to both RHC's. The control system is rate control attitude hold with a maximum rate of approximately 12 deg/sec in pitch and roll, and 6 deg/sec in yaw. When the RHC's are in detent, the attitude when rates fall below 3 deg/s is held, so that large attitude overshoots do not occur. If both RHC's are out of detent at the same time, the commands are summed.

To fly to nominal MECO in CSS, roll should be maintained at 180° and yaw should be commanded to keep the VI vector (secondary bearing pointer on the HSI) on the nose. This is the most efficient yaw profile to fly. For high inclination flights, a yaw profile on the ADI cue card may be flown if performance margins are comfortable. Pitch may be flown using the ADI cue card, but the easiest way is to use the BFS ASCENT TRAJ display. It is best to keep the current vehicle state bug and the two predictor bugs on the TRAJ line and make small (<5°) attitude changes. The results should be observed for a couple of data update cycles before making larger corrections. Since  $\dot{H}$  is an extremely critical MECO target, it is recommended to abandon altitude control after about 20,000 fps and concentrate on controlling  $\dot{H}$  by keeping the bug centered on the  $\dot{H}$  scale on the left side of the BFS ASCENT TRAJ display. If this is kept centered, a nominal  $\dot{H}$  at MECO will result. A MECO  $\dot{H}$  off by half the scale would be acceptable.

While the CDR is flying attitude, the PLT should take MAN throttle and fly full throttle up to 3g. The PLT should then throttle to maintain 3g. Engine shutdown should occur at MECO minus approximately 150 fps. This should be done by depressing all three shutdown pb's. System lagtime plus engine tailoff should result in achieving desired MECO VI.

AUTO ET SEP should occur at MECO + 18 (AUTO or CSS) and is evident in the three-engine red lights going out. If there is a SEP INH message, it is either due to a rate in any axis exceeding 0.7 deg/s or a feedline disconnect valve fail to close. If this is the case, the rate/error switch should be moded to low scale. If there is a rate exceedance problem, the crew should wait for the rates to damp and SEP will occur automatically. If it is not a rate problem, a feedline disconnect valve failure should be assumed and the appropriate procedures in the Ascent Checklist should be exercised. If a critical underspeed condition exists, a manual ET SEP should be executed. This will override the SEP INH. Assuming an on-time ET SEP is in order, ET SEP should occur after an AUTO -Z translation to obtain -4 fps  $\Delta V$ . The software transition to MM 104 and the appearance of the MNVR display on the CRT's will indicate the completion of the -Z maneuver. If the THC is moved out of detent prior to the completion of the -Z, the maneuver will terminate with no moding. If for any reason the -Z maneuver is not completed either automatically or manually, the crew can mode by keying in OPS 104 PRO.

Upon entrance into MM 104, OMS-1 targets will appear on the MNVR display. Nominally, on DI flights, these targets are a dummy set and are not to be used. Nominally, on standard insertion (SI) flights, the MM 104 targets are the nominal OMS-1 targets. If ATO was selected pre-MECO, an ATO target set

will come up in MM 104. Current HA and HP are used in conjunction with the OMS 1/2 TGTING chart in the Ascent Checklist to determine which OMS maneuver targets should be used post-MECO if COMM does not exist. For a complete discussion of OMS target selection see section 3.2. If COMM exists, the ground will make a target recommendation and update TIG time. For SI flights, the procedures for nominal and ATO OMS-1 are identical. However, on DI flights an OMS-1 is not required nominally. The ATO target is designed for a lower than nominal orbit (perigee = 105 n. mi). This is a safe orbit with a lifetime of at least 2 days (ATO Mode, sec. 2.3). Once the proper OMS-1 target solution is available (both PASS and BFS), the crew should mode the ADI to INRTL and begin an AUTO maneuver to burn attitude. When the correct attitude is reached, the error needles will be centered, and the ADI attitude and the commanded attitude on the MNVR display should match. If a higher maneuver rate than 0.5 deg/s (AUTO rate) is desired, the RHC can be taken to hard stop in the manual DAP mode. TIG slips of a couple of minutes are acceptable, except for big underspeeds. The OMS-1 burn cue card contains the procedures for burn execution. (See OMS-1 burn section.) If a large underspeed exists, the CDR should maintain the vehicle at a low angle of attack (+20°) between OMS-1 and OMS-2. This is to avoid aerodynamic drag effects during the post-OMS-1 coast.

a. SSME failure

(1) Cue

Red or amber status lights  
 Pressure decay  
 SM alert  
 MCC call  
 Physiological cues

(2) Display

MAIN ENGINE STATUS It  
 MPS PRESS Pc gauge  
 SSME FAIL message  
 BFS GNC SYS SUMM 1

(3) Discussion

The amber MAIN ENGINE STATUS lights on panel F7 will be lit and an SM alert issued for any of the following conditions:

- Command path failure - Two command channels lost.
- Data path failure - Both PRI and SEC data lost
- Electronic lockup - Loss of flow meter data used for mixture ratio control results in main engine controller freezing the engine at the last commanded position

- Hydraulic lockup - One or more of the following engine valves is outside of position limits.

Main fuel valve  
Main oxidizer valve  
Oxidizer preburner valve  
Chamber coolant valve

Throttling capability is lost. If an engine is running in hydraulic lockup at MECO, it will be shut down pneumatically.

The red MAIN ENGINE STATUS lights will be lit if an engine redline limit has been exceeded, or if the engine is in shutdown phase.

The LIMIT SHUTDN switch on PNL C3 enables or inhibits the engine controller-initiated shutdown based on engine redline limits. If the switch is in the 'ENABLE' position, the limit logic will shutdown any engines exceeding redline limits. If the switch is in 'INHIBIT', the limit logic will inhibit the shutdown of engines exceeding redline limits. If the switch is in the AUTO position and a main engine shuts down, the shutdown of a second engine will be inhibited automatically. The crew can mode this switch to 'ENABLE' then back to 'AUTO', in order to re-enable the main engine limit shutdown logic, once the vehicle reaches single engine completion capability. This will allow a second engine to shutdown, if limits are violated, while inhibiting the third, and last remaining engine, from shutdown.

If a main engine fails, the PLT will turn off the ac bus sensors to preclude a second engine shutdown due to a faulty ac bus sensor if an ac phase is lost. Additional crew actions for an engine failure will depend upon the abort performance capability remaining after the failure.

#### b. Abort Initiation

##### (1) Cue

Failure and Flight Rules  
MCC call  
Abort light  
OMS  $\Delta V$  required

##### (2) Displays

ASCENT TRAJ  
ASCENT TRAJ 2  
OMS-1 MNVR EXEC

##### (3) Crew action

F6 ABORT MODE - as required  
ABORT pb - push

or  
 SPEC 51 - abort select item entry  
 or  
 Crew entering abort OMS targets

(4) Discussion (also see sec. 3.1.5.)

The MCC is prime for abort mode calls and will alert the crew of the need to select RTLS, TAL, or AOA by lighting the abort select pb. Pre-MECO the crew action is to turn the abort select switch to the appropriate abort selection and push the abort pb. If the pb does not work, RTLS may be selected by keying in OPS 601 PRO. TAL, AOA and ATO may be initiated on the OVERRIDE display (SPEC 51). Post-MECO it is recommended that OMS I-targets be used for ATO and AOA instead of using the abort switch. The intact aborts have been designed for the one engine out case, but can be accomplished with no engine failures and, in some cases with two engine failures.

For the NO-COMM case, the crew must make their own abort decisions based on the type of failure, the NO-COMM mode boundaries, and the OMS-1 TARGETING card (sec. 3.1.5).

For SSME failures prior to the TWO ENGINE TAL call, RTLS will be selected at 2+30 or as soon as possible after the engine failure, whichever is later. There is no need to select RTLS earlier since active guidance will not commence until alpha-limiting is terminated at about 2+30. For engine failures after the TWO ENGINE TAL call, TAL will be selected. Three-engine RTLS abort selection (for systems failures) will occur at 3+40. RTLS (OPS 602) can also be selected in MM 104. This is required for three-engine out contingency aborts that occur during second stage.

AUTO TAL selection occurs in the TAL capability window (cue card) for an engine-out abort. TAL can be selected as late as 19,000 fps and still result in an acceptable OMS dump and a heads up roll maneuver. Except for late cases, TAL selection is generally not time-critical. TAL cannot be selected post-MECO.

ATO is initiated pre-MECO for uphill cases requiring a pre-MECO OMS dump. Initiation would normally occur in the ATO abort region (prior to PRESS TO MECO). Guidance uses the same MECO targets for ATO as for nominal ascent, although a large underspeed could exist at MECO for the ATO case. The OMS-1/2 targets will reflect ATO selection and must be changed if other targets are desired. ATO may not be selected after a nominal OMS-1 (N/A for DI).

AOA cannot be selected pre-MECO. The abort selection switch is labeled AOA-S/TAL, and pre-MECO execution of this selection will result in a TAL abort. Execution of this selection post-MECO will call AOA OMS targets. For a complete discussion of post-MECO OMS targeting see section 3.2.



Upmoding is not a legal transition with the rotary switch. However, in some cases, upmoding may be accomplished by manually entering the desired I-TGT.

If a contingency abort is required, the crew will follow the appropriate CONT ABORT procedures.

c. BFS Engagement

(1) Cue

PASS nonconvergence  
Loss of a redundant set  
Loss of control  
BFC light

(2) Crew action

To initiate BFS:

RHC BFS engage pb - push (either RHC)

(3) Discussion

The BFS is discussed in section 2.9. The BFS can be engaged by either crewmember via the BFS engage pb on the top of the RHC. In general, BFS engage is called for if there is a loss of PASS capability.

d. Feedline Disconnect Valve Failure

(1) Cue

ET SEP INHIBIT, but rates within limits

(2) Display

ASCENT TRAJ 2  
C&W class 3 message

(3) Crew action

Determine if SEP INH is caused by feedline disconnect valve failure. Follow FEEDLINE DISCONNECT VALVE FAILURE procedures, in Ascent Checklist.

(4) Discussion

After MECO and prior to ET SEP, LO<sub>2</sub> and LH<sub>2</sub> valves on either side of the ET and the Orbiter close, isolating both sides. If, at ET SEP, the ET LO<sub>2</sub> and LH<sub>2</sub> tanks are pressurized and either of the feedline disconnect valves have failed to close, a propulsive

moment will be induced at SEP by venting of the open valves. The resulting motion, depending on its magnitude, could cause Orbiter/ET recontact. For the LO<sub>2</sub> line, assuming a pressure of 22 psi in the tank, an open 17-inch line could deliver about 6000 lb of thrust. For the LH<sub>2</sub> tank, assuming a pressure of 34 psi in the tank, an open 17-inch line could deliver about 10,000 lb of thrust.

To avoid this problem, the software checks the position of the valves prior to SEP. If the valves have not closed, a SEP INH message is flashed on the CRT. This message will also appear if rates in any of the three axes exceed 0.5 deg/s or if there are multiple flight aft (FA) MDM failures.

If the SEP INH message occurs, the crew will check the pitch, yaw and roll rates. If the rates <0.5 deg/s, then it is assumed that there must be a problem with closure of the feedline disconnect valves. As per the ascent procedures card; after moding ET SEP switch to MAN and referring to the OMS 1/2 TGTING card for targets, the crew will proceed to either the OMS-1 BURN or POST-OMS-1 sections of the checklist. If an OMS-1 burn is required, ET SEP will be initiated at TIG-6 or MECO+6, whichever comes first. If no OMS-1 is required, ET SEP will be initiated at MECO+6. In either case, the goal is to maximize ET venting time prior to SEP, thus reducing the thrusting moment at SEP and minimizing the chances of Orbiter/ET recontact. The SEP is initiated by depressing the SEP pb with ET SEP in MAN.

### 3.1.5 Abort Selection via System Flight Rules and Abort Mode Boundaries

There are two kinds of events which will require the selection of an abort trajectory: (1) failures of critical Shuttle systems such as OMS, RCS, environmental control and life support system (ECLSS), etc., that can preclude the successful completion of a nominal mission, and (2) the failure of Shuttle main engines or degradation of engine performance. The flight rules that govern these two types of scenarios are incorporated into various real time MCC calls and the SYS FLIGHT RULES and NO COMM MODE BOUNDARIES cards in the Ascent Checklist.

The SYS FLIGHT RULES card (fig. 3.1-13) provides the crew with a summary of the flight rules governing RTLS and TAL selection in response to critical systems failures. The NO COMM ABORT MODE BOUNDARIES card (fig. 3.1-14) provides the crew with a summary of the ascent abort mode boundaries. Using this card, the crew may track the vehicle present abort capability in the event of a communication loss. If COMM exists, the MCC will determine the abort mode based on applicable Flight Rules and a real-time assessment of ascent performance using the abort region determinator (ARD). The ARD program resides in the mission operations computer (MOC).

#### 3.1.5.1 SYS Flight Rules

The SYS FLIGHT RULES card provides the crew with a list of critical systems failures which require an RTLS, TAL, or LATE TAL abort. These failures are discussed in the following pages and are listed in the flight rules. Flight rules regarding those failures that the crew does not have insight into onboard are not referenced on the card.

#### SYS FLIGHT RULES

|  | RTLS | TAL/<br>LATE TAL |
|--|------|------------------|
| <b>OMS - 2 He TKs</b><br>1 OX & FU TKs (diff pods)<br>2 OX or 2 FU TKs |      | X                |
| <b>APU/HYD - 2 ↓ &amp; 1 failing</b>                                   | X    | X                |
| <b>CABIN LEAK - dp/dt &gt; .15</b>                                     | X    | X                |
| <b>CRYO - All O<sub>2</sub>(H<sub>2</sub>)</b>                         | X    | X                |
| <b>2 FREON LOOPS ↓</b>   | X    | X                |
| <b>2 MAIN BUSES ↓</b>  | X    |                  |
| <b>THERMAL WINDOW PANE</b>   | X    |                  |

Figure 3.1-13.- SYS FLIGHT RULES card.

In most cases, the additional insight provided by the MCC is necessary to accurately and fully diagnose a failure and select the best response. If COMM exists, the MCC will help diagnose onboard failures and recommend the highest priority abort mode available. In the event of sudden multiple failures, the additional insight provided by the MCC is critical. In such cases it is unlikely that the crew would be able to accurately diagnose all the failures and select the best abort mode without MCC insight. However, a much more likely scenario such as a slow degradation or leak can be assessed with the information available on the SYS FLIGHT RULES cue card in the event of a COMM loss.

RTLS/TAL/LATE TAL will be selected in the following instances:

a. OMS capability

If there is a severe loss of OMS deorbit capability, it will not be possible to continue uphill and deorbit. In this case a TAL or LATE TAL will be required. This loss of OMS capability can result from several possible failures: (1) a loss of both He tanks, (2) a loss of one OMS prop tank on each side, and (3) a loss of all four prop tanks.

A loss of He pressurant in both pods renders the propellant system useless. A mixed crossfeed, in the two propellant tanks failure scenario, is not thought to be feasible as helium may leak through the damaged propellant tanks. Thus, the pressurant on each side could be depleted as well as the propellant. Lastly, if there is a loss of both Ox and Fu tanks, there will obviously be insufficient OMS capability to continue uphill.

b. APU/HYD

In the case of 2 APU/HYD down and the third failing, the trajectory option with the minimum time to the ground is desired in order to land prior to a complete loss of hydraulics. Since this is so time critical, a nominal MECO followed by deorbit would be least desirable.

c. Cabin leak

The loss of cabin pressure integrity ( $dP/dT > .15$ ) impacts both breathing oxygen and equipment cooling. The option requiring the minimum time to the ground is required.

d. CRYO

In the case of a loss, or impending loss, of all cryo O<sub>2</sub> or H<sub>2</sub> tanks, an RTLS or TAL is required. A loss of cryo O<sub>2</sub> or H<sub>2</sub> will result in a loss of fuel cells and electrical power.

## e. Loss of 2 Freon loops

The loss of two Freon loops will eventually result in the loss of all three fuel cells due to a lack of cooling. Even with an extensive powerdown and a fuel cell purge, the lifetime of electrical power production is very limited due to the temperature and water buildup resulting from the loss of Freon loop cooling. Due to the time critical nature of this failure, RTLS is preferable over TAL.

## f. Main buses

The failure of two main buses precludes ET door closure. Due to the thermal severity of TAL entry trajectories, RTLS is preferred to TAL. An uphill press is preferable to TAL if RTLS is no longer possible.

## g. Thermal window pane

Heating during nominal, TAL, or late TAL entries is severe. In the case of a failed thermal window pane, the RTLS is preferable due to its benign heating characteristics.

## 3.1.5.2 NO COMM MODE BOUNDARIES

The NO COMM MODE BOUNDARY data is located on the lower half of page 2.2 in the Ascent Checklist. Figure 3.1-14 contains the NO COMM MODE boundaries cue card for STS-26. Table 3.1-III contains additional mode boundary data, and includes some of the groundrules employed in the generation of the various data points.

This data is primarily generated with the space vehicle dynamics simulation (SVDS) and simulation and optimization of rocket trajectories (SORT) programs. SVDS has either 6 degrees of freedom (DOF) or 3-DOF fidelity while SORT is strictly a 3-DOF sim. Values generated with these and other software tools are used to build the Ascent Checklist prelaunch. The NO COMM MODE BOUNDARIES will not reflect off-nominal performance such as that resulting from a PC shift or stuck throttle. During ascent the MCC ARD calculates abort mode boundaries based on actual vehicle performance. The ARD takes real-time performance into account when predicting real-time mode boundaries.

Some of the abort boundaries are designed with flight performance reserve (FPR) margins. The FPR is an MPS propellant allowance for such uncertainties as engine performance, propellant loading, aerodynamic characteristics, and atmospheric conditions. On an RTLS with nominal performance, ( $0\sigma$  dispersions) the RTLS  $3\sigma$  FPR would remain, unburned, in the ET at MECO. On an RTLS with  $3\sigma$  dispersions, the  $3\sigma$  FPR would be burned. FPR requirements are developed by the Space Shuttle Program Office (SSPO) and published in the trajectory design data package (TDDP) at the start of each trajectory design cycle.

|                     |       |                      |                      |
|---------------------|-------|----------------------|----------------------|
| NEG RETURN (104)    | 8300  | 2 ENG BEN (104)      | 6400                 |
| PRESS TO ATO (104)  | 9300  | ABORT TAL BEN        |                      |
| LAST MRN (104)      | 11300 | EO VI                | <input type="text"/> |
| PRESS TO MECO (104) | 11500 | DROOP AML (109)      | 11400                |
| DROOP BYD (109)     | 11300 | SE BYD (109)         | <input type="text"/> |
| SE BYD (104)        | 13700 | SE BEN (109)         | <input type="text"/> |
| LAST BEN (104)      | 14600 | 2 ENG MRN (104) 7000 |                      |
| SE PRESS (104)      | 18200 | ABORT TAL MRN        |                      |
| LAST AUTO BYD       |       | EO VI                | <input type="text"/> |
| 2 or 3 engine (65)  | 19000 | DROOP GDV (109)      | <input type="text"/> |
| 1 engine (104)      | 20000 | SE BYD (109)         | <input type="text"/> |
| LAST LATE TAL BYD   | 24600 | SE BEN (109)         | <input type="text"/> |
| LAST LATE TAL KIN   | 24900 | SE MRN (109)         | <input type="text"/> |
| LAST LATE TAL HDS   | 25500 |                      |                      |

Figure 3.1-14.- NO COMM MODE BOUNDARIES card.

TABLE 3.1-III.- ASCENT MODE BOUNDARIES (STS-26, CYCLE 1B)

| Abort boundary     | Throttle | FPR | MECO            | V <sub>I</sub><br>(fps) | Time<br>(MET) | OMS dump<br>(sec) |
|--------------------|----------|-----|-----------------|-------------------------|---------------|-------------------|
| 2E BANJUL          | 104 %    | 2   | R/V             | 5900                    | 2:34          | 284               |
| 2E BEN GUERIR      | 104 %    | 2   | R/V             | 6400                    | 2:56          | 284               |
| 2E MORON           | 104 %    | 2   | R/V             | 7000                    | 3:22          | 284               |
| NEGATIVE RETURN    | 104 %    | 3   | R/V             | 8300                    | 4:05          | 297               |
|                    | 109 %    | 3   | R/V             | 8400                    | 4:09          | 297               |
|                    | 109 %    | 0   | R/V             | 8600                    | 4:14          | 297               |
| PRESS TO ATO       | 109 %    | 0   | 245 fps U/S     | 8700                    | 4:17          | 145               |
|                    | 104 %    | 2   | 245 fps U/S     | 9300                    | 4:35          | 145               |
| PRESS TO MECO      | 109 %    | 0   | 245 fps U/S     | 10100                   | 4:56          |                   |
| LAST 2E MORON      | 104 %    | 2   | R/V             | 11300                   | 5:21          | 249               |
| PRESS TO MECO      | 104 %    | 2   | 245 fps U/S     | 11500                   | 5:25          |                   |
| SE BANJUL          | 109 %    | 0   | flt cntrl limit | 11900                   | 5:32          | 105               |
|                    | 104 %    | 0   | R/V             | 13900                   | 6:08          | 103               |
| LAST 2E BEN GUERIR | 104 %    | 2   | R/V             | 14600                   | 6:19          | 160               |
| SE PRESS TO MECO   | 109 %    | 2   | 485 fps U/S     | 18000                   | 7:06          |                   |
|                    | 104 %    | 2   | 485 fps U/S     | 18200                   | 7:08          |                   |
| LAST BANJUL        | 3065 %   | N/A | R/V             | 19000                   | 7:18          |                   |
|                    | 2065 %   | N/A | R/V             | 19000                   | 7:18          |                   |
|                    | 10104 %  | N/A | R/V             | 20000                   | 7:20          |                   |

The ascent abort mode boundaries can change both in definition and time of occurrence on a mission-to-mission basis. The mode boundary times change significantly flight to flight due to differences in mass properties, environmental modeling, and performance characteristics. The boundary names may also change. For example, some flights will not have a Press to ATO boundary. Also, the TAL landing sites may change.

Other factors significantly affect the definition and complexity of ground mode boundary assessment and calls and crew procedures. For example, the STS-26 prime TAL site is an out-of-plane site (Ben Guerir). The reduced ascent performance during powered flight inherent to out-of-plane sites requires that the crew perform a TAL landing site redesignation to a contingency inplane site when the downrange energy becomes too high to reach the out-of-plane site in the event of an engine failure. It is evident in figure 3.1-15, that the out-of-plane site, Ben Guerir, provides less TAL coverage than the in-plane site, Banjul. A negative out-of-plane site capability call will be given by the Flight Dynamics Officer (FDO).

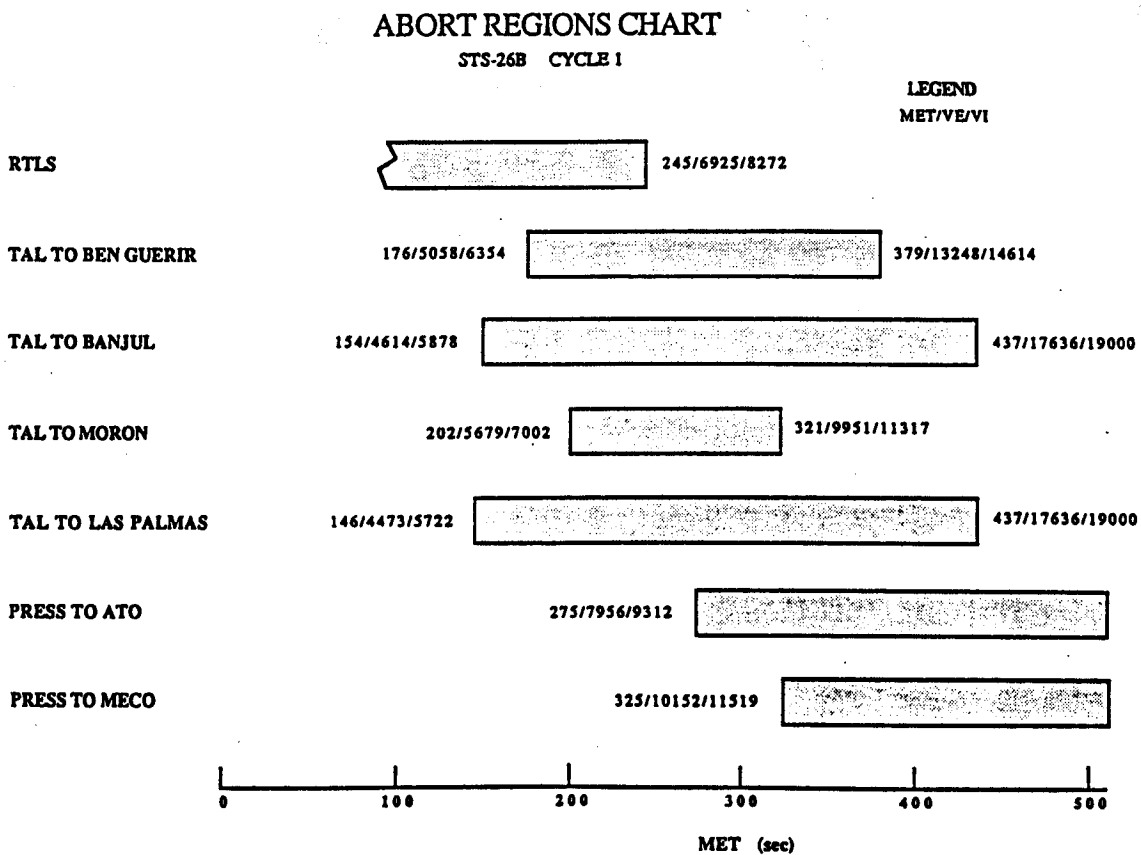


Figure 3.1-15.- STS 26-B abort coverage.



Another factor in the prediction and design of abort boundaries is the use of abort shaping via three-phase PEG or psuedo-MECO targeting. This has the effect of lofting the trajectory and closing down (shortening) exposure to TAL. NEGATIVE RETURN will occur later and the uphill press call will come earlier. We should also note that higher inclination flights will require a different philosophy of calls and checklist mode boundaries than low inclination flights.

The following discussion will focus on the cue card and mode boundaries associated with STS-26. As mentioned earlier, these may vary from flight to flight. Any questions concerning the mode boundaries and calls associated with a particular flight should be addressed to the FDO office. Figure 3.1-15 shows the abort coverage for STS 26-B cycle 1. The mode boundaries correspond to the beginning and end of each bar.

#### (1) Two-engine TAL

The TWO-ENGINE TAL boundary is the earliest  $V_I$  at which AUTO guidance may be used to successfully complete a TAL abort to the designated primary TAL landing site with two functioning engines. With one engine out at this velocity the Orbiter can reach the R-V target line, assuming  $2\sigma$  low performance and abort throttles for the two remaining engines. TAL selection is assumed to occur 15 sec after the main engine failure. This will allow time for MCC confirmation of the engine failure and evaluation of the required abort mode.

There is usually an overlap of RTLS and TAL capability (fig. 3.1-15). TAL is the preferred abort mode for engine and systems failures in this overlap region, as single engine completion capability is attained much earlier for TAL than RTLS.

#### (2) Negative return

The NEGATIVE RETURN boundary represents the latest  $V_I$  at which AUTO guidance may be used to successfully complete an RTLS abort. With one engine out at this velocity the Orbiter can reach the R-V target line, assuming  $3\sigma$  low performance and abort throttles for the two remaining engines. Past this  $V_I$ , the Orbiter will have too much downrange energy to successfully return to KSC. RTLS selection is assumed to occur 15 sec after the engine failure. This will allow time for MCC confirmation of the engine failure and evaluation of the required abort mode.

For engine failures prior to the TWO ENGINE TAL call, RTLS will be selected at 2+30 MET or as soon as possible after the engine failure, whichever is later. There is no need to select RTLS earlier, since active guidance will not commence until alpha-limiting is terminated at about 2+30 MET. Three-engine RTLS will be selected at 3+40 MET. This is done in order to delay a commitment to RTLS until the last possible moment.

For an SSME out during first stage, maximum throttle will be selected prior to RTLS selection if the  $H$  at SRB SEP is less than the PRTLS

minimum performance constraint (flight specific). Maximum throttle is required to avoid unacceptable  $P_{TOTAL}$  (P is pressure) conditions due to the depressed staging conditions.

If the ARD should indicate an inability to achieve a 3 SSME AOA with nominal throttle to steep targets with a  $2\sigma$  confidence level at negative return, the MCC will call for an RTLS abort unless TAL capability exists to the prime site.

If there is an abort gap between NEGATIVE RETURN and TWO ENGINE TAL (e.g., stuck throttle), the NEGATIVE RETURN and TWO ENGINE TAL calls will be based on throttling the good engine to maximum throttle.

(3) Press to ATO

The PRESS TO ATO boundary represents the earliest engine out  $V_I$  at which the Orbiter can successfully reach the design underspeed at MECO, assuming  $2\sigma$  low performance and abort throttles for the remaining two engines, pre-MECO abort selection, and usage of AFT RCS to AFT RCS PRESS quantity. The press-to-orbit criteria is based on the ability to achieve the design underspeed constraints. These include ET impact constraints, minimum performance capability, minimum altitude, minimum net positive suction pressure (NPSP) limit, and contingency c.g. envelope protection.

The selection of ATO pre-MECO may invoke a pre-MECO OMS dump, variable IY steering, and/or abort MECO targets to improve performance. Abort throttles are assumed since TAL is preferred over maximum throttle.

This call only occurs on those flights requiring a pre-MECO OMS dump in order to achieve the design underspeed. STS 26 will have a PRESS TO ATO call.

(4) Press to MECO

The PRESS TO MECO boundary represents the earliest engine out  $V_I$  at which the Orbiter can successfully reach the design underspeed at MECO, assuming  $2\sigma$  low performance, and abort throttles from the remaining two engines. No pre-MECO abort selection is required. The press-to-orbit criteria is based on the ability to achieve the design underspeed constraints. These include ET impact constraints, minimum performance capability, minimum altitude, minimum NPSP limit, and contingency c.g. envelope protection. Abort throttles are assumed since TAL is preferred over maximum throttle.

(5) Single engine TAL (109 percent/104 percent)

The single engine inplane TAL (DROOP BYD) 109 percent boundary represents the lowest  $V_I$  at which AUTO guidance can be used to

successfully reach MECO and ET SEP with the simultaneous failure of two main engines without trajectory droop below 265,000 ft. Vehicle trajectories which droop below 265k ft during powered flight violate ET heating constraints, and loss of the vehicle is expected. The resulting safe ET SEP state will provide bailout capability. CSS may be required for a short period of time until guidance convergence.

The single engine TAL (SE BYD) 104 percent boundary represents the lowest  $V_I$  at which AUTO guidance can be used to achieve the desired TAL site range-velocity target line with the simultaneous failure of two main engines.

Single engine TAL boundaries are designed for two different engine failure scenarios. The single engine in-plane TAL boundaries (SE DROOP and SE BYD) are based on the simultaneous failure of two SSME's, while the sequential engine-out single engine TAL boundaries will be determined real time with the TAL REDESIGNATION cue card and MCC calls. Both simultaneous (simo) and sequential (seq) engine failure boundaries assume  $2\sigma$  performance from the remaining engine, protection of the minimum droop altitude and guidance convergence limits, and a 15-sec decision delay in abort selection/runway redesignation.

The identification of TAL boundaries for sequential engines out is more complicated than for simultaneous engines out. If there is a loss of COMM, the TAL REDESIGNATION cue card (fig. 3.1-16) will indicate to the crew which TAL site is attainable in the case of a sequential engine out TAL. This is illustrated in the following example using the STS-26 cue card.

As reflected on both the NO COMM MODE BOUNDARIES card and TAL REDESIGNATION card, the prime TAL site for STS-26 is Ben Guerir, an out-of-plane site. If TAL to Ben Guerir is initiated due to an engine failure, the crew should locate the  $V_I$  of the engine failure, rounding down, in the 1ST EO  $V_I$  row of the REDESIGNATION cue card. The three numbers in a column immediately below are the single engine TAL boundaries for that particular scenario and should be entered in the appropriate slots on the mode boundary card. Using figure 3.1-16 and assuming that the first engine failed at  $V_I = 7330$  fps, the 1ST EO  $V_I$  would be rounded down to 7300. The single engine TAL boundaries would be 13,500, 13,900, and 15,000 for Las Palmas (GDV), Banjul (BYD), and Ben Guerir (BEN), respectively. In this case the vehicle will be able to reach the GDV target line, after selecting TAL to Ben Guerir due to an engine out at 7330 with a second engine failure at 13,500 fps, assuming maximum throttle and nominal performance from the remaining engine.

**BEN TAL REDESIGNATION**

NOTE: ALL NOS. ARE 109% THROTTLE;  
FOR 104% THROTTLE, ADD 300 FT/S

| 1ST EO VI        | 6400  | 6500  | 6600  | 6700  | 6800  | 6900  |
|------------------|-------|-------|-------|-------|-------|-------|
| SE REDES GDV (4) | 13200 | 13200 | 13200 | 13200 | 13300 | 13300 |
| SE REDES BYD (5) | 14700 | 14600 | 14500 | 14400 | 14300 | 14200 |
| SE BEN (2)       | 15700 | 15600 | 15500 | 15400 | 15400 | 15300 |

| 1ST EO VI        | 7000  | 7100  | 7200  | 7300  | 7400  | 7500  |
|------------------|-------|-------|-------|-------|-------|-------|
| SE REDES GDV (4) | 13300 | 13400 | 13400 | 13500 | 13500 | 13500 |
| SE REDES BYD (5) | 14100 | 14000 | 13900 | 13900 | 13800 | 13700 |
| SE BEN (2)       | 15200 | 15100 | 15100 | 15000 | 15000 | 14900 |

| 1ST EO VI        | 7600  | 7700  | 7800  | 7900  | 8000  | 8100  |
|------------------|-------|-------|-------|-------|-------|-------|
| SE REDES GDV (4) | 13600 | 13600 | -     | -     | -     | -     |
| SE REDES BYD (5) | 13700 | 13600 | 13500 | 13500 | 13500 | 13400 |
| SE BEN (2)       | 14900 | 14800 | 14700 | 14600 | 14600 | 14500 |

| 1ST EO VI        | 8200  | 8300  | 8400  | 8500  | 8600  | 8700  |
|------------------|-------|-------|-------|-------|-------|-------|
| SE REDES GDV (4) | -     | -     | -     | -     | -     | -     |
| SE REDES BYD (5) | 13400 | 13300 | 13300 | 13200 | 13200 | 13200 |
| SE BEN (2)       | 14500 | 14400 | 14400 | 14300 | 14300 | 14200 |

| 1ST EO VI        | 8800  | 8900  | 9000  | 9100  | 9200  | 9300  |
|------------------|-------|-------|-------|-------|-------|-------|
| SE REDES GDV (4) | -     | -     | -     | -     | -     | -     |
| SE REDES BYD (5) | 13100 | 13100 | 13100 | 13000 | 13000 | 13000 |
| SE BEN (2)       | 14200 | 14100 | 14100 | 14000 | 14000 | 13900 |

Figure 3.1-16.- BEN TAL REDESIGNATION card (ASC-8a/26/A/C).

It is important to note that if a TAL site redesignation is required, as is in this case for GDV and BYD, selected TAL site change is required posthaste on the HORIZ SIT display (SPEC 50) in order to begin crossranging to the selected site. Also, if 109 percent throttle on the remaining SSME is called for, it should be selected ASAP as this boundary  $V_I$  assumes a 15-sec delay in max throttle selection time.

(6) Single engine press to MECO

This boundary represents the lowest  $V_I$  after which the critical underspeed can be attained with two engines out simultaneously, assuming abort throttles and  $2\sigma$  low performance from the remaining engine. AFT RCS to AFT quantity 1 may be committed from post-MECO delta-V purposes since it can reduce TAL exposure while protecting for a nominal reentry. The critical underspeed, is defined in the same manner as the design underspeed, less the ET impact constraint. If there is a gap between single engine press to MECO and last single engine AUTO TAL, this call will be based in real time on the following changes in the groundrules, in order of preference:

- Waiver of ET IP constraints
- ARCS to ARCS quantity 1
- AOA shallow targets
- Nominal performance from the remaining engine ( $0\sigma$ )
- Relaxation of AOA forward X c.g. limit to 1073 in.
- Max throttle
- Relax TAL aft X c.g. limit to 1115 in.

LATE TAL is preferred over commitment of forward RCS or ARCS to AFT RCS quantity 2.

(7) Last TAL

This boundary represents the last time, with a single engine failure, that AUTO guidance can be used to achieve the designated TAL landing site R-V line. If a sufficient amount of OMS is not dumped pre-MECO, the dump may be completed in MM 304. The engines are throttled down to 65 percent for three engine and two engine cases where  $V_I > 13900$  fps (flight specific) at TAL initiation. This will provide for a longer pre-MECO dump.

(8) Last LATE TAL BYD

This boundary represents the highest MECO velocity acceptable for successful completion of a LATE TAL. This abort option is applicable to the early MECO's where  $V_I$  is below the AOA range. In this case, TAL is not selected. For systems TAL's, the engines are manually shut down at the velocity listed on the top of the SYS Flight Rules card to achieve the MECO R-V target line.

## 3.2 OMS TARGETING

### 3.2.1 OMS TGT Rationale

The Shuttle is deliberately targeted to be suborbital at MECO so that the ET will reenter and impact in a safe target area. The crew must perform at least one OMS burn to achieve a safe orbit. For large MECO underspeeds a second OMS burn may be required to remain on orbit for an extended period or to perform an AOA. PEG 4 guidance utilizes target I-loads (TIG, C1, C2, HT and  $\Theta T$ ) for OMS burns. TIG is the time of ignition. C2 and C1 are the slope and intercept that define the linear relationship between the horizontal (VHOR) and vertical (VVER) components of the burn velocity ( $VVER = C2 VHOR + C1$ ). HT is the height of the target above the Earth surface, and, the angle  $\Theta T$  defines the angular location of the target. In OPS 1,  $\Theta T$  is the downrange angle from the launch site to the radius target vector. In OPS 3,  $\Theta T$  is measured from TIG to EI.

PEG 7, or external  $\Delta V$  guidance mode, is designed to guide the vehicle through a constant inertial thrust attitude maneuver that achieves a specified velocity change. It is used presently in the DI/SAFE HP maneuver for small MECO underspeeds on DI missions.

Most PEG 4 targets for the prime AOA landing site are in the onboard software. However, the crew must key in targets for delayed cases and for alternate AOA landing sites. The MCC is prime for target selection since the ground can better evaluate combinations of failures (i.e., MECO underspeeds plus OMS leaks) and the resulting system capabilities. Also, the MCC can compute a more optimal real-time targeting solution for uplink. However, if there is a loss of COMM, the crew has enough information onboard to make the correct selection in most cases.

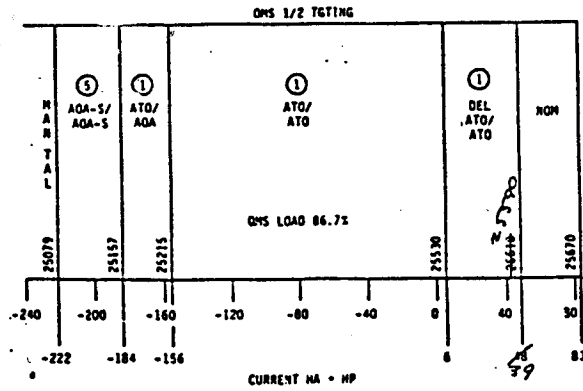
Standard Insertion (SI) flights require a two-burn sequence to achieve orbit or AOA deorbit. The SI nominal OMS-1 maneuver is done prior to reaching the MECO apogee. This will create a shift in the line of apsides with most of the OMS-1 "kick" to apogee. Apogee is raised to the final desired orbital radius while perigee is raised close to the MECO apogee. The nominal OMS-2 burn will then raise perigee and circularize the orbit.

Direct Insertion (DI) flights require only one OMS burn (OMS-2) centered about the apogee established at MECO. Because of this there is very little shift in the line of apsides and thus higher burn efficiency. Virtually all of the kick is to perigee, and the desired final orbit is nominally achieved after this single burn.

During second stage powered flight the Orbiter is guided toward a MECO state defined by altitude (h), inertial flightpath angle ( $\gamma_I$ ), inertial velocity ( $V_I$ ), and inertial plane (IY) targets. It is possible to reach a nominal MECO h,  $\gamma_I$  and IY with an underspeed (lower than nominal  $V_I$ ) due to engine failures or performance degradations during powered flight. This may require alternate OMS targets or an abort selection after MECO. Any underspeed at MECO will increase the  $\Delta V$  requirements associated with a

OMS 1 TARGETING  
(STD INSERTION)

|   |               |               |
|---|---------------|---------------|
| DELAY DO NOT DELAY BURN IF CUR HA < <span style="border: 1px solid black; padding: 2px;">70</span>          |               |               |
| FAILURE   | OMS 1 TARGET  | OMS 2         |
| OMS - 1 He TK<br>1 PRPLT TK<br>2 OMS ENG<br>2 N2 TKS (I'cnect to RCS)<br>EPS - MNA & B<br>MNA & C<br>ET SEP | DELAYED ATO   | N/R           |
| FEEDLINE DISC VLV   | DELAYED NOM   | NOM           |
| OMS - 2 He TKS<br>- 1 OX & 1 FU TK<br>diff PODS<br>- 2 OX & 2 FU TK   | DELAYED AOA-S | AOA/<br>AOA-S |
| ON TIME<br>2 FREON LOOPS<br>2 H2O LOOPS   | NOMINAL       | AOA           |
| CABIN LEAK<br>(BKUP dP/dT > .15)  |               |               |



NOTE: IF 1 ENG & ΔV > 500  
1 OMS = 4X RCS

OMS

| He   | %  | He   | %  |
|------|----|------|----|
| N/A  | 90 | 2950 | 40 |
| 4140 | 80 | 2675 | 30 |
| 3840 | 70 | 2390 | 20 |
| 3540 | 60 | 2125 | 10 |
| 3250 | 50 |      |    |

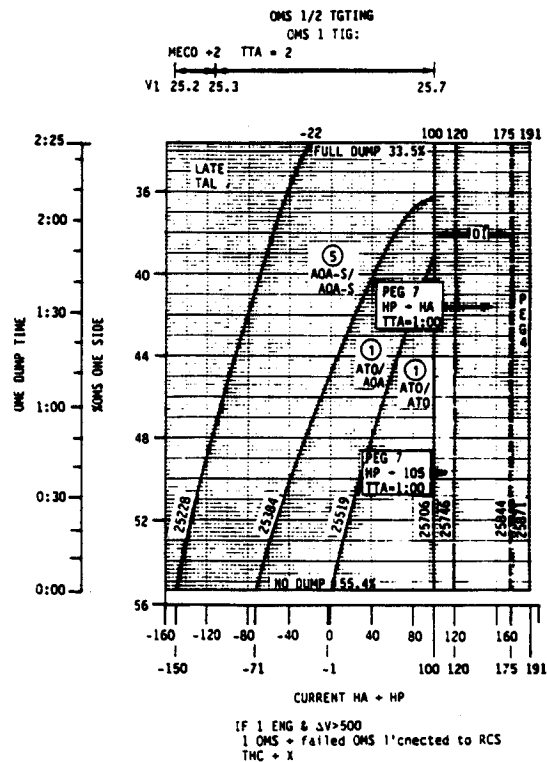
Figure 3.2-1.- STS 61-C OMS-1 targeting cards.

OMS 1 TARGETING  
(DIR INSERTION)

|   |              |                                   |
|---|--------------|-----------------------------------|
| FAILURE   | OMS 1 TARGET | OMS 2                             |
| OMS - 1 or 2 He TK<br>1 PRPLT TK<br>2 OMS ENG<br>2 N2 TKS (I'cnect to RCS)<br>EPS - MNA & B, MNB & C<br>MNA & C<br>ET SEP | NO OMS 1     | PEG 7<br>TTA-1<br>CUTOFF<br>HP=85 |
| APU/HYD - 2+ +1 failing   | NO OMS 1     | AOA                               |
| OMS - 1 OX & 1 FU TK<br>diff PODS<br>- 2 OX or 2 FU TK  | NO OMS 1     | AOA/<br>AOA-S                     |
| 2 FREON LOOPS<br>2 H2O LOOPS<br>CABIN LEAK<br>(BKUP dP/dT > .08)  | NO OMS 1     | AOA                               |
| CRYO - A11 O2 (H2)  | NO OMS 1     | AOA                               |

OMS

| He   | %  | He   | %  |
|------|----|------|----|
| N/A  | 90 | 2955 | 40 |
| N/A  | 80 | 2670 | 30 |
| N/A  | 70 | 2390 | 20 |
| 3400 | 55 | 2120 | 10 |
| 3250 | 50 |      |    |



IF 1 ENG & ΔV > 500  
1 OMS = failed OMS I'cnect to RCS  
THC = X

Figure 3.2-2.- STS 26-B OMS-1 targeting cards.

3.2-2

particular OMS-1 target. Figures 3.2-1 and 3.2-2 show the OMS-1 targeting cards for both an SI (flight STS 61-C) and a DI mission (flight STS-26). Note that systems aborts will be discussed for SI missions in which different OMS-1 burns are required for different failures. Also, the systems flight rules targeting option card has been revised for STS-26. Subsequent SI cue cards will reflect these flight rules changes.

For direct insertion missions, the system failure will designate whether an AOA deorbit or orbit insertion OMS-2 burn will be performed.

Although the underspeed (targeting card) takes precedence over systems failures, the systems failures will be discussed first. The systems failures chart assumes no underspeed at MECO and no other major failure (i.e., combination of OMS and APU/HYD failures are not considered).

Some critical failures could affect both the primary and redundant systems which should cause the crew to return as quickly as possible in an AOA mode. These system failures include a loss of both of the Freon coolant loops, or the loss of two H<sub>2</sub>O loops. Additionally, a cabin leak rate that exceeds a dP/dT of -0.08 psi/min (formerly .12) is considered a critical loss of cabin integrity. A dP/dT of -0.08 is estimated to provide sufficient N<sub>2</sub> margin to reach the primary landing site from launch (about revolution (rev) 3). If a leak rate greater than -0.08 occurs, an AOA must be done.

|  |                |     |
|--|----------------|-----|
| <b>ON TIME</b><br><br>2 FREON LOOPS<br>2 H <sub>2</sub> O LOOPS<br>3 AV BAY FANS<br>(BAYS 1,2)<br>CABIN LEAK<br>(BKUP dP/dT > .12) | <u>NOMINAL</u> | AOA |
|--|----------------|-----|

None of these failures affect the integrity of the OMS, therefore the quickest and safest AOA return would be prudent. For an SI mission that would be a nominal OMS-1 target followed by an AOA steep OMS-2 burn. The nominal OMS-1 burn allows the crew to maintain options to go to orbit as long as possible. For a DI flight, an immediate AOA OMS-2 deorbit burn would be selected.

**OMS 1 TARGETING  
(STD INSERTION)**

| DELAY DO NOT DELAY BURN IF CUR HA < <span style="border: 1px solid black; padding: 2px;">70</span> **                      |                    |       |
|--|--------------------|-------|
| FAILURE  | OMS 1 TARGET       | OMS 2 |
| OMS - 1 He TK<br>1 PRPLT TK<br>2 OMS ENG<br>2 N <sub>2</sub> TKS (I'cnect<br>to RCS)<br>EPS - MNA & B<br>MNA & C<br>ET SEP | <u>DELAYED ATO</u> | N/R   |

3.2-3



Other failures, especially those which interfere with the orbit insertion process, will tolerate a delay (DATO) in doing the OMS-1 burn (SI) to allow a better evaluation of the extent of the failure. Analysis of  $\Delta V$  requirements for delayed SI cases indicates that the OMS-1 burn can be delayed to approximately 20 min MET, as long as a nominal MECO is achieved. This allows the crew time to check the failure, accurately assess the situation, and retarget the OMS-1 burn without rushing. In the case of a nominal MECO followed by a burn utilizing the nominal OMS-1 target, a delay of the burn will cause a slight increase in OMS-1  $\Delta V$  even though the Orbiter is still climbing to apogee (total  $\Delta V$  is equivalent or better, depending on height of final orbit). This is caused by preserving the AOA deorbit burn capability, should it be required later. A deorbit burn is performed at apogee and must meet certain entry conditions. Note that for all large underspeeds at MECO the OMS-1 burn should not be delayed. The note at the top of the OMS-1 TARGETING card indicates when the burn should not be delayed. Current HA is a quick way to check the criticality of the underspeed at MECO.

|                   |                    |     |
|-------------------|--------------------|-----|
| FEEDLINE DISC VLV | <u>DELAYED NOM</u> | NOM |
|-------------------|--------------------|-----|

A 482 first implemented on STS-26 removed the Delayed Nominal burn section from the checklist. For SI missions occurring subsequent to this change, the FEEDLINE DISC VLV failure will not be listed on the OMS-1 TARGETING card. The procedures for this failure will reside in the OMS burn sections of the checklist (SI and DI). However, it is still uncertain whether a delayed nominal target or the nominal OMS-1 target with a TIG delay will be used for SI flights.

A delay of the ATO OMS-1 burn will cause a decrease in the OMS-1  $\Delta V$  because the OMS-1 burn for an apogee preserving AOA deorbit is more optimal when performed closer to nominal MECO apogee (due to geometry and requirement for radial component on OMS-1; total  $\Delta V$  approximately the same). The SI Delayed ATO OMS-1 target is unique in that the orbit obtained by this burn is 105 by 80-n. mi. and does not require an OMS-2 burn unless desired, since an 80-n. mi. perigee is considered safe for at least five revs.

Failure to separate from the ET requires additional time to work the required procedures. If the burn must be made before the tank is released, then an ATO target (SI) or the PEG 7 perigee kick (DI) should be used to minimize the ET footprint when it is released.

For SI missions, those failures that cause the loss of half of the OMS capability may still make the ATO mode feasible, depending on the remaining propellant available for insertion and deorbit. These failures include the loss and suspected loss of a single propellant or helium tank. High leak rates that cannot support an entire OMS-1 burn are considered totally failed. If a different propellant tank on each pod has failed, a mixed crossfeed procedure must be worked before a burn can be done.

The OMS can also be incapacitated by a loss of electrical power for motors that drive valves and servomechanism (servo) units. The loss of main buses A and B will shut down the service to the primary and secondary left OMS engine power supply for the gimbal servos. It also takes out crossfeed capability from that side. The loss of main buses A and C will do the same for the right side. The loss of main buses B and C takes out the right OMS ignition and crossfeed capability. Prior to STS-26 it was thought that the main B and C combination was acceptable. Therefore, the STS 61-C chart does not include this as a critical failure requiring DATO. These three main bus failure combinations each leave half the OMS capability and only one operable OMS engine and can be treated like the other OMS failures as far as targeting is concerned. There are malfunction procedures to follow for all the systems problems.

For loss of both OMS engines because of engine failures or loss of OMS N<sub>2</sub>, the OMS propellant will be interconnected to the RCS jets. For a failed OMS N<sub>2</sub> tank, the associated engine will not be used until the deorbit burn in order to conserve the final engine restart. If N<sub>2</sub> REG PRESS > 328 psia, two restarts are possible. Even though all the propellant is available, for failures requiring RCS jets to be used, the cheaper target is burned since the RCS is not as efficient as the OMS.

|   |                      |               |
|---|----------------------|---------------|
| OMS - 2 He TKS<br>- 1 OX & 1 FU TK<br>diff PODS<br>- 2 OX & 2 FU TK | <u>DELAYED AOA-S</u> | AOA/<br>AOA-S |
|---|----------------------|---------------|

For SI missions, the delayed AOA-S/AOS-S target set provides the most optimum  $\Delta V$  scenario for no underspeed at MECO and is used when not enough  $\Delta V$  is available to support any other option (shallow AOA's are sensitive to NAV errors and reentry heating, and are therefore undesirable).

In the case of a helium leak with a successful mixed crossfeed, enough Helium may be lost to degrade the total OMS capability below 50 percent. In this case a delayed AOS-S/AOS-S is the only option.

If the total OMS capability is gone, then the RCS thrusters must provide the necessary control. The loss of different propellants from different pods is essentially equivalent to the loss of both pods due to the lack of time to handle the reconfiguration of the tanks in the GPC before OMS-1 on an SI mission. For some of these cases the use of RCS aft and forward for the minimum  $\Delta V$  target to get the Orbiter to the ground is the best that can be done.

The OMS-1/2 targeting chart (fig 3.2-3) provides the crew with information describing the appropriate OMS-1/2 target sets as a function of MECO underspeed. This chart assumes no system failures but does account for any ATO dump performed pre-MECO. The correct target set may be obtained by the crew as a function of orbital energy (HA + HP) and the amount of OMS propellant remaining at the MM 104 transition. If a pre-MECO OMS dump was performed, the crew should time the dump as a backup to the OMS gauges to

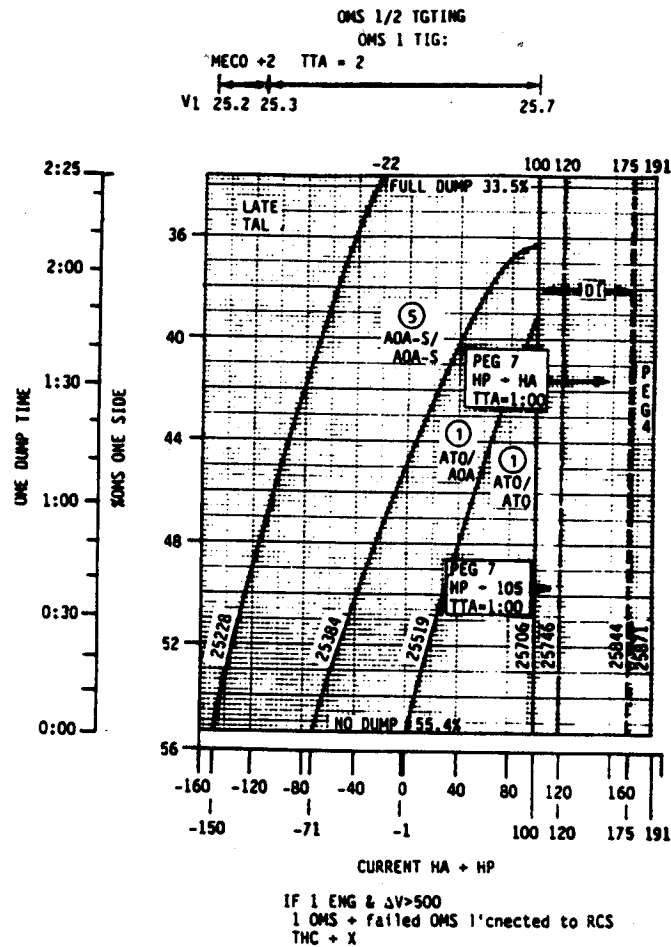


Figure 3.2-3.- STS 26 OMS 1/2 TGTING card (ASC/26/FIN).

protect for gauging error. The current HA and HP should be obtained from the OMS-1 MNVR EXEC display after the MM 104 transition.

For example, on mission STS 26, let us assume that the current HA by HP at MM 104 is 70 by -80 n. mi. If we assume that a full pre-MECO OMS dump was performed, than the chart (fig. 3.2-3) shows that the crew should perform an AOA shallow OMS-1 burn (I-TGT 5) followed by an AOA shallow OMS-2 burn (I-TGT 5). In the case that no pre-MECO ATO OMS dump is performed (same HA + HP), the chart shows that the crew should perform an ATO OMS-1 burn (I-TGT 1) followed by an AOA steep OMS-2 burn (I-TGT 6) instead of the AOA shallow OMS-1 and OMS-2 option. This chart is used as a backup for the crew in case there is no communication (comm) with the ground.

The chart also carries MECO VI numbers for the no-dump case as a backup for the HA + HP calculations. The note on the graph, "If 1 ENG & ΔV > 500 then 1 OMS + 4X RCS," indicates that with a ΔVTOT of 500 fps or more, +X RCS

must be used as well as the one OMS engine since you are too low in the atmosphere to safely do a single OMS burn. This reduces the burn TGO.

When using the chart and the systems failure card together, the worst case requirements shall prevail. On STS 61-C that means that, for no underspeed and one OMS propellant tank failure, a delayed ATO will be performed; conversely, with full OMS capability but a large underspeed (HA + HP = -160), an AOA-S will be required. On STS-26 that means that for no underspeed and an OMS tank failure, a PEG 7 burn to raise perigee to 85 n. mi. will be performed; conversely, with full OMS capability but a large underspeed (HA + HP = -100, no OMS dump), an AOA-S will be required. For combinations of failures; i.e., an OMS tank loss plus an underspeed, ground help will probably be required. As stated previously, the ground is prime for all target selections if COMM exists.

After OMS-1 is burned, the OMS-2 TARGETING card (fig. 3.2-4) will be checked to determine what OMS-2 target should be burned.

| OMS 2 TARGETING<br>(STD INSERTION)   |                                 |
|--|---------------------------------|
| FAILURE  | OMS 2 TARGET                    |
| OMS - 1 PRPLT TK   | PEG 7; TTA-1<br>CUTOFF Hp = 100 |
| OMS - 2 N2 TKS (1'nect<br>to RCS)<br>2 OMS ENG<br>1 He TK<br>EPS - MNA & B<br>MNA & C        | PEG 7; TTA-1<br>CUTOFF Hp = 80  |
| OMS - 2 OX or 2 FU or<br>2 HE TKS<br>1 OX & 1 FU TK<br>diff PODS                             | AOA/AOA-S                       |
| 2 FREON LOOPS<br>2 H2O LOOPS<br>3 AV BAY FANS (BAYS 1,2)<br>CABIN LEAK<br>(BKUP dP/dT > .12) | AOA                             |

Figure 3.2-4.- STS 61-C OMS-2 TARGETING card.

The OMS-2 TARGETING card covers failures that occurred during or after the OMS-1 burn that would impact the OMS-2 target selection. As before, certain system failures that eliminate the primary and backup system require immediate attention and the soonest possible return. Since this return is probably from a nominal OMS-1 burn, then an AOA steep return is selected. The failures that require this action are the loss of both Freon loops, loss of both water coolant loops, loss of three of the four fans in avionics bays 1 and 2, and a cabin leak rate in excess of  $dP/dT = 0.08$  (previously 0.12). Similarly, the loss of two oxidizers and 2 fuel tanks eliminates future OMS propellant usage and requires that the RCS provide the deorbit capability

for an AOA return. For these failures the AOA steep is performed if possible; otherwise, the AOA shallow must be used.

Other OMS propellant failures retain partial  $\Delta V$  capability and therefore permit the more desirable ATO. If only one propellant from either pod is lost or different propellants from different pods are lost (equivalent to one pod lost), then sufficient  $\Delta V$  remains to permit the perigee to be raised to 100 n. mi. for these cases. A 100-n. mi. perigee orbit is considered safe for 24 hr.

A greater loss of OMS capability occurs if both OMS engines fail, leaving the propellant available but only through the RCS jets, or both helium tanks fail, allowing only the remaining charge in the propellant tanks to drive the propellant to the engine. For these situations, the  $\Delta V$  requirement for OMS-2 must be minimized to provide no more  $\Delta V$  than needed to raise perigee to the lowest acceptable level of 80 n. mi.

The loss of electrical buses will shut down OMS-related motors and servos. One of the OMS engines will be lost if either main buses A and B or A and C fail. Subsequent to STS 61-C it was found that the loss of main buses B and C was also critical. Since the OMS-1 burn was probably nominal, the OMS-2 maneuver should be targeted to raise perigee to the minimum altitude of 80 n. mi. via PEG 7 guidance to allow time to reconfigure the electrical load or recover the lost buses. This option would permit increasing the orbit if the problem is resolved but also permit a minimum  $\Delta V$  deorbit if necessary.

OMS

| He   | %  | He   | %  |
|------|----|------|----|
| N/A  | 90 | 2950 | 40 |
| 4140 | 80 | 2675 | 30 |
| 3840 | 70 | 2390 | 20 |
| 3540 | 60 | 2125 | 10 |
| 3250 | 50 |      |    |

The OMS He pressure versus OMS quantity table is used by the crew as a backup to the OMS gauges in the event of gauge or pressure transducer failures for either or both of the OMS propellant tanks. The OMS He pressure quantities can be obtained from the BFS SYS SUMM display and may be used prior to the OMS-1/OMS-2 burn as a check.

The OMS REQUIRED tables (fig. 3.2-5) are used to determine the appropriate abort mode in the event of an OMS propellant shortage, or to confirm that sufficient OMS propellant is available for completion of the abort mode indicated by the OMS 1/2 targeting cards. The percent of available OMS fuel required to complete various abort options is listed versus post-OMS-1 HP. It is important to note that this chart is built to accommodate only cases where ATO target 1 was used for OMS-1. If another target set was used, these quantities will not be valid. Both the DUAL POD and SINGLE POD tables

assume that only OMS propellant is used and include approximately 3 percent per pod for gauging error and unusable propellant.

The chart provides information for three different deorbit scenarios; ATO OMS-2 followed by a shallow deorbit burn, AOA steep OMS-2 deorbit burn, and AOA shallow OMS-2 deorbit burn. For example, using figure 3.2-5, a post ATO 1 OMS-1 burn HP of 65 n. m. requires 36 percent remaining in one pod to complete the AOA steep deorbit burn with one pod. To complete this deorbit maneuver with two pods requires 40 percent remaining, or roughly 20 percent per pod.

**NOTE**

These tables only apply after  
ATO OMS 1 burn (ITGT = ①)

| <b>DUAL POD - OMS REQUIRED</b><br>Includes 7.6% unusable (3.8% per pod) |  |                              |                                |
|---|--|------------------------------|--------------------------------|
| POST OMS 1<br>HP  | ATO OMS 2 &<br>SHALLOW D/O<br>BURN (%) | AOA STEEP<br>D/O BURN<br>(%) | AOA SHALLOW<br>D/O BURN<br>(%) |
| 90  | 42                                     | 48                           | 37                             |
| 85  | 43                                     | 46                           | 36                             |
| 80  | 45                                     | 44                           | 35                             |
| 75  | 46                                     | 43                           | 33                             |
| 70  | 47                                     | 41                           | 31                             |
| 65  | 49                                     | 40                           | 30                             |

| <b>SINGLE POD - OMS REQUIRED</b><br>Includes 3.8% unusable |  |                              |                                |
|--|--|------------------------------|--------------------------------|
| POST OMS 1<br>HP   | ATO OMS 2 &<br>SHALLOW D/O<br>BURN (%) | AOA STEEP<br>D/O BURN<br>(%) | AOA SHALLOW<br>D/O BURN<br>(%) |
| 90   | 38                                     | 44                           | 33                             |
| 85   | 39                                     | 42                           | 33                             |
| 80   | 41                                     | 41                           | 31                             |
| 75   | 42                                     | 39                           | 29                             |
| 70   | 44                                     | 38                           | 27                             |
| 65   | 45                                     | 36                           | 26                             |

Figure 3.2-5.- Post-ATO(1) OMS  
required (ASC/26/FIN).

3.2.2 OMS Targeting Options

3.2.2.1 Standard Insertion

For STS 61-C, the nominal MECO velocity was 25670 fps, and the altitude was 57 n. mi. The post-MECO orbit was 83 by -2 n. mi. (HA X HP). The OMS-1 and OMS-2 target options discussed in this section are representative of the current targeting options available on SI flights. Target data contained in this section, unless otherwise specified, pertains to STS 61-C cycle 1 and is typical of SI flights. The target data described below is summarized in table 3.2-I and figures 3.2-6 and 3.2-7. Note that the target altitudes are based on spherical Earth models and are slightly higher than actual values.

TABLE 3.2-I.- STS 61-C OMS BURN TARGETS

| STS-61C CYCLE 1 AOA TO EDWARDS (PRIMARY) |     |             |     |      |     |              |         |         |     | OMS TARGET SUMMARY SHEET |         |         |              |       |         |       |       |  |  |
|--|-----|-------------|-----|------|-----|--------------|---------|---------|-----|--------------------------|---------|---------|--------------|-------|---------|-------|-------|--|--|
| TGT (OMS-1)                              |     | TGT (OMS-2) |     | ARE  | ARE | MECO         | OMS-1   |         |     |                          | OMS-2   |         |              |       |         |       |       |  |  |
| ONBD                                     | NCC | ONBD        | NCC | CASE | IFB | APOGEE RANGE | TGTS    | TIG     | HT  | THETA                    | TGTS    | TIG     | MECO+ ETSEP+ | C1    | C2      | WT    | THETA |  |  |
| 16                                       | 16  | 16          | 16  | 1    | 7   | 0            | NOM     | MECO+ 2 | 165 | 165.1                    | NOM     | 44:23   | 35:50        | 0     | 0.0000  | 166.4 | 341.8 |  |  |
|  |     |             |     |      |     |              | I-LOAD  |         |     |                          | I-LOAD  |         | 35:40        |       |         |       |       |  |  |
| 16                                       | 12  | 12          | 12  | 1    | 9   | 0            | NOM     | MECO+ 2 | 165 | 165.1                    | AOA-ST  | 49:50   | 40:38        | 14823 | -0.5963 | 65.8  | 95.8  |  |  |
|  |     |             |     |      |     |              | I-LOAD  |         |     |                          |         | -00:47  | 40:20        |       |         |       |       |  |  |
| 16                                       | 11  | 11          | 11  | 1    | 10  | 0            | NOM     | MECO+ 2 | 165 | 165.1                    | AOA-SH  | 29:05   | 19:53        | 15178 | -0.6034 | 65.8  | 178.8 |  |  |
|  |     |             |     |      |     |              | I-LOAD  |         |     |                          |         | -00:47  | 19:35        |       |         |       |       |  |  |
| 17                                       | 17  | 17          | 17  | 1    | 7   | -1           | DEL-NOM | MECO+12 | 169 | 236.0                    | DEL-NOM | 1:02:22 | 53:57        | 0     | 0.0000  | 168.0 | 407.0 |  |  |
|  |     |             |     |      |     |              | KEY-IN  |         |     |                          | KEY-IN  |         | 53:39        |       |         |       |       |  |  |
| 17                                       | 10  | 10          | 10  | 1    | 9   | -1           | DEL-NOM | MECO+12 | 169 | 236.0                    | AOA-ST  | 37:08   | 27:56        | 15378 | -0.6174 | 65.8  | 148.2 |  |  |
|  |     |             |     |      |     |              | KEY-IN  |         |     |                          |         | -00:47  | 27:38        |       |         |       |       |  |  |
| 17                                       | 8   | 8           | 8   | 1    | 10  | -1           | DEL-NOM | MECO+12 | 169 | 236.0                    | AOA-SH  | 33:48   | 24:36        | 14719 | -0.5853 | 65.8  | 157.4 |  |  |
|  |     |             |     |      |     |              | KEY-IN  |         |     |                          |         | -00:47  | 24:18        |       |         |       |       |  |  |
| 1  | 1   | 1           | 1   | 2    | 8   | 1            | ATO     | MECO+ 2 | 112 | 235.0                    | ATO     | 1:03:10 | 53:18        | 0     | 0.0000  | 113.0 | 415.0 |  |  |
|  |     |             |     |      |     |              |         |         |     |                          |         |         | 53:00        |       |         |       |       |  |  |
| 1  | 6   | 6           | 6   | 2    | 9   | 1            | ATO     | MECO+ 2 | 112 | 235.0                    | AOA-ST  | 51:51   | 41:59        | 16625 | -0.6658 | 65.8  | 85.0  |  |  |
|  |     |             |     |      |     |              |         |         |     |                          |         | -00:01  | 41:41        |       |         |       |       |  |  |
| 1  | 7   | 7           | 7   | 2    | 10  | 1            | ATO     | MECO+ 2 | 112 | 235.0                    | AOA-SH  | 41:43   | 31:51        | 16983 | -0.6726 | 65.8  | 120.4 |  |  |
|  |     |             |     |      |     |              |         |         |     |                          |         | -00:01  | 31:33        |       |         |       |       |  |  |
| 5  | 5   | 5           | 5   | 4    | 10  | 3            | AOA-SH  | MECO+ 2 | 95  | 225.0                    | AOA-SH  | 49:12   | 39:20        | 19072 | -0.7529 | 65.8  | 85.3  |  |  |
|  |     |             |     |      |     |              |         |         |     |                          |         | -00:03  | 39:02        |       |         |       |       |  |  |
| 1  | 13  | 1           | 13  | 2    | 8   | -1           | DEL-ATO | MECO+12 | 112 | 235.0                    | ATO     | 1:01:43 | 53:18        | 0     | 0.0000  | 113.0 | 415.0 |  |  |
|  |     |             |     |      |     |              | KEY-IN  |         |     |                          |         |         | 53:00        |       |         |       |       |  |  |
| 1  | 13  | 6           | 14  | 2    | 9   | -1           | DEL-ATO | MECO+12 | 112 | 235.0                    | AOA-ST  | 51:11   | 41:59        | 16625 | -0.6658 | 65.8  | 86.1  |  |  |
|  |     |             |     |      |     |              | KEY-IN  |         |     |                          |         | -00:47  | 41:41        |       |         |       |       |  |  |
| 1  | 13  | 7           | 15  | 2    | 10  | -1           | DEL-ATO | MECO+12 | 112 | 235.0                    | AOA-SH  | 41:03   | 31:51        | 16983 | -0.6726 | 65.8  | 121.4 |  |  |
|  |     |             |     |      |     |              | KEY-IN  |         |     |                          |         | -00:47  | 31:33        |       |         |       |       |  |  |
| 4  | 4   | 4           | 4   | 4    | 10  | -1           | DELAYED | MECO+12 | 100 | 175.0                    | AOA-SH  | 51:28   | 42:16        | 18491 | -0.7382 | 65.8  | 72.7  |  |  |
|  |     |             |     |      |     |              | AOA-SH  |         |     |                          |         | -00:47  | 41:58        |       |         |       |       |  |  |

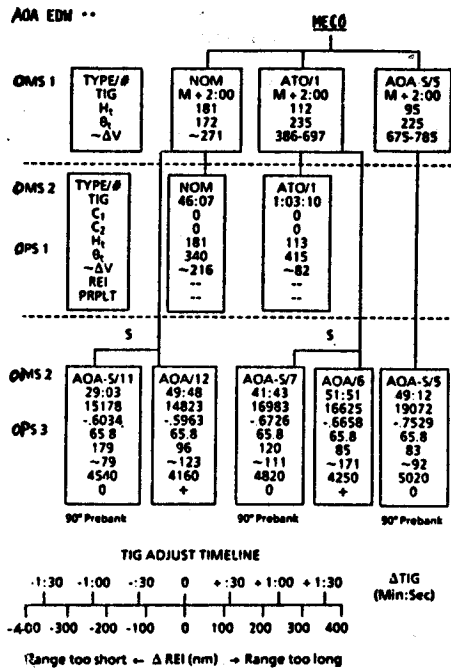


Figure 3.2-6.- STS 61-C OMS targets - on time.

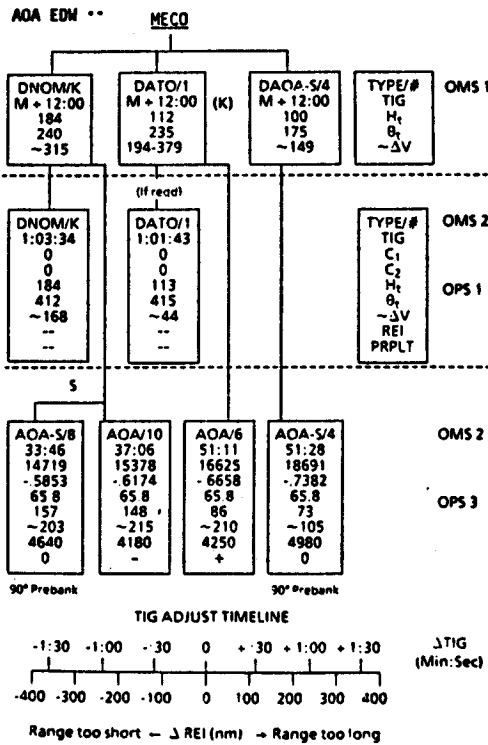


Figure 3.2-7.- STS 61-C OMS targets - delayed.



Most targets are available in the software and can be selected by the ABORT MODE rotary switch or by I-TGT selection (item 35) on XXXXX MNVR YYYYY. I-TGT selection via the MNVR display is the preferred way to select targets post-MECO, since use of the abort pb may not call up the desired target required for a specific AOA scenario. A description of the target hierarchy is included in the XXXXX MNVR YYYYY display writeup in section 3.1.2.

a. Option 1: Nominal OMS-1 - Nominal OMS-2

The nominal target set, ITGT=0, is I-loaded and will come up automatically in MM 104. Note that if an ATO has been selected pre-MECO, ATO targets will appear. In this case the crew must manually key in nominal targets if they are desired. For STS 61-C the nominal OMS-1 burn occurs at a TIG of MECO+2 min with a total  $\Delta V$  of 240 fps. The post OMS-1 orbit is 160 by 50 n. mi. For SI flights, the post OMS-1 apogee is positioned to preserve a minimum  $\Delta V$  capability for AOA steep deorbit on OMS-2, if necessary. The nominal OMS-2 burn is done near apogee at 00:46:02 (HR:MIN:SEC) MET with a  $\Delta V$  of 196 fps. This burn circularizes the orbit at 160 n. mi. This target can be used for underspeeds of up to 114 fps off the nominal MECO velocity. The OMS budget is built to provide this underspeed capability while protecting for nominal mission completion.

Options 2 and 3 use the same OMS-1 target as Option 1. The same NO COMM OMS-1 targeting rationale would apply in those cases as well. Options 2 and 3 provide for systems failures and/or performance degradations requiring AOA that occur post OMS-1.

b. Option 2: Nominal OMS-1 - steep AOA

This target set provides for insertion into a 160 by 50 n. mi. orbit with a nominal MECO state and a nominal OMS-1 burn as in option 1. It also provides an AOA steep deorbit OMS-2 burn of 407 fps. This burn is made at a TIG of 00:49:50 MET. MECO underspeeds of up to 114 fps are acceptable. These targets are used when noncritical, non-OMS failures occur before OMS-2.

While the OMS-1 target is I-loaded, the OMS-2 AOA target can be selected in MM 105 via the ABORT pb or via item entry (I-TGT=12) on the MNVR EXEC display. This latter method is referred to as "dial-a-target". The required deorbit I-load target data (TIG, C1, C2,  $\Theta T$ , HT) will appear and will be transferred to the DEORB MNVR COAST display after moding the software from MM 105 to MM 301. If necessary, the crew may key-in the desired AOA deorbit targets after proceeding from MM 105 to OPS 3 on the MNVR EXEC display. For AOA's the crew should not do a load (item 22) until OPS 3 since  $\Theta T$  is measured differently between OPS 1 and OPS 3. In OPS 1,  $\Theta T$  is the downrange angle from the launch site to the radius target vector in degrees. In OPS 3,  $\Theta T$  is the angle from OMS-2 TIG to EI.

c. Option 3: Nominal OMS-1 - shallow AOA

This target set provides for insertion into a 160 by 50 n. mi. orbit with a nominal MECO state and a nominal OMS-1 burn as in options 1 and 2. However, this target set utilizes a shallow AOA deorbit OMS-2 target. The OMS-2  $\Delta V$  is 53 fps and TIG is nominally set at 00:29:05 MET. This target set would only be used in the event of a severe  $\Delta V$  capability loss after the OMS-1 burn. This deorbit target (I-TGT 11) is the minimum  $\Delta V$  target available after a nominal OMS-1 and can be selected via the MNVR EXEC. A steep deorbit target is preferred over a shallow one, if performance allows, since shallow targeting assumes 90° prebank from EI-5 through first bank command.

d. Option 4: Delayed nominal OMS-1 - nominal OMS-2

This set of targets is similar to option 1 except that the OMS-1 burn is delayed for 12 min after MECO and is used for the feedline disconnect failure case. In this scenario, the Orbiter remains attached to the ET until the ET has vented enough hydrogen and oxygen to avoid the danger of a vent pressure induced recontact at ET SEP. This target is designed for a nominal MECO energy state and does not provide for situations involving underspeeds or other failures requiring downmode to ATO. Both OMS targets are key-in targets. The OMS-2 TIG should be selected at TTA-1 min to center the burn about apogee.

For STS 61-C, the OMS-1  $\Delta V$  is 288 fps, which places the Orbiter in a 161 by 81 n. mi. orbit post OMS-1 with apogee 240° from the launch site. The OMS-2 burn of 142 fps would circularize the orbit at 160 n. mi. This burn is initiated at 01:02:22 MET.

Options 5 and 6 use the same OMS-1 target as option 4. The same no-comm OMS-1 targeting rationale would apply in those cases as well. These options provide for systems failures and/or performance degradations requiring AOA that occur post OMS-1.

e. Option 5: Delayed nominal OMS-1 - steep AOA

This target set utilizes the same OMS-1 target as option 4, but a steep AOA deorbit target is used for OMS-2. The OMS-2 burn of 351.2 fps is initiated at 00:37:08 MET, 148° from EI. This option will be used if a failure and/or performance degradation requiring AOA occurs after the delayed nominal OMS-1 burn is started. The OMS-2 targets are entered by selecting I-TGT = 10.

f. Option 6: Delayed nominal OMS-1 - shallow AOA

This target is similar to option 4 except that a shallow AOA entry is made. The OMS-2 burn of 177 fps is made at 00:33:48 MET and 157° ahead of the EI. Like option 3, this option would only be used when severe loss in  $\Delta V$  capability occurred after OMS-1 burn ignition. On flights with similar OMS-2  $\Delta V$  requirements for options 5 and 6, this OMS-2 target (I-TGT 8) will not be used. If the velocity requirement for

steep is similar to shallow, it is hard to justify a shallow deorbit with the reduced level of confidence inherent to the shallow option.

g. Option 7: ATO OMS-1 - ATO OMS-2

This set of targets is used for MECO underspeed conditions that fall within the specified ATO underspeed range requiring a downmode from the nominal OMS-1 burn. On STS 61-C (cycle 1), the maximum ATO underspeed was 466 fps. For an underspeed of 404 fps, an OMS-1 burn of 571 fps is made 2 min after MECO and is targeted to raise the orbit to 105 by 60 n. mi. and place apogee at 235° from the launch site to preserve the AOA capability. The OMS-2 burn of 82 fps raises the orbit to 105 by 105 n. mi. This burn is initiated near apogee at 01:03:10 MET.

These targets are loaded automatically when the ATO mode is selected on the ABORT rotary switch I-TGT = 1. The OMS-2 targets are displayed on the MNVR display after the crew modes into OPS 105. OMS-2 TIG occurs in the vicinity of apogee to maximize burn efficiency.

Options 8 and 9 use the same OMS-1 target as option 7. The same no-comm OMS-1 targeting rationale would apply in those cases as well. These options provide for systems failures and/or performance degradations requiring AOA that occur post OMS-1. Additionally, burning the ATO common target allows the crew to hold off committing to an AOA until after the first burn.

h. Option 8: ATO OMS-1 - steep AOA

This target set utilizes the ATO common target (as does option 7) but includes a steep AOA deorbit OMS-2 maneuver. The OMS-2 burn of 171 fps begins at 00:51:51 MET, 85° from EI. The lower propellant requirement increases underspeed capability to allow the MECO underspeed coverage to be increased to 523 fps. The OMS-2 targets are entered by selecting I-TGT = 6.

i. Option 9: ATO OMS-1 - Shallow AOA

This target set utilizes the ATO common target (like options 7 and 8) but requires a shallow AOA deorbit target for OMS-2. The OMS-2 burn of 110 fps is made at 00:41:42 MET, 120° from EI. This target gives the same underspeed coverage as option 8, but utilizes less propellant and is intended for use in performance-critical cases such as propellant failures occurring post-OMS-1 ignition. The OMS-2 targets are selected via keyboard entry of I-TGT = 7.

j. Option 10: AOA-shallow OMS-1 - shallow AOA

This set of targets will be used only for severe MECO underspeed where the ATO OMS-1 burn cannot be used because of the high  $\Delta V$  requirement from either the nominal or the abort MECO. The OMS-2 target set protects for a maximum change in HA + HP between OMS burns of 5 n. mi. In this way, a drag limit is imposed on the postburn target.

For STS 61-C, the AOA-S OMS-1 target was designed to raise the orbit to 84 by 54 n. mi. The target orbit for the AOA-S/S is flight dependent but will not violate the basic groundrules described above. On STS 61-C, this target provides coverage to an underspeed of 600 fps. For an underspeed of 559 fps, the required  $\Delta V$  is 741.9 fps. The OMS-2 burn of 92 fps is initiated at 00:49:12 MET, 83.3° from EI.

Post-MECO, the crew will depress the abort pb with the abort rotary switch in the TAL/AOA-S position. In this manner OMS-1 AOA shallow targets will be called up automatically. The crew may also select the AOA shallow abort mode by keying in the AOA shallow target (I-TGT = 5). The deorbit targets will automatically appear on the MNVR display after entering MM 105 and will be carried across the OPS transition.

k. Option 11: Delayed ATO OMS-1 - ATO OMS-2

This set of targets is used for failures occurring prior to OMS-1 resulting in a significant decrease in available onboard  $\Delta V$  (e.g., one OMS pod out). Delaying the burn to MECO+12 allows additional time to evaluate the failures. For STS 61-C, delayed ATO OMS-1 burn coverage existed for MECO underspeeds up to 140 fps. If no underspeed condition exists at MECO, the OMS-1  $\Delta V$  is approximately 192 fps. This would put the Orbiter in a 104 by 81 n. mi. orbit with apogee at 235° from the launch site. This orbit could be maintained for three to five orbits if needed before deorbiting. If sufficient propellant is available, then an OMS-2 burn of 44 fps would circularize the orbit at 103 n. mi. and thus extend the flight time to about 24 hours. The ATO OMS-2 burn would be made near apogee at 01:01:43 MET.

The OMS-1 target may be entered manually, selected via I-TGT 1 on the MNVR EXEC display, or selected automatically via ATO selection with the ABORT MODE rotary switch. If either of the latter two methods are employed, the TIG time will have to be changed. If the rotary switch is used, both OMS-1 and OMS-2 targets will automatically be selected. The TIG for OMS-2 should be made 30 sec prior to apogee.

Options 12 and 13 use the same OMS-1 target as option 11. The same no-comm OMS-2 targeting rationale would apply in those cases as well. These options provide for systems failures and/or performance degradations requiring AOA that occur post OMS-1. Additionally, burning the ATO common target allows the crew to hold off committing to an AOA until after the first burn.

l. Option 12: Delayed ATO OMS-1 - steep AOA

This target set utilizes the same OMS-1 target as option 11, but a steep AOA deorbit is used for OMS-2. The OMS-2 target is similar to option 8 and will be used when a failure requiring AOA occurs after the delayed OMS-1 burn. The OMS-2 burn of 210 fps, is started at 00:51:11 MET, 86.1° from EI. The crew will enter the deorbit targets by selecting I-TGT = 6 in MM 105.

m. Option 13: Delayed ATO OMS-1 - Shallow AOA

This target set is similar to option 12 except that a shallow AOA deorbit is used for OMS-2. The same rationale for target selection applies except that this target set would be used if a severe  $\Delta V$  shortage occurs post OMS-1. The OMS-2 burn of 139 fps is initiated at 00:41:03 MET and utilizes targets similar to option 9 which the crew enters by selecting I-TGT = 7. This target set could be used if an OMS loss occurred after the OMS-1 burn started.

n. Option 14: Delayed AOA shallow OMS-1 - shallow AOA

This target set will be used when nominal MECO conditions have been achieved but the onboard  $\Delta V$  capability has been severely degraded (i.e., the loss of two helium tanks) prior to MECO. OMS-1 TIG occurs closer to apogee of the MECO orbit due to the TIG delay (MECO+12 min), thus reducing the  $\Delta V$  requirement. For mission STS 61-C, an OMS-1 burn of 148.7 fps is required and places the Orbiter in a 94 by 68 n. mi. orbit with the apogee  $175^\circ$  from the launch site. An AOA shallow deorbit burn is performed to minimize the OMS-2 velocity requirement. This burn of 105 fps is started at 51:23 MET targeting for EI  $73^\circ$  away. These targets are selected by entering I-TGT = 4 or keying in the targets on the MNVR display.

### 3.2.2.2 Direct Insertion

On STS-26, nominal MECO occurs at a velocity of 25871 fps and an altitude of 57 n. mi. The post-MECO orbit was 156 by 35 n. mi. (HA X HP). The OMS-1 and OMS-2 target options discussed in this section represent the current targeting options available on DI flights. Target data contained in this section, unless otherwise specified, pertains to STS-26 cycle 1 and is typical of DI flights. The target data described below is summarized in table 3.2-II and figures 3.2-8 and 3.2-9. Note that the target altitudes are based on spherical Earth models and are slightly higher than actual values.

TABLE 3.2-II.- DIRECT INSERTION TARGET OPTIONS

STS-76A CYCLE 1 AOA TO EDW (PRIME LANDING SITE) QVS TARGET SUMMARY TABLE QV's IMPLANT APPROXIMATE

| ONBD | MCC | ONBD | MCC | AOA (ONS-2) | AME | AME  | IFC | MECO APOCIE DESIGN RANZ | MECO UNDSPP DESIGN RANZ | TGTS  | TIG    | ONS-1     |             |           | TGTS  | TIG     | TIG/ADJ | MECO* ETSEP* | CI (EPS) | C2 (ND) | HTCT (MM) | THETA (MM) | THETA DISPLAY (MM) | RANZ | SVI (FPS) |
|------|-----|------|-----|-------------|-----|------|-----|-------------------------|-------------------------|-------|--------|-----------|-------------|-----------|-------|---------|---------|--------------|----------|---------|-----------|------------|--------------------|------|-----------|
|      |     |      |     |             |     |      |     |                         |                         |       |        | HTCT (MM) | THETA (DEC) | SVI (FPS) |       |         |         |              |          |         |           |            |                    |      |           |
| 16   | 16  | 16   | 16  | 16          | 1.7 | 0.0  | 0.0 | 156                     | 0                       | 0     |        |           |             |           |       | 39:53   | 31:23   | 10.0000      | 0.0000   | 167.0   | 326.0     | 0000.0     | 0000.0             | 43.2 |           |
| --   | --  | 11   | 11  | 9           | -1  |      |     | 156-150                 | 0                       |       |        |           |             |           |       | 42:56   | 33:18   | 14043.       | -0.5968  | 65.0    | 125.6     | 4186.8     | 251.3              |      |           |
| --   | --  | 10   | 10  | 10          | -1  |      |     | 156-150                 | 0                       |       |        |           |             |           |       |         | 33:28   |              |          |         |           |            |                    |      |           |
| --   | --  | 9    | 9   | 9           | -1  |      |     | 156-150                 | 0                       |       |        |           |             |           |       | 22:43   | 13:25   | 15580.       | -0.6201  | 65.0    | 205.0     | 4486.3     | 92.5               |      |           |
| --   | --  | 9    | 9   | 9           | -1  |      |     | 158-95                  | 175                     |       |        |           |             |           |       | 35:38   | 25:26   | 15620.       | -0.6289  | 65.0    | 159.2     | 4233.9     | 604.5              |      |           |
| --   | --  | 8    | 8   | 10          | -1  |      |     | 158-95                  | 175                     |       |        |           |             |           |       | 23:27   | 13:25   | 14821.       | -0.5905  | 65.0    | 204.6     | 4578.4     | 342.4              |      |           |
| 3    | 2   | 2    | 2   | 2           | 0   | -1-1 |     | 67                      | 386                     | ATO   | MECO-2 | 114.0     | 235.0       | 353.8     | ATO   | 1:03:22 | 53:18   | 0.00         | 0.0000   | 113.0   | 415.0     | 0.0        | 0.0                | 93   |           |
| 3    | 3   | 3    | 3   | 3           | 2   | 2    |     | 67                      | 386                     | ATO   | ITA-2  |           |             |           |       | 89:00   | 53:00   |              |          |         |           |            |                    |      |           |
| 3    | 3   | 3    | 3   | 3           | 2   | 2    |     | 67                      | 386                     | ATO   | MECO-2 | 114.0     | 235.0       | 353.6     | ATO   | 52:01   | 41:59   | 16625.       | -0.6650  | 65.0    | 65.4      | 4237.8     | 173.9              |      |           |
| 3    | 4   | 4    | 4   | 4           | 10  | 3    |     | 67                      | 386                     | ATO   | ITA-2  |           |             |           |       | 41:51   | 41:41   |              |          |         |           |            |                    |      |           |
| 5    | 5   | 5    | 5   | 5           | 11  | 4    |     | 60                      | 622                     | AOASH | MECO-2 | 95.0      | 225.0       | 563.1     | AOASH | 41:53   | 31:51   | 16983.       | -0.6726  | 65.0    | 120.7     | 4020.7     | 120.0              |      |           |
|      |     |      |     |             |     |      |     |                         |                         |       | ITA-2  |           |             |           |       | 49:23   | 39:20   | 19872.       | -0.7529  | 65.0    | 63.2      | 3855.4     | 93.9               |      |           |
|      |     |      |     |             |     |      |     |                         |                         |       |        |           |             |           |       |         | 39:02   |              |          |         |           |            |                    |      |           |

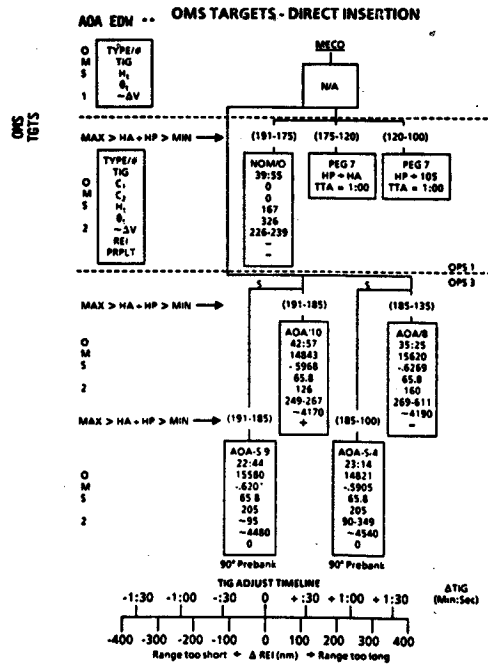


Figure 3.2-8.- STS 26-B OMS targets - DI.

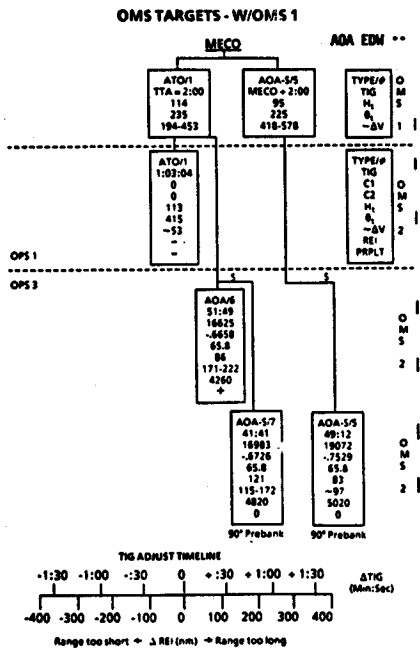


Figure 3.2-9.- STS 26-B OMS targets - W/OMS-1.

Most targets are available in the software and can be selected with the ABORT MODE rotary switch or by I-TGT selection (item 35) on XXXXX MNVR YYYYY. I-TGT selection via the MNVR display is the preferred way to select targets post-MECO since use of the abort pb may not call up the desired target set required for a specific AOA scenario.

a. Option 1: DI - nominal OMS-2

In MM 104, a nominal OMS-1 target set is loaded by the software and targets the vehicle to a 160 n. mi. post-MPS dump apogee. This target set is designed to disable the OMS-1 burn for the nominal mission and will not be executed by the crew. The nominal OMS-2 target is I-loaded and will come up automatically in MM 105. Note that if ATO was selected pre-MECO, ATO OMS-1 targets will appear. In this case the crew must manually key in nominal targets if they are desired. For STS 26-B, the nominal OMS-2 burn occurs at a TIG of 39:55 with a total  $\Delta V$  of 221 fps. This burn will circularize the orbit at 160 n. mi. Nominally, the OMS-2 burn is done near apogee to increase burn efficiency. This target set can be used for MECO underspeeds from 0 to 30 fps with the nominal OMS-2 TIG. The OMS budget is built to provide this underspeed capability while protecting for nominal mission completion.

b. Option 1A: DI - Safe HP

The DI/safe HP maneuver is required for the MECO underspeed range of 30 to 165 fps. If the nominal PEG 4 OMS-2 targets were burned in this underspeed region, the theta target would produce a large undesirable apsidal rotation, making the burn non-optimum. The alternate approach is to use the PEG 7 external  $\Delta V$ , in which the crew can load a large  $\Delta V_X$  component long the velocity vector and initiate the burn 1 min prior to apogee (TTA = 1 min). During the OMS burn the crew will monitor the current perigee and shut down the OMS engines via the arm/press switches after the perigee reaches a safe altitude. In the underspeed range of 30 to 125 fps this maneuver will circularize at MECO HA. For underspeeds of 125 to 165 fps this maneuver will raise perigee to 105 n. mi. The crew may then elect to perform additional OMS burns to continue the mission or perform a deorbit maneuver at a later time.

Options 2, 3, 4, and 5 use the same OMS-1 target as option 1. Options 2 to 5 are used for systems problems requiring immediate deorbit from a nominal MECO state.

c. Options 2 and 3: DI - steep AOA

As indicated above, these targets will be used for systems problems requiring immediate deorbit from a near nominal MECO energy state. These failures are listed on the OMS-1 and OMS-2 targeting pages of the checklist. Option 2 (I-TGT 10) will provide coverage for  $191 > (HA+HP) > 185$ . Option 4 (I-TGT 8) will provides coverage for  $185 > (HA+HP) > 135$ . For STS-26, the option 2 burn of the 543 fps will occur at a TIG of 42:57,  $126^\circ$  from EI. The option 4 burn of 543 fps will occur at a



TIG of 35:24, 160° from EI. Due to the apogee range covered by the latter target, the specific  $\Delta V$  value could vary substantially.

These targets will be selected via "dial-a-target" on the MNVR EXEC display in MM 105, but will not be loaded until OPS 3. This is due to the fact that  $\Theta T$  is measured differently in OPS 1 than in OPS 3. In OPS 1,  $\Theta T$  is the downrange angle from the launch site to the radius vector of the target in degrees. In OPS 3,  $\Theta T$  is the angle from OMS-2 TIG to EI.

d. Options 4 and 5: DI - Shallow AOA

As with the AOA steep targets (options 2 and 3), these targets will be used for systems problems requiring immediate deorbit from a near nominal MECO energy state. Since shallow deorbit is less desirable than steep, these targets are reserved for performance-critical cases where sufficient  $\Delta V$  does not exist to do an AOA steep.

Failures requiring AOA are listed on the OMS-1 and OMS-2 targeting pages of the checklist. Option 3 (I-TGT 9) will provide coverage for 191 > (HA+HP) > 185. Option 5 (I-TGT 4) will provide coverage for 185 > (HA+HP) > 100. For STS 26-A the option 3 burn of 92 fps will occur at TIG of 22:44, 205° from EI. The option 5 burn of 90 fps will occur at a TIG of 23:13, 205° from EI. Due to the apogee range covered by this target, this  $\Delta V$  value could vary substantially.

e. Option 6: ATO OMS-1 - ATO OMS-2

On STS 26 this target is designed for the 166 to 352 fps MECO underspeed range. As a rule of thumb, the larger the underspeed at MECO, the smaller the TTA of the MECO orbit. To optimize the burn (minimize  $\Delta V$ ) it is best to burn in the vicinity of apogee because this will minimize apsidal shift. Therefore, if the TTA is greater than 2 min after the MM 104 transition, the crew will key in the delayed TIG and perform the burn near apogee. For large MECO underspeeds where TTA is less than 2 min, the burn will be performed at MECO+2 min.

For an STS 26 MECO underspeed of 256 fps, the OMS-1 ATO burn of 240 fps selected via I-TGT 1 is done at apogee -2 minutes (but no earlier than MECO+2 min) keyed in the MNVR display. Apogee will be 235° downrange from the launch site. The OMS-2 burn of 53 fps is done at 1:03:03. Target apogee is 415° from the launch pad. Options 7 and 8 provide steep and shallow deorbit opportunities respectively for deorbit after using this OMS-1 burn.

f. Option 7: ATO OMS-1 - Steep AOA

After the TTA = 2 min ATO OMS-1 burn (same as option 6 OMS-1) is complete, the crew will use the dual or single pod OMS required tables on page 2-9 of the checklist to determine whether sufficient prop remains to continue uphill via ATO or deorbit on OMS-2 is required. Option 7 provides an opportunity for steep deorbit after the ATO OMS-1

burn. The OMS-2 burn of 191 fps, selected via I-TGT 6, is initiated at 00:51:48 MET, 86° from EI.

g. Option 8: ATO OMS-1 - shallow AOA

After the TTA = 2 min ATO OMS-1 burn (same OMS-1 target as option 6) is complete, the crew will use the dual or single pod OMS required tables on page 2-9 of the checklist to determine whether sufficient propellant remains to continue uphill via ATO or deorbit with OMS-2 is required. Option 8 provides a shallow deorbit opportunity. The OMS-2 burn of 138 fps, selected via I-TGT 7, is initiated 00:41:40 MET, 121° from EI.

Since AOA steep is preferred over AOA shallow, the steep deorbit (option 7) will be used for deorbit after the TTA = 2 min ATO OMS-1 burn if possible. The shallow target will be used in performance-critical cases where there is not sufficient propellant to complete a steep deorbit burn.

h. Option 9: AOA-Shallow OMS-1 - shallow AOA

This target set will be used for severe MECO underspeeds where the ATO OMS-1 burn cannot be used because of the high  $\Delta V$  requirements from either the nominal or abort MECO. The shallow OMS-1 burn targets are designed to minimize OMS propellant usage while satisfying the post OMS-1 drag constraint. The drag constraint requires that the change in (HA+HP) between OMS-1 cutoff and OMS-2 ignition will not exceed 5 n. mi.

For STS-26, the AOA-shallow OMS-1 target was designed to raise the orbit to 87 by 59 n. mi. The target orbit for the AOA-S/S is flight dependent but will not violate the basic groundrules described above. On STS-26, this target provides coverage to an underspeed of 633 fps. For an underspeed of 643 fps, the required  $\Delta V$  is 563 fps. The OMS-2 burn of 94 fps is initiated at 00:49:11 MET, 83° from EI.

Post-MECO, the crew will depress the abort pb with the abort rotary switch in the TAL/AOA-S position. In this manner OMS-1 AOA shallow targets will be called up automatically. The crew may also select the AOA shallow abort mode by keying in the AOA shallow target (I-TGT = 5). The deorbit targets will automatically appear on the MNVR display after entering MM 105 and will be carried across the OPS transition.

### 3.3 ASCENT/ABORT CREW PROCEDURES RATIONALE

This section describes crew procedures and provides supporting rationale for nominal, ATO, AOA, RTLS, TAL, LATE TAL, and Contingency Abort phases of flight. Procedures for each flight phase are discussed sequentially, as per the Ascent Checklist, with rationale accompanying each procedure.

Table 3.3-I gives a sequential listing of the ascent and abort sequence of events. This timeline begins prelaunch and progresses through OMS-2 for nominal and ATO flight; through entry interface for AOA; through landing for TAL, LATE TAL, and RTLS; and through the bailout for contingency aborts. For each event, the following information has been provided:

- a. Name of the event
- b. The corresponding crew procedure
- c. The location of discussion pertaining to this procedure. In addition to procedures and rationale, this discussion will cover event-related operational information such as event resultant configuration changes, ground support and interfacing, procedures rationale, crew monitoring and manual control techniques, major changes or constraints in performance capabilities, and any backup procedures associated with the event.

TABLE 3.3-I.- SUMMARY LIST OF EVENTS

| Cue                     | Event                                | Page   |
|-------------------------|--------------------------------------|--------|
|                         | <u>Nominal</u>                       |        |
| -2:25:0 to lift-off     | Prelaunch activities                 |        |
|                         | Ascent powered flight procedures     | 3.3-15 |
| Pc and physiological    | SSME start to roll complete          | 3.3-17 |
| THROT and MPS Pc        | SSME throttling (bucket)             | 3.3-17 |
| "Pc < 50"               | SRB separation                       | 3.3-21 |
| Evap out temp < 60°     | Flash evaporator activation          | 3.3-23 |
| MPS Pc                  | 3g throttling                        | 3.3-24 |
| Pc and SSME status lts  | MECO and ET separation               | 3.3-24 |
|                         | Attitude check                       | 3.3-24 |
| CRT time, OMS Pc, TIG-2 | OMS-1 burn procedures                | 3.3-28 |
|                         | Post OMS-1 procedures                | 3.3-32 |
|                         | Postburn status                      | 3.3-32 |
|                         | Alpha management                     | 3.3-33 |
|                         | APU/HYD shutdown (not AOA)           | 3.3-33 |
|                         | FES and heater activation            | 3.3-34 |
|                         | AC bus sensor                        | 3.3-34 |
|                         | Major mode change                    | 3.3-34 |
| In MM105                | OMS-2 burn setup                     | 3.3-35 |
|                         | MPS powerdown                        | 3.3-36 |
|                         | MPS vacuum inerting activate         | 3.3-36 |
|                         | ET umbilical door closure            | 3.3-37 |
|                         | OMS burn prep                        | 3.3-38 |
|                         | OMS-2 burn attitude MNVR             | 3.3-39 |
| After LOS               | Seat safing and adjustment           | 3.3-39 |
| OMS-2 TIG-5             | MPS vacuum inerting terminate        | 3.3-40 |
| CRT time, OMS Pc, TIG-2 | OMS-2 burn procedures                | 3.3-40 |
|                         | OPS 1 RCS burn                       | 3.3-41 |
| Post OMS-2 burn         | Post OMS-2 procedures                | 3.3-47 |
|                         | OMS TVC gimbal check                 | 3.3-48 |
|                         | OMS/RCS postburn reconfiguration     | 3.3-49 |
| AOS/LOS                 | Major mode change                    | 3.3-49 |
|                         | Uplink block and unblock             | 3.3-49 |
| SSME status lts         | <u>Monitoring and Manual Control</u> |        |
|                         | SSME failure                         | 3.1-53 |
|                         | Abort initiation                     | 3.1-54 |
|                         | BFS engagement                       | 3.1-56 |
|                         | Feedline disconnect valve failure    | 3.1-56 |

TABLE 3.3-I.- Continued

| Cue                            | Event                             | Page   |
|--------------------------------|-----------------------------------|--------|
|                                | <u>AOA Procedures</u>             |        |
| Post-OMS-1<br>OMS-1 TIG + 2:21 | Alpha management                  | 3.3-51 |
|                                | HYD depress (AOA only)            | 3.3-51 |
|                                | AOA del pad                       | 3.3-52 |
|                                | OPS reconfiguration               | 3.3-53 |
|                                | OMS 2 burn setup                  | 3.3-54 |
|                                | OMS TVC gimbal check              | 3.3-55 |
|                                | Seat adjustment                   | 3.3-55 |
|                                | OMS burn prep                     | 3.3-56 |
|                                | OMS burn TIG adjust (if required) | 3.3-56 |
|                                | MNVR to deorbit burn attitude     | 3.3-57 |
|                                | Vacuum inerting terminate         | 3.3-57 |
|                                | Underburn                         | 3.3-57 |
|                                | OMS/RCS reconfiguration, MM 303   | 3.3-58 |
|                                | Determine prebank                 | 3.3-58 |
|                                | Post burn                         | 3.3-59 |
|                                | MNVR to EI-5 Att                  | 3.3-60 |
|                                | OMS gimbal powerdown              | 3.3-60 |
|                                | Forward RCS dump                  | 3.3-60 |
|                                | Isolate FWD RCS                   | 3.3-61 |
|                                | State vector change (if required) | 3.3-62 |
|                                | Horiz sit config                  | 3.3-62 |
|                                | <u>TAL</u>                        |        |
| Abort initiation               | Tal initiation                    | 3.3-64 |
|                                | TAL dump                          | 3.3-64 |
|                                | Second engine failure             | 3.3-65 |
|                                | Roll heads up                     | 3.3-66 |
|                                | MECO                              | 3.3-66 |
|                                | ET separation                     | 3.3-67 |
|                                | ET door closure                   | 3.3-67 |
|                                | OPS 301 PRO                       | 3.3-67 |
|                                | MPS dump                          | 3.3-68 |
|                                | MPS system cleanup                | 3.3-69 |
| After ET SEP                   | NAVAID management                 | 3.3-69 |
|                                | <u>LATE TAL procedures</u>        |        |
| MECO + 18                      | MECO                              | 3.3-71 |
| MM 104                         | ET separation                     | 3.3-72 |
| MM 104                         | Roll heads up                     | 3.3-72 |
|                                | OPS 3 transition                  | 3.3-72 |
|                                | MPS dump                          | 3.3-72 |
|                                | OMS dump                          | 3.3-72 |
|                                | Entry setup                       | 3.3-72 |

TABLE 3.3-I.- Concluded

| Cue   | Event   | Page    |
|---|---|---------|
|   | <u>RTLS</u>   |         |
| MM 601 initiation                             | MPS throttling (3-eng RTLS)   | 3.3-76  |
| MM 601 initiation                             | Pre-MECO OMS/RCS dump (RTLS)  | 3.3-77  |
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| MCC time, PPA monitor, PRPLT                  | Pitcharound maneuver (RTLS)   | 3.3-78  |
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| Major mode change                             | MM 602 transition, alpha recovery phase, elevon and body flap activation (RTLS) | 3.3-85  |
| ET UMBILICAL DOOR tbs                         | ET umbilical doors closure (RTLS)   | 3.3-87  |
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|   | Tacan AOS and management (RTLS)   | 3.3-89  |
| KEAS = 54 and 77                              | Pitch and roll RCS jets deactivation and speedbrake operation (RTLS)            | 3.3-90  |
| KEAS = 121                                    | RCS activity light reconfiguration (RTLS)                                       | 3.3-92  |
| 1.65 g  | Nz hold phase (RTLS)  | 3.3-92  |
| $\dot{H} > -250$ fps, $\alpha > \alpha_{ref}$ | S-turns (RTLS), alpha transition phase (RTLS)                                   | 3.3-94  |
| MM change, Mach = 3.2                         | Transition to MM603, nominal TAEM interface (RTLS)                              | 3.3-95  |
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|   | <u>Contingency abort</u>  |         |
|   | 2 eng out blue  | 3.3-105 |
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|   | 3 eng out green   | 3.3-143 |
|   | 3 eng out red (LATE TAL)  |         |
|   | <u>RTLS contingency abort</u>   |         |
|   | 2 eng out blue  | 3.3-114 |
|   | 2 eng out yellow  | 3.3-122 |
|   | 2 eng out orange  | 3.3-124 |
|   | 2 eng out green   | 3.3-129 |
|   | 2 eng out red   | 3.3-146 |
|   | 3 eng out orange  | 3.3-127 |
|   | 3 eng out green   | 3.3-132 |
|   | 3 eng out blue  | 3.3-134 |
|   | 3 eng out yellow  | 3.3-138 |

### 3.3.1 Nominal/ATO Procedures

This section contains a discussion of the crew procedures and supporting rationale for prelaunch, nominal powered flight, nominal post-MECO, and ATO post-MECO phases of flight.

#### 3.3.1.1 Prelaunch Procedures

Prelaunch activities are controlled by the Launch Control Center (LCC). The LCC will give calls to initiate an activity and will expect a call from crewmembers when an activity is complete. A series of automated checks and operations are done during prelaunch. Therefore, the crew will not manipulate switches or CRT's without LCC concurrence. The first time (T-) listed alongside the procedures in the checklist does not reflect the planned hold times. There are two planned holds after crew ingress: 10 min at T-20 min and 10 min at T-9 min. The second time (L-) listed in the checklist does reflect the planned hold times.

The immediate crew actions to be done for a recycle after T-5 min are given in the recycle procedures. These procedures are printed on the page preceding the normal prelaunch procedures. The procedures are short and self-explanatory. These procedures include only the time-critical steps. The Orbiter test conductor (OTC) will call the individual steps for the rest of the recycle procedure. The normal prelaunch procedures start here.

|                      |                             |
|----------------------|-----------------------------|
| 1: GNC GPC MEMORY    | 2: GNC 104 GND IMU CNTL/MON |
| 3: GNC 1 DPS UTILITY |                             |

• -2:25:00 PRE-INGRESS SW RECONFIGURATION |

**NOTE**

ASP configures OI PCMMU  
PWR - 1\*\*\*(C3), RCS/OMS HTR  
FWD,AFT RCS JET 1,2,3,4  
(eight) - OFF (A14), ESS  
BUS SOURCE FC (three) - ON,  
AC BUS SNSR (three) - OFF  
(1 sec) then AUTO TRIP (R1)

• -1:50:00 A INGRESS ORBITER & SEATS  
(-2:10:00)

**NOTE**

During seat ingress COMM  
PWR - ON (L5, R6)  
CCU PWR - ON (A11, A15, MO39M)

05/09 AUD VOX SENS (as needed) - adj  
R10/L9 as reqd  
MO42F Contact LCC (OTC & NTD) on A/G 1

• -1:45:00 POST INGRESS SW RECONFIGURATION  
(-2:05:00)

**NOTE**

ASP turns on RCS 1,2,3,4  
DRIVERS (eight) (014,015  
& 016), OMS ENG VLV (two)  
(014,016), GPC OUTPUT 5 - B/U  
(06), TACAN MODE (three) - GPC  
(07), RADAR ALTM (two) - ON (08)

Install ASC Flip Cards and Ascent  
ADI Cards

✓Cue Card positions

-1:35:00  
(-1:55:00)

**NOTE**

ASP doing C/W VOL adjust,  
expect MA

3.3-5

The Ascent Checklist prelaunch procedures start just prior to crew ingressing the Orbiter 2 hr 10 min before launch. The computer configuration is four computers running the precount GNC OPS 9 software and a fifth computer loaded with the BFS software in halt. Just prior to crew ingress, the astronaut support personnel (ASP) configure switches for lift-off that the flightcrew cannot reach and that need to be configured as close to lift-off as possible. The RCS jet heaters are turned off to reduce the electrical loads during ascent by the ground crew because the flight crew cannot reach the switches (panel A14). The electrical loads are a concern because low voltage at the SRB interface could prevent SRB SEP. Prelaunch the ac bus sensors are in the monitor mode during the time no one is in the Orbiter and are configured to AUTO/TRIP at this time (will be placed in 'MONITOR' position 8 min prior to launch). The RCS drivers and the OMS engine valves are left off as long as possible as a safety precaution. The ground crew assists the flightcrew into the seats and configures switches on the overhead panels.

|                      |                             |
|----------------------|-----------------------------|
| 1: GNC GPC MEMORY    | 2: GNC 104 GND IMU CNTL/MON |
| 3: GNC 1 DPS UTILITY |                             |

• -1:30:00 A ASTRO COMM CHECK  
(-1:50:00)

LCC will contact CDR, PLT, MS1 &  
MS2 on A/G 2, ICOM A, ICOM B  
then A/A

• A A/G VOICE CHECK

B A/G 1 Voice Check  
05/09 L,R AUD A/G 2 (two) - OFF  
A/A (two) - OFF  
Voice check with MCC

A/G 2 Voice Check  
L,R AUD A/G 2 (two) - T/R  
A/G 1 (two) - OFF  
Voice check with MCC

A/A Voice Check  
L,R AUD A/A (two) - T/R  
A/G 2 (two) - OFF  
Voice check with MCC

A Simo Voice Check (Launch Config)  
L,R AUD A/G 1 (two) - T/R  
A/G 2 (two) - T/R  
Voice check with MCC

When in the seats, the crew will conduct an intercom and air-to-ground voice check with LCC and MCC. This checks all the communication loops. The CDR and PLT will check each of their loops individually. Since the other crewmembers do not have access to their communication switches, they will check all loops simultaneously. Extensive communication checks are performed pre-ingress (before cryo loading).



NOTE  
Side hatch closure

- -1:10:00 C CABIN LEAK CHECK  
(-1:30:00)
  - L2 CAB VENT ISOL - OP (tb-OP)  
      ✓VENT tb - CL
  - 01 ✓CAB PRESS - increasing to 16.7 (MA)

The ground crew will close the side hatch by T-1:10:00. After the side hatch is closed, the cabin pressure is increased (cabin over pressurized). This is done with the vent valves open and vent isolation valves closed, then later in reverse, so both sets of valves can be verified.

|                      |                             |
|----------------------|-----------------------------|
| 1: GNC GPC MEMORY    | 2: GNC 104 GND IMU CNTL/MON |
| 3: GNC 1 DPS UTILITY |                             |

- -1:01:00 (DEU Equivalent)  
(-1:21:00)

✓2: GNC 104 GND IMU CNTL/MON

NOTE  
IMU preflight align begins

NOTE  
Flt crew functions from this point on will be initiated by a call from the OTC to proceed. The flt crew will report back to the OTC after completion

The launch processing system (LPS) calls up SPEC 104 and commands the start of the IMU preflight alignment. The crew functions from this point on will be initiated by a call from the OTC to proceed. The crew will report back to OTC after the function is complete. The crew will not take action unless authorized by OTC.

- -50:00 P H2O BOILER PREAMBINATION  
(-1:10:00)
  - R2 ✓BLR CNTLR (three) - ON  
      N2 SPLY (three) - ON

NOTE  
Vent vlv operation may occur earlier or later at LCC direction

At T-50 min, the crew will turn on the water boiler controllers and the boiler N<sub>2</sub> supply to prepare for APU startup. The boiler (BLR) CNTLR enables the logic and valve control circuits and enables the steam vent heaters. The boiler N<sub>2</sub> supply switch activates a valve to maintain N<sub>2</sub> pressure in the H<sub>2</sub>O tank. This procedure ensures that the water spray boiler (WSB) system steam vent heaters will be on by about an hour before launch to prevent freezing during ascent. The nitrogen supply valves are opened to pressurize the WSB water storage tank to allow proper initialization of the BFS management computation of water quantity.

- 45:00 C CABIN VENT REDUNDANCY CHECK  
 (-1:05:00)
  - L2 CAB VENT ISOL - CL (tb-CL)  
VENT - OP (tb-OP)

This procedure checks the two cabin vent isolation valves individually and continues the cabin leak check.

- 32:00 C PASS/BFS TRANSFER PREP  
 (-52:00)
  - 3: GNC GPC MEMORY
  - 06 GPC 5 MODE - STBY (tb-RUN)
  - C3 ✓BFC CRT SEL - 3+1  
DISP - ON
  - 3: BFS, GNC BFS MEMORY
  - CRT3 PASS/BFS XFER ENA - ITEM 25 EXEC

At T-32 min, preparation is made for the PASS/BFS transfer (one-shot transfer). The BFS display is called (BFS is standalone), and the crew enables the transfer. This sets the BFS to receive the data when the LPS commands the transfer at T-22 min.

|                        |                             |
|------------------------|-----------------------------|
| 1: GNC GPC MEMORY      | 2: GNC 104 GND IMU CNTL/MON |
| 3: BFS, GNC BFS MEMORY |                             |

- 30:00 OMS GN2 PRESS  
 (-50:00)
  - C3 OMS ENG (two) - ARM/PRESS
- CABIN VENT
  - L2 CAB VENT ISOL - OP (tb-OP)  
(kTaxon)
  - ✓VENT tb - OP
  - 01 ✓CAB PRESS - decreasing

The OMS ENG switches being placed in ARM/PRESS energizes the engine pressurization valves open. The engine pressurization valve, when energized open, allows GN<sub>2</sub> supply tank pressure to be directed into a regulator, through a check valve and an in-line reservoir, and to a pair of engines. This allows the ground to check the OMS status. The crew will open the cabin vent valves on a call from the ground to allow cabin pressure to bleed back to ambient pressure.

- 25:00 A A/G VOICE CHECK  
 (-45:00)
  - Simo Voice Check (Launch Config)  
Voice check with MCC
  - Update Abort Winds Pad, ASC Flip  
Book, and ALTM, 1-7 (if reqd)

At T-25 min, an air-to-ground voice check is performed on all loops simultaneously. Any update needed for RTLs, winds, ascent profile, or altimeter settings will be given to the crew during the voice check.

• -22:00 PASS/BFS TRANSFER (DEU Equivalent)  
(-42:00) (ONE-SHOT TRANSFER)

1: GNC 100 GTS DISPLAY

CRT3 /ITEM 25 - (no \*)

At T-22 min, the LPS initiates the one-shot PASS/BFS transfer. The GTS display automatically comes up on CRT 1 and the PASS/BFS transfer, item 15, is executed by the LPS. When the transfer is complete, the asterisk (\*) next to PASS/BFS XFER ENA, item 25, on BFS MEMORY display disappears and is verified by the crew on CRT 3. The data transferred to the BFS can include the launch polynomials, IMU calibration data, accelerometer data, SRB chamber coefficients and compensation bias, plus estimated mass of the Orbiter with the ET.

01 Report cabin pressure to OTC

NOTE

Vent vlv closure may occur earlier or later at LCC direction

• -21:00 C CLOSE VENT VLVS  
(-41:00)

L2 CAB VENT ISOL - CL (tb-CL)  
VENT - CL (tb-CL)

On request, CDR will read cabin pressure from panel 01 to the OTC, then on call the crew will close the cabin vent valves. This is done when the cabin has reached ambient pressure.

1: GNC 100 GTS DISPLAY 2: GNC 104 GND IMU CNTL/MON  
3: BFS, GNC BFS MEMORY

NOTE

At T-20 there will be a planned 10 minute hold

• -20:00 OPS 1 LOAD (DEU Equivalent)  
(-30:00)

1: GNC LAUNCH TRAJ 2: GNC LAUNCH TRAJ  
1: GNC O GPC MEMORY  
1: GNC FAULT

Report faults other than from unpowered equipment

CRT1 GNC, SPEC 99 PRO

NOTE

Gnd-Controlled Fuel Cell Purge

There is a 10-min planned hold at T-20 min. There are no prescheduled activities during planned holds; this time is set aside to catch up, if required, so that all functions will be ready when OPS 1 is initiated. At the end of the hold, the LPS does the OPS 1 transition for the PASS. After OPS 1 has been loaded as indicated by the OPS 1 display appearing on the CRT and a ground call, the crew will report, then clear any faults.

The IMU software configures from a velocity tilt mode to a biased inertial mode at the transition to OPS 1. One-g and Earth rate drift compensation factors are used to determine platform torquing requirements to cover the mode transition period and to maintain a predefined launch alignment until the platform becomes inertial at T-8 sec. In the inertial mode, compensation is limited to the zero-g factors used to ensure accurate inertial operation.

● -19:00 BFS TO OPS 1  
 (-29:00)

3: BFS, GNC FAULT

CRT3 GNC, SPEC 99 PRO  
 06 GPC 5 MODE - RUN (tb-RUN)

CRT3 GNC, OPS 101 PRO

3: BFS, GNC LAUNCH TRAJ 1'

3: BFS, GNC FAULT

Report faults other than from  
 unpowered equipment

CRT3 GNC, SPEC 99 PRO

On call the CDR clears the BFS fault page, then places the BFS GPC in RUN and transitions it to OPS 1. The fault page is cleared again; so any fault after this time will not be confused with faults that might occur during the OPS 1 transition.

1: GNC FAULT      2: GNC LAUNCH TRAJ

3: BFS, GNC FAULT

● P HORIZ SIT CONFIG

2: GNC 50 HORIZ SIT

3: BFS, GNC 50 HORIZ SIT

ALTM - ITEM 9 +               

|           | PASS ITEM |     | BFS ITEM |     |
|-----------|-----------|-----|----------|-----|
| PTI       | INH       | 1   |          |     |
| TAL SITE  | 2(3,4,5)  | 40/ | 2(3,4,5) | 40/ |
| RTLS SITE | 1         | 41/ | 1        | 41/ |
| PRI       | KSC 15    | 3*/ | KSC 15   | 3*/ |
| SEC       | KSC 33    | 4/  | KSC 33   | 4/  |
| TAC       | 59Y       | 5/  | 59Y      | 5/  |

\* If RWY KSC 33 selected: \*  
 \* 08 MLS CH tw (three) - 6 \*

|             |           |     |           |     |
|-------------|-----------|-----|-----------|-----|
| G&N         | OVHD      | 6/  | OVHD      | 6/  |
| XEP         | NEP       | 7/  | NEP       | 7/  |
| AIM         | NOM       | 8/  | NOM       | 8/  |
|             | (or CLSE) |     | (or CLSE) |     |
| SPDBK       | NOM       | 39/ |           |     |
| TAC         | INH       | 20/ | INH       | 20/ |
| DRAG H      | AUT       | 22/ | AUT       | 22/ |
| ADTA H      | INH       | 26/ | INH       | 26/ |
| ADTA TO G&C | INH       | 29/ | AUT       | 28/ |
| TAC         | DELTA     | 35/ |           |     |
| HUD         | 0         | 37/ |           |     |
|             | 0         | 38/ |           |     |

After entering OPS 1, the crew enters the altimeter settings for the RTLS site and checks the HSD setup. The HSD should be initialized in the correct configuration but may vary from flight to flight. If winds or weather require KSC 33 instead of KSC 15, an item 4 will have to be executed. Also, the MLS channel will have to be changed. Since the TAL target changes depending on the flight inclination, it is not called out in the procedure.

The crew verifies the status of the OMS interconnect discrete.

- CONFIG OMS I'CNCT (PASS/BFS)**

|  |                    |
|--|--------------------|
| P CRT2   | 2: GNC 51 OVERRIDE |
| 3: BFS OVERRIDE  |                    |
| ITEM 5 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> I'CNCT |                    |
| 1: GNC LAUNCH TRAJ   | 2: GNC SYS SUMM 1  |
| 3: BFS, GNC SYS SUMM 2   |                    |

- |                        |                   |
|------------------------|-------------------|
| 1: GNC LAUNCH TRAJ     | 2: GNC SYS SUMM 1 |
| 3: BFS, GNC SYS SUMM 2 |                   |

- 16:00  
(-26:00) **MPS He RECONFIGURATION**

R2 MPS He ISOL A,B (s1x) - OP  
PNEU He ISOL - OP

The crew sets the onboard switches to correspond to the LPS-commanded positions. This protects the SSME's from being shut down due to an inadvertent GPC command to close the isolation valves.

- CONFIG OMS/RCS XFEED VLVS**

**NOTE**  
OMS/RCS XFEED vlvs are reconfigured for launch by LPS

C CRT3 Report RCS QTYs F,L,R OXID,FU

|   | OXID                     | FU                       |
|---|--------------------------|--------------------------|
| F | <input type="checkbox"/> | <input type="checkbox"/> |
| L | <input type="checkbox"/> | <input type="checkbox"/> |
| R | <input type="checkbox"/> | <input type="checkbox"/> |

3: BFS, SM SYS SUMM 2

The LPS reconfigures the OMS/RCS crossfeed valves to open. The crew then reports the quantities from BFS GNC SYS SUMM 2 so the ground can calibrate their calculations.

- NOTE**  
At T-9 there will be a planned 10 min hold

**WEATHER UPDATE (if reqd)**  
Update Abort winds, RWY and ALTM setting

-9:00 **'GO FOR LAUNCH' - All**

C2 EVENT TIMER - START  
F7 ✓EVENT TIME ind - counting down

**NOTE**  
GLS starts

At T-9 min, there is a planned 10-min hold which is the last planned hold. The GO/NO-GO for launch calls are given. If required, the RTLS winds, runway, or altimeter will be updated. The ground launch sequencer (GLS), which is the automatic LPS, takes control at T-9 minutes. The EVENT TIMER is set up even though the CRT timer will also be counting to lift-off.

- -8:00 P AC SNSR TO MONITOR
  - R1 AC BUS SNSR (three) - OFF (1 sec),  
then MONITOR

Since loss of a bus could cause loss of electrical redundancy to a main engine, these switches are placed in monitor so they cannot disconnect a bus, while still giving C&W for over/undervoltage or overload conditions.

- -7:00 NOTE  
ACCESS ARM RETRACT  
✓Seat in launch position

At T-7 min, the access arm is retracted. The crew checks that their seats are in the launch position. The OTC will not call this out as the seats are set when the crew ingresses the vehicle.

|                       |                   |
|-----------------------|-------------------|
| 1: GNC LAUNCH TRAJ    | 2: GNC SYS SUMM 1 |
| 3: BFS, SM SYS SUMM 2 |                   |

- -6:00 P APU PRE START
  - R4 ✓HYD LG RET/CIRC VLV - CL
  - R2 ✓BLR N2 SPLY (three) - ON  
✓PWR (three) - ON  
✓CNTLR/HTR (three) - A  
✓APU AUTO SHUT DN (three) - ENA  
CNTL PWR (three) - ON  
HYD MN PUMP PRESS (three) - LO  
✓APU SPEED SEL (three) - NORM  
✓OPER (three) - OFF  
✓FUEL PUMP/VLV COOL (two) - OFF  
✓FUEL TK VLV (three) - CL  
✓HYD CIRC PUMP (three) - GPC  
✓cb APU FU TK VLV ENA (six) - c1  
APU FUEL TK VLV (three) - OP  
✓APU/HYD RDY tb (three) - gray
  - \* If any tb not gray, \*
  - \* consult LCC before \*
  - \* continuing \*

All APU's have to be running and hydraulic pressure up at T-4 min or an AUTO launch hold will occur. However, APU fuel needs to be conserved for use in flight. Therefore at T-6 min, APU prestart is performed so that at T-5 min the APU start procedure will be as short as possible.

To get the ready-to-start tb gray, four conditions have to be met:

- a. Gas generator bed > 190° F and turbine speed < 80 percent.
- b. Either one of the fuel tank isolation valves is open. This allows fuel to flow from the fuel tank to the APU assembly.
- c. Hydraulic main pump press is in LOW position. This will reduce hydraulic system main pump discharge pressure from 2950 + 50 psig to

<1000 psig which precludes loading the APU at startup and reduces the turbine spin-up time.

d. WSB system has been activated which requires the following conditions to be met:

- (1) Controller A or B be enabled
- (2) Steam vent temperature > 130° F
- (3) GN<sub>2</sub> shutoff valves are open
- (4) Hydraulic bypass valve is in the proper position

The fuel tank valves will remain closed until APU start. The valves are insulated and, with no fuel flow, will overheat due to the heat from the solenoids which control the valves.

• -5:00 > APU START

R2 APU OPER (three) - START/RUN  
 F8 ✓HYD PRESS ind (three) - LO green  
 R2 ✓READY TO START tb (three) - bp  
 HYD MN PUMP PRESS (three) - NORM  
 F8 ✓HYD PRESS ind (three) - HI green  
 R2 HYD CIRC PUMP (three) - OFF  
 F7 ✓HYD PRESS It - off

All three APU's have to be started and the hydraulics pressured by T-4 min or an AUTO launch hold and probable scrubs will occur. The check at T-4 min is because the main engine purge sequence, gimbal checks, and start sequences are performed between T-4 min and T-3.8 sec and require all three hydraulic systems. In addition, hydraulic pressure is required to perform the aerosurface slew test and to move the aerosurfaces to their launch positions at T-3:45. All three APU's are started simultaneously. The first step resets prestart conditions, turns gas generator (GG)/fuel pump heaters off, starts 9.5-sec timer inhibiting an underspeed shutdown during startup due to slow spin up, opens the secondary fuel control valve and inhibits circulation pump power logic. After the APU's are started, the pump press is returned to normal. The circulation pump is turned off by the APU start, so the switch is placed in the OFF position to prevent inadvertent activation.

|                       |                   |
|-----------------------|-------------------|
| 1: GNC LAUNCH TRAJ    | 2: GNC SYS SUMM 1 |
| 3: BFS, SM SYS SUMM 2 |                   |

• C HTR RECONFIG

L2 FLASH EVAP FDLN HTR (two) - OFF

|                       |
|-----------------------|
| 3: BFS, SM SYS SUMM 1 |
|-----------------------|

To reduce the electrical power load at the SRB interface, heaters are turned off during ascent.

- -4:00 A CLOSE VISOR

NOTE  
Motion/Vibration may be  
felt in crew module due  
to Main Engine gimbal  
profile cks at -3:25 and  
move to start at -3:10

All crewmembers close their visors at T-4 min. A difference can be seen in the O<sub>2</sub> flow when this happens. Closing visors close to launch assures no prelaunch limit violation on PPO<sub>2</sub>.

-3:30 GLS transfers power to the Orbiter fuel cells

- -2:30 P CLEAR C/W MEMORY

|                      |                 |
|----------------------|-----------------|
|                      | 2: GNC 99 FAULT |
| 3: BFS, GNC 99 FAULT |                 |

Verify no unexpected errors  
CRT2 GNC, SPEC 99 PRO  
CRT3 GNC, SPEC 99 PRO

|                        |                   |
|------------------------|-------------------|
| 1: GNC LAUNCH TRAJ     | 2: GNC SYS SUMM 1 |
| 3: BFS, GNC SYS SUMM 1 |                   |

C3 C/W MEM - CLEAR

The last actions the crew has before lift-off are to clear the PASS and BFS fault summary pages and to clear the C&W memory. This is done so any faults after lift-off will not be confused with faults that occurred prelaunch. From this point on, the crew will use the Ascent Procedures card in the flip book for actions.

At T-35 sec, the vent doors start opening for launch. The vent opening is staggered at six 5-sec intervals. The position of the vents is verified prior to launch by the redundant set (RS) launch sequencer. The crew has no way to monitor or control the vent doors during OPS 1.

The LPS controls the countdown sequence until T-35 sec, when the flight software takes control of the sequence. The flight software continues to watch for an LPS-generated hold through main engine start and until it commands SRB ignition. Nominal CRT configuration for launch should be PASS TRAJ on CRT 1, PASS SYS SUMM on CRT 2, and BFS TRAJ on CRT 3. The BFS CRT SEL switch should be in 3+1 so that if the BFS is engaged, CRT 1 picks up the BFS TRAJ display. The complete switch configuration is defined in the Ascent Checklist switchlist.



The crew will monitor the start of SSME's on the (Pc) gauges. At 6.6 sec after SSME start, the SRB's are ignited and lift-off occurs. If all engines do not achieve a 90-percent rated power level (RPL) within 4.6 sec, shutdown of the engines will occur automatically. At lift-off, the MM changes to first stage (MM 102).

16mm cameras will be used on some flights to record ascent. The 16mm cameras have a limited amount of film. They are turned on via remote controller as close to lift-off as possible.

### 3.3.1.2 Nominal Powered Flight Procedures

3.3.1.2.1 ASCENT PROCEDURES card. - The ASCENT PROCEDURES card (fig. 3.3-1) is a very highly abbreviated outline of actions to be taken and items to be monitored during ascent. This section will expand on the card and provide further explanation of some of the steps. For the purposes of this discussion we will use an example of an SI ASCENT PROCEDURES card. The main difference between DI and SI procedures pre-MECO lies in the OMS-1 burn reference. While an SI card automatically refers the crew to the OMS-1 burn section post-MECO, the DI card refers the crew there only if an OMS-1 is required based on the OMS-1/2 TGTING chart on page 2-5 of the checklist. Also, a manual MPS dump is required for DI flights. On an SI flight, this will occur automatically at OMS-1 ignition. All procedures from the card will be denoted with a "●" marker. Additional procedures have been added from other cue cards and flight rules to enhance the discussion.

## ASCENT PROCEDURES

R180 LVLH \*\*

|      |                   |      |
|------|-------------------|------|
| 0.7M | ✓P <sub>C</sub> → | 85%  |
| 1.3M | ✓P <sub>C</sub> → | 65%  |
| 1.5M | ✓P <sub>C</sub> → | 104% |

'P<sub>C</sub> < 50' (✓rates < 5,2,2)  
 (Backup AUTO SEP 2:16)  
 \* 'SEP INH' + 5 sec - MAN SRB SEP \*

✓TMECO  
 \* NOT STABLE (10 sec) \*

\* NO COMM - CSS & MAN THROT \*

3:00 ✓EVAP OUT (T < 60)  
 MECO ✓V<sub>I</sub> = |25670|  
 \* If Man Throttle (3 eng) \*

\* Man Shutdn at |25550| \*

ET SEP (MECO+18)  
 \* 'SEP INH' & rates < .7, .7, .7: \*

\* OPS 104 PRO, ET SEP - MAN \*

\* Assume Feedline Fail: \*

\* ASC C/L, DELAYED OMS 1 \*

✓PASS/BFS MM104  
 ✓ATT within 10° of SEP ATT  
 \* If not - delay maneuvers until \*

\* TIG -1:19 \*

✓TGTS  
 Go to OMS 1 BURN

Figure 3.3-1.- STS 61-C Ascent Procedures card (SI flight).

If the MPS P<sub>C</sub> < 90 after 4.6 sec or any MAIN ENG STATUS light is amber prior to SRB ignition, sequential shutdown occurs. The MAIN ENG SHUT DN pb's do not work until SRB ignition. The SSME start time is 6.6 sec before the SRB ignition. This allows 4 sec for SSME's to reach 90 percent + 2.6 sec for twang. The twang is the oscillation, at ignition, due to the main engine position on the stack (moment arm). At lift-off, the MM changes to first stage (MM 102) which has an open loop guidance scheme based on VREL (I-loads) but modified somewhat to account for solid rocket motor (SRM) performance dispersions. The crew monitors SSME start on the P<sub>C</sub> gauges.

00:00 Lift-off  
 00:07 Tower Clear  
 Roll Program - Report  
 00:08 M=.1 MPS PRESS Pc ind (three) → 104 percent

- \* If no roll MNVR initiated: \*
- \* engage BFS \*
- \* If SSME fail: \*
- \* AC BUS SNSR (three) - OFF \*

SRB ignition is lift-off. The nominal crew task from SSME start until MM 104 is one of monitoring. However, they should be prepared to take whatever action is necessary in off-nominal situations, as defined by the Flight Rules shown in the Flight Data File (cue cards and checklists). The SSME's are initially commanded to 100 percent, and, when VREL > 60 fps, the command is changed to 104 percent. Guidance will command a constant pad attitude until VREL > 127 fps. This ensures the vehicle is clear of the tower even if three engines have failed. LCC-to-MCC handover occurs as the tower is cleared. The termination of the vertical rise is indicated by a command roll, pitch, and yaw maneuver which puts the crew heads down and aligned with the launch azimuth. The crew should watch for a vertical rise followed by a combination roll, pitch, and yaw maneuver (primarily roll) to the launch azimuth. Roll attitude is 180° when on the launch azimuth. Failure to initiate the roll maneuver at the corresponding VREL indicates incorrect subtask sequencing within Guidance. For this failure, the BFS will be engaged after the crew verifies it is calling for the maneuver by observing the attitude errors on the BFS TRAJ display, since the onboard displays are inadequate for the crew to execute the roll/pitch profile manually through the critical high q regime.

At lift-off both ADI ATT switches are in REF. The LVLH position is not usable for monitoring the initial roll maneuver because of a discontinuity at pitch = 90° as it is on the pad. This discontinuity is the result of a mathematical singularity in the LVLH reference frame transformation equations. As soon as the roll maneuver is complete (180° roll on ADI) (T+20 sec) both ADI ATT switches should be moded to LVLH to simplify monitoring and piloting tasks. LVLH also pins the ADI yaw to zero. Yaw is displayed on the HSI as a delta from NORTH. LVLH presents a true roll attitude ADI. Throughout first stage flight, the crew should monitor vehicle attitude and attitude rates versus cue card numbers. Attitude errors are not a good indicator of flight dynamics because of load relief, engine thrust, etc. and should not be closely monitored.

|      |     |   |      |
|------|-----|---|------|
| 0.7M | ✓Pc | → | 85%  |
| 1.3M | ✓Pc | → | 65%  |
| 1.5M | ✓Pc | → | 104% |

As dynamic pressure rises, the loads on the vehicle rise. The SSME's are throttled down through a single or multistep (mission dependent) throttle

bucket to avoid exceeding the maximum  $\bar{q}$  limit of the vehicle. If throttling does not occur, manual throttles should be selected. First stage guidance has been modified to account for SRB performance dispersions such that the impact of any dispersion is reduced by adjusting the throttle and pitch commands (Adaptive Guidance). For low performing SRB's, the throttle level is increased and the vehicle is pitched down. For high performing SRB's, the throttle level is decreased and the vehicle is pitched up.

Early in first stage, Adaptive Guidance computes the time difference, from an I-load time value, that a reference velocity (VREL) is reached. Based on this time difference and some I-loaded scaling factors, the first stage throttle and pitch profiles are modified. When V RHO MAG is greater than the reference velocity VREF\_ADJUST, with no engine failures, the time difference TDEL\_ADJUST from the reference time TREF\_ADJUST is computed by the equation:

$$TDEL\_ADJUST = \overbrace{\left( \frac{TGD}{(CURRENT\ TIME)} - \frac{T\_GMTLO}{(L/O\ TIME)} \right)}^{MET} - \frac{TREF\_ADJUST}{(I-LOAD)}$$

When the MET is equal to TREF\_ADJUST, TDEL\_ADJUST is equal to zero and the SRB's are performing as per the nominal design. If TDEL\_ADJUST > 0 then we reached the reference velocity later than design, and the acceleration during the first TREF\_ADJUST seconds must have been less than expected (cold SRB case). If TDEL\_ADJUST is < 0 then the reference velocity was reached sooner than design, and the acceleration during the first TREF\_ADJUST seconds must have been greater than expected (hot SRB case). This is illustrated in figure 3.3-2.

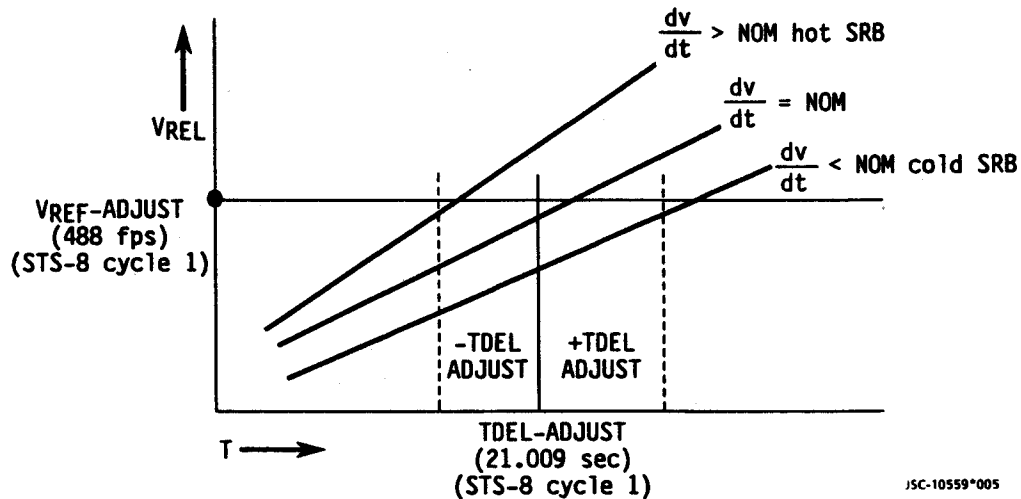
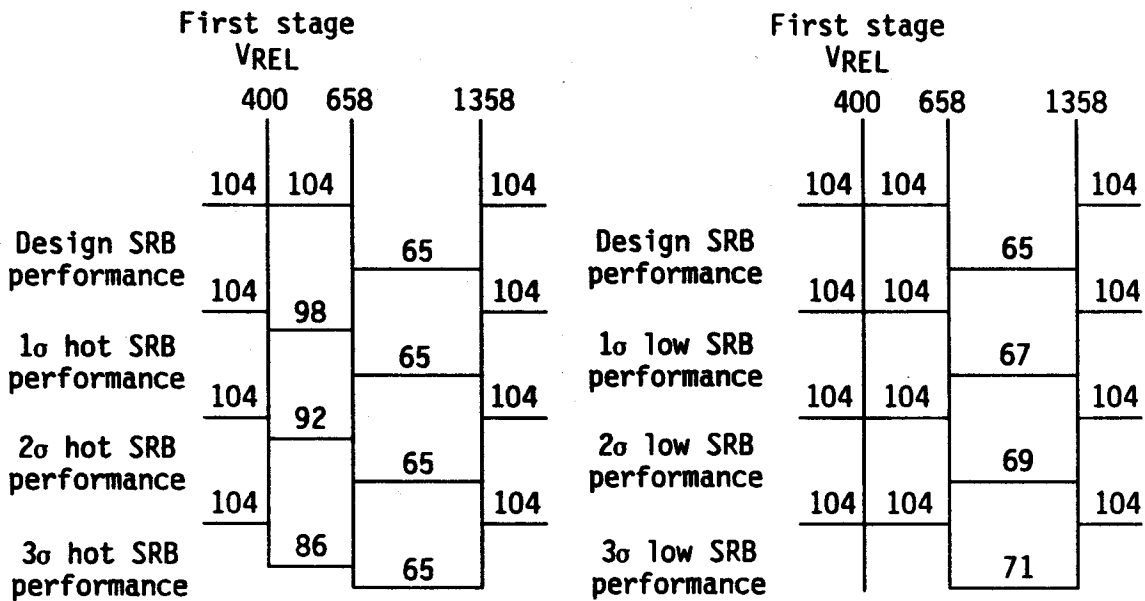


Figure 3.3-2.- VREF adjust versus TREF adjust.

Thus, it can be seen that the sign of TDEL\_ADJUST is determined by whether we have hot or cold SRB's, and the magnitude of TDEL\_ADJUST is a measure of the delta from nominal performance. Guidance uses this information to shape the first stage throttle and pitch profiles. On STS-26 the nominal throttle bucket has one step. Adaptive guidance will use two throttle segments that may be varied in depth in a manner similar to figure 3.3-3. The I-loads are set up such that, for the hot SRB case, the first segment of the throttle bucket will be decreased as a function of the magnitude of TDEL\_ADJUST, followed by a second segment that is a constant throttle level. For the cold SRB case, the first segment may be maintained at a constant level followed by a variable depth second stage. The guidance equations limit the throttle setting to a minimum of 65 percent and a maximum of 104 percent. It should be noted that, for the hot SRB case illustrated below, the second level is maintained at 85 percent and the I-loads used to adjust the first segment throttle level are chosen assuming a second segment of 85 percent.



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Figure 3.3-3.- Throttle buckets (STS-26).

The pitch adjustment is made to the pitch command as a function of TDEL\_ADJUST, a pitch scaling factor and load relief. A typical pitch delta is shown in figure 3.3-4. As load relief is terminated, the pitch adjustment is ramped out. If an engine fails prior to the velocity breakpoint for the beginning of maximum load relief, the pitch factor is set to zero. Some ascent trajectories are designed so that only the throttle profile is modified, with no pitch adjustments (the pitch scaling factor I-load is set to zero) for the cold SRB case.

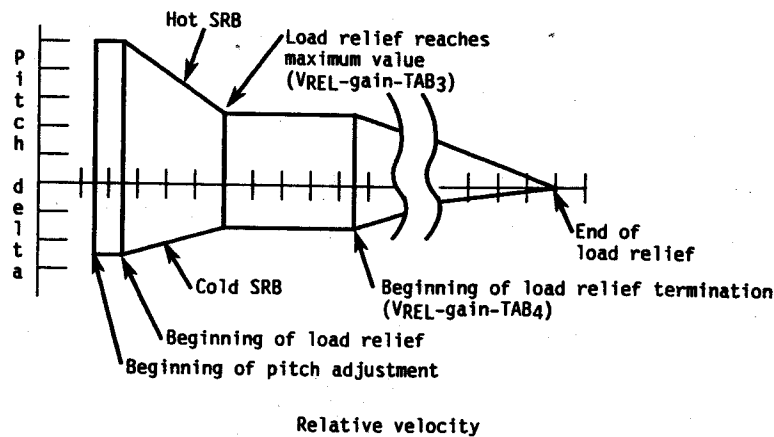


Figure 3.3-4.- Max  $\bar{q}$  pitch adjustments.

Load relief, mentioned above, begins about 25 sec MET. Vehicle accelerations (NZ and NY) are measured by the IMU's, and nominal guidance commands are modified if necessary to keep loads acceptable. The net result is that the vehicle will turn into an unexpected wind. A less than expected tailwind will appear as a headwind to flight control. If the vehicle yaws into a crosswind, it also rolls to keep the thrust vector in the desired plane. Since the crew is briefed prelaunch on winds and expected dynamic response, load relief should not present any surprises.

The velocity and throttle settings listed on the ASCENT PROCEDURES card are premission design values. The throttle changes should be monitored on the Pc gauges and on the CRT as a guide to the actual performance.

If the throttle command is not decreased or increased, the boost throttling task is not being executed and manual throttle will be initiated.

|      |              |               |      |
|------|--------------|---------------|------|
| 0.7M | $\sqrt{P_C}$ | $\rightarrow$ | 85%  |
| 1.3M | $\sqrt{P_C}$ | $\rightarrow$ | 65%  |
| 1.5M | $\sqrt{P_C}$ | $\rightarrow$ | 104% |

At 1.5 Mach, verify that the SSME's have throttled back up to 104 percent, RPL. Max  $\bar{q}$  will usually occur just prior to throttle up.

The  $\bar{q}$  is indicated by the KEAS on the AMI. The onboard calculation of KEAS uses the Patrick atmosphere model ( $KEAS \sim 17.5 \sqrt{\bar{q}}$ ) whereas most calculations of KEAS use the 1962 standard atmosphere model ( $KEAS \sim 17.2 \sqrt{\bar{q}}$ ). Therefore, the KEAS will read higher than expected for a given  $\bar{q}$ .

Loss of control in first stage is defined as off-scale rate needles (5 deg/s). BFS will be engaged in ascent for loss of control until end of load relief (1 min 30 sec). After 1 min 30 sec, CSS may be attempted before the BFS is engaged. Use manual throttle for any CSS takeover.

- 'Pc < 50' ( $\sqrt{\text{rates}} < 5,2,2$ )  
(Backup AUTO SEP 2:16)  
\* 'SEP INH' + 5 sec - MAN SRB SEP \*

At 2 min the crew should see the "Pc < 50" flashing on the ASCENT TRAJ displays. SRB SEP is indicated by a flash out-the-window and the CRT reflecting a change to MM 103.

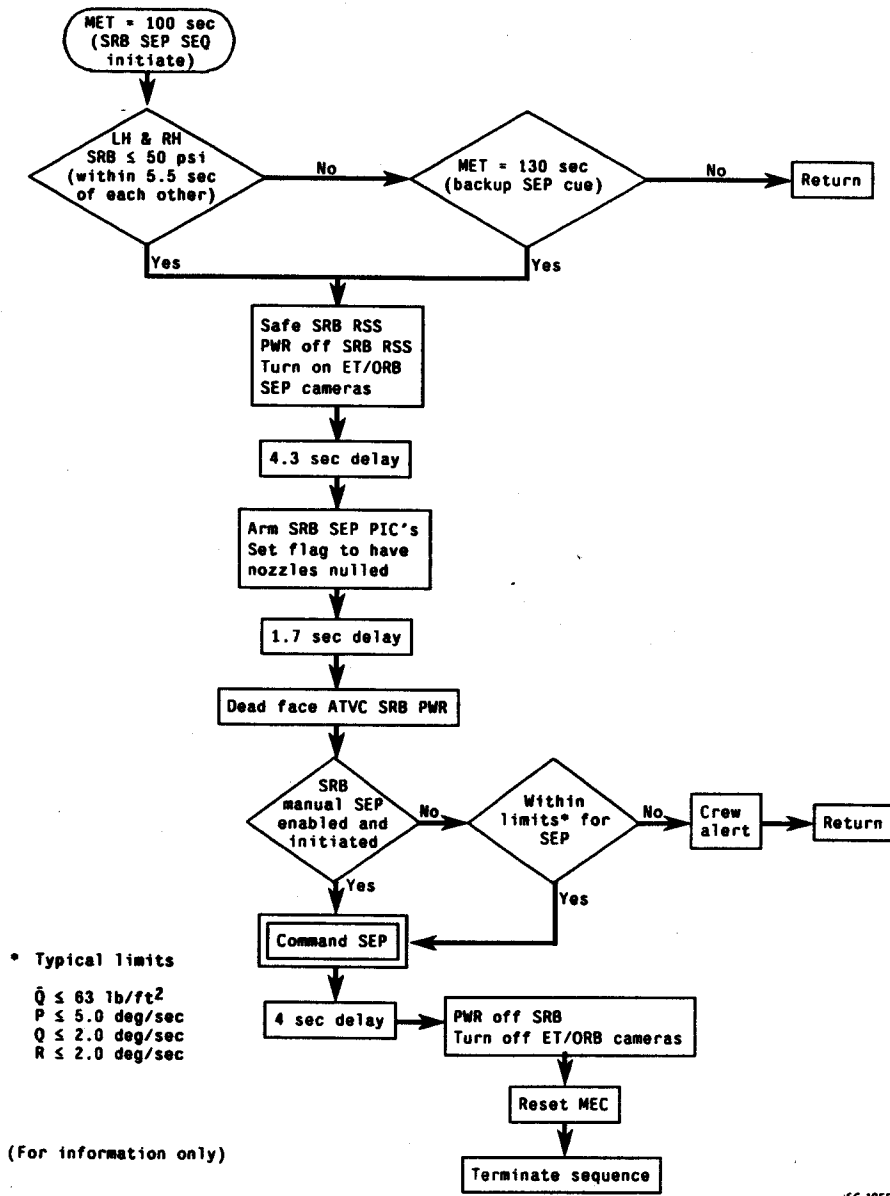
AUTO SRB SEP should nominally occur at a MET between 2:06 and 2:07. The crew should expect it shortly after "Pc < 50" appears on the ASCENT TRAJ display. However, it must be noted that the SRB SEP sequence will occur only if MECO (three engines out) has not yet occurred. Loss or shutdown of three SSME's during first stage flight will set a software MECO CONFIRMED flag which will prevent the SRB sequence from starting.

After T+100 sec, the sequence monitors both the left and right SRB chamber pressures and normally begins the SEP process when two of three sensors for each chamber pressure drop below 50 psia. A backup time (currently an I-loaded value of 136 sec) is available for the sequence. Should all Pc sensors fail "high" on one SRB, the sequence will not begin until the backup time is reached to assure that SEP is not attempted with excessive SRB thrust. The backup time represents the latest time that slow-burning SRB could have some residual tailoff thrust from combustion chamber pressures not exceeding 50 psia. Should all Pc sensors fail "low" on an SRB, the respective times at which the left and right SRB chamber pressures drop below 50 psia are noted. If the interval which these two times establish exceeds an I-loaded maximum differential (5.9 sec), then the sequence will not begin until the backup time is reached. If this time differential is not exceeded, the SEP sequence is initiated when the second engine Pc drops below 50 psia. The crew has no way to start the sequence.

The SRB SEP sequence includes time delays for thrust decay to acceptable limits (6 sec) and delays to permit nulling of the SRB nozzles (1.7 sec).

The AUTO sequence monitors selected rate gyro roll, pitch, and yaw rates and compares their absolute values to stored limits. If the RGA rates or the  $\bar{q}$  exceeds I-loaded limits, SRB SEP will be inhibited and the crew will be alerted (SEP Inhibit (INH) will flash on the TRAJ display). The rate limits are currently  $\bar{q} < 63 \text{ lb/ft}^2$ ,  $P < 5 \text{ deg/s}$   $Q < 2 \text{ deg/s}$ ;  $R < 2 \text{ deg/s}$ .

Should a SEP INH occur, the sequence will halt and resume when the out-of-limit condition has been corrected or the crew manually overrides the INH by selecting SRB SEP - MAN/AUTO and depressing the SRB SEP pb. If an INH condition occurs due to vehicle rates, but the rates are converging, the crew will take no action. The AUTO SEP sequence must be initiated prior to having an abort gap because of retention of the SRB's. If the rates are divergent, the crew will override and perform a manual SEP 5 sec after SEP INH occurs. This time preserves the abort mode overlap even if the sequence is started on the backup timer and prevents overriding the inhibit too early. If the vehicle rates are within limits and an inhibit condition occurs, it should be assumed erroneous and the crew will override. A simplified SRB SEP sequence is shown in figure 3.3-5.



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Figure 3.3-5.- SRB SEP sequence.

After SRB SEP, MCC will give a call on first stage performance. This information will be used in the event COMM is lost and a hydraulic or electrical lockup occurs on an SSME. An SSME in hydraulic or electrical lockup, when coupled with a low vehicle performance, will be manually shutdown at  $V_I > 23k \text{ fps}$ , using the AC PWR switches and the SHUTDN pb to prevent a violation of the engine LO2 NPSP requirement near MECO. Low NPSP can cause high-pressure oxidizer turbo pump (HPOT) overspeed and uncontained engine damage.



- √TMECO
  - \* NOT STABLE (10 sec) \*
  - \* NO COMM - CSS & MAN THROT \*

After staging, the crew should monitor closed loop guidance convergence by noting TMECO on the TRAJ display become stable and within a couple of seconds of the expected MECO time. If it has not stabilized within 10 sec, check with MCC. If no COMM, select CSS and manual throttle.  $\alpha$ -limiting is released when MET  $\geq$  150 sec and altitude  $\geq$  200K ft.

Throughout second stage flight the crew should monitor the trajectory using the BFS ASCENT TRAJ 2 display, or the ADI cue card if the display is not available. They should also keep abreast of their abort mode capability as defined on the NO COMM MODE BOUNDARY, and CONTINGENCY ABORT and TAL REDESIGNATION cue cards, and as called from the ground.

During MM 103 (and 601), internal checks are made with the PEG task to ensure that the current steering solution and resultant predicted burnout state are converged within an acceptable envelope of the desired target conditions. At the initiation of each mode, the convergence checks are nominally passed within two or three guidance cycle (4-6 sec). A sudden change in the actual acceleration (engine failure) after initial convergence will nominally cause the convergence checks to fail for one guidance cycle. Allowing two guidance cycles as pad, 10 sec is the longest reasonable interval for PEG to fail convergence. Failure to achieve convergence for more than 10 sec indicates an internal problem which prevents the PEG solution from satisfying the target conditions. Manual guidance/throttle will be initiated for this failure.

- 3:00 √EVAP OUT (T < 60)

At 3 min the EVAP OUT Temp Meter on panel (PNL) 01 should show temperature below 60°. By this time, the FES PRI A controller should have lowered the evaporator out temperature to below 60°. If the temperature is not below 60°, the crew refers to EVAP OUT TEMP HIGH cue card.

The flash evaporator system (FES) is only effective above 100,000 ft. There is no Orbiter cooling before the FES is activated. The GPC position of the FES controllers allows the BFS to automatically turn on the FES at transition to MM 103.

If the MN ENG LIMIT SHTDN switch is in the 'AUTO' position and a main engine shuts down, the shutdown of a second engine will be inhibited automatically. The crew can mode this switch to 'ENABLE' then back to 'AUTO', in order to re-enable the main engine limit shutdown logic, once the vehicle reaches single engine completion capability. This will allow a second engine to shut down, if limits are violated, while inhibiting the third, and last, remaining engine from shutdown. The crew should check with the ground to verify that this action is consistent with the present system status prior to taking action (if COMM exists).

-07:25 3-g Throttling  
 \* If > 3g and throttle CMD not \*  
 \* decreasing: \*  
 \* Manual throttle & CSS \*

Throttle down to 65 percent

During second stage guidance, the g-limits software determines the average acceleration experienced since the previous guidance cycle. If the sensed acceleration exceeds 94.7 fps, g-limiting is activated to decrease the throttle CMD proportional to the acceleration error. The throttle CMD is decremented until the sensed acceleration decreases below another limit (92 fps). A constant throttle CMD with acceleration exceeding 94.7/s<sup>2</sup> indicates the g-limiting task is not being executed. Manual guidance/throttle will be initiated for this failure. Six seconds before MECO, the throttle will go to 65 percent to prepare for MECO. They should note 3g-throttling commencing about a minute before MECO (if not, takeover MAN THR) and expect MECO at the TMECO time or MECO velocity.

MECO  $\sqrt{V_I} = \underline{25670}$   
 \* If Man Throttle (3 eng) \*  
 \* Man Shutdn at 25550 \*

At MECO (determined by "seat-of-the-pants" feel, SSME Pc meter tapes dropping to zero, SSME status lights coming on red, and BFS TRAJ line velocity bug walking past "CO"), the crew checks the cutoff velocity on the AMI tape. The velocity should be close to 25,670 which is the cutoff velocity for 28.5° inclination (due east) SI flights. 25871 fps is the cutoff velocity for due east DI flights. The exact cutoff velocity will vary depending on the mission inclination. The 'MECO CONFIRMED' flag must be set in the flight software before ET SEP will be commanded. The illumination of the DAP lights on PNL C3 is a good cue that 'MECO CONFIRMED' is set. If no 'MECO CONFIRMED', push all three shutdown pb's.

The first indication of an underspeed condition is cutoff velocity significantly less than 25,670. The crew will get confirmation from the ground of the true MECO condition. If a no COMM situation exists, MNVR display solution and OMS TARGETING cue cards will confirm an underspeed condition.

If in manual throttle, a manual main engine shutdown is required using the ENG SHUTDOWN pb's on PNL C3. Due to the  $\Delta V$  from the SSME thrust tailoff (~100 fps) and PLT response time, the PLT pushes the pb's when  $V_I = 25,550$  for three engines running, and/or the V bug at CO.

- ET SEP (MECO+18)
  - \* 'SEP INH' & rates < .7, .7, .7: \*
  - \* OPS 104 PRO, ET SEP - MAN \*
  - \* Assume Feedline Fail: \*
  - \* ASC C/L, DELAYED OMS 1 \*

ET SEP should occur approximately 18 sec after MECO. This will be indicated by the SSME red status lights going off, followed shortly by the software moding to MM 104 (after AUTO -Z translation achieves -4 fps). If the THC is moved out of detent prior to the completion of the -Z, the maneuver will terminate with no moding. If for any reason the -Z maneuver is not completed automatically, the crew can mode guidance by completing the -Z maneuver manually via the THC or by doing an OPS 104 PRO.

The crew has the ability to start the AUTO ET SEP sequence, to inhibit it, or to override automatic inhibits with the ET SEP switch and pb. The nominal ET SEP sequence is initiated when the SSME OPS sequence sets the MECO CONFIRMED flag. The ET SEP sequence will then run cyclicly, performing major functions such as umbilical unlatch and retract, wait for engine prevalues to be commanded closed, ET tumble system arm, electrical dead-facing, INH and SEP mode checks, and finally, structural SEP. The sequence will check pitch, roll, and yaw rates, LH<sub>2</sub> and LO<sub>2</sub> feedline disconnect valve positions, and the status of flight aft MDM numbers 2, 3, and 4. If any rate exceeds 0.7 deg/s (I-load) or if a valve or multiple MDM malfunction is detected, SEP will be inhibited and a crew alert generated. The crew is alerted by flashing SEP INH on the TRAJ display. The condition that caused the INH must be satisfied or overridden before the sequence will continue. Unlike RTLS ET SEP, there is no timed bypass of inhibiting conditions. If a SEP INH occurs, the rates are checked by placing the ADI rate switch in the low (1 deg/s) position.

If rates are less than 0.7 deg/s with a SEP INH indication, the crew should assume a feedline disconnect valve failure has occurred. The crew proceeds to MM 104 to determine whether the OMS-1 burn can be delayed or not. The burn should not be delayed if current HA < 70. This is a quick look reference. If targeting requires an underspeed ATO (AOA-S), manual ET SEP is performed, and ATO (AOA-S) OMS-1 is burned prior to apogee (TTA=0). ET SEP switch to MAN avoids unexpected SEP, should the SEP INH condition go away. Since there is no foolproof way to determine whether the valves closed for some dual FA MDM failures, or to differentiate between a sensor failure and a feedline disconnect valve failing to close, the crew assumes the valve failed to close. Delaying ET SEP 6 min will allow residual propellant pressure in the Orbiter and ET to bleed down below 1000 lb, so that no propulsive thrust will occur from a stuck open valve. This minimizes the possibility of recontact after SEP due to the impulse of escaping propellant from the ET. The 61-C checklist calls for execution of the delayed OMS-1 procedures. For STS-26 and subsequent missions the delayed OMS-1 section has been deleted. The procedures for this failure are included in the OMS burn sections of the Ascent Checklist.

If the SEP INH is due to excessive rates, the crew will wait for the rates to damp out. The AUTO sequence will then resume and separate the ET. If manual ET SEP is attempted with high rates, recontact could occur. The crew can INH the AUTO ET SEP sequence any time by placing the ET SEP switch to MAN. The sequence will resume when the ET SEP switch is returned to AUTO.

- ✓PASS/BFS MM104
- ✓ATT within 10° of SEP ATT
  - \* If not - delay maneuvers until \*
  - \* TIG -1:19 \*
- ✓TGTS
- Go to OMS 1 BURN

If the FCS has failed to maintain the Orbiter within 10° of the ET SEP attitude during the -Z translation, the crew should not perform any immediate maneuvers. Recontact with the ET could result. Maneuvering to the OMS-1 attitude should be delayed until OMS-1 TIG-1:19 for the same reason. Waiting approximately 20 sec allows the Orbiter time to drift farther from the ET and still gives enough time to maneuver to the OMS-1 burn attitude. The PLT starts on the OMS-1 targeting process using the MNVR display and the appropriate OMS TARGET cards. When the MNVR display comes up, the crew will check the targets (TIG, C1, C2,  $\theta$ T, HT) to ensure they are nominal (or ATO if a pre-MECO abort has been selected). To check for a complete discussion of OMS target selection, see the OMS targeting section 3.2. It should be remembered that the ground will always give a target recommendation if COMM is available. Nominal and ATO (either on-time or delayed) procedures are identical with the exception of the targets. ATO is merely a lower altitude orbit (105 n. mi. circular). It is a safe orbit with a lifetime of at least 2 days. Once the proper OMS-1 target solution is available (both PASS and BFS), the crew should mode the ADI ball to inertial and begin AUTO maneuver to burn attitude. When the correct attitude is reached, the error needles should be centered, and the ADI attitude and the commanded attitude on the MNVR display should match. If a higher maneuver rate than 0.5 deg/s (AUTO rate) is desired, go to the hard stop in manual DAP mode. TIG slips of a couple of minutes are no problem, except for big underspeeds. Once in attitude the burn should be executed per the OMS-1 BURN cue cards. (See OMS-1 burn section.)

MCC gives

'NAV state, OMS-1 Target Selection, Go for APU Shutdown on Time' and at LOS 'Configure for LOS'.

The MCC will give information concerning any NAV state anomalies at this time. If the NAV state is bad, the information from the OMS MNVR EXEC display and the OMS Targeting card may be wrong. The MCC will give information on the appropriate action, i.e., burn on-time or delayed, expect a NAV update or burn an external  $\Delta V$  burn. The MCC will give the crew the OMS-1 target to be burned. The MCC will give a 'Go for APU shutdown' at the appropriate time if there is no reason to expect an AOA.

Just prior to loss of signal (LOS), MCC will call "Configure for LOS". This is the call for C3 uplink (UPLK) - GPC block (BLK). This step has to be done at all LOS's during ascent and entry (when SM is not available). At all AOS's during ascent and entry, UPLK - ENA is done. These steps are to prevent unwanted uplinks from getting into the GPC's.

### 3.3.1.3 OMS-1 Procedures

On a DI mission, the Orbiter attains mission apogee (HA) at MECO. No OMS-1 maneuver is required. The nominal OMS-2 maneuver will circularize the orbit at the mission apogee. On an SI mission, the Orbiter HA at MECO is much lower than on a DI. This is because the SI MECO occurs at a lower  $V_I$  (earlier) than DI MECO. The OMS-1 maneuver is done at orbital apogee and is time-critical due to the low altitude of the post-MECO orbit and the location of orbital apogee ( $TIG = MECO+2$ ). As on a DI mission, the SI OMS-2 maneuver will circularize the orbit at the mission altitude.

To select the required OMS-1 targets, the crew will evaluate the status of Orbiter critical systems and the MECO energy state ( $V_I$ , HA, HP). Target selection is discussed in section 3.2 of this document.

Since DI flights nominally do not require an OMS-1 burn, the ASCENT cue card calls for a +X settling burn and manual MPS dump, followed by the post OMS-1 procedures after checking the OMS targets. The ASCENT cue card for SI flight refers the crew to the OMS-1 procedures directly after checking the OMS targets.

There is only one OMS-1 BURN card (fig. 3.3-6). However, two-engine, one-engine, and RCS varieties are available for other burns. The OMS procedures in the PLT Overhead Flipbook are used for any OMS malfunctions prior to OMS-1, but during OMS-1 the OMS BURN MONITOR card is used. These procedures are discussed in the Ascent/Orbit/Entry Pocket Checklist Handbook.

OMS 1 BURN

```

* DELAYED BURNS:
* MECO +2 +X xlation, MAN MPS DUMP
* /DUMP/STOW complete (B/F lite out)
* /MCC for APU Shutdn
* (if time permits)
* FEEDLINE FAIL:
* TIG -1:30 or MECO +6:
* ET SEP - SEP

MNVR - BURN ATT .. (/INRTL)
/MPS DUMP SEQ - GPC
/CNTRLR PWR (two) - ON
DAP - AUTO/DISC ..
/OMS ENG (two) - ARM/PRESS
Note ΔVTOTI .. TIG [ ] [ ] : [ ] [ ]

-:15 EXEC ..
:00 TIG .. (/Pc, ΔVTOT, ENG VLVs; start watch)
* OMS PRPLT FAIL:
* Failed ENG - OFF
* XFEED (two) - CL
* TK ISOL (two) - CL
* He PRESS (two) - CL
* OMS ENG FAIL:
* Failed ENG - OFF
* If ΔV < 500, OMS XFEED at
* If ΔV > 500:
* Interconnect failed 1/2 of
* OMS to RCS ΔVTOT
* THC +X at FAIL
* (stop when QTY = 3%)
* RCS COMPLETION:
* Interconnect to either
* OMS that was ENG FAIL
* THC +X (OMSX vs RCS ΔV)
* OMS TK SW (if reqd)
CUTOFF ..
+:02 OMS ENG (two) - OFF ..
Trim inplane X,Z residuals < 2 fps

```

Figure 3.3-6.- OMS-1 BURN card (STS-26).

Since OMS-1 is the first OMS burn, engine hardware failures will not be detected prior to ignition. The only hardware failure which can be detected prior to the burn is a propellant tank failure. In this case the OMS PRPLT FAIL procedure in the gray region of the OMS-1 BURN card should be carried out before executing the burn.

```

* DELAYED BURNS:
* MECO +2 +X xlation, MAN MPS DUMP
* /DUMP/STOW complete (B/F lite out)
* /MCC for APU Shutdn
* (if time permits)
* FEEDLINE FAIL:
* TIG -1:30 or MECO +6:
* ET SEP - SEP

```

If a delayed burn is required, such as a DATO, the crew will initiate a manual MPS dump. Otherwise the dump will begin at OMS-1 ignition.

With the deletion of the delayed OMS-1 section of the Ascent Checklist (STS-26 and subs), the feedline disconnect valve failure procedures reside in the OMS-1 BURN and POST OMS-1 sections of the checklist. In the event of such a failure, the ET would be allowed to vent until TIG-1:30 min or MECO+6 min, whichever is sooner. The goal is to allow as much time for ET

venting as possible to minimize the risk of an Orbiter/ET recontact due to thrust generated by the open ET feedline disconnect. If an OMS-1 maneuver is not required, as is the case with nominal DI, the post-OMS-1 section of the checklist contains procedures for separating from the tank.

- MNVR - BURN ATT .. (✓INRTL)
- ✓MPS DUMP SEQ - GPC
- ✓CNTLR PWR (two) - ON
- DAP - AUTO/DISC ..
- ✓OMS ENG (two) - ARM/PRESS

As the switches are configured for OMS-1 at launch, no OMS switches require manipulation (nominally) prior to OMS-1. However, the cue card does contain reminders to the crew to confirm several switch positions. The OMS-1 MNVR EXEC display is used for target selection and burn configuration and will come up automatically at transition to MM 104. Maneuvering to burn attitude can be done either manually or in AUTO via item 27 on the OMS-1 MNVR EXEC display. The DAP is activated at MECO, zero thrust. The manual mode is entered by moving the stick out of detent. The manual mode remains in effect until the RHC is returned to detent and the C3 DAP-AUTO pb is depressed. Only manual mode is available in BFS.

The attitude for the OMS-1 burn on the OMS MNVR EXEC display is an inertial attitude. If an automatic maneuver is to be done (PASS only), the crew will check that the DAP is in AUTO before executing item 27. The maneuver to OMS-1 attitude is done at 0.5 deg/s. A manual maneuver is performed if a higher rate is needed to attain burn attitude on time, although the burn can generally be up to 2 min late. If a manual maneuver to attitude has been used, the crew must return the DAP to AUTO prior to OMS ignition.

The GPC position for the MPS dump sequence switch allows the MPS dump to automatically start at OMS-1 ignition and terminate after an I-loaded time (2 min 21 sec). This pressurized dump releases residual LO<sub>2</sub> and LH<sub>2</sub> from the manifold line. Failure to dump this propellant would result in a higher vehicle landing weight and could result in ruptured lines during entry due to gas expansion.

The flight controller power is checked ON in case manual takeover during the burn is necessary. OMS-1 trims are I-loaded and manual trim entries via item entry will have no effect on the vehicle burn configuration. Additionally, the OMS ENG switches are confirmed to be in the ARM/PRESS position. This will allow engine ignition and a 2-sec N<sub>2</sub> purge upon cutoff.

- Note ΔVTOTI ..    TIG   :
- :15 EXEC ..
- :00 TIG .. (✓Pc, ΔVTOT, ENG VLVs; start watch)


The OMS-1 BURN card is the only card to call explicitly for a notation of ΔVTOT prior to ignition. This is due to the extremely short timeline between MECO and OMS-1 ignition (2 min). In other burn scenarios, there is usually plenty of time for the crew to study the MNVR EXEC display and note ΔVTOT. The OMS-1 ΔVTOT required is highly flight specific and can exhibit large variations depending on the MECO state.

Fifteen seconds before TIG, EXEC will begin to flash on the OMS MNVR EXEC display signaling the crew to enable the burn by hitting EXEC. At ignition the crew should check various data sources to confirm that the burn is proceeding nominally. The OMS Pc gauges should read approximately 104 percent. The BFS GNC SYS SUMM 2 display should be examined for three things: the engine control valves (ENG VLV 1 and 2) should read approximately 100 percent, which corresponds to fully open; He pressure should be decreasing slowly as the propellant is expended; and the engine inlet pressures should drop to approximately 200 psi during the burn. The OMS quantity gauge should begin to function 15 sec after ignition. Also,  $\Delta VTOT$  should be decrementing nominally.

At this time (unless a manual dump was performed prior to TIG) the crew should set a timer to indicate when the MPS dump will be complete for APU shutdown in case the BDYFLP light is not working. The BDYDPF lights are cued to two events: MPS dump complete and SSME's to stow. Since the MPS dump is done in the stow position, the BDYFLP lights will extinguish upon dump complete.

- \* OMS PRPLT FAIL: \*
- \* Failed ENG - OFF \*
- \* XFEED (two) - CL \*
- \* TK ISOL (two) - CL \*
- \* He PRESS (two) - CL \*

Unlike the OMS-2 and deorbit burns, there is no criterion for terminating the burn in the event of a propellant failure since the OMS-1 burn must be completed. The actions are to turn off the engine on the side a propellant failure occurs and to isolate both the fuel and oxidizer tanks on that side from the rest of the plumbing. In this way propellant will not be lost through any leaks below the tanks that may have occurred.

- \* OMS ENG FAIL: \*
- \* Failed ENG - OFF \*
- \* If  $\Delta V < 500$ , OMS XFEED at \*
- \* If  $\Delta V > 500$ : \*
- \* Interconnect failed 1/2 of \*
- \* OMS to RCS  $\Delta VTOT$  \*
- \* THC +X at FAIL  \*
- \* (stop when QTY = 3%) \*
- \* RCS COMPLETION: \*
- \* Interconnect to either \*
- \* OMS that was ENG FAIL \*
- \* THC +X (OMS% vs RCS  $\Delta V$ ) \*
- \* OMS TK SW (if reqd) \*

Turning the engine off with the OMS ENG switch will cause guidance to down-mode to a single-engine burn, with a resulting attitude and error needle change. The OMS ENG switch of a failed engine is set OFF, which will reconfigure guidance for a single-engine burn. If  $\Delta VTOT < 500$  fps at the time of an engine failure, the burn is completed with the single remaining OMS engine. To keep the Y c.g. within entry limits (an AOA may be required), half the remainder of the burn is done with propellant from the failed side using the OMS XFEED reconfiguration shown in the PLT Overhead Flipbook OMS card. The XFEED cue is half the  $\Delta VTOT$  remaining at the time the engine fails. To use the  $\Delta VTOT$  cue, the crew must note  $\Delta VTOT$  at the time of the failure.



In the event of an engine failure the crew may freeze the present CRT readout for future reference if there is not enough time to note this information immediately. This may be accomplished by depressing the SPEC key on CRT 1 or 2 at the time of the engine failure. This will freeze the DEORBIT MNVR EXEC display. Similarly, freezing the BFS GNC SYS SUMM 2 display on CRT 3 allows the failed OMS engine switch to be moved to OFF while retaining the present engine ball valve condition for failure diagnosis. After checking the single engine burn reconfiguration, the crew can read off the  $\Delta VTOT$  at the engine failure time and enter half of this value into the space provided on the cue card to use as a crossfeed cue.

If  $\Delta V > 500$ , the card calls for interconnecting OMS to RCS and burning the +X RCS jets as well as the single OMS engine. This is because the burn arc is twice as long with one engine as with two engines. Also, guidance will have difficulty achieving an acceptable target with such a large  $\Delta V$ . The RCS jets are interconnected to the OMS propellant on the side of the failed engine due to OMS tank constraints, and in order to help balance propellant.

A  $\Delta V$  of 500 fps for OMS-1 represents a large underspeed which will require either an ATO or an AOA. Four +X RCS jets deliver a little more than half the thrust of OMS engine. However, since the resulting burn is less efficient than a strictly OMS-OMS burn, the total thrust is only increased by about 50 percent. Guidance does not recognize the fact that the +X engines are burning and TVC will not behave as usual. However, the burn TGO will decrement correctly as TGO is based on VGO.

The error needles will be displayed in pitch and yaw. In AUTO mode, the PLT will observe the small error needle displacement but should not take manual control. Flying out the errors in manual mode will result in an arcing, less efficient, but nevertheless successful burn.

- \* OMS ENG FAIL:
- \* Failed ENG - OFF
- \* If  $\Delta V < 500$ , OMS XFEED at
- \* If  $\Delta V > 500$ :
- \* Interconnect failed 1/2 of
- \* OMS to RCS  $\Delta VTOT$
- \* THC +X at FAIL
- \* (stop when QTY. = 3%)
- \* RCS COMPLETION:
- \* Interconnect to either
- \* OMS that was ENG FAIL
- \* THC +X (OMS $\Delta$  vs RCS  $\Delta V$ )
- \* OMS TK SW (if reqd)

CUTOFF ..

+ :02 OMS ENG (two) - OFF ..

Trim inplane X,Z residuals < 2 fps



the delta should be passed to MCC at the next COMM pass. This information is used by the flight dynamics officer (FDO) in the OMS-2 calculations.

Following a MECO underspeed condition, the Orbiter trajectory could be low enough that drag effects of the upper atmosphere could significantly affect vehicle performance. LVLH pitch = 0 will minimize drag. This procedure will not be necessary for the nominal case, but should be performed when an off-nominal OMS-1 is performed. This may not always be necessary but is the safer approach. The procedure has been simplified, calling for a maneuver to pitch 340° (-20°) and letting the Orbiter drift for 10 min. After 10 min at 4 deg/min, the Orbiter will be +20° in pitch. The crew will again maneuver to -20°. This is continued until it is time to maneuver to the OMS-2 burn attitude.

- \* C ALPHA MANAGEMENT (if reqd) \*
  - \* \*
  - \* If underspeed ATO or AOA-S OMS 1 \*
  - \* and Post OMS 1 HP ≤75 nm: \*
  - \* Maneuver to LVLH R180, P340, Y000 \*
  - \* (maintain LVLH P = 0 ±20) \*
  - \* After 10 minutes: \*
  - \* Maneuver to LVLH P = 340 \*
  - \* After 10 minutes: \*
  - \* Maneuver to Burn Attitude \*
- B F7/F8 FLT CNTLR PWR (two) - OFF  
C3 /DAP - AUTO

Both flight controller power switches are turned off at this time to prevent inadvertent inputs to the RHC, thus downmoding the DAP to manual. This will also prevent any RCS jet firings or a DAP downmode caused by hardware problems with the controller. Erroneous firing of the jets is not a serious problem if the magnitude of the input is small. However, the DAP should be checked to make sure that it has not downmoded.

- P APU/HYD SHUTDOWN (Not AOA)
- F4 /BDY FLP pb - 1t off (MPS stowed)  
(~2 min 21 sec)
- R4 HYD MPS/TVC ISOL VLV (three) - CL  
Hold 5 sec / (tb-CL)
- R2 /APU AUTO SHUT DN (three) - ENA
- BLR PWR (three) - OFF
- N2 SPLY (three) - OFF
- APU OPER (three) - OFF (MA)
- FUEL TK VLV (three) - CL
- /Shutdn (Hyd Press)
- CNTLR PWR (three) - OFF (MA)
- FUEL PUMP/VLV COOL A - AUTO

- HYD DEPRESS (AOA only) will be discussed in the AOA section.

Due to the limited amount of APU fuel onboard the Orbiter, it is necessary to shut down the APU's as soon as they are no longer needed for ascent, and after the completion of the MPS dump sequence. Prior to LOS, the MCC will give the crew a 'GO for APU shutdown'. This call will be made only if the MCC trajectory officer (TRAJ) and all systems will support at least an ATO. The crew will shut down the APU's when the BDYFLP light goes out or on time,



The second OMS burn is executed in MM 105. This is also the transition point from systems cue cards to the Ascent Pocket Checklist (C/L). In some cases, the Ascent Pocket C/L has additional steps to be taken at this time for failures that occurred during ascent. Therefore, the Ascent Pocket C/L should be consulted for failures even though the cue card procedures have been completed.

|                             |                        |
|-----------------------------|------------------------|
| 1: GNC OMS 2 MNVR EXEC      | 2: GNC OMS 2 MNVR EXEC |
| 3: BFS, GNC OMS 2 MNVR EXEC |                        |

### B OMS 2 BURN SETUP

✓OMS 2 TARGETING, Flip Book

CRT1 TRIM LOAD - ITEM 6 +0.4 -5.7  
+5.7 EXEC

\* For single eng burn (good eng): \*  
 \* TRIM LOAD LY - ITEM 7 + 5.2 EXEC \*  
 \* RY - ITEM 8 - 5.2 EXEC \*  
 \* OMS L - ITEM 2 EXEC \*  
 \* R - ITEM 3 EXEC \*  
 \* XFEED: Failed engine Prop to good \*  
 \* engine \*  
 \* For RCS burn: \*  
 \* RCS SEL - ITEM 4 EXEC \*

#### NOTE

Onboard computed TIG may vary slightly but is acceptable

#### NOTE

If AOA, verify/enter appropriate ABORT TGT number in MM105 but do not LOAD targets until OPS 3

\* If BFS, do not manually \*  
 \* enter targeting data \*  
 \* (ITEMS 5-18) until MM301 \*

✓Targets, OMS TARGETS

LOAD - ITEM 22 EXEC  
 TIMER - ITEM 23 EXEC

CRT3 ✓BFS TGT

After completion of the OMS-1 burn, the crew will proceed (PRO) to MM 105 to prepare for the OMS-2 burn. A second OMS burn cannot be done in MM 104. The appropriate target will be determined and will be verified by the MCC. If an AOA is required, the targets should be entered with an abort target number in OPS 1 since the number is not a legal entry in OPS 3. However, the target will not be loaded until the software has moded to OPS 3, because the  $\Theta$  target parameter ( $\Theta T$ ) is referenced differently in OPS 3 and OPS 1.  $\Theta T$  is the angle between the launch site and the desired target altitude at the end of the coast phase in OPS 1 and is the angle between the deorbit burn TIG and EI in OPS 3. The value of  $\Theta T$  listed in the checklist for an AOA is meaningful only in OPS 3.

The OMS gimbals should be trimmed to the appropriate values before the OMS-2 burn. Prior to the OMS-1 burn, these trim values are set by I-loads. For

subsequent burns, the setting at the completion of the previous burn is used unless manually changed. If the BFS is not engaged, the BFS trim is not updated through the OMS burn. The gimbals will not actually move to the trim angles until guidance becomes active 15 sec before the burn begins. After the appropriate target and trims are entered, they are loaded. The solution is verified in both the primary and backup system and the  $\Delta V$  should be approximately equal to the value on the OMS TGTS card. Further explanation is given in the OMS targeting section.

|                             |                        |
|-----------------------------|------------------------|
| 1: GNC OMS 2 MNVR EXEC      | 2: GNC OMS 2 MNVR EXEC |
| 3: BFS, GNC OMS 2 MNVR EXEC |                        |

**P MPS POWERDOWN**

R2    MPS ENG PWR (six)        - OFF  
       He ISOL (six)           - GPC  
       ✓He I'CONNECT (three) - GPC

**NOTE**

Expect multiple MAs for  
 MPS He P as regs bleed down

**MPS VACUUM INERTING ACT**

R2    ✓MPS PNEU He ISOL        - OP  
  
 R4    MPS H2 PRESS LINE VENT - OP  
       (Start watch)  
       FILL/DRAIN LH2 OUTBD - OP  
               INBD - OP  
       L02 OUTBD - OP  
               INBD - OP

After 1 minute:  
 MPS H2 PRESS LINE VENT - GND

After completion of the MPS dump, the MPS will be powered down and vacuum-inerted by the PLT. Vacuum-inerting allows any traces of LO<sub>2</sub> and LH<sub>2</sub> left after the propellant dump to be vented into space. Both the LO<sub>2</sub> lines and the LH<sub>2</sub> lines will be inerted simultaneously. The fill/drain valves consist of some of the large He-actuated valves and should not be moved unless He is trapped in the actuator to oppose the motion of the actuator. This prevents slamming the valve open. To accomplish this objective, the valve is commanded to the current valve position for 2 to 10 sec, which traps He to resist the motion of the actuator. Once He is trapped, the valve is commanded to the required position and the trapped He cushions the motion of the valve in the manner of a gas shock absorber. The inerting will be performed for 30 min, terminating 5 min prior to OMS-2 (after the SEAT SAFING AND ADJUSTMENT). During the inerting process, a definite pressure decay may be noted in both the LO<sub>2</sub> and LH<sub>2</sub> lines on the BFS (GNC SYS SUMM 1 display). Vacuum-inerting will also be performed on an AOA until OMS-2 TIG-10 min. Vacuum-inerting ensures that the MPS system will not become pressurized or outgas on orbit, contaminating the experiments.

● P ET UMBILICAL DOOR CLOSURE

|                             |                        |
|-----------------------------|------------------------|
| 1: GNC OMS 2 MNVR EXEC      | 2: GNC OMS 2 MNVR EXEC |
| 3: BFS, GNC OMS 2 MNVR EXEC |                        |

P ET UMBILICAL DOOR CLOSURE

|  |
|--|
| <b>WARNING</b>   |
| The ET CTRLINE LATCHES must be stowed prior to L,R DR closure to prevent door drive damage |

\* If CTRLINE LATCHES do not stow, \*  
 \* or doors do not close, or doors \*  
 \* do not latch, contact MCC \*  
 \* If NO COMM, prior to OPS 2 or \*  
 \* OPS 3 transition: \*  
 \* 



 \*  
 \* ET UMB DR CLOSE - ITEM 40(30) \*  
 \* EXEC \*

**NOTE**

Double times for single motor operation

R2 ET UMB DR  
 MODE - GPC/MAN  
 CTRLINE LAT - STO  
 ✓After 6 sec, CTRLINE LAT tb - STO  
 L,R DR (two) - CL (tb-bp)  
 After 24 sec, L,R DR tb - CL  
  
 L,R LAT (two) - LAT (tb-bp)  
 After 6 sec, L,R LAT tb - LAT  
 MODE - GPC  
  
 CTRLINE LAT - GND  
 L,R DR (two) - OFF  
 L,R LAT (two) - OFF

The ET umbilical doors must be closed prior to entry. This is usually done manually via panel R2 switches. However, during OPS 1 there is a software backup in case of a switch failure. The crew should always ensure that the doors are closed prior to leaving OPS 1.

In the MPS VACUUM INERTING procedure the MPS H2 PRESS LINE VENT is opened to expel hydrogen in the line out through the umbilical door (opened for at least 1 min). The umbilical doors should not be closed until this line has been closed to avoid trapping any hydrogen in the well.

The ET UMB DR MODE switch is placed in GPC/MAN to enable the manual switches. It also enables power to the door motors. After the doors are closed and latched, the switch is returned to GPC to disable the power. If the software backup is used, the mode switch should be in GPC and item 40 executed on the OVERRIDE display (on the BFS OVERRIDE display it is item 30).





|                             |                        |
|-----------------------------|------------------------|
| 1: GNC OMS 2 MNVR EXEC      | 2: GNC OMS 2 MNVR EXEC |
| 3: BFS, GNC OMS 2 MNVR EXEC |                        |

B Wedge Install OMS 2/ORBIT BURN and OMS  
BURN MONITOR Cue Cards (F6/F8)

**OMS 2 BURN ATTITUDE MNVR**

B F6/F8 ✓ADI ATT (two) - INRTL  
ADI RATE - 1  
C Mnr to OMS 2 Burn Attitude

|                        |
|------------------------|
| 3: BFS, GNC SYS SUMM 2 |
|------------------------|

The OMS-2 BURN cue cards are put up in preparation from OMS-2.

The RHC/THC (FLT CNTLR PWR) power is normally turned off, to avoid unwanted RCS firings if a crewmember accidentally hits the stick. Before an OMS burn, the controller power is turned on, in case the crew has to take over manual control. Maneuvering to the burn attitude is generally done via the AUTO MNVR option (item 27 on OMS-2 MNVR EXEC). The OMS MNVR display burn attitude is in inertial coordinates, so the ADI must be in INRTL to crosscheck the display attitude. In general, the burn will not be done with the ADI in INRTL, so the crew must remember to reconfigure the ADI switch after the preburn maneuver.

If the Orbiter attitude differs by more than 5° from the desired burn attitude at ignition, the OMS TVC will correct the attitude and complete the burn successfully. It is not necessary to waste RCS propellant to keep the Orbiter's attitude exactly at the desired burn attitude prior to ignition, although a transient will cause higher propellant usage than necessary.

In addition to checking the ADI attitude with the CRT BURN ATT, the crew should verify that the error needles are centered at this attitude.

If any of the cross-checks disagree, the crew should consult MCC. This would indicate that something must be wrong with guidance. If the needles are centered, then the crew can hit the attitude REF pb near (the ADI switches) to load this attitude for use during the burn.

**B SEAT SAFING AND ADJUSTMENT**

Open Visor  
Remove from pocket and install:  
Panel Jettison T-Handle Pin  
Adjust Back Angle  
Take antmotion sickness  
medication

## ● TIG-5 P VACUUM INERTING TERMINATE

R4 MPS FILL/DRAIN  
 LH2,LO2 OUTBD (two) - CL  
 Wait 10 sec ..... - GND  
 LH2,LO2 INBD (two) - GND

R2 MPS PNEU He ISOL - GPC

\* If MPS PRPLT DUMP B/U LH2 VLV \*  
 \* sw was set to OP, set sw to CL \*

TIG-2 B Go to OMS 2/ORBIT BURN Cue Card

At a convenient time before the crew gets out of their seats, the panel jettison T-handle is safed, and the antimotion sickness medication is taken. The VACUUM INERTING TERMINATE is then done.

## 3.3.1.4 OMS-2

On a DI mission, the Orbiter attains mission apogee (HA) at MECO. On a SI mission, the Orbiter attains mission apogee (HA) after the OMS-1 maneuver. In both these cases, while HA is well above the atmosphere, perigee (HP) is too low for the vehicle to remain in orbit. The nominal OMS-2 maneuver will circularize the orbit at the mission altitude.

For an ATO, the OMS-2 burn raises the perigee to a safe height which allows the Orbiter to stay in orbit while problems are being corrected. If severe problems have necessitated an AOA, the OMS-2 burn must set up the Orbiter for an acceptable EI. In this case, the OMS-2 burn is actually a deorbit burn and the DEORBIT BURN cards should be used (discussed in the Entry Flight Procedures Handbook).

As long as the perigee is sufficient for the Orbiter to remain in orbit for a few revolutions, the cutoff conditions of a nominal or ATO OMS-2 burn are relatively unconstrained, in contrast to the tight REI,  $\Delta V$ , and Y c.g. constraints of a deorbit burn. Of course, it is desirable to achieve the planned orbit, but this is an issue of mission success rather than safety. Because the cutoff conditions of an OMS-2 burn are less constrained, a lot of the complicated burn completion procedures in the DEORBIT BURN cue cards are unnecessary for OMS-2. Also, no special propellant balancing procedures, such as the UNBALANCED PRPLT DEORBIT BURN, are necessary for OMS-2, since a small c.g. offset poses no problem on-orbit. Any offset can be corrected by crossfeeding on-orbit or during the burn.

Because of these simplifications, the OMS-2 BURN card procedures are the same as the Orbit Procedures and, in general, are a subset of the DEORBIT BURN card procedures. Only OMS-2/ORBIT OMS (fig. 3.3-7) and OPS 1/RCS BURN (fig. 3.3-8) cards are used for OMS-2.

HOOK  
VELCRO

**OMS 2/  
ORBIT OMS  
BURNS**

ASC-2a/A, O/A

HOOK  
VELCRO

/MM105/202(302)  
 /BURN ATT (INRTL) then REF, pb - push  
 /ENG SEL CNTL PWR (two) - ON  
 /DAP - AUTO(PASS)/DISC /DAP TRANS - NORM  
 /GIMBAL TRIM

2 engine: P = +0.4 LY = -5.7 RY = +5.7  
 1 engine: P = +0.4 LY = +5.2 RY = -5.2  
 L,R OMS He PRESS/VAP ISOLA (two) - OP  
 wait 2 sec ..... B (two) - GPC (OP for SE  
 burn)

|            |     |    |    |
|------------|-----|----|----|
|            | GPC | OP | CL |
| ORB BURN A |     |    |    |
| B          |     |    |    |

TIG-2 SEL OMS ENG(s) - ARM/PRESS (/P VLVs OP)  
 IF P VLV CL: Aff OMS ENG - OFF

WARNING

Do not burn affected engine if:  
 OMS N2 TK P < 470(523) (NONCRIT  
 He TK P < 640 BURN)  
 FU ENG IN P < 216(244)  
 OX ENG IN P < 151(244)

ΔVTOT: OMS XFEED RETURN (Planned Single  
 Engine)

- :15 EXEC  
 If OMS ENG Pc MSG and non critical burn - Affected  
 Eng - OFF  
 If Leaking OMS PROP burn RCS + X TIG -15 sec to  
 OMS IGN + 1 sec  
 :00 TIG : (/Pc, PVTOT, ENG VLVs; start watch)

**OMS PRPLT FAIL:**  
 • HP < 100 (CONTINUE BURN):  
 • Failed OMS ENG - OFF  
 • /XFEED (two) - CL  
 • TK ISOL (two) - CL  
 • He PRESS (two) - CL  
 • HP > 100 (STOP BURN):  
 • OMS ENG (two) - OFF  
 • /Failed OMS XFEED (two) - CL  
 • TK ISOL (two) - CL  
 • He PRESS (two) - CL

**OMS ENG FAIL:**  
 • ASCENT or CRIT O/O (Continue Burn)  
 • Failed ENG - OFF  
 • OMS XFEED at → 1/2 ΔVTOT     
 at FAIL

**RCS COMPLETION:** (Hp < 80 or CRIT O/O)  
 • Interconnect to either OMS that was ENG FAIL  
 • THC + X (Hp = 80)  
 • Post burn, AFT RCS RECONFIG

CUTOFF :  
 + :02 OMS ENG(s) - OFF  
 Trim inplane X,Z residuals < 2 fps

HOOK  
VELCRO

**OPS 1  
RCS BURN**

ASC-2b/A, O/A

HOOK  
VELCRO

**AFT RCS**

/RCS BURN CONFIG:  
 OMS TK ISOL (all) - OP  
 L(R) OMS XFEED (two) - OP  
 R(L) OMS XFEED (two) - CL  
 AFT L,R RCS XFEED (four) - OP  
 TK ISOL (six) - CL

XFEED at  
 1/2 ΔVTOT  
 (if reqd)

TIG-2 L,R  
 He PRESS/VAP ISOLA - OP  
 ...Wait 2 sec... B - OP

/MM105  
 /CNTLR PWR (two) - ON  
 /BURN ATT (INRTL) then REF, pb-push  
 /RCS SEL  
 :00 + X :  
 Maintain PITCH ATT ERR ± 3°  
 Monitor OMS data  
 Monitor ΔVTOT

CUTOFF RELEASE THC

**FWD RCS**

FRCS BURN PREP

Load DUMMY target for FRCS  
 attitude  
 RCS SEL - ITEM 4 EXEC  
 TIG = TTA -2:00 or as reqd  
 ΔVX = -2 1 (ITEM 19)  
 ΔVY = 0 (ITEM 20)  
 ΔVZ = -1 0 (ITEM 21)  
 LOAD - ITEM 22 EXEC  
 TIG-10 Mnvr to ATT (error needles)  
 When in attitude:  
 ADI ATT - REF (push)  
 Load External ΔV Burn Target  
 ΔVX = +80  
 ΔVY = 0  
 ΔVZ = 0  
 LOAD - ITEM 22 EXEC  
 TIMER - ITEM 23 EXEC  
 /VGX = negative  
 /VGOY = 0  
 /VGOZ = +20 ± 2  
 /REF ball - 0,0,0

NOTE

Error needles invalid during burn  
 Burn time = ~2X TGO  
 TGT Hp = 80 for ASCENT

:00 -X :  
 CUTOFF CUR HP = TGT HP    RELEASE THC

Figure 3.3-7.- OMS-2/ORBIT OMS BURNS card.

Figure 3.3-8.- OPS 1/RCS BURN card.

Note that the OMS BURN MONITOR card is used during the OMS-2. In contrast to the relative simplicity of the OMS-2 BURN card, the OMS BURN MONITOR card is in general more complex than the DEORBIT BURN MONITOR card. This is because the ascent procedures are designed to preserve the capability of at least one more OMS burn (deorbit), whereas this is not a concern in the deorbit procedures.

The OMS-2 TARGETING card contains the information necessary to determine whether the OMS-2 burn should be nominal, ATO or AOA. This decision to downmode is based either on excessive ΔV requirements after OMS-1 or on

systems failures. The OMS-2/ORBIT OMS BURN card covers either the two-engine or one-engine burn.

|                |                                       |                |
|----------------|---------------------------------------|----------------|
| HOOK<br>VELCRO | <b>OMS 2/<br/>ORBIT OMS<br/>BURNS</b> | HOOK<br>VELCRO |
|----------------|---------------------------------------|----------------|

ASC-2a/A,O/A

/MM105/202(302)  
 /BURN ATT (INRTL) then REF, pb - push  
 /ENG SEL CNTL PWR (two) - ON  
 /DAP - AUTO(PASS)/DISC /DAP TRANS - NORM  
 /GIMBAL TRIM  
 2 engine: P = +0.4 LY = -5.7 RY = +5.7  
 1 engine: P = +0.4 LY = +5.2 RY = -5.2  
 L,R OMS He PRESS/VAP ISOL A (two) - OP  
 wait 2 sec ..... B (two) - GPC (OP for SE  
 burn)

|            |     |    |    |
|------------|-----|----|----|
|            | GPC | OP | CL |
| ORB BURN A |     |    |    |
| ORB BURN B |     |    |    |

TIG-2 SEL OMS ENG(s) - ARM/PRESS (/P VLVs OP)  
 IF P VLV CL: Aff OMS ENG - OFF

**WARNING**

Do not burn affected engine if:  
 OMS N2 TK P < 470(523) (NONCRIT  
 He TK P < 640 BURN)  
 FU ENG IN P < 216(244)  
 OX ENG IN P < 151(244)

|  |  |  |
|--|--|--|
|  |  |  |
|--|--|--|

ΔVTOT: OMS XFEED RETURN (Planned Single Engine)

-15 EXEC  
 If OMS ENG Pc MSG and non critical burn - Affected Eng - OFF  
 If Leaking OMS PROP burn RCS + X TIG -15 sec to OMS IGN + 1 sec  
 :00 TIG (/Pc, PVTOT, ENG VLVs; start watch)

Most of the setup for the OMS-2 burn should be completed before coming to this card. The first few checks are simply verification of the burn configuration. The FLT CNTLR PWR - ON action is required as the CNTLR PWR was turned off after OMS-1.

There are no explicit crew actions to perform during a nominal burn. After engine cutoff, there is no need to trim velocity residuals, as is done for a deorbit burn, because of the less stringent cutoff requirements going into orbit.

After the OMS has sat dormant for a period of time, it is possible that small leaks in the system could lead to reduced pressure between the He PRESS valves (closed when the OMS is not in use) and the check valves. With the lines in this condition, there is a concern that if both the A and B valves open together, the resultant pressure surge will create a "water hammer" effect that could break the tank pressure relief valve. For this reason the procedures specify the opening of the A and B valves separately. Before a two-engine burn, the cards call for manually opening the A He PRESS/VAP ISOL valves for a short time. This repressurizes the lines in case any leakage has occurred. The A valves are then set to GPC, as are the B valves. The GPC closes the A valves and leaves the B valves closed. Both sets of valves can now be opened simultaneously by the GPC at TIG with no danger of a pressure surge.

```

• OMS PRPLT FAIL:
• HP < 100 (CONTINUE BURN):
• Failed OMS ENG - OFF
• /XFEED (two) -CL
• TK ISOL (two) -CL
• He PRESS (two) -CL
• HP > 100 (STOP BURN):
• OMS ENG (two) - OFF
• /Failed OMS XFEED (two) -CL
• TK ISOL (two) -CL
• He PRESS (two) -CL

```

The decision that a loss of engine Pc is a propellant failure rather than an engine failure is based on criteria specified on the OMS BURN MONITOR card (ASC/ORB/ENT PKT C/L PROC HANDBOOK).

The uncertainty of the propellant status in this situation makes it prudent to not go higher than is absolutely necessary to achieve a stable orbit for a few revs. This gives the crew time to analyze the propellant situation. It may be possible to raise the orbit and continue the mission, or if this is impossible, then the Orbiter can do a deorbit burn on revs 2 to 6. A perigee of 100 n. mi. gives at least six revs retention time on-orbit, based on an ATO apogee of 105 n. mi. Hence, the crucial observation after a propellant failure is whether the current perigee height, HP, is < 100 n. mi. or  $\geq$  100 n. mi. CUR is displayed in the upper right hand box on the OMS-2 MNVR EXEC display along with targeted HP (TGT).

|     |     |     |
|-----|-----|-----|
|     | HA  | HP  |
| TGT | XXX | XXX |
| CUR | XXX | XXX |

The crew should scan this data during a burn to keep aware of the present condition of the vehicle in the event of a critical systems failure requiring immediate action.

If HP < 100 n. mi. at the time of the propellant FAIL, the burn is continued with one engine. 100 n. mi. ensures a limited duration orbit capability and a minimum deorbit  $\Delta V$  requirement. If the thermal environment, as a result of propellant leakage, prohibits immediate use of the pod then the safe orbit allows time for propellant sublimation and subsequent pod reuse when the thermal environment is acceptable.

With the switch actions indicated, the failed propellant system is isolated and secured, as above.

When the burn is terminated at HP = 100, guidance sees a large  $\Delta VTOT$  remaining. Guidance will assume that the crew is going to do an RCS +X completion and will reconfigure TGO and the ADI error needles accordingly. While in MM 105, the option remains open to retarget for another OMS burn, possibly with just one OMS engine. An OMS burn cannot be done after a PRO to MM 106; also, it is not possible to go back to MM 105, as that is an invalid transition. The nominal OMS-2 postburn procedures in the Ascent Checklist tell the crew to PRO to OPS 106 following the OMS/RCS postburn reconfiguration. However, if they shut down at 100 n. mi. because of a propellant failure, they should wait for MCC confirmation before taking this step.

- HP > 100 (STOP BURN):
- OMS ENG (two) - OFF
- ✓Failed OMS XFEED (two) - CL
- TK ISOL (two) - CL
- He PRESS (two) - CL
- OMS ENG FAIL:
- ASCENT or CRIT O/O (Continue Burn)
- Failed ENG - OFF
- OMS XFEED at → 1/2 ΔVTOT [ ] [ ] [ ]
- at FAIL

If one engine fails (bipropellant valve closes), there is no change in the total OMS ΔV capability for the mission since all the propellant on the failed engine side can be burned through the good engine via crossfeed. Hence, if an engine fails, the crew continues the burn and switches the failed engine off.

For a propellant failure, turning off the OMS ENG switch is important. This closes the bipropellant valves and prevents a potentially harmful propellant mixture from entering the combustion chamber. With an engine failure the bipropellant valves are closed, as that is the source of the failure. Switching off the OMS ENG switch on the failed engine signals Guidance and Flight Control to reconfigure for a single-engine burn.

When the crew is satisfied that the reconfiguration has been successfully accomplished, they should start crossfeeding OMS propellant from the failed side, at the proper time, to keep the Y c.g. balanced. Crossfeeding during OMS-2 is not as critical as during a deorbit burn because c.g. balance on-orbit is not critical; however, it is best to keep propellant quantities on the two sides in rough balance during the mission so that a subsequent propellant failure will not deprive the Orbiter of more than half its remaining propellant. Hence, if everything is going smoothly after reconfiguring for a single-engine burn, the crew should carry out the crossfeed.

ΔVTOT is used to determine the proper time to begin crossfeeding. For the OMS-2 conditions, each 1 percent of OMS propellant corresponds approximately 6.8 fps of ΔV. To use the ΔVTOT cue the crew must note the ΔVTOT at the time of the failure. Equalization of propellant usage is accomplished by dividing the remaining ΔVTOT between the two propellant pods. Depressing the SPEC key on the CRT when an engine fails saves the OMS-2 MNVR EXEC display so that the information will be available to the crew as they need it. Similarly, freezing the BFS GNC SYS SUMM 2 display on CRT 3 allows the failed OMS engine switch to be positioned to OFF and still preserve the engine ball valve condition for failure diagnosis. After monitoring the single engine burn reconfiguration, the crew can read the ΔVTOT at their leisure and enter half this value into the space provided on the cue card to use as a crossfeed cue.

- RCS COMPLETION: (Hp < 80 or CRIT O/O)
- Interconnect to either OMS that was ENG FAIL
- THC + X (Hp = 80)
- Post burn, AFT RCS RECONFIG
- CUTOFF
- :02 OMS ENG(s) - OFF
- Trim inplane X,Z residuals < 2 fps

If the HP < 80 the orbit is not considered safe. For this reason the burn must be continued until HP = 80.

After engine shutdown at TIG = 0, the N<sub>2</sub> purge valves open for 2 sec to clear out the engine intake and regenerative cooling fuel lines. This is to prevent the fuel from freezing in the lines. The purge can only take place if the OMS ENG switch is in the ARM/PRESS position; hence, the crew should wait 2 sec after engine shutdown (Pc = 0 is the actual shutdown cue) to switch the OMS ENG to OFF.

The OPS 1/RCS BURN card is used when no OMS engines are available for OMS-2. It contains the burn setup and procedures for either an AFT RCS burn or a forward (FWD) RCS burn (fig. 3.3-9).

This burn will only be performed if at least two ENG or PRPLT failures occur prior to OMS-2. For all failures except a dual OMS PRPLT FAIL, the OMS-1 burn will have been completed with the RCS interconnected to the remaining good OMS propellant system. This configuration is not changed between OMS-1 and OMS-2. However, the RCS OMS-2 BURN card requires confirmation of the interconnect switch configuration. The crew selects RCS (item 4 on the MNVR display) as part of the OMS-2 burn setup.

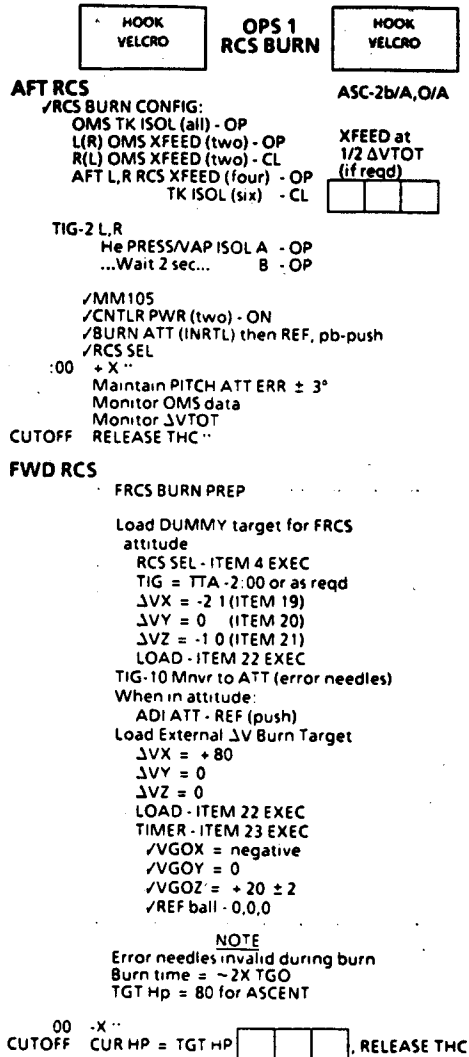


Figure 3.3-9.- OPS/RCS BURN card.

:00 + X "  
 Maintain PITCH ATT ERR ± 3°  
 Monitor OMS data  
 Monitor ΔVTOT  
**CUTOFF** RELEASE THC "

The burn is initiated by depressing the THC.

There is no AUTO flight control for RCS burns. However, closed loop guidance is active and the ADI error needles will indicate the proper Orbiter attitude to achieve the desired velocity. The cue card reminds the crew to follow the needles.



Nominally, only the pitch errors affect the in-plane velocity component and this, in turn, affects the HP at cutoff. Yaw errors alter the out-of-plane component of the burn which has almost no effect on the resulting orbit. For this reason, pitch errors are more critical than yaw errors. However, any propellant burned out of plane is wasted, and in a performance critical situation this is unacceptable. If the crew is doing a planned RCS burn as the result of at least one propellant failure, this would be the case and there would be no margin for waste. Therefore, the crew should restrict yaw attitude errors, as well as pitch, to less than  $\pm 3^\circ$  if possible.

Since the OMS propellant system is being used, all propellant checks that the crew performs during an OMS engine burn should be done here as well. "Monitor OMS data" should remind the crew to do this.

For a deorbit burn,  $\Delta VTOT$  is the cutoff cue. For OMS-2 the cue is HP = 80, but  $\Delta VTOT$  should always be monitored.

There is no guided cutoff for an RCS burn. The burn is terminated by the CDR releasing the THC. For OMS-2 the purpose of the RCS burn is merely to get into a stable orbit for a few revs. Hence, the crew should monitor the CUR HP as the cutoff cue. Note that, depending on the ascent scenario, the target HP (TGT HP) may be greater than 80. The crew should ignore this parameter and monitor the CUR HP. After cutoff, the PLT reconfigures ascent/entry RCS attitude control for AFT RCS propellant use, following the procedures in the INTERCONNECT, OMS XFEED card.

There is no gray failure section on this card. If a planned RCS OMS-2 is being done, there is not much else that can go wrong. The exception would be if both OMS engines had failed and both propellant systems were good at the start of the burn, and if the OMS propellant system to which the RCS is interconnected to subsequently failed. In this scenario the crew should try switching to the other OMS propellant system. It is quite possible that the RCS +X jets will be damaged as a result of the propellant failure. However, this is the only action available.

#### POST OMS-2 PROCEDURES

After OMS-2 cutoff, the crew will proceed to the post OMS-2 procedures. At this time the crew will note any deviation from the planned TIG. This information will be passed to the MCC.

The PLT will safe the OMS after the OMS-2 burn and configure the RCS for on-orbit use. If the OMS-2 burn is an AOA deorbit burn, the OMS should be safed and the RCS configured for entry.

|                         |                         |
|-------------------------|-------------------------|
| 1: GNC OMS 2 MNVR COAST | 2: GNC OMS 2 MNVR COAST |
| 3: BFS, GNC SYS SUMM 2  |                         |

● C POST BURN STATUS

NOMINAL

ΔTIG

 :   

B F6/F8 FLT CNTLR PWR (two) - OFF  
C3 ✓DAP - AUTO

● C OMS TVC GIMBAL CHECK

CRT1 SECONDARY CHECK  
Perform SEC L,R then PRI L,R GMBL CK

This gimbal check is done primarily to check out the entire gimbal system prior to on-orbit burns. OPS 1 is preferred over OPS 2 for this procedure as the data sample rate in OPS 1 is higher than in OPS 2. The post-OMS-2 gimbal check is the only planned execution (nominally) of this procedure due to lube considerations.

If the secondary gimbals are checked first, the primary drives may be left in control for the burn without any further reconfiguration, unless one of the primary gimbals fails the check.

Crew activity sequence for doing a preburn gimbal check:

- |                                    |  |
|------------------------------------|--|
| a. Select secondary gimbals        | ITEM 30 EXEC (L)<br>ITEM 31 EXEC (R)<br>Confirm asterisks by SEC                               |
| b. Initiate secondary gimbal check | ITEM 34 EXEC<br>Confirm asterisk by GMBL CK and<br>gimbal motion (angle readout on<br>display) |
| c. Secondary gimbal check finished | Confirm asterisk disappears  |
| d. Select primary gimbals          | ITEM 28 EXEC (L)<br>ITEM 29 EXEC (R)<br>Confirm asterisks by PRI                               |
| e. Initiate primary gimbal check   | ITEM 34<br>Confirm asterisk by GMBL CK and<br>gimbal motion (angle readout on<br>display)      |
| f. Primary gimbal check finished   | Confirm asterisk disappears  |

The gimbal angle readout on the display is only sufficient to confirm that the gimbal check is in progress. You cannot get enough information from this readout to confirm independently that the gimbals are working properly. You have to rely on FDI and MCC to catch any problems. If no down arrows appear, then the gimbal drive has passed the test.

The OMS He PRESS/VAPOR ISOL valves should be closed except during OMS burns to prevent loss of the high pressure He in the event of a leak in the propellant system and to prevent possible mixing of fuel and oxygen in the lines.

**P OMS/RCS POST BURN RECONFIGURATION**

- 07 AFT L,R RCS
  - He PRESS A (two) - GPC (tb-OP)
  - B (two) - CL (tb-CL)
  - TK ISOL (six) - OP (tb-OP)
  - XFEED (four) - CL (tb-CL)
- 08 FWD RCS
  - He PRESS A - GPC (tb-OP)
  - B - CL (tb-CL)
- L,R OMS
  - He PRESS/VAP ISOL (four) - CL
  - ✓TK ISOL (four) - OP (tb-OP)
  - ✓XFEED (four) - CL (tb-CL)

|                         |                         |
|-------------------------|-------------------------|
| 1: GNC OMS 2 MNVR COAST | 2: GNC OMS 2 MNVR COAST |
| 3: BFS, GNC SYS SUMM 2  |                         |

**MAJOR MODE CHANGE**

CRT1 GNC, OPS 106 PRO

|                         |                         |
|-------------------------|-------------------------|
| 1: GNC OMS 2 MNVR COAST | 2: GNC OMS 2 MNVR COAST |
|-------------------------|-------------------------|

- B C4A/ Stow ASC PKT C/L (Helmet Bag)
- R3A Unstow ORBIT Cue Cards & ORB PKT C/L

Go to POST INSERT, POST INSERTION ..

- \* If ATO, go to POST INSERT, \*
- \* ATO POST INSERTION \*
- \* If Rev 3 deorbit required, \*
- \* go to DEORBIT PREP, ORBIT \*
- \* 3 DEORBIT PREP \*

**UPLINK BLOCK AND UNBLOCK**

a. Cue

Communications loss of signal (LOS) or acquisition of signal (AOS)

b. Crew action

- At LOS:
  - C3 UPLINK BLOCK - ALL
- At AOS:
  - C3 UPLINK BLOCK - NONE
  - I/O RESET EXEC

c. Displays

None

## d. Discussion

Uplink is blocked anytime the vehicle does not have COMM with the ground. This is done to keep unwanted uplink from being accepted by the Orbiter. This is done automatically during on-orbit operations (OPS 2), but has to be done manually via the UPLINK BLOCK switch for ascent (OPS 1) and entry (OPS 3). When uplink is allowed again (UPLINK BLOCK - NONE), an I/O RESET has to be executed to reestablish the interface with the network signal processors.

When the ground informs the crew of LOS or AOS, they will remind them to do this by the call CONFIGURE FOR LOS (or AOS).

### 3.3.2 AOA Procedures

After MECO the crew will be directed to either of two sections in the ascent checklist: for nominal MECO DI flights, the Post-OMS-1 section; for nominal and underspeed MECO SI flights and underspeed MECO DI flights, the OMS-1 Burn section. In any AOA scenario, DI or SI, the crew will move to the AOA section of the checklist from the Post-OMS-1 section. The OMS-1 burn and post-OMS-1 procedures were discussed in section 3.3.1. Section 2.4 covered AOA targeting and abort selection. This section will discuss procedures found in the AOA section and AOA specific procedures found in the Post-OMS-1 section of the Ascent Checklist.

- \* C ALPHA MANAGEMENT (if reqd) \*
- \* \*
- \* If underspeed ATO or AOA-S OMS 1 \*
- \* and Post OMS 1 HP  $\leq 75$  nm: \*
- \* Maneuver to LVLH R180, P340, Y000 \*
- \* (maintain LVLH P = 0  $\pm 20$ ) \*
- \* After 10 minutes: \*
- \* Maneuver to LVLH P = 340 \*
- \* After 10 minutes: \*
- \* Maneuver to Burn Attitude \*

In order to limit atmospheric drag effects, alpha management is required for all AOA's selected due to MECO underspeed. After OMS-1 the Orbiter trajectory could be low enough for drag effects of the upper atmosphere to significantly affect vehicle performance. LVLH pitch = 0 will minimize drag. The crew will pitch the vehicle to 340° (-20°) and let the Orbiter drift for 10 min. After 10 min at the orbital drift pitch rate of -4 deg/min, the Orbiter will be at +20° in pitch with regards to LVLH. The crew will then pitch to 340° LVLH again. This maneuver is continued until the maneuver to OMS-2 burn attitude.

- \* P HYD DEPRESS (AOA only) \*
- \* \*
- \* F4  $\checkmark$ BDY FLP pb - 1t off (MPS stowed) \*
- \* (~2 min 21 sec) \*
- \* R4 HYD MPS/TVC ISOL VLV (three) - CL \*
- \* Hold 5 sec  $\checkmark$ (tb-CL) \*
- \* R2  $\checkmark$ APU SPEED SEL (three) - NORM \*
- \*  $\checkmark$ AUTO SHUT DN (three) - ENA \*
- \* HYD MN PUMP PRESS (three) - LO (MA) \*

The APU's and WSB's will not be shut down. They are left on to avoid problems associated with hot restarts (e.g., malfunctions in the injector cooling system and potential damage to the APU).

The three hydraulic systems will be placed in the depress mode to unload the APU's and conserve fuel. They will be repressurized shortly after EI to provide hydraulic power to the aerosurface during entry. A master alarm will be generated as the hydraulic pressure drops to the depress mode.

The AOA pads are basically the same as the end of mission pads except that some information is provided premission. For AOA, the primary HP (PRI HP) is equal to the backup HP since you will not redesignate to another landing site for underburns. The approximate value of PRI HP is the target HP (from the MNVR display) plus HP capability obtained from use of forward RCS and 90° prebank. TOT AFT QTY 1 (percent) is the quantity on both the left and right RCS at the entry redline. TOT AFT QTY 2 (percent) is the quantity on both the left and right RCS at the no yaw jet entry redline.

| AOA DEL PAD  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
|--|-----------------------|--|--|---|---|---|--|---|---|--|--|-----|---------------------|----|-----------------------|--|--|
| DEORBIT  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| PRPLT  | ( )                   |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| BURN CUE CARD:   |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| PRI HP = B/U HP = TGT HP + <table border="1" style="display: inline-table; vertical-align: middle;"> <tr><td style="width: 20px; height: 20px;"></td><td style="width: 20px; height: 20px;"></td></tr> <tr><td style="text-align: center;">37</td><td style="text-align: center;">(All steep entries)</td></tr> <tr><td style="text-align: center;">25</td><td style="text-align: center;">(All shallow entries)</td></tr> </table> = <table border="1" style="display: inline-table; vertical-align: middle;"> <tr><td style="width: 20px; height: 20px;"></td><td style="width: 20px; height: 20px;"></td></tr> </table> |                       |  |  |   |   |   |  |   |   |  |  | 37  | (All steep entries) | 25 | (All shallow entries) |  |  |
|  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| 37   | (All steep entries)   |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| 25   | (All shallow entries) |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
|  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| TOT AFT QTY 1 (%)  |                       |  |  |   |   |   |  | 9 | 6 |  |  |     |                     |    |                       |  |  |
| TOT AFT QTY 2 (%)  |                       |  |  |   |   |   |  | 4 | 3 |  |  |     |                     |    |                       |  |  |
| FRCS: DUMPTO % <table border="1" style="display: inline-table; vertical-align: middle;"> <tr><td style="width: 20px; height: 20px;"></td><td style="width: 20px; height: 20px;"></td></tr> </table> OX <table border="1" style="display: inline-table; vertical-align: middle;"> <tr><td style="width: 20px; height: 20px;"></td><td style="width: 20px; height: 20px;"></td></tr> </table> FU   |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
|  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
|  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| ENTRY/LANDING  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| EI-5 MM303   |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| INRTL ATT (7-22)   | R                     |  |  |   | P |   |  |   | Y |  |  |     |                     |    |                       |  |  |
| EI-5 MM304 PREBANK (ENT Mnvr Cue Card) ALT M SET (7-25)  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| VREL 1ST REVERSAL  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| <table border="1" style="display: inline-table; vertical-align: middle;"> <tr><td style="width: 20px; height: 20px;"></td></tr> </table> L   |                       | <table border="1" style="display: inline-table; vertical-align: middle;"> <tr><td style="width: 20px; height: 20px;"></td></tr> </table> R |  | <table border="1" style="display: inline-table; vertical-align: middle;"> <tr><td style="width: 20px; height: 20px;"></td></tr> </table> OVHD |   | <table border="1" style="display: inline-table; vertical-align: middle;"> <tr><td style="width: 20px; height: 20px;"></td></tr> </table> STRT |  |   |   |  |  | deg | RWY                 |    |                       |  |  |
|  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
|  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
|  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
|  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| WINDS: (ENT Mnvr Cue Card)   |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| 50K /  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| 40K /  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| 30K /  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| 20K /  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| 7K /   |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| SURFACE /  |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |
| REMARKS:   |                       |  |  |   |   |   |  |   |   |  |  |     |                     |    |                       |  |  |

The post OMS-1 procedures will indicate to the crew at which point it is necessary to move to the AOA section of the checklist. After going to the AOA procedures section, the crew should reconfigure the cockpit for deorbit and entry and transition the PASS and BFS to OPS 3. OPS 3 is resident in the BFS GPC but loaded from mass memory in the PASS. Also, the crew should verify that the DAP is in manual prior to the OPS transition to prevent unwanted jet firings when OPS 3 comes up.

|                             |                        |
|-----------------------------|------------------------|
| 1: GNC OMS 2 MNVR EXEC      | 2: GNC OMS 2 MNVR EXEC |
| 3: BFS, GNC OMS 2 MNVR EXEC |                        |

B C4F/ Stow ASC PKT C/L  
R3F Unstow ENT PKT C/L

F6/F8 Install DEORBIT BURN and DEORBIT BURN MONITOR Cue Cards (R3A)

Stow Ascent Cue Cards (R3A)

NOTE

Verify/enter appropriate ABORT  
TGT number in MM105 but do not  
LOAD targets until OPS 3

\* If BFS, do not manually \*  
\* enter targeting data \*  
\* (ITEMS 5-18) until MM301 \*

|                             |                        |
|-----------------------------|------------------------|
| 1: GNC OMS 2 MNVR EXEC      | 2: GNC OMS 2 MNVR EXEC |
| 3: BFS, GNC OMS 2 MNVR EXEC |                        |

**RECONFIGURATION DPS FOR ENTRY**

CAUTION

If recovering string(s)  
due to failed GPC(s), all  
FCS CH(s) to AUTO prior  
to OPS 301 PRO

CRT1 GNC, OPS 301 PRO (✓DAP)  
CRT3 BFS, GNC, OPS 301 PRO

CRT1 GNC, OPS 302 PRO ..

Once in OPS 3, the targets should be verified from the OMS TARGETS cards. Also, the runway selection should be verified on SPEC 50. This is particularly important if the AOA landing site is not the primary AOA landing site. By this time, a DEL PAD should have been read up from the ground, which contains information relative to the upcoming AOA. PRPLT, the amount (lb) of OMS propellant to be burned during deorbit, including wasting (burned out of plane), should be loaded in item 18 of the MNVR display preceded by a + or - (direction) per the OMS TARGETS card. If this information is not available from the ground, the crew can calculate this number using either the c.g. wheel or the HP41C calculator. The purpose of wasting propellant is to adjust the vehicle c.g. for entry. In cases where all the OMS propellant is required for the OMS-2 burn, obviously no wasting is required. Wasting calculations should reflect an appropriate FWD RCS dump quantity. This is a flight specific number, but it is preferable to dump all of it if vehicle c.g. allows. This number will be provided by the ground on the DEL PAD.

1: GNC DEORB MNVR EXEC    2: GNC DEORB MNVR EXEC  
 3: BFS, GNC DEORB MNVR EXEC

C3    OI PCMMU FORMAT - FXD

**B OMS 2 BURN SETUP**

CRT1    TRIM LOAD - ITEM 6 +0.4 -5.7  
 +5.7 EXEC

- \* For single engine burn (good engine): \*
- \* TRIM LOAD LY - ITEM 7 +5.2 EXEC \*
- \*            LOAD RY - ITEM 8 -5.2 EXEC \*
- \* OMS L - ITEM 2 EXEC \*
- \*            R - ITEM 3 EXEC \*
- \* For RCS burn: \*
- \* RCS SEL - ITEM 4 EXEC \*
- \* XFEED:Failed engine PROP to good engine \*

1: GNC DEORB MNVR EXEC    2: GNC DEORB MNVR EXEC  
 3: BFS, GNC DEORB MNVR EXEC

1: GNC 50 HORIZ SIT

**AOA RWY OPTIONS**

| ETR LOW INCLINATIONS |        |                   |     |
|----------------------|--------|-------------------|-----|
| SITE                 | RWY    | TACANS            | MLS |
| 1                    | KSC 15 | TTS 59Y - COF 97  | 8   |
|                      | KSC 33 | TTS 59Y - COF 97  | 6   |
| 12                   | NOR 17 | SNG 121Y - HMN 92 | 8   |
|                      | NOR 23 | SNG 121Y - HMN 92 | -   |
| 13                   | EDW 04 | EDW 111 -         | -   |
|                      | NOR 35 | SNG 121Y -        | -   |
| 14                   | EDW 23 | EDW 111 - PMD 92  | -   |
|                      | EDW 15 | EDW 111 - PMD 92  | -   |
| 15                   | EDW 22 | EDW 111 - PMD 92  | 8   |
|                      | EDW 17 | EDW 111 - PMD 92  | 6   |

✓RWY selection

1: GNC 50 HORIZ SIT    2: GNC DEORB MNVR EXEC  
 3: BFS, GNC DEORB MNVR EXEC

1: GNC DEORB MNVR EXEC

✓Or enter Target from OMS TARGETS

**NOTE**

Onboard computed TIG & 0T may vary slightly and are acceptable if REI is correct

CRT1    LOAD - ITEM 22 EXEC  
 TIMER - ITEM 23 EXEC

CRT3    ✓BFS TGT



Once all the targets are entered correctly (PASS and BFS) and SPEC 50 is checked to ensure the proper runway selection, a load (item 22) should be done to get the target solution.

A TVC gimbal check is performed and the seats are adjusted for entry. Then the OMS is configured for the burn.

If the secondary gimbals are checked first, the primary drives may be left in control for the burn without any further reconfiguration, unless one of the primary gimbals fails the check.

Crew activity sequence for doing a preburn gimbal check:

- |                                    |  |
|------------------------------------|--|
| a. Select secondary gimbals        | ITEM 30 EXEC (L)<br>ITEM 31 EXEC (R)<br>Confirm asterisks by SEC                         |
| b. Initiate secondary gimbal check | ITEM 34 EXEC<br>Confirm asterisk by GMBL CK and gimbal motion (angle readout on display) |
| c. Secondary gimbal check finished | Confirm asterisk disappears  |
| d. Select primary gimbals          | ITEM 28 EXEC (L)<br>ITEM 29 EXEC (R)<br>Confirm asterisks by PRI                         |
| e. Initiate primary gimbal check   | ITEM 34<br>Confirm asterisk by GMBL CK and gimbal motion (angle readout on display)      |
| f. Primary gimbal check finished   | Confirm asterisk disappears  |

The gimbal angle readout on the display is only sufficient to confirm that the gimbal check is in progress. You cannot get enough information from this readout to confirm independently that the gimbals are working properly. You have to rely on FDI and MCC to catch any problems. If no down arrows appear, then the gimbal drive has passed the test.

● C OMS TVC GIMBAL CHECK  
(Perform during S-band AOS)

CRT1 SECONDARY CHECK

Perform SEC L,R then PRI L,R  
GMBL CK

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

● SEAT ADJUSTMENT

Adjust Back Angle

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

P OMS BURN PREP

```

08 L,R OMS
   ✓He PRESS/VAP ISOL A (two) - GPC
   B (two) - CL
   ✓TK ISOL (four) - OP (tb-OP)
   XFEED (four) - CL (tb-CL)

.....RCS BURN PREP (I'cnect OMS to RCS).....
.
. P 08 L,R OMS
.   He PRESS/VAP ISOL (four) - CL
.   ✓TK ISOL (four) - OP (tb-OP)
.   L OMS XFEED (two) - OP (tb-OP)
.   R OMS XFEED (two) - CL (tb-CL)
.
.   07 AFT L,R RCS
.   XFEED (four) - OP (tb-OP)
.   TK ISOL (six) - CL (tb-CL)
.
.....

```

When the solution comes up, the REI is checked against the expected REI on the OMS TARGETS card. If they do not agree within 50 n. mi., TIG should be adjusted per the TARGETS card and a new solution computed until the numbers do agree. If the range is too long, time is added to the TIG. If the range is too short, time is subtracted from TIG. This is done to make the onboard solution compatible with the ground solution.

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

OMS BURN TIG ADJUST (if reqd)

CRTX LOAD - ITEM 22 EXEC  
 TIMER - ITEM 23 EXEC

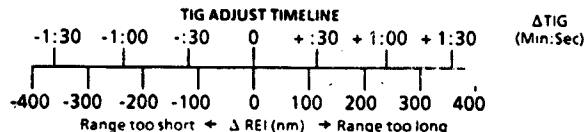
Determine  $\Delta TIG$  (if  $REI - REF > 50$ ) from  
OMS TARGETS

CRTX Enter new TIG

LOAD - ITEM 22 EXEC  
 TIMER - ITEM 23 EXEC

Repeat until  $\Delta RANGE < 50$

CRT3 ✓BFS TGT



When the onboard solution is satisfactory, the crew should begin the maneuver to burn attitude (item 27). Procedures for the deorbit burn are covered in the Entry Flight Procedures Handbook.

• **MNVR TO DEORBIT BURN ATTITUDE**

- B F6/F8 ✓ADI ATT (two) - INRTL  
 ✓ERR (two) - 5  
 ✓RATE (two) - 5
- C Mvnr to Deorbit Burn Attitude  
 (✓ADI ATT with CRT BURN ATT)

At this time, the vacuum inerting is terminated and the burn is performed using the appropriate deorbit burn card.

• **TIG-10 P VACUUM INERTING TERMINATE**

- R4 MPS FILL/DRAIN  
 LH2,LO2 OUTBD (two) - CL  
 Wait 10 sec... - GND  
 LH2,LO2 INBD (two) - GND
- R2 MPS PNEU He ISOL - GPC

3: BFS, GNC SYS SUMM 2

TIG-2 B R3A Go to DEORBIT BURN Cue Card

If the burn must be completed using AFT RCS, usage should not go beyond the TOTAL AFT QTY 2 (percent) on the DEL PAD. This is the no yaw jet limit. The burn should be completed with FWD RCS if required per the BURN card. AFT QTY 1 protects the entry programmed test inputs (PTI's).

When the burn is completed, the Vx and Vz residuals should be trimmed to <2 fps (<0.5 fps if shallow) with the THC. The crew should check for any prebank requirements. Underburns will require a prebank to dissipate excess energy as outlined by the prebank tables in the Ascent Checklist. Shallow AOA's always require at least a 90° prebank to reduce the risk of skip out. Pre-bank data should be copied into the ENTRY MANEUVERS cue card.

The OMS/RCS systems are next reconfigured for the post-deorbit burn phase of flight.

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

P OMS/RCS POST BURN RECONFIGURATION

```

.....
. If I'CNCT .
. Perform I'CNCT RETURN .
. (ASC PKT C/L, RCS) .
.....

```

07 AFT L,R RCS  
 ✓He PRESS (four)- OP (tb-OP)  
 ✓TK ISOL (six) - GPC (tb-OP)  
 ✓XFEED (four) - GPC (tb-CL)

08 L,R OMS  
 He PRESS/VAP ISOL (four) - CL  
 ✓TK ISOL (four) - OP (tb-OP)

\* If OMS PRPLT FAIL: \*  
 \* ✓Affected TK ISOL (two) - CL \*

✓XFEED (four) - CL (tb-CL)

Determine Prebank  
 Determine  $\Delta$ HP (CUR HP - TGT HP)

Use PREBANK TABLE  
 Record Prebank on ENT MNVR Cue  
 Card

At this point the crew will determine what prebank, if any, is required (to compensate for underburns) based on the  $\Delta$ HP and prebank tables.

Determine Prebank  
 Determine  $\Delta$ HP (CUR HP - TGT HP)

Use PREBANK TABLE  
 Record Prebank on ENT MNVR Cue  
 Card



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

C CRT1 /or load INRTL EI-5 MM303 ATT from DEL PAD:

R - ITEM 21 +

P - ITEM 25 +

Y - ITEM 26 +

MNVR to EI-5 Att

- \* If UNDERBURN, or no DEL PAD, ignore \*
- \* INRTL ATT ERR needles and Mnvr to \*
- \* LVLH R001, Y358 and P per table \*
- \* below \*

| TIME to EI (min) | LVLH PITCH (deg) |
|------------------|------------------|
| 20               | 339              |
|                  | 343              |
|                  | 347              |
|                  | 351              |
|                  | 355              |
| 15               | 359              |
|                  | 3                |
|                  | 7                |
|                  | 11               |
|                  | 15               |
| 10               | 19               |
|                  | 23               |
|                  | 27               |
|                  | 31               |
|                  | 35               |
| 5                | 39               |

Next, the OMS gimbal positions are checked and the gimbals powered down for entry. Also, the FRCS dump is initiated at this time.

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

**C OMS GIMBAL POWERDOWN**

Verify gimbal positions:

|   |      |      |
|---|------|------|
|   | L    | R    |
| P | +5.9 | +5.9 |
| Y | +6.4 | -6.4 |

CRT1 GMBL OFF - ITEM 32 EXEC  
- ITEM 33 EXEC

**P FORWARD RCS DUMP**

**NOTE**

Use BFS Qtys for all calculations

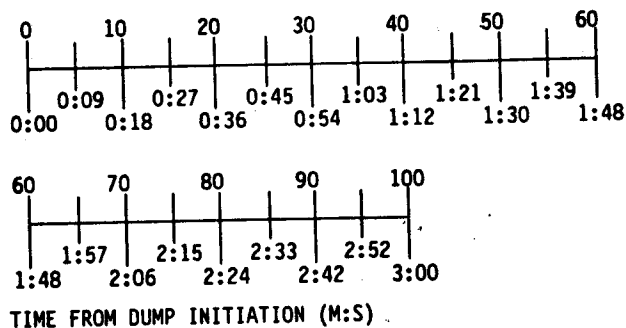
Determine FWD RCS 'DUMP TO %' using lowest of Ox or Fu qty (calculator, cg wheel, or DEL PAD)

Once in the desired attitude, the amount of FWD RCS to be dumped should be determined from the DEL PAD, c.g. wheel, or calculator. The crew should start the dump via items 36 and 37 on the MNVR display and stop the dump (item 38) at the appropriate time per the table in the checklist.

The four-jet and two-jet dump tables list the dump times associated with a desired dump quantity (percent) for four- and two-jet FRCS dumps. After the dump is complete, the FRCS manifold isolation valves are closed because the forward jets are not required for entry flight control.

**FOUR JET DUMP:**

F RCS PRPLT TO BE DUMPED (%)



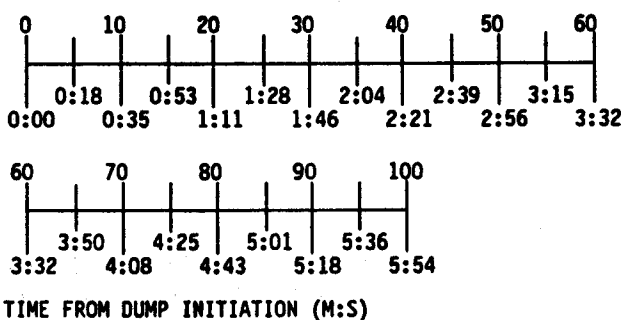
**NOTE**

During dump disregard FRCS qty

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

**TWO JET DUMP:**

F RCS PRPLT TO BE DUMPED (%)



**NOTE**

During dump, disregard FRCS QTY

- CRT2 FWD RCS ARM - ITEM 36 EXEC  
 DUMP - ITEM 37 EXEC  
 (Start watch)  
 When dump time achieved:  
 OFF - ITEM 38 EXEC

**ISOLATE FWD RCS**

- When dump complete:  
 O8 FWD RCS  
 MANF ISOL 1,2,3,4 (four) - CL  
 (tb-CL)

A final check of SPEC 50 (PASS and BFS) should be made and the correct RWY verified and loaded. Note in the checklist that the PASS and BFS configurations are listed. If BFS is engaged, it should be configured as the PASS. If a significant downtrack error in the state vector exists, it will be updated at this time with a  $\Delta T$ .

2: GNC 50 HORIZ SIT

3: BFS, GNC 50 HORIZ SIT

P STATE VECTOR CHANGE (if reqd)

CRT2  $\Delta T$  - ITEM 18

|   |  |  |   |  |  |
|---|--|--|---|--|--|
| ( |  |  | . |  |  |
|---|--|--|---|--|--|

LOAD - ITEM 16 EXEC  
 .....wait 8 sec(min).....  
 CRT3 PASS/BFS SV XFER - ITEM 17 EXEC  
 LOAD - ITEM 16 EXEC

HORIZ SIT CONFIG

ALTM - ITEM 9

+

|  |  |   |  |  |
|--|--|---|--|--|
|  |  | . |  |  |
|--|--|---|--|--|

|                          |                | <u>PASS ITEM</u> |      | <u>BFS ITEM</u> |
|--------------------------|----------------|------------------|------|-----------------|
| AREA                     | ✓correct AREA/ | 2✓               |      | 2✓              |
| RWY                      | RWY selected   | 3✓               |      | 3✓              |
|                          | per DEL PAD    | 4✓               |      | 4✓              |
| TACAN                    |                | 5✓               |      | 5✓              |
| G&N                      | OVHD           | 6✓               | OVHD | 6✓              |
| NEP                      |                | 7✓               |      | 7✓              |
| AIM                      | NOM            | 8✓               | NOM  | 8✓              |
| SPD BRK                  | NOM            | 39✓              |      |                 |
| TAC                      | INH            | 20✓              | INH  | 20✓             |
| DRAG H                   | AUT            | 22✓              | AUT  | 22✓             |
| ADTA H                   | INH            | 26✓              | INH  | 26✓             |
| ADTA TO G&C              | INH            | 29✓              | AUT  | 28✓             |
| TAC                      | DELTA          | 35✓              |      | -               |
| Failed TACANs deselected |                | ✓                |      | ✓               |
| HUD                      | Blank          | 37✓              |      |                 |
|                          | Blank          | 38✓              |      |                 |

\* If BFS engaged: \*  
 \* Set HSD BFS ITEMS to PASS Config \*

If the APU's have been shut down, a hot restart is required as per the Entry Pocket Checklist. A final switch check (in the checklist) is done and the vent doors are closed at EI-5. Go to the ENTRY MANEUVERS cue card for the subsequent entry. A discussion of the entry can be found in the Entry Flight Procedures Handbook. An AOA entry is identical to an EOM entry.



3.3.3 TAL Procedures

The TAL procedures discussed in this section are from the STS-26B Ascent Checklist (figs. 3.3-10 and 3.3-11). This section will discuss each of the procedures in the checklist in the order that they appear.

PILE

**AUTO TAL CDR**

ABORT TAL/AOA-S

\* No Joy: \*

\* [G51] AOA ITEM 1 EXEC, ITEM 3 EXEC \*

[G50] SEL SITE, RWY (PASS/BFS) ..

| SITE | RWY              | TACANS   | MLS | LENGTH         |
|------|------------------|--|-----|----------------|
| 2    | BEN 36<br>BEN 38 | BEN 69 - CBA 116 (DME)<br>BEN 69 - CBA 116 (DME) | 6   | 14000<br>14000 |
| 3    | MRN 21<br>MRN 03 | MRN 100 - AOG 23<br>MRN 100 - AOG 23             | -   | 11840<br>11840 |
| 4    | GDV 03<br>ANL 02 | GDV 76 (DME) ---<br>CVS 100 (DME) ---            | -   | 9900<br>10890  |
| 5    | BYD 32<br>BYD 14 | BYD 69 - B176 (DME)<br>BYD 69 - B176 (DME)       | 6   | 11700<br>11700 |

V<sub>I</sub> - [15.4K] Roll to Heads Up

----- MECO -- BFS - C/O BUG (V<sub>I</sub> approx [24.0K]) ----- MECO -----

MECO+18 ✓ET SEP, ✓AUTO -Z TRANS  
MECO+35 ✓MM104  
✓P=10±30, Y=0±30; RATES < .5°/sec  
✓ET DOORS MOVING  
PASS OPS 301 PRO (Start watch) ..  
\* No joy in 68 sec: BFS - ENGAGE \*  
\* BFS, OPS 301 PRO \*

**MM304**

✓P, Y - SPDBK, BDY FLP - AUTO

|                            | WINDS  |
|----------------------------|--------|
| BFS, OPS 301 PRO (✓MM304)  | 50K /  |
| [G50] SHORT SPDBK, ITEM 39 | 40 /   |
| ✓Bugs, HDG, RANGE, α = 40° | 30 /   |
| Adjust seat                | 20 /   |
|                            | 7 /    |
|                            | SURF / |

V = 10 ✓SPDBK → 81% SPDBK @ 3000 FT

✓TACAN MODE (three) - GPC

V = 5 AIR DATA PROBES (two) - DEPLOY (✓Heat) ..  
✓RUD, AIL TRIM  
M = 3.2 ✓SPDBK → 65%;  
M = 2.7 HUD PWR (two) - ON ..  
M = 2.0 Ensure ADTA to G&C else THETA limits  
M = .9 P, R/Y - CSS, SPDBK - MAN (as reqd)  
✓NWS - GPC  
POST LANDING: ENT C/L, POST LANDING

Figure 3.3-10.- TAL CDR page (ASC/26/FIN).

AUTO TAL PLT

HOOK

\* If 2 ENG and V<sub>I</sub> > [13.9K] and \*  
\* INPLANE or 3 ENG any V<sub>I</sub>: \*  
\* MAN THROT, Pc → 65%, AUTO THROT \*

✓OMS DUMP

\* If/When second Eng Fail: \*  
\* ME SHUTDN pb (two) - push \*  
\* [G51] DUMP ARM, START \*  
\* IF OMS He PRESS < 2K: DUMP STOP \*

----- MECO ----- BFS - C/O BUG (V<sub>I</sub> approx [24.0K]) ----- MECO -----

MM104  
ET DOORS - CL .. (✓Doors moving)  
\* If BFS engaged: \*  
\* OPS 301 PRO (✓MM304) \*

**MM304**

[G51] OMS DUMP ARM, START  
\* If PRE-MECO DUMP incomplete \*  
\* and NO ICNCT fail/ \*  
\* PROP fail/OMS Eng fail: \*  
\* ICNCT ENA \*  
✓ET DOORS - CL  
L, R LAT (two) - LAT  
FWD RCS MANF ISOL 1,2,3,4 - CL (tb-CL)  
✓ET SEP, SRB SEP - AUTO  
V = 10 ✓RCS Qty > [ ] % each side  
\* If RCS < [ ] %:  
\* G51 Aft RCS INH, ITEM 13 EXEC \*  
V = 7 ✓TACANS and MLS channels  
TACANS INCORPORATE ..  
MLS (three) - ON ..  
I/O RESET - EXEC ..  
V = 4.4 MPS/TVC ISOL VLV (three) - CL ..  
Hold 5 sec, ✓(tb-CL)  
[G51] ✓AIR DATA, INCORPORATE ..  
[G50] ENTER ALT SETTING [ ] [ ] [ ] [ ] [ ]  
M = 2.7 HUD PWR (two) - ON ..  
M = 0.9 ✓R FLT CNTLR PWR - ON (IF GPC, NWS REQD)  
H = 10K ✓BDY FLP - TRAIL  
POST LANDING: ENT C/L, POST LANDING

Figure 3.3-11.- TAL PLT page (ASC/26/FIN).

## ABORT TAL/AOA-S

\* No Joy: \*  
 \* **G51** AOA ITEM 1 EXEC, ITEM 3 EXEC \*  
**G50** SEL SITE, RWY (PASS/BFS) ..

| SITE | RWY              | TACANS   | MLS    | LENGTH         |
|------|------------------|--|--------|----------------|
| 2    | BEN 36<br>BEN 18 | BEN 69 - CBA 116 (DME)<br>BEN 69 - CBA 116 (DME) | 6<br>- | 14000<br>14000 |
| 3    | MRN 21<br>MRN 03 | MRN 100 - AOG 23<br>MRN 100 - AOG 23             | -<br>- | 11840<br>11840 |
| 4    | GDV 03<br>AML 02 | GDV 76 (DME) ---<br>CVS 100 (DME) ---            | -<br>- | 9900<br>10890  |
| 5    | BYD 32<br>BYD 14 | BYD 69 - BJ76(DME)<br>BYD 69 - BJ76(DME)         | 6<br>- | 11700<br>11700 |

TAL is selected by placing the ABORT rotary switch in the TAL/AOA-S position and pushing the abort pb. A pre-MECO selection modes guidance to TAL and replaces the nominal MECO targets with TAL MECO targets. The target IY plane is redefined with the geodetic latitude and longitude of the selected TAL site and guidance begins steering in that direction. Additionally, the OMS dump is started. Selection of TAL post-MECO will call up AOA-S targets. Thus, AUTO TAL cannot be initiated post-MECO. Should the abort pb not work, TAL can be initiated on SPEC 51 (PASS and BFS). TAL initiation is indicated by a title change on the ascent trajectory displays and by the start of the OMS dump.

After TAL initiation, the CDR should call up the HORIZ SIT display and verify that the landing site selected is the correct choice. The prime TAL site for STS-26 is out of plane (Ben Guerir). This will be selected via SPEC 50 prelaunch. After press uphill capability (press to ATO or press to MECO, whichever comes first) has been attained, the TAL site is switched by the crew to the inplane site. In the unlikely event that a systems TAL is required before last Ben Guerir, the target would have to be reselected.

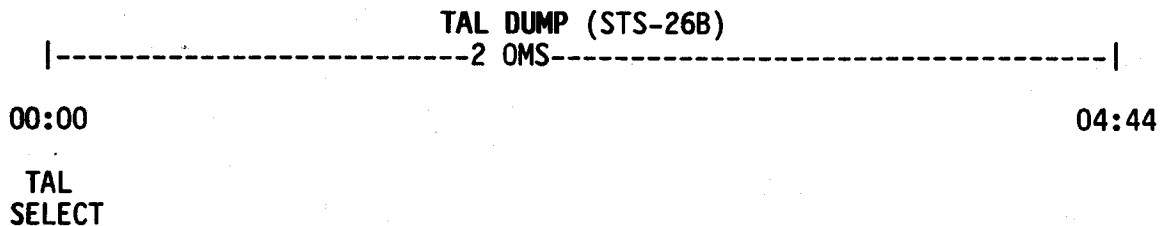
\* If 2 ENG and  $V_I > 13.9K$  and \*  
 \* INPLANE or 3 ENG any  $V_I$ : \*  
 \* MAN THROT, Pc → 65%, AUTO THROT \*

## ✓OMS DUMP

If an inplane two-engine TAL is initiated after the specified velocity (13.9k for STS-26B) or if any three-engine TAL is initiated, there will not be enough time to complete the OMS dump. In this case, the engines should be throttled down to 65 percent to gain extra dump time. If the Orbiter is still flying with the PASS, the throttles will stay at 65 percent after return to AUTO. If throttle control remains in manual, the engines must be shut down manually. However, if the BFS is subsequently engaged, the engines will throttle back to the K-MAX level (104 percent).

OMS propellant is dumped to improve performance, to reduce landing weight, to meet tank landing constraints, and to control the c.g. Depending on the flight, the OMS-RCS interconnect may be enabled (ENA) or inhibited (INH) prior to lift-off. If the interconnect is enabled, OMS propellant will be dumped through the 2 OMS engines, 20 null jets and the 4 +X jets. The dump

is set to a predetermined timed duration (I-load) (see the STS-26 TAL dump timeline below). If the dump is not completed prior to MECO, some OMS propellant may be dumped in MM 304 prior to 0.05g (AUTO dump cutoff). TAL MECO occurs at 360k ft. Previously, this altitude was 330k ft. Among other things this increased altitude will increase the time to reach 0.05g, and thus increase the MM 304 dump capability. MECO flight path angle is another important factor in MM 304 dump time. The more positive flight path angle resulting from a low level cutoff actually increases dump time.



- \* If/When second Eng Fail: \*
- \* ME SHUTDN pb (two) - push \*
- \* [G51] DUMP ARM, START \*
- \* If OMS He PRESS < 2K: DUMP STOP \*

Should a second engine fail during an abort, the OMS engines will continue to burn. If dumping with the interconnect enabled, the interconnect will be terminated. The crew must (1) push the two failed engine shutdown pb's to notify guidance that there are two SSME's out (if shutdown limits are inhibited) and (2) start the contingency dump on SPEC 51. Upon notification of the engine failures, the abort sequencer will automatically command a mode 2 interconnect, thus enabling single engine roll control (SERC). The normal TAL dump logic (for interconnected dumps) assumes that all 24 jets are burning. However, SERC does not utilize all the jets at once. Therefore, guidance thinks propellant usage is higher than it actually is, and a timed dump would terminate before the required amount of OMS propellant is dumped. The contingency dump is necessary to ensure that the dump is complete.

The contingency logic will dump down to a final gauge value which is roughly equivalent to that of the design timed dump. Both dumps protect for the 100 fps post-MECO separation burn (approximately 3390 lb for STS-26B) and roughly the same amount of propellant should be dumped in either dump scenario (unless SERC interferes with the autodump logic). The contingency dump logic includes a 5-sec interconnect delay as opposed to 35 sec for the timed dump. Both the timed dump and the contingency dump utilize 24 ARCS jets.

The OMS dump should be stopped if the helium pressure decreases to 2000 psi; this is to ensure that helium will not be ingested into the RCS jets and cause an explosion.

The powered flight portion of the TAL is fairly benign dynamically and structurally and is not difficult to fly. If CSS is required, the crew should fly to the lower line on the BFS TRAJ 2 display to reach the MECO targets.

Trajectory droop, as well as guidance convergence and main engine performance, is a decisive factor in defining the earliest single engine TAL capability. Drooping below the 265k ft limit will result in either an explosion due to ET heating, or a loss of control, or both. The single engine TAL (SE TAL) boundaries are discussed in section 3.1.5.

If two engines fail near the SE TAL (or MIN DROOP) boundary, the crew should throttle up to 109 percent and pitch up (away from the Earth) to minimize the droop. It will be necessary to pitch up to near vertical  $\sim 65^\circ - 70^\circ$  on the ADI, until the thrust-to-weight ratio improves. This will minimize sink rate and enable the Orbiter to stay above 265k ft. When thrust/weight is greater than one, the Orbiter will climb and begin to accelerate downrange again.

Yaw steering is monitored on the HSI. At abort selection, the target inertial plane is redefined and the primary bearing pointer will reflect this change in the orbital plane. Some TAL landing sites, such as Banjul, require little or no yaw steering. However, the yaw steering task may be significant for different sites and/or inclinations.

•  $V_I \sim \boxed{15.4K}$  Roll to Heads Up

----- MECO -- BFS - C/O BUG ( $V_I$  approx  $\boxed{24.0K}$ ) --- MECO ----

The ET can be subjected to large amounts of heating at the lower altitudes of the TAL trajectory. In order to lessen this effect, the vehicle is rolled, at a predetermined VREL, to a heads-up attitude prior to MECO. The roll generally occurs about  $V_I = 15.4k$  fps (the crew has a  $V_I$  indication only) for due east trajectories and will occur at a lower  $V_I$  for higher inclination flights. If TAL selection occurs after this cue, guidance will roll the vehicle immediately. The roll should be done expeditiously at 5 deg/s. There will be a change in the pitch attitude required (on the order of 20 to 30 deg) to compensate for the change in the thrust vector direction as the vehicle rolls about the body axis.

After the roll, it is important to have the altitude and altitude rate under control by about  $V_I = 22k$  fps, because the vehicle accelerates very rapidly in this region. If need be, an altitude discrepancy can be accepted as long as the altitude rate is as close to zero as possible. It is far better to have a zero or small positive flightpath angle and a low altitude than to reach the target altitude exactly with a large negative flightpath angle. There are two cues to use for the correct MECO velocity. The BFS TRAJ has a cutoff line at the top of the screen. This scale is redefined for the TAL; although the numbers do not change, the bug will indicate the correct MECO velocity. If the BFS is not working or if the TRAJ display is not present, a velocity of 24k fps is a good indicator and, for low inclination flights, represents a lower limit of the MECO velocities to be expected when successfully reaching the Banjul R/V line.

Manual MECO should be done, if necessary, with some leading of  $V_I$  because ~120 fps will be added during tailoff. SEP INH can be caused by rates exceeding 0.7 deg/s or a feedline disconnect valve failure. Should the SEP INH message occur, the crew should check the rates and attitude and damp them if necessary. The crew will then push the ET SEP switch and pb if the sequence has not resumed, since the vehicle will be entering the atmosphere within a few minutes, and it is imperative to get the ET off before the dynamic pressure builds up. The SSME's will automatically move to stow shortly after MECO.

```

---- MECO -- BFS - C/O BUG (VI approx [24.0K]) --- MECO --- BFS - C/O BUG (VI approx [24.0K]) -- MECO ----
MECO+18  ✓ET SEP, ✓AUTO -Z TRANS
MECO+35  ✓MM104
          ✓P=10±30, Y=0±30; RATES < .5°/sec
          ✓ET DOORS MOVING
          PASS OPS 301 PRO (Start watch) **
          * No joy in 68 sec: BFS - ENGAGE *
          * BFS, OPS 301 PRO
          MM104
          ET DOORS - CL ** (✓Doors moving)
          * If BFS engaged: *
          * OPS 301 PRO (✓MM304) *

```

A 17-sec -Z translation of 11 fps is done automatically giving additional separation distance. This burn should not be interrupted, either with the RHC or THC, as guidance looks for the 11 fps  $\Delta V$  as a cue to mode to MM 104. Should the -Z burn be interrupted, it can be manually continued to obtain 11 fps, or the GPC's can be manually moded to MM 104. It is always best to complete the translation rather than simply mode to MM 104, in order to maximize the distance between the tank and the Orbiter.

TAL MECO occurs about 2700 n. mi. from the landing site. For inplane landing sites, very little banking for azimuth control is necessary if it is started early enough. Waiting to null out the delta azimuth until late in the entry can severely cut back vehicle crossrange capability. If the vehicle has excess energy at MECO, guidance will perform a series of roll reversal S-turns to dissipate energy. Shortly after MECO, the Orbiter will enter blackout and there will be a loss of communication until about  $V_I = 12k$  fps, where an S-Band acquisition is obtained through Dakar or TDRS.

The FDO will recommend the best approach to the field. Overhead is preferred to straight in as it preserves the capability to downmode to straight in, and a left approach is preferred to a right in order to give the CDR an unobstructed view of the runway while on the HAC. CSS should be engaged at  $M \sim 0.9$ . Minimum ground service and support will be provided, and security may present some problems.

The PASS will mode to OPS 0 while doing the mass memory access for the transition to OPS 3. This is probably the most time-critical transition of any flight phase as there is no flight control and the vehicle is in free drift. If required, two tape accesses are done on mass memory unit (MMU) 1 and two are done on MMU 2. The second attempt on MMU 2 requires only one string for loading. The transition to OPS 3 could take as long as 68 sec, but nominally takes approximately 20 sec or less.

Venting or random jet firings could produce an extreme attitude or rate buildup during free drift. To avoid this occurrence, the CDR should verify that the body rates and attitude are within limits prior to moding the OPS 3. The only instrument available in MM 104 is the ADI. Fortunately, it is a three-axis ball, and the CDR can verify that the pitch and yaw attitudes are within limits.

After the PASS is moded to MM 301, it cascades to MM 304. There have been very few problems with the transition in test cases and simulations. However, if the PASS does not mode, the crew should engage the BFS and key in OPS 301 PRO. This should be an immediate transition since the BFS does not need to access the MMU.

The period between ET SEP and MM 304 is critical. The vehicle is starting to enter the atmosphere and the transition digital auto pilot (TRANS DAP) is not designed for atmospheric flight. All procedures in this area must be done quickly and accurately. This cannot be emphasized enough. All systems problems should be ignored until the vehicle has been provided with the correct entry flight control unless they are of an extremely critical nature. The ET door closure should be performed expeditiously. The doors will be latched in MM 304. The OPS transition needs to be done as soon as possible (ASAP) since only about 3 min exist between ET SEP and the start of dynamic pressure buildup.

The unpressurized MPS dump begins automatically upon entrance to MM 304. LH<sub>2</sub> is vented through the fill/drain and RTLS dump valves. LOX is dumped from the main oxidizer valves through the engine bells, then through the LOX fill drain valves and the engine bells. This dump continues down to VREL = 4500 fps.

| MM304                        |       | MM304                                  |   |
|------------------------------|-------|--|---|
| ✓P,Y - SPDBK, BDY FLP - AUTO | WINDS | 651 OMS DUMP ARM, START                |   |
| BFS, OPS 301 PRO (✓MM304)    | 50K   | * If PRE-MECO DUMP incomplete *        |   |
| ✓650 SHORT SPDBK, ITEM 39    | 40    | * and NO ICNCT fail/                   |   |
| ✓Bugs, HDG, RANGE, α = 40°   | 30    | * PROP fail/OMS Eng fail:              | * |
| Adjust seat                  | 20    | * ICNCT ENA                            | * |
|                              | 7     | ✓ET DOORS - CL                         |   |
|                              | SURF  | L, R LAT (two) - LAT                   |   |
| V = 10                       |       | FWD RCS MANF ISOL 1,2,3,4 - CL (tb-CL) |   |
| ✓SPDBK → 81%                 |       | ✓ET SEP, SRB SEP - AUTO                |   |
| SPDBK @ 3000 FT              |       | ✓RCS Qty > [ ] % each side             |   |
|                              |       | * If RCS < [ ] %:                      | * |
|                              |       | * 651 Aft RCS INH; ITEM 13 EXEC *      |   |
|                              |       | ✓TACANS and MLS channels               |   |

Once in MM 304, the PLT will start the MM 304 OMS dump which will add ~100 fps ΔV. This separation burn is important because of a possible ET rupture during entry. If there is a need, the dump will be interconnected. The PLT will verify that the ET doors have closed and then close the FRCS manifold isolation valves. The PLT should verify that the ET SEP and SRB SEP switches are in AUTO to ensure that the weight-on-wheels (WOW) and weight-on-nose-gear (WONG) discrettes are properly set at touchdown. At VREL = 10 the PLT will monitor the TAL aft RCS (ARCS) dump. This dump will follow a TAL I-load timer. If there is a degradation in the RCS and a dump is not desired, the dump may be inhibited on SPEC 51. Also, the TACAN and MLS

channels should be positioned as outlined on the AUTO TAL CDR page and the landing site table.

Upon entrance into MM 304, all initializations and discretives are set and any OMS targeting is terminated. The CDR should then mode the BFS into OPS 3 and check the PASS speedbrake option. Since the shortfield technique is automatically selected for the TAL, an ITEM 39 EXEC will be required if the nominal speedbrake setting is desired. Flight control will set the correct entry alpha, approximately 40°. If in CSS, the CDR will pitch up to 40°.

At VREL = 10, the crew should check the speedbrake and verify that the TACAN's are in GPC mode.

|  |   |  |
|--|---|--|
| ✓TACAN MODE (three) - GPC                  | V = 7                                     | TACANS INCORPORATE **                            |
|  |   | MLS (three) - ON **                              |
|  |   | I/O RESET - EXEC **                              |
| V = 5                                      | AIR DATA PROBES (two) - DEPLOY (✓Heat) ** | V = 4.4  |
| M = 3.2                                    | ✓RUD, AIL TRIM                            | MPS/TVC ISOL VLV (three) - CL **                 |
| M = 2.7                                    | ✓SPDBK → 65%;                             | Hold 5 sec, ✓(tb-CL)                             |
| M = 2.0                                    | HUD PWR (two) - ON **                     | [G51] ✓AIR DATA, INCORPORATE **                  |
| M = .9                                     | Ensure ADTA to G&C else THETA limits      | [G50] ENTER ALT SETTING <input type="text"/>     |
|  | P,R/Y - CSS, SPDBK - MAN (as reqd)        | M = 2.7 HUD PWR (two) - ON **                    |
|  | ✓NWS - GPC                                | M = 0.9 ✓R FLT CNTLR PWR - ON (IF GPC, NWS REQD) |
| POST LANDING: ENT C/L, <u>POST LANDING</u> |   | H = 10K ✓BDY FLP - TRAIL                         |
|  |   | POST LANDING: ENT C/L, <u>POST LANDING</u>       |

At VREL ~ 7 the PLT will incorporate TACAN's, power up the MLS LRU's, and do an I/O RESET. The incorporation of NAVAID data into navigation processing is a Guidance and Procedures Officer (GPO) call if COMM exists. The ground will recommend the best course of action to take to improve the accuracy of the PASS and BFS state vectors. The Entry FPH contains a more complete discussion of entry navigation. The MPS/TVC ISOL VLV switches should be closed at VREL = 4.4. The unpressurized MPS dump should be complete at this point. Air data is incorporated via SPEC 51 and the barometric altimeter setting entered on SPEC 50. At M = 2.7, the head up display (HUD) is powered up. At M = 0.9, the right flight controller power is verified on, and at H = 10k ft the bodyflap is verified in 'trail position.'

At VREL = 10, the speedbrake should be at 81 percent. The TACAN's should be in GPC mode to allow AUTO selection of the TACAN channel assigned to the selected site.

MM 304 is quite similar to the normal EOM entry. A full description of the entry can be found in the Entry Flight Procedures Handbook.

### 3.3.4 LATE TAL Procedures

LATE TAL provides intact TAL abort capability using nominal EOM guidance (OPS 3) following a MECO between  $V_I = 22k$  fps and AOA capability. A TAL abort is never declared and the OMS is dumped solely in MM 304. The MECO is most likely unplanned, although it is possible that a systems problem could develop after the last AUTO TAL capability ( $V_I = 19k$  fps) requiring an immediate landing. For a late systems problem, the crew would do a manual MECO at the specified velocity via the main engine pb's.

The LATE TAL procedures listed in this section are excerpts from the STS-26 Ascent Checklist (figs. 3.3-12 and 3.3-13). This section will discuss each of the procedures in the checklist in the order that they appear. Many of the differences between LATE TAL and AUTO TAL result from the fact that TAL cannot, as of yet, be selected post-MECO. Therefore, some of the procedures that are automated in AUTO TAL must be performed manually in LATE TAL.

As indicated by the NO COMM MODE BOUNDARY cue card, the last opportunity for AUTO TAL selection occurs at  $V_I = 19k$  fps. TAL selection after this boundary would not allow sufficient time for the roll to heads up and OMS dump. In MM 304 the roll to heads up occurs automatically, and the OMS propellant dump may be initiated. The dump will automatically terminate at .05g to avoid structural failure in the OMS tanks. STS-26 and subsequent flights will use a 360k ft TAL MECO altitude. These improvements will lengthen the post-MECO dump time. For these reasons, the  $V_I = 19k$  fps boundary is being reexamined. A number of TAL enhancements which would allow TAL to be declared as late as the target velocity are also under consideration, such as an I-loaded velocity roll cue. If TAL is selected prior to this flag, AUTO flight control would roll the vehicle to heads up pre-MECO. If TAL is selected after this boundary, flight control would not begin the roll as sufficient time does not exist to complete the maneuver. This change is proposed in order to avoid a partial roll at MECO and ET SEP.



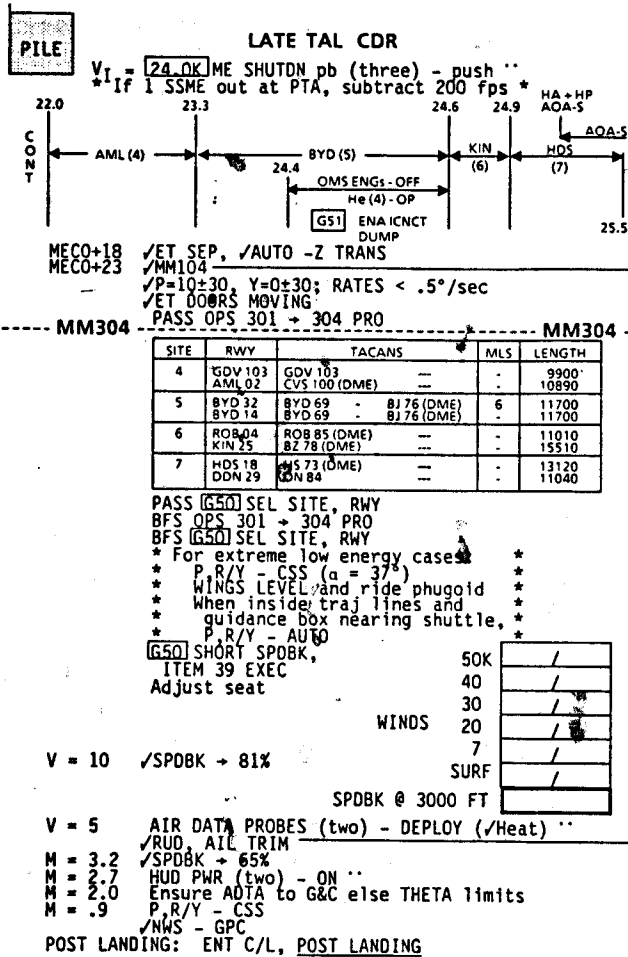


Figure 3.3-12.- LATE TAL CDR (ASC/26/BAS C).

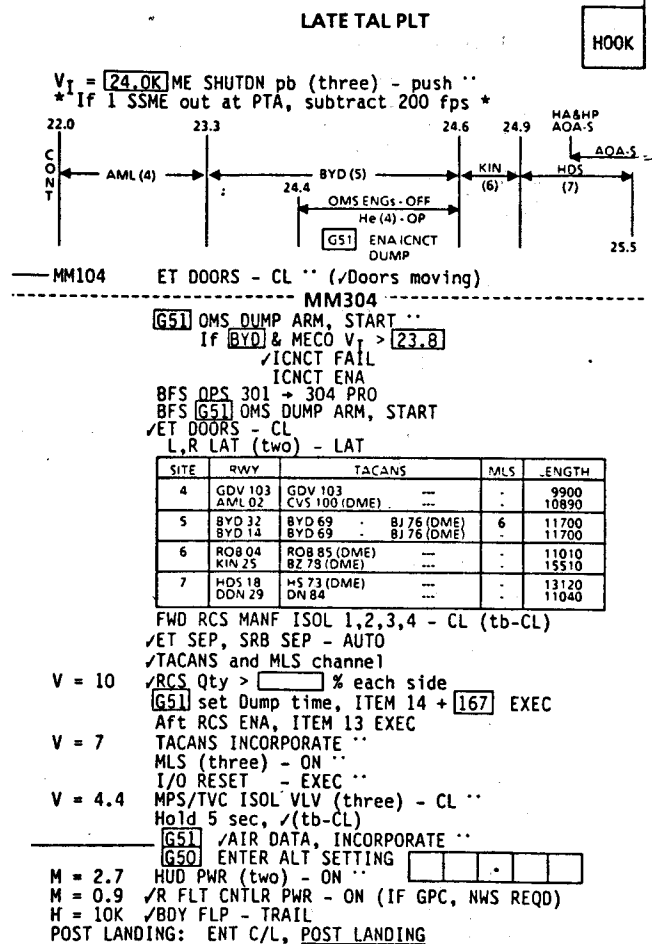


Figure 3.3-13.- LATE TAL PLT (ASC/26/BAS C).

The pb cutoff velocity cue takes into account the change in velocity due to the main engine tailoff. This number is currently under review and may require flight specific updates. If the first engine failure occurs at PRESS-to-ATO, a bias of about -200 fps to the shutdown velocity is required.

The chart below the target velocity shows TAL site coverage for a range of early MECO conditions. These boundaries do not imply successful R/V line MECO conditions and do not protect against performance dispersions.

A cutoff velocity greater than that indicated for the last Banjul (BYD) opportunity will necessitate selection of another site. The appropriate site should be selected based on the cutoff velocity. A real-time downrange abort evaluator will give the MCC insight into the real-time abort capability based on a MECO state propagation. If COMM exists, the MCC will provide a site selection based on the MECO energy state.

If the MECO state falls within the OMS ENG's OFF range, the OMS engine switches (C3) should be moded to OFF prior to the burn. The OMS will be dumped solely through the RCS jets in order to minimize additional  $\Delta V$ . If the nonpropulsive dump is used, it is necessary to stop the dump manually at OMS He pressure < 2000 psi because the AUTO cutoff at the gauge value is bypassed in the logic. The chart also includes an indication of when the burn should be done with the interconnect enabled.

|         |                                   |       |       |                               |
|---------|-----------------------------------|-------|-------|-------------------------------|
| MECO+18 | ✓ET SEP, ✓AUTO -Z TRANS           | ----- | MM104 | ET DOORS - CL (✓Doors moving) |
| MECO+23 | ✓MM104                            | ----- |       | MM304                         |
|         | ✓P=10±30, Y=0±30; RATES < .5°/sec | ----- |       |                               |
|         | ✓ET DOORS MOVING                  | ----- |       |                               |
|         | PASS OPS 301 → 304 PRO            | ----- |       |                               |
| -----   | MM304                             | ----- |       |                               |

ET SEP will proceed nominally. As in AUTO TAL, any SEP INH messages should be ignored. The tank separation with the ET SEP button is necessary in order to avoid carrying the tank back into the atmosphere.

The CDR will PRO to OPS 3 after verification that the ET doors are moving to the close position. The PASS must be manually moded through to MM 304.

As with AUTO TAL, the unpressurized MPS dump begins automatically upon entrance to MM 304. LH<sub>2</sub> is vented through the fill/drain and RTLS dump valves. LOX is dumped from the main oxidizer valves through the engine bells, then through the LOX fill drain valves and the engine bells. This dump continues down to a relative velocity of 4500 fps.

Upon entrance to MM 304 guidance will roll the vehicle heads up and the PLT will start the OMS dump on SPEC 51. The OPS 1 BFS will "hear" the PASS dump start (via DK listen), but it will reset the dump start upon transition to OPS 3. Due to this fact, the dump start on BFS SPEC 51 will also be required after the CDR modes the BFS to OPS 3.

Prior to the BFS OPS 3 PRO, the CDR will select the appropriate runway on SPEC 50. In low energy cases, the CDR will fly an optimum energy wings level trajectory until the vehicle is within the trajectory lines on the VERT SIT display. At this time the CDR will select AUTO pitch, roll and yaw.

The PLT will verify that the ET doors are closed, close the FRCS manifold isolation valves and mode the ET SEP and SRB SEP pb's to AUTO. This is to ensure that the WOW and WONG discrettes are properly set at touchdown. The PLT will next start the ARCS dump. Since TAL was not declared, guidance does not have the TAL dump timer I-load. Therefore, the PLT will have to key in the timer. All the PLT procedures from this point on are identical to AUTO TAL.

After the runway selection is made, the CDR will check the short speedbrake setting on SPEC 50 (item 39). The remaining LATE TAL procedures are identical to AUTO TAL in progression and rationale.

### 3.3.5 RTLS Procedures

#### 3.3.5.1 Step-by-Step Rationale

The RTLS procedures discussed in this section are excerpts from the STS-26B Ascent Checklist (fig. 3.3-14). This section will discuss each of the procedures in the checklist in the order that they appear.

RTLS is selected by placing the abort rotary switch in the RTLS position and depressing the abort pb. As per the flight rules, RTLS will be selected no earlier than 2:30 MET upon completion of alpha limiting. RTLS selection time is discussed in detail in section 2.7 of this document.

In the event of an abort rotary switch malfunction, RTLS may also be selected via the OPS 601 PRO CRT entry.

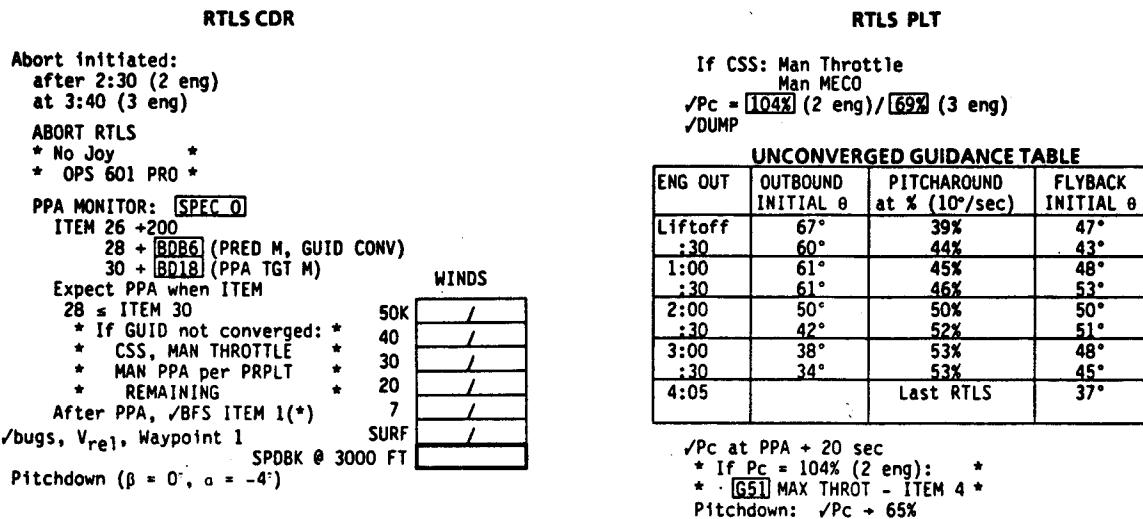


Figure 3.3-14.- STS-26 RTLS pre-MECO procedures.

Guidance will initiate the RTLS pitcharound based in part on a comparison of the predicted final mass at powered pitchdown to an I-loaded mass target (MBOD1 or MBOD2). When these numbers converge and when the thrust direction check and guidance convergence criteria are met, the pitcharound maneuver is initiated. During fuel dissipation, the CDR will call up the GPC MEMORY display (SPEC 0) and call for the current calculated vehicle mass (item 28) and the I-loaded mass target (item 30). Pitcharound should be expected when item 28 and item 30 reach the same value. If guidance is not converged, the CDR should take CSS and pitch around at the manual propellant remaining percentage from the unconverged guidance table on the RTLS PLT page. Note that this data is generated preflight, while the SPEC 0 PPA monitor data reflects actual performance. Also note that it is much better to pitch

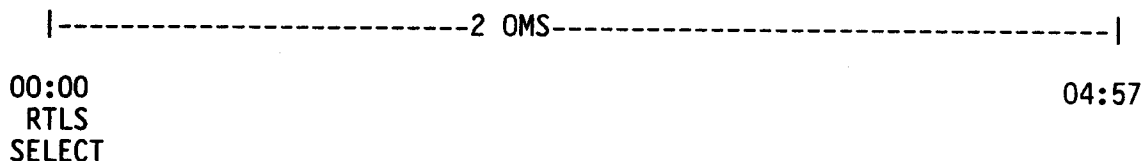
around slightly early then slightly late as late pitcharounds may result in not reaching a nominal RTLS MECO state.

If the CDR has selected CSS, the PLT should select manual throttles and will perform a manual throttle down and MECO.

For the single-engine failed case, guidance will throttle the remaining two engines to the abort throttle setting, currently 104 percent, upon RTLS selection. For three-engine RTLS aborts, guidance will throttle the three engines down to 69 percent. This will provide rough equivalence to the two-engine case in total thrust (approximately 208 percent total).

After checking the throttle levels, the PLT will verify that the OMS dump is proceeding nominally. OMS propellant is dumped at the initiation of MM 601 to improve performance, to reduce landing weight, to meet tank landing constraints, and to control the c.g. Depending on the flight, the OMS-RCS interconnect may be enabled or inhibited prior to lift-off. If the interconnect is inhibited, OMS propellant will be dumped through the two OMS engines. If the interconnect is enabled, OMS propellant will be dumped through the 2 OMS engines and 24 ARCS jets (20 null jets and 4 +X jets). The dump is set to a predetermined I-loaded time duration (STS-26 RTLS dump timeline below) but will terminate automatically at MECO prep (fine count-down), MECO confirmed, or the timer, whichever comes first.

#### RTLS DUMP (STS-26B)



As stated earlier, the crew will use the propellant remaining percentage on the RTLS TRAJ display, in conjunction with the unconverged guidance table on the RTLS PLT page as a cue for pitcharound only in the event of unconverged guidance only. In the present flight software, the predicted final mass on SPEC 0 will not be updated unless guidance is converged. This is presently under review and may result in the submission of a flight software change request to enable this calculation when guidance is unconverged. This would give the crew a more accurate indication of when pitcharound is required in the event of guidance unconvergence and NO COMM.

The unconverged guidance table should not be used unless guidance is unconverged since the data therein is generated prelaunch, and guidance will be using a more accurate calculation as the pitcharound cue. Crews typically watch the propellant remaining closely and wait until about 3 to 5 percent after the expected pitcharound value to take CSS and pitcharound. As long as guidance is converged, this should not be necessary. It is also important to note that this table is designed with the two-engine RTLS case in mind. The three-engine RTLS case is similar in total thrust profile to a late engine failure RTLS (312 percent total thrust up to the latest select time followed by 208 percent total thrust during the fuel dissipation

phase). For this reason, the crew should expect pitcharound data for the three-engine case to match the Last RTLS engine-out data on the table.

A change is under consideration to add a count down to pitcharound cue to the RTLS TRAJ display. This will be based on the same predicted final mass computation data that the current procedures call for on SPEC 0 and would eliminate the need for this procedure. Another suggestion is to change the software such that the predicted final mass calculation will be performed even when guidance is unconverged. If this change is implemented, the crew will have a more accurate cue for pitcharound in the guidance unconverged/NO COMM case, utilizing all three of the conditions AUTO guidance uses for the pitcharound cue.

| WINDS |   |
|-------|---|
| 50K   | / |
| 40    | / |
| 30    | / |
| 20    | / |
| 7     | / |
| SURF  | / |

After PPA,  $\sqrt{\text{BFS}}$  ITEM 1(\*)  
 $\sqrt{\text{bugs, } V_{\text{rel}}, \text{Waypoint 1}}$  SPDBK @ 3000 FT  
 Pitchdown ( $\beta = 0^\circ, \alpha = -4^\circ$ )

$\sqrt{\text{Pc}}$  at PPA + 20 sec  
 \* If Pc = 104% (2 eng): \*  
 \* **G51** MAX THROT - ITEM 4 \*  
 Pitchdown:  $\sqrt{\text{Pc}}$  + 65%

If guidance is calling for full throttle (104 percent) and it is at least 20 sec after pitcharound, the crew should enable K-MAX-SECONDARY (109 percent) via SPEC 51 (ITEM 4 EXEC). Guidance will only select the throttle required and will not automatically implement the new maximum throttle level. This change is delayed until after PPA, as throttling does not nominally begin until this time, and guidance will always call for 104 percent until flyback.

The PLT should verify that the SSME's throttle down to 65 percent during powered pitchdown, which occurs 20 sec prior to MECO.

After PPA, the CDR should check to see that the BFS has moded to flyback via item 1 on the BFS RTLS TRAJ 2 display. The CDR should also note the course pointer (VREL), and waypoint 1 (MECO TGT) converging. These should be converged by MECO. Powered pitchdown is an especially critical phase if flying in CSS. At MECO, the yaw needs to be zeroed out and the alpha stabilized at  $-4^\circ$ . If the alpha target is overshoot or undershot by a significant margin, the vehicle may go out of control. Also, if SEP is delayed, the rapid buildup of  $\dot{q}$  could prevent a safe SEP and result in a loss of control.

| MECO    | MECO   | MECO | MECO   |
|---------|--|------|--|
| KEAS=77 | $\sqrt{\text{ET DOORS}}$ - Closing<br>$\sqrt{\text{SPDBK}}$ + 80%<br>$\sqrt{\text{ET SEP, SRB SEP}}$ - AUTO<br>Adjust seat<br>$\sqrt{\text{TACANS, INCORPORATE}}$ **<br>* If KSC TACAN Fail: *<br>* TACAN Ch 97X (COF), ITEM 5 EXEC *<br><b>G51</b> $\sqrt{\text{AIR DATA, INCORPORATE}}$ **   |      | ET SEP (MECO + 14)<br>$\sqrt{\text{MM602}}$ ( $\alpha > 10^\circ$ and SEP + 10 sec)<br>$\sqrt{\text{P,R/Y, SPDBK, BDY FLP}}$ - AUTO<br>$\alpha = 50^\circ$ until $-1.8g$ , maintain 2.2g<br><br>Adjust seat  |
| MM603   | MPS/TVC ISOL VLV (three) - CL **<br>Hold 5 sec, $\sqrt{\text{(tb-CL)}}$<br>H = 85K MLS (three) - ON **<br>If Rwy 33(15): MLS CH (three) - 6(8)<br>I/O RESET - EXEC **<br>M = 2.7 HUD PWR (two) - ON **<br>M = 0.9 $\sqrt{\text{R FLT CNTLR PWR}}$ - ON (IF GPC, NWS REQD)<br>H = 10K $\sqrt{\text{BDY FLP}}$ - TRAIL<br>POST LANDING: ENT C/L, <u>POST LANDING</u> |      | H > -250 $\sqrt{\alpha}$ vs Mach<br>V = 5 AIR DATA PROBES (two) - DEPLOY ( $\sqrt{\text{Heat}}$ ) ** -<br>$\sqrt{\text{RUD, AIL TRIM}}$<br>M = 3.2 $\sqrt{\text{SPDBK}}$ + 65%<br>M = 2.7 HUD PWR (two) - ON **<br>M = 2.0 Ensure ADA to G&C else THETA limits<br>M = .9 P,R/Y - CSS, SPDBK - MAN (as reqd)<br>$\sqrt{\text{NWS-GPC}}$<br>POST LANDING: ENT C/L, <u>POST LANDING</u> |

ET SEP will occur approximately 14 sec after MECO. At ET SEP, a -Z translational maneuver is performed by firing 10 RCS jets (6 ARCS and 4 FRCS) in the downward direction. Guidance will overlay a commanded 2 deg/s pitch rate on top of this continuous commanded burn. The net result will be a pulsed aft burn in conjunction with the continuous forward burn in order to achieve the desired pitch rate. Guidance will transition to MM 602 and begin alpha recovery phase when the vehicle pitches above  $\alpha = 10^\circ$ . Once alpha has recovered, guidance will hold an alpha of  $50^\circ$  until guidance begins pitching the Orbiter down to hold an Nz of approximately 2.2g. When H reaches -250 fps, guidance will begin to bank the vehicle to attain the desired heading. Prior to this phase, the vehicle will fly wings level.

After entry into MM 602, the CDR should verify that the vehicle is flying in auto pitch, roll/yaw, speedbrake, and bodyflap. The RTLS entry procedures are similar to the AUTO TAL procedures execution and rationale.

Post-MECO, the PLT should check that the ET doors are closing (automatically) after separation. At an airspeed of 77 KEAS, the speedbrake should move to 80 percent in order to enhance lateral stability by allowing the elevons to be trimmed down (into the airstream).

The PLT should make sure that the ET SEP and SRB SEP pb's are in AUTO to ensure that WOW and WONG will be set correctly on touchdown. The PLT should verify TACAN incorporation and, if the KSC TACAN is no good, select secondary TACAN via item 5 EXEC on SPEC 50. The PLT should also verify air data incorporation. Once in MM 603 the PLT should close the MPS/TVC ISOL VLV's. At 85,000 ft the MLS should be powered on followed by an I/O RESET, EXEC. The RTLS entry procedures are similar to the AUTO TAL procedures execution and rationale.

### 3.3.5.2 Topical Rationale

#### a. RTLS MPS THROTTLING

##### (1) Cue

RTLS Abort, MM 601 initiation (three-SSME RTLS only)

##### (2) Displays

RTLS TRAJ 2 (BFS)  
MPS Pc gauges

##### (3) Crew action

Monitor

F7 MPS PRESS Pc - 104 percent (two-engine)  
69 percent (three-engine)

**(4) Discussion**

At abort initiation, for a three-SSME RTLS, the SSME's will be throttled back to 69 percent to simulate a two-SSME RTLS in total thrust. For a two-SSME RTLS, the throttles will remain at 104 percent. The throttles will remain at the appropriate abort throttle setting from abort initialization until the pitcharound maneuver is completed.

Once the pitcharound is completed, the engines will be throttled to 100 percent for a two-SSME RTLS and 70 percent for a three-SSME RTLS. These values are initial settings only, and the throttles may be varied (3 to 5 percent) during the flyback phase to ensure that there will not be less than 2 percent of the ET propellant remaining at MECO. MPS throttling is used during the flyback phase, in conjunction with flyback thrust attitude control, for fine weight control. If it appears that the vehicle will have too much propellant at MECO, the operative engines will throttle down, and a higher thrust attitude will preserve the vertical thrust component at the expense of the horizontal component. The increased flyback time will more than compensate for the reduced propellant flow with the net result that more fuel will be dissipated during flyback. The converse is true if it appears that the vehicle will be short of propellant. If a three-engine RTLS is being flown, the engines will be throttled down to resemble the two-engine case. Thus, prior to pitcharound, the three engines will be throttled to 69 percent. The trajectory and timeline are similar in both cases. It is important to note that if manual throttle is selected after pitcharound, a return to AUTO will not regain throttling for weight control. The throttle setting will remain at the last commanded manual setting.

**b. RTLS FUEL DISSIPATION ATTITUDE****(1) Cue**

RTLS Abort, MM 601 initiation

**(2) Displays**

ADI  
RTLS TRAJ  
RTLS TRAJ 2 (BFS)

**(3) Crew action**

Monitor

**(4) Discussion**

Once an RTLS abort is initiated, AUTO guidance will pitch the vehicle to an I-loaded fuel dissipation attitude (in pitch) which

is held constant with respect to the inertial reference frame until the start of pitcharound. On STS-26B the required pitch attitude varies from 67° for an SSME-out at lift-off to 34° for an SSME-out at 3:30 MET, as shown in table 3.3-II. These values are listed in the unconverged guidance table on the RTLS PLT page (2-11) of the Ascent Checklist. This card lists the fuel dissipation attitude and ET propellant remaining at pitcharound versus engine-out time as a backup in case guidance is unconverged. An RTLS abort will not be initiated earlier than 2:30. For RTLS aborts selected after the I-loaded value VLATE, the vehicle will not assume a fuel dissipation attitude, but will pitcharound immediately.

TABLE 3.3-II.- UNCONVERGED GUIDANCE TABLE

| Eng out        | Outbound initial $\theta$ | Pitcharound at % (10°/sec) | Flyback initial $\theta$ |
|----------------|---------------------------|----------------------------|--------------------------|
| Liftoff<br>:30 | 67°<br>60°                | 39%<br>44%                 | 47°<br>43°               |
| 1:00<br>:30    | 61°<br>61°                | 45%<br>46%                 | 48°<br>53°               |
| 2:00<br>:30    | 50°<br>42°                | 50%<br>52%                 | 50°<br>51°               |
| 3:00<br>:30    | 38°<br>34°                | 53%<br>53%                 | 48°<br>45°               |
| 4:05           |                           | Last RTLS                  | 37°                      |

### c. RTLS PITCHAROUND MANEUVER

#### (1) Cue

ET propellant remaining  
Time from MCC  
Pitch rate = -10 deg/s  
PPA monitor (SPEC 0)

#### (2) Displays

RTLS TRAJ  
ADI  
Clock  
RTLS TRAJ 2 (BFS)  
OMS Pc  
SPEC 0



## (3) Crew action

## Monitor

Note predicted pitcharound time from MCC

If guidance is unconverged, the crew should initiate pitcharound at the time received from the MCC if it is available, or use the unconverged guidance table (10 deg/s to initial flyback pitch attitude).

## (4) Discussion

Pitcharound is essentially an inplane maneuver done at a pitch rate of approximately 10 deg/s which will orient the Orbiter/ET configuration in a heads-up attitude, pointing back toward the launch site (retrograde). Once the pitcharound is completed, flyback guidance will be initiated to null the downrange velocity and add sufficient uprange velocity for the Orbiter to glide to the RTLS runway.

For late RTLS aborts (selected after the I-loaded value VLATE), the vehicle will not assume a fuel dissipation attitude but will pitcharound immediately. RTLS pitcharound is usually delayed in order to burn off excess propellant until the MPS propellant remaining is sufficient to achieve the required RTLS MECO targets. Coarse weight control is achieved by selection of the time to begin the constant rate pitcharound. MPS throttling during flyback is used for fine weight control.

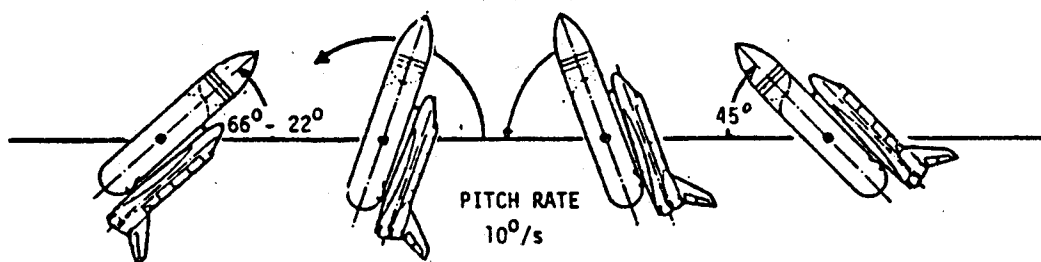


Figure 3.3-15.- RTLS pitcharound maneuver.

## d. PRE-MECO OMS/RCS DUMP (RTLS)

## (1) Cue

RTLS Abort, MM 601 initiation

## (2) Displays

OMS PRESS Pc gauge  
RCS/OMS PRPLT QTY

## (3) Crew action

Monitor

    √OMS dump  
F7    OMS PRESS Pc  
O3    RCS/OMS PRPLT QTY

## (4) Discussion

It is important that the c.g. and vehicle weight are within limits during entry and landing for an RTLS. This task is partially accomplished by dumping (burning) OMS/RCS propellants to a predetermined level. The OMS dump begins immediately after entrance to MM 601 and terminates based on an I-loaded timer, MECO prep, or MECO confirmed. This duration is fixed regardless of the abort initiation time. Depending on the flight, the OMS propellant may or may not be dumped with the interconnect enabled. If the interconnect is enabled, the dump will begin through the two OMS engines. After a 36 sec interconnect sequence, the OMS propellant will begin dumping through the 24 ARCS jets as well. The Orbiter has a relatively narrow range of acceptable longitudinal and lateral c.g. locations. Failure to burn the planned amount of OMS propellants (RCS to a lesser extent post-MECO) can result in reduced static margin and pitch stability problems, lateral stability problems, or a combination of both.

ARCS propellant is dumped post-MECO at MM 602 plus 20 sec. The RCS dump is done post-ET SEP so that -Z translation capability will be guaranteed. The ARCS propellant is dumped through the four +X jets. In the past this dump has been set to a timer of either 130 or 270 sec, depending on the flight in question. At present this dump is under review, and the timer has been limited to 88 sec. This number will probably be raised as a result of the review.

## e. POWERED PITCHDOWN (RTLS)

## (1) Cues

Range ( $\Delta R$  bug on RTLS TRAJ or  
RTLS TRAJ 2 reaches PD mark)  
Time  
Pitchdown maneuver

## (2) Displays

RTLS TRAJ  
ADI  
RTLS TRAJ 2 (BFS)

## (3) Crew action

Monitor  
√Powered Pitchdown to  
 $\alpha = -4^\circ, \beta = 0^\circ$

## (4) Discussion

This maneuver starts approximately 20 sec prior to MECO. At this point PPD targeting is terminated and guidance will begin active MECO targeting with the R-V-gamma line I-loads (3). This maneuver takes the mated vehicle from a relatively high angle of attack of the required separation attitude ( $\alpha = -4^\circ$ , pitch rate =  $-.25$  deg/s). MECO will occur when the desired cutoff velocity has been achieved based on the MECO R-V line. AUTO guidance will stabilize the vehicle at least 5 sec prior to MECO. At the start of PPD, the SSME's are throttled back to 65 percent.

If CSS has been selected, manual throttles should be selected and the engines throttled to the PPD throttle level. MECO must be performed manually when the  $\Delta R$  bug reaches the CO mark (RTLS TRAJ display). For three-engine RTLS cases, pitchdown must be started earlier. In this case, the PD3 mark should be used as the pitchdown cue.

## f. MECO (RTLS)

## (1) Cues

Delta range bug ( $\Delta R$ ) reaches CO tick  
Sensed deceleration  
Engine Pc gauges fall to zero  
MAIN ENGINE STATUS lts - red

## (2) Displays

RTLS TRAJ  
RTLS TRAJ 2 (BFS)  
AMI (ACCEL)

## (3) Crew actions

Monitor

If the crew has selected manual throttles and the  $\Delta R$  bug is at the CO tick, MECO should be commanded via the three main engine shutdown pb's on panel C3.

If there is a command or data path failure the crew will mode the affected engine MPS ENG PWR switch to OFF (two per engine).

(4) Discussion

Active targeting for MECO begins at PPD. Guidance targets for PPD utilize gamma altitude, mass, and the PPD R-V line. After PPD, guidance targets to the I-loaded MECO R-V-gamma line. This line is defined by three I-loads; TGT6, TGT7, and TGT8 (OI7 software). Throughout PRTLs, guidance continues to fly in the same inertial plane as was defined at lift-off. A target altitude is selected, consistent with velocity, to keep dynamic pressure within limits. Guidance will command MECO based on either guidance targeting or dry sensors, whichever comes first. Nominally guidance will command shutdown based on the targeting criteria described above. However, if the ARM flag in the SSME OPS sequence has been set, the GPC's will check the ET sensors. If these sensors read dry, then a shutdown timer will be initiated. The current value of this timer is 0 sec.

If in manual throttle, the main engine shutdown pb's should be used. If a command or data path failure exists, then the appropriate ENGINE POWER ac switches (two per engine on panel R2) should be placed in OFF. This is because a data path failure will mask a command path failure. It should be noted that an MPS dump cannot be accomplished for any engine which has been shut down by the ENGINE POWER switches on panel R2. If data path failure or power switch shutdown occurs on more than one engine, the crew will perform an ITEM 4 EXEC (ET SEP - AUTO) on the OVERRIDE display to start the ET SEP.

Since guidance attempts to fly to the R-V-gamma line at MECO, the post-MECO energy state may be high or low if the engines are not shut down on time, thus producing an off-nominal energy state in relationship to the landing site. Nominally, some excessive energy is planned for in the design. The vehicle will require larger S-turns during GRTLs to null out the additional energy.

g. ET SEP, -Z TRANSLATION (RTLs)

(1) Cues

MAIN ENGINE STATUS LIGHTS OUT  
Time (13.6 sec. after MECO command)

## (2) Displays

MAIN ENGINE STATUS lts  
 RTLS TRAJ 2 (BFS)  
 ADI  
 Rudder position indicator  
 AMI  
 HSI

## (3) Crew action

Monitor the AUTO SEP sequence and subsequent -Z translation (fig. 3.3-16)

√Attitude

Alpha =  $-4^\circ$ , range: + 2 to  $-89^\circ$

(Note: Within this range, guidance will not generate a SEP INH. However, the vehicle will probably go out of control if SEP is done at angles of attack below  $-8^\circ$  to  $-10^\circ$ )

Beta =  $0^\circ \pm 2^\circ$

Pitch rate =  $-0.25$  deg/s, range: +.25 to -5.00

Yaw rate = 0 deg/s  $\pm 0.5$

Roll rate = 0 deg/s  $\pm 5.0$

## (4) ET SEP (MECO+13)

√MAIN ENG STATUS lts (three) - OFF

NOTE

If SEP INH, AUTO seq will perform SEP in 6 sec.

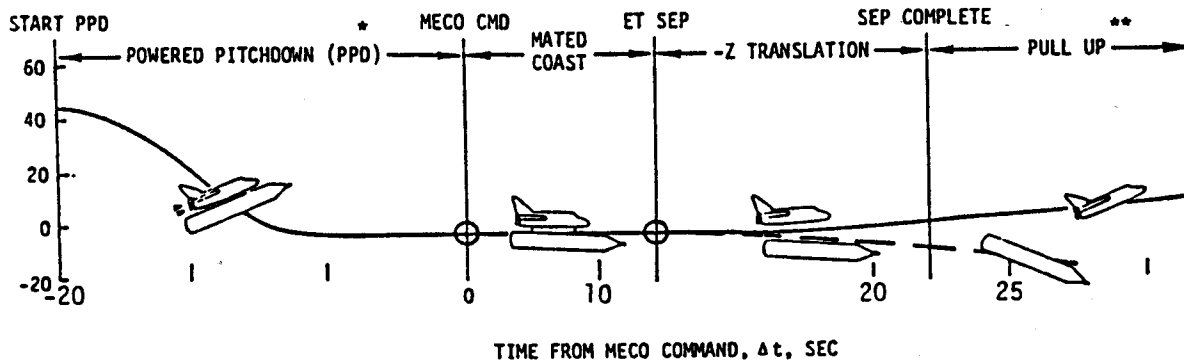
Rudder activated for yaw control

-Z XLATION complete (10 seconds,  $\alpha > 10$  deg)  
 MM 602 Transition

## (5) Discussion

ET SEP occurs 13.6 sec after MECO command. The SEP sequence begins at MECO and is accomplished in the AUTO mode without crew intervention. If there is a reason for delay of ET SEP, placing the mode switch in the MAN position will delay the SEP until returned to AUTO or the ET SEP pb is pushed. In the MAN mode, ET SEP will not occur unless the SEP pb is depressed, which will initiate a 'FAST SEP'.

ORBITER ANGLE  
OF ATTACK,  $\alpha$ , DEG



- \* PPD IS 20 SEC FOR OFT
- \*\* PULL UP  $\dot{\alpha} = 2$  DEG/SEC TO  $\alpha = 50$  DEG

Figure 3.3-16.- RTLS ET SEP transition region.

If the SEP constraints have been violated, the AUTO sequence will be inhibited for up to 6 sec. The sequence constantly checks to see if out-of-limits conditions have been satisfied. If so, the sequence continues. After 6 sec (19.6 sec after MECO), the alpha, beta, and rate constraints will be ignored and the ET will separate without any crew intervention. At ET SEP, the red main engine status lights will extinguish.

Immediately following the ET SEP, the vehicle starts a -Z translation maneuver. This maneuver is initiated using four forward and six aft RCS jets burning down.

The RCS jets perform a -Z translation for 5 sec and a controlled pitchup at 2 deg/s to an angle of attack of 50°. When the angle of attack is greater than 10° and approximately 10 sec have elapsed, the transition to MM 602 will occur. This -Z translation is done to prevent recontact with the ET and prepare for the alpha recovery phase of GRTLS. If required the crew can manually perform this maneuver using the THC and RHC. Five seconds after physical SEP, the rudder is activated to provide augmented roll control.

## h. MM 602 TRANS, ALPHA RECOVERY PHASE, ELEVON AND BDYFLP ACTIVATION

## (1) Cue

Attitude rates  
 End of -Z translation (10 sec and  $\alpha > 10^\circ$ )  
 CRT display changes - VERT SIT 1 appears

## (2) Display

ADI  
 AMI  
 VERT SIT 1 display

## (3) Crew action

Monitor. If VERT SIT 1 does not appear at the end of the -Z translation burn, the crew will perform an OPS 602 PRO.

1: GNC VERT SIT 1

3: BFS, GNC VERT SIT 1

NOTE

On MM 602 transition, elevons  
 and BDYFLP activate

Monitor alpha recovery ( $\alpha = 50^\circ$ )

## ALPHA RECOVERY PHASE

## (4) Discussion

The transition to MM 602 occurs at the end of the -Z translation burn (10 sec from ET SEP,  $\alpha > 10^\circ$ ) and initiates the Alpha Recovery phase of GRTLs. During this phase, guidance will bring the Orbiter attitude from the low angle of attack required for ET SEP to a high alpha ( $50^\circ$ ) and a wings-level attitude in preparation for atmospheric flight. This attitude is maintained as the normal load factor increases to within 0.35g of the constant normal acceleration value (2g) used for the Nz hold phase. The value of the angle of attack influences the subsequent aerodynamic loads experienced by the Orbiter, the minimum alpha reached during the Nz hold phase, and the Orbiter range potential. There is no energy management performed during this phase. The ADI pitch error needle displays the alpha error during the alpha transition phase. Following the -Z translation burn, the Orbiter pitches up at 2 deg/s to an alpha of  $50^\circ$ . The alpha recovery, Nz hold, and alpha transition phases are illustrated in figure 3.3-17.

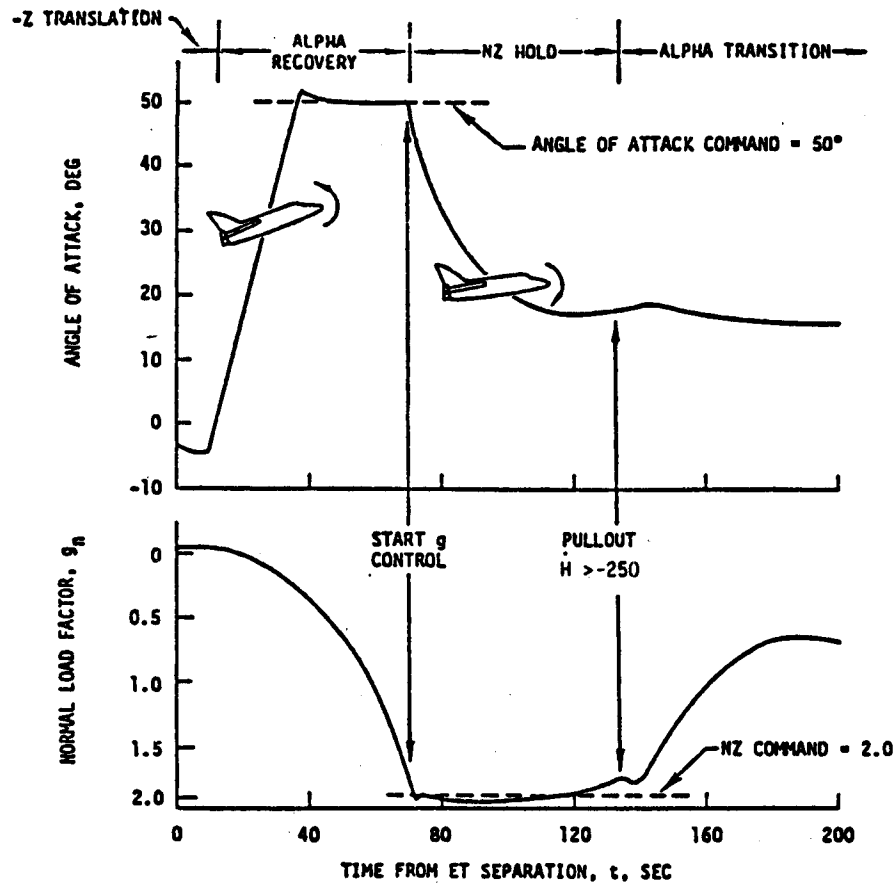
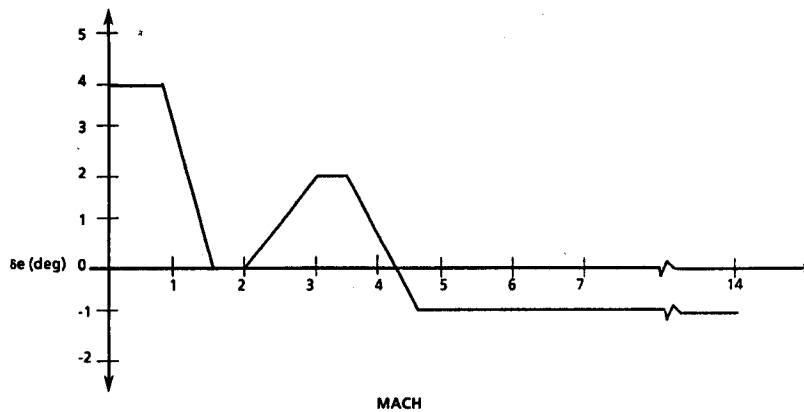


Figure 3.3-17.- Alpha recovery, Nz hold, and alpha transition phases.

Attitude control after the ET SEP burn is accomplished by both RCS thrusters and aerodynamic surfaces until 77 KEAS ( $q = 20$ ), when the RCS pitch and roll thrusters have been deactivated. The GTRLS FCS automatically schedules the elevons and controls the BDYFLP to null the elevon trim CMD. Pitch will be provided by the elevons and RCS jets.

The standard GTRLS elevon trim schedule is shown in figure 3.3-18. Since the RTLS is a relatively low speed abort, heating is not as big a driver as it is in AOA and nominal reentry cases. For this reason, one generic GTRLS elevon trim schedule is sufficient. The correct elevon schedule should be selected automatically during an RTLS; so a SPEC 51 item entry should not be necessary.





## ELEVON SCHEDULE

| VELOCITY (FPS) | DEFLECTION(DEG) |
|----------------|-----------------|
| 16000          | +1.0            |
| 14000          | -1.0            |
| 4500           | -1.0            |
| 3500           | +2.0            |
| 3000           | +2.0            |
| 2000           | 0.0             |
| 1500           | 0.0             |
| 900            | +4.0            |

Figure 3.3-18.- GRTLS elevon schedule (STS 26-B).

## i. ET UMBILICAL DOORS CLOSURE (RTLS)

## (1) Cue

MM 602 TRANS, ET UMBILICAL DOOR tb's

## (2) Display

VERT SIT 1

## (3) Crew action

R2 CTRLINE LATCH tb - STO (ET DOORS closing)

|   |                         |   |
|---|-------------------------|---|
| * | If not STO:             | * |
| * | ET UMB DR MODE SW - MAN | * |
| * | CTRLINE LATCH - STOW    | * |
| * | LATCH tb - STO          | * |
| * | L,R, (two) - CLOSE      | * |
| * | LATCH (two) - LATCH     | * |
| * | L,R, tb (two) - CL      | * |
| * | LATCH tb (two) - LAT    | * |

## (4) Discussion

For an RTLS, the ET umbilical doors are closed automatically 2 sec after ET SEP. The first step in this sequence (fig. 3.3-19) is to stow the centerline latch (the sequence allows 6 sec for this). Therefore, 8 sec after ET SEP, the centerline latch should be stowed with the talkback indicating STO. The transition to MM 602 occurs 10 sec after ET SEP, and by this time the centerline latch talkback should be indicating STO, giving a good indication to the crew that the AUTO sequence is working properly. If the talkback does not show stow (STO), then the AUTO sequence is not working properly, and the crew should manually close the doors using the ET UMBILICAL DOOR CLOSURE cue card.

If the ET umbilical doors are not closed, the aerodynamic characteristics of the Orbiter could be adversely affected, with the possibility of the doors ripping loose and damaging portions of the vehicle.

The AUTO sequence will take 66 sec to close the doors. The sequence should terminate at approximately TMECO+1:20.

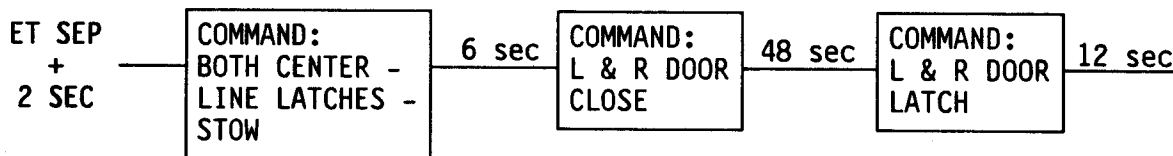


Figure 3.3-19.- RTLS ET umbilical doors closure sequence.

## j. MPS DUMP (RTLS)

## (1) Cue

MM 602 transition

## (2) Display

VERT SIT 1

Engine manifold pressure

## (3) Crew action

None - crew awareness

## (4) Discussion

Failure to dump MPS propellants will result in a c.g. position further aft than desired, reducing the static margin and pitch stability. The fuselage vent doors should be closed during the LH<sub>2</sub> dump (they are closed automatically at the MM 602 TRANS). The MPS dump is done in AUTO and will terminate at VREL = 4500 fps. LH<sub>2</sub> is dumped overboard through a special 1-1/2-inch RTLS dump line on the port side of the aft fuselage. LO<sub>2</sub> venting is done through the engine nozzles. LH<sub>2</sub> dumping is aided by helium pressure and may be considered completed when a noticeable drop is observed on the engine manifold pressure gauges.

## k. TACAN AOS and Management (RTLS)

## (1) Cue

MM 602 transition

## (2) Display

VERT SIT 1  
HORIZ SIT  
HSI

## (3) Crew action

As soon after the MM 602 TRANS as possible the crew should call up a SPEC 50 (HORIZ SIT) and using the tacan management matrix, select AUTO or FORCE for the tacans. After tacan lockon, the PLT selects tacan as the HSI source.

## (4) Discussion

Before lift-off, the HORIZ SIT display is configured as it is for nominal entry. At the transition to MM 602, the Orbiter will be within range of the TACAN stations. Therefore, as soon as possible after the transition, the crew should call up SPEC 50 (HORIZ SIT) and by using the TACAN management matrix in the checklist and table 3.3-III, the ratios and residuals (on HORIZ SIT), and, with MCC concurrence, place TACAN in AUTO or FORCE.

It is highly desirable to update NAV with TACAN data before ranging starts. If COMM with the MCC is lost and has not been re-established by 110,000 ft altitude, there is a NO COMM TACAN matrix (table 3.3-III) that will be used to update NAV. This is the same as for nominal entry.

TABLE 3.3-III.- TACAN MATRICES (FLIGHT RULES - ALL REV FINAL)

|   | RATIO <1               | RATIO <1  |   | 1-LOCK  |
|---|------------------------|---|---|---|
|   |                        | BAD TACAN   | BAD STATE VECTOR  |   |
| PRE-COMM (ASSUME NO COMM IF VREL <6000 @ FPS, NOM AOS + 2 MIN, H = 130K FT) | REMAIN IN INHIBIT      | REMAIN IN INHIBIT   | REMAIN IN INHIBIT   | REMAIN IN INHIBIT   |
| COMM  | GROUND CALL:<br>AUTO @ | GROUND CALL;<br>INHIBIT<br><br>IF STATION, SWITCH TO B/U CH<br><br>IF LRU, ΔSTATE UPDATE AS REQD  | GROUND CALL;<br>ΔSTATE OR FORCE<br><br>RETURN TO AUTO WHEN RATIO <1 | GROUND CALL;<br>DESELECT MISSING TACAN'S<br><br>(RESELECT NON-FAILED TACAN LRU'S WHEN 2 LOCK) |
| NO COMM   | AUTO                   | TROUBLESHOOT TO DETERMINE CAUSE OF EDITING<br><br>a. SWITCH GROUND STATIONS<br>b. CHECK IMU STATUS<br>c. OBSERVE RESIDUAL, RATIO BEHAVIOR<br>d. MONITOR WITH HSI<br><br>_____ |   | WAIT UNTIL VREL <5500 FPS @ THEN<br><br>DESELECT MISSING TACAN'S (DO NOT FORCE)               |
|   |                        | AUTO  | FORCE   |   |

NOTES:

- ① FOR RTLS, VREL < 6500 FPS.
- ② FOR RTLS, VREL < 4700 FPS.
- ③ EVEN THOUGH THE RATIO IS <1, TACAN DATA WILL NOT BE ACCEPTED IF GROUND RADAR INDICATES THAT INCORPORATION OF DATA WILL DEGRADE THE NAV SATE.

1. PITCH AND ROLL RCS JETS DEACTIVATION SPEEDBRAKE (SPBK) OPERATIONS (RTLS)

(1) Cue

KEAS = 54 roll jets inactive  
 KEAS = 77 SPBK activated, opening to 100%  
 Pitch jets inactive

(2) Display

- VERT SIT 1 display
- AMI (EAS)
- RCS lights
- Speed brake indicator
- GNC SYS SUMM 1 display

(3) Crew action

Monitor SPBK opening. Crew awareness for pitch and roll jet deactivation.

(4) Discussion

Use of the aft roll and pitch RCS thrusters is terminated when dynamic pressures of 10 and 20 lb/ft<sup>2</sup>, respectively, are reached. The aft yaw jets, which are used as the primary mode for lateral control during low dynamic pressure, remain available to assist the ailerons and rudder for lateral control until Mach = 1.

When a dynamic pressure of 20 lb/ft<sup>2</sup> is reached, the speedbrake is ramped from 0 to 98.6° (~82 percent) relative to the hingeline, to enhance lateral stability by allowing the elevons to be trimmed down (puts elevons in airstream). The approved speedbrake schedule for GRTLS is shown in figure 3.3-20. Below Mach = 1, the speedbrake position is modulated by TAEM guidance.

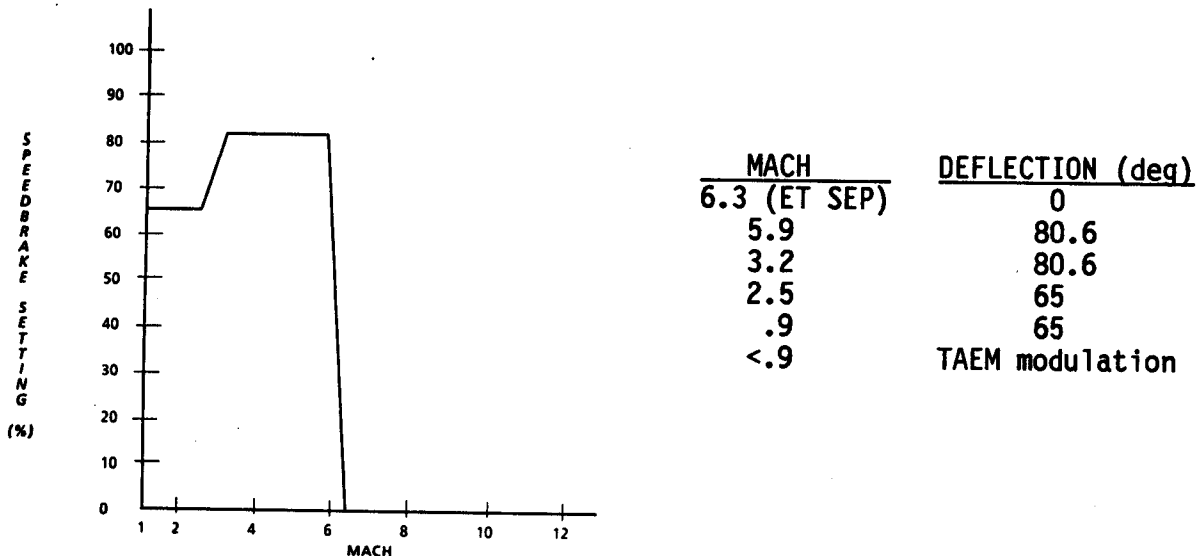


Figure 3.3-20.- RTLS SPBK schedule (STS 26-B).

m. RCS ACTIVITY LIGHT RECONFIGURATION (RTL5)

(1) Cue

121 KEAS ( $\bar{q} = 50 \text{ lb/ft}^2$ )

(2) Display

AMI

(3) Crew action

Monitor

KEAS = 121 RCS activity lts reconfigured:

ROLL lts - 3 or 7 yaw jets

PITCH lts - elevon rate saturation

(4) Discussion

At  $\bar{q} = 50 \text{ lb/ft}^2$ , the roll and pitch RCS activity lights are reconfigured by the software to indicate the FCS workload to the crew. Both left and right sides of the roll light will illuminate simultaneously if three or four yaw jets are commanded on by the FCS. The lights indicate commands from the FCS to the jet select logic, not actual jet firings. Also, since the minimum on-time for an RCS jet is 80 milliseconds, the commands to the light have been lengthened to allow the crew time to identify which light has failed. Both halves of the pitch light will illuminate if priority rate limiting (PRL) issues a flag for elevon rate saturation; ie., either the left or right elevon is driving at 20 deg/s or greater.

n. Nz HOLD PHASE (RTL5)

(1) Cue

Nz approaches Nz desired minus 0.35g

( $2 - .35 = 1.65\text{g}$ ), a starts

decreasing, Nz increases to

Nz desired.

(2) Display

VERT SIT 1

Normal accelerometer

AMI (ACCEL)

ADI

## (3) Crew action

Monitor.

$N_z = 58 \text{ ft/sec}^2$  (1.8g)  $N_z$  HOLD PHASE  
 $N_z$  constant at  $71 \text{ ft/sec}^2$  (2.2g)

## (4) Discussion

If alpha does not start a gradual decrease from  $50^\circ$  as  $N_z$  surpasses 1.8g, an  $N_z$  overshoot will occur. Excessive g-loading could cause structural damage or failure and could also dissipate sufficient energy, if sustained too long, to impact RTLS range capability.

The  $N_z$  hold phase is open loop and begins with an initial angle of attack of  $50^\circ$  (fig. 3.3-21). As the Orbiter descends into the atmosphere,  $\bar{q}$  increases with increasing density. This causes  $N_z$  to increase. When  $N_z$  actual is within 0.35g of  $N_z$  desired, the alpha will decrease gradually as  $N_z$  actual builds to  $N_z$  desired (flight dependent). Alpha will then be gradually decreased to maintain  $N_z$  desired. All ranging techniques, including S-turns, are inhibited during this phase. The  $N_z$  hold phase is terminated when  $H > -250$  and  $\alpha > \alpha$  reference (fig. 3.3-21). Guidance then switches to the alpha transition phase. The ADI pitch error needle displays  $N_z$  error during this phase, and AMI ACCEL displays  $N_z$  in MM 602.

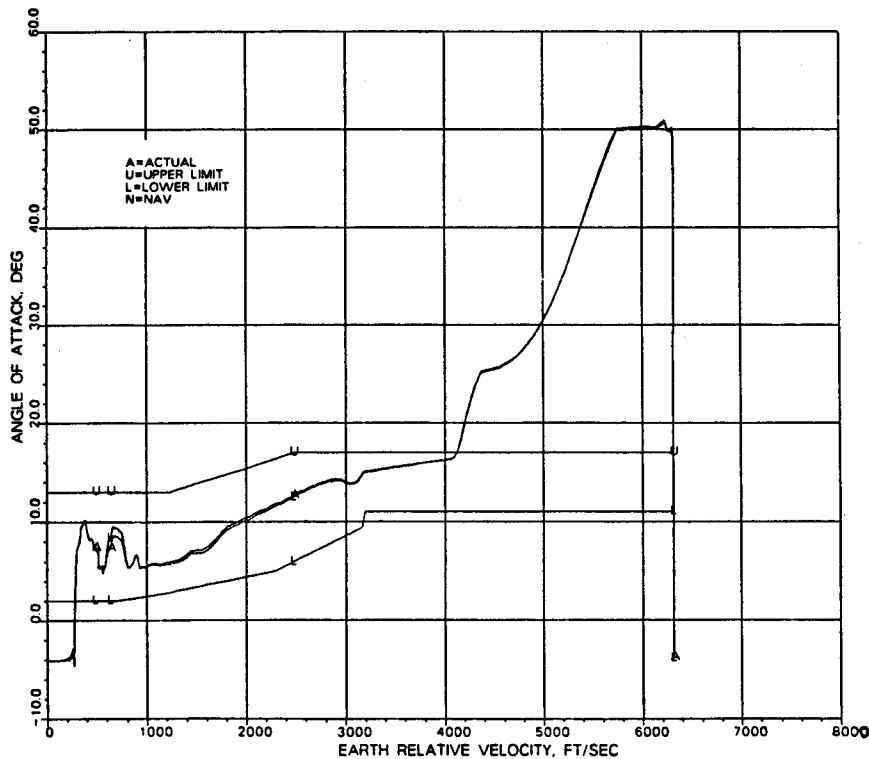


Figure 3.3-21.- Alpha profile (STS 26-B).

## o. AMMONIA BOILER ACTIVATION (RTLS)

## (1) Cue

H = 120,000 ft

## (2) Display

AVVI

## (3) Crew action

Monitor

h = 120,000; NH<sub>3</sub> boiler active

- \* NH<sub>3</sub> BOILER not active \*
- \* If FREON EVAP OUT TEMP hi, \*
- \* NH<sub>3</sub> CNTLR (two) - SEC/ON \*

## (4) Discussion

At 120,000 ft, the ammonia boiler will be automatically activated by the GPC. Activation will be monitored by MCC, and a call will be made to the crew if the event has not taken place. Onboard configuration of NH<sub>3</sub> boiler activation can be made by noting the temperature on the FREON EVAP OUT TEMP display on panel 01. Also, the Freon loop C&W will trigger when the loop is higher than 60° F. If AUTO activation fails to take place, the crew action is

L1: NH<sub>3</sub> BOILER (two) - SEC/ON.

## p. ALPHA TRANSITION, S-TURNS (RTLS)

## (1) Cue

$\dot{H} > -250$  fps and  $\alpha > \alpha$  reference

## (2) Display

VERT SIT 1  
AVVI  
AMI  
ADI

## (3) Crew action

Monitor:

Orbiter on HAC - alpha profile (VERT SIT 1)  
S-turn



## (4) Discussion

The alpha-transition phase guidance logic is initiated and the Nz-hold phase terminated when  $H > -250$  fps and  $\alpha > \alpha$  reference. During this phase, an angle of attack command is generated as a linear function of Mach number which can be monitored on the VERT SIT 1 Mach-alpha profile (fig. 3.3-21). Also, a bank maneuver is performed, either to null any heading errors to the heading alignment circle (HAC) tangency point, or to dissipate excess energy by turning away from the HAC (S-turns). The maximum bank angle for this phase is  $50^\circ$ . The ADI pitch error needle displays alpha error for this phase.

Because the alpha-recovery and the Nz-hold phases are both open loop and not part of energy management, and because sufficient energy must be available to cope with open loop energy losses from headwinds and unfavorable L/D variations, GRTLS is intentionally targeted to produce an excess energy state at the initiation of the alpha-transition phase. Therefore, S-turns will nominally be started and, in most cases, completed during the alpha-transition phase. The starting and stopping of S-turns can be monitored on the VERT SIT 1 display using the E/W scale.

At Mach = 3.2, the alpha-transition phase will end and guidance will start the nominal terminal area energy management (TAEM) phases. Software will mode from MM 602 to MM 603, and the Orbiter symbol on VERT SIT 1 will switch from the Mach-alpha profile to the range-altitude lines.

## q. TRANSITION TO MM 603, NOMINAL TAEM INTERFACE (RTLS)

## (1) Cue

Mach = 3.2

## (2) Display

AMI  
VERT SIT 1  
ADI

## (3) Crew action

Monitor  
Mach - 3.2 TAEM ACQUISITION PHASE  
MM 603 TRANS

\* If no transition 'GNC, OPS 603 PRO'\*

**(4) Discussion**

Nominal TAEM interface and the MM 603 TRANS occur at Mach = 3.2. At TAEM interface, guidance will do one of two things:

- (a) If the vehicle was in an S-turn at the MM 603 TRANS, the TAEM S-turn phase will be initiated and the S-turn continued until the E/W is below the S-turn termination reference, at which time the TAEM acquisition phase will begin.
- (b) If the vehicle was not S-turning at the MM 603 TRANS, the TAEM acquisition phase will be initiated and the E/W will be tested to determine if an S-turn is required. If an S-turn is required, the TAEM S-turn phase will be initiated. If no S-turn is required, guidance will stay in the TAEM acquisition phase.

The GRTLS TAEM guidance phases - S-turn, acquisition, heading alignment, and prefinal - are identical to the nominal entry TAEM guidance except:

- (a) The energy per unit weight, altitude, and dynamic pressure references are extended to higher speeds to include all possible conditions existing when the trajectory is stabilized following the load relief maneuver.
- (b) To provide greater energy control, the bank angle limit during S-turn is increased from 30 deg/s to 50 deg/s.

The ADI pitch error needle starts displaying Nz error at TAEM interface. Also at MM 603 TRANS (TAEM interface), the Orbiter symbol on vertical SIT 1 switches from the Mach- $\alpha$  profile to the range-altitude lines.

**r. RTLS TAEM AND POSTLANDING DELTAS FROM NOMINAL ENTRY****Discussion**

The MPS/TVC ISOL valves must be closed by the crew before the low altitude/high maneuvering regions of TAEM to prevent PRL. Another constraint on these valves is that they must remain open during the MPS dump, which means they cannot be closed until after Mach = 4.5.

The landing gear (LG) HYD ISOL valves must be open to allow hydraulic pressure to the landing gear system. Nominally, the valves are opened automatically at MM 603 TRANS. The crew must verify that the valves are opened prior to gear deployment, although it is not required that it be done at exactly Mach = 3.2. This is checked at Mach = 2.9 on nominal entry.

The MLS LRU's are powered off prelaunch to conserve electrical power. The MLS switches are not activated until H = 85k ft for RTLS.

The rest of the events, starting with deploying the air data probes, are very similar, if not identical, to the nominal entry events. The postlanding procedures for RTLS are the same as for nominal end of mission except that the hydraulic load test is not done.

### 3.3.6 Contingency Abort Procedures

#### 3.3.6.1 Background

Contingency abort flight analyses and procedures development have been under way since December 1977. The ejection seats that were available during the Shuttle OFT were to be used after a contingency abort had delivered the Orbiter to an acceptable ejection envelope. The ejection seats were removed before STS-5 and the emphasis on contingency abort flight analysis and procedures development began to decline. Very little analysis or simulation was performed after 1983.

Recently the decision was made to evaluate crew bailout capability. In the summer of 1986, funds were allocated to begin comprehensive contingency abort analyses and procedures development. The goals of the study were to improve the chances of a successful contingency abort in all regions and improve, simplify, and automate crew procedures where possible. The study has involved NASA, Rockwell, Honeywell, Lockheed, and other personnel in analyzing structural, thermal, venting, external tank (ET) separation, guidance, and flight control aspects of the Shuttle/Orbiter during a contingency abort.

Two very important ingredients in the study were the development of improved Orbiter aerodynamic data, and the use of man-in-the-loop simulators in procedure development. Improved aerodynamic data are important because contingency aborts take the Orbiter into unique regimes of Mach and angle of attack where standard Orbiter aero coefficients could previously only be extrapolated. Wind tunnel tests were used to validate the preliminary aerodynamics incorporated in the simulators for the initial phases of the study. These preliminary aerodynamics contain new data for longitudinal aero, but only extrapolated data for lateral stability aero. The procedures outlined in this document were developed using these preliminary aerodynamics. More complete wind tunnel data is currently in development at Ames Research Center and should be incorporated in simulators by the Spring of 1988. Another phase of the study will then begin, and the effect of the new aerodynamics on flight procedures will be investigated.

A further important ingredient was the development of ET/Orbiter synthesized aero data for use in the unmanned digital simulations which cover important portions of the unusually large envelope of aerodynamic conditions encountered in contingency aborts. The large volume of the proximity portion of the separation aero data has imposed approximations in the application in the manned simulator because of its limited core and the necessity to run in real time. These limitations are avoided in the non-real time digital

simulation which has been especially valuable in defining ET separation performance at the off-nominal conditions of contingency abort.

The Shuttle Avionics Integration Laboratory (SAIL) and the Systems Engineering Simulator (SES) were used in the contingency abort study. Over 500 runs in the SES and 44 runs in the SAIL have been used to define procedures, evaluate survivability regions, and investigate automation techniques. The SES contained the preliminary aero data base for this study, and is a much better tool for analysis than was available for the pre-STs-1 contingency abort studies. A man-in-the-loop simulator is a critical ingredient in the success of contingency abort studies because it allows rapid trial-and-error testing of new flight techniques, and permits crew members and engineers to evaluate and test new procedures as quickly as possible.

### 3.3.6.2 Overview

Contingency aborts early in the ascent trajectory require guiding the vehicle to a safe gliding flight condition where bailout or a ditch can be performed. Contingency aborts that occur later in ascent may have the capability to reach a downrange landing site. MCC calls or the NO COMM MODE BOUNDARIES indicate when landing capability is available.

The contingency abort cue cards show the procedures on an engine out/event timeline and are color coded for easy reference. Although it appears that there are many different contingency abort procedures, they are similar. A contingency abort may be divided into three major phases.

#### a. Powered flight

If any thrust is available, the Shuttle is maneuvered to minimize the entry sink rate and rolled to a heads-up attitude.

#### b. External tank separation

ET SEP must be performed before the Orbiter enters the atmosphere. For some cases, a 6-sec FAST SEP is performed while the Orbiter and ET are pitching down at 4 deg/s. If  $\dot{q}$  is greater than 2 lb/ft<sup>2</sup> and increasing, the Orbiter must be at a negative angle of attack for successful separation from the ET.

#### c. Entry

The contingency abort entry is similar to that of an RTLS, but the wide range of initial velocities, high sink rates, and altitudes can result in high normal load factors (Nz) and heating rates. The entry is divided into three phases:

- (1) Alpha recovery - The Orbiter is pitched to an angle of attack that gives maximum lift and drag.

- (2) Nz hold/pullout - As the load factor increases, angle of attack is decreased to maintain the Nz limit. This Nz is held until the Orbiter has completed a pullout from its dive into the atmosphere.
- (3) Alpha-Mach schedule - When the sink rate has reduced to -250 fps, the Orbiter has achieved pullout, and the CDR transitions to flying a wings level angle of attack ( $\alpha$ ) versus Mach number profile.
- (4) Bailout or ditching - The crew will place the Orbiter in an attitude hold and then bail out.

The PASS is taken to OPS 6 (RTLS) during an early contingency abort. OPS 6 provides the flight control needed to fly the contingency abort maneuver. In higher speed aborts the OPS 6 flight control may result in some attitude oscillation because the gains were designed for the lower Mach regime of RTLS, OPS 3 is not used because it may take too long to load it from the MMU's.

a. Powered flight

If two SSME's fail, the thrust remaining on the good SSME is used to reduce the sink rate that will occur during entry. This can be done by directing the thrust vector to minimize the altitude loft and maximize the horizontal velocity. Another way to describe this is that it should minimize the calculated apogee altitude, since apogee altitude combines the effects of current altitude and flight-path angle.

If two SSME's fail at an inertial velocity between approximately 7,000 and 12,000 fps, a vertical thrust vector is used. However, if the engine failure occurs earlier in the ascent when the Shuttle has a large positive altitude rate or if significant thrust is available (i.e., a stuck throttle abort), the thrust vector is pointed towards the horizon to prevent further lofting of the Shuttle trajectory. This thrust vector orientation increases velocity and reduces the severity of the entry pullout. At a  $V_I$  greater than ~12,000 fps, the Shuttle may have enough energy to continue to a downrange landing site.

Powered flight also extends the time available for dumping OMS propellant. The dump reduces Orbiter weight and moves the X c.g. forward. Reducing weight decreases the peak  $\dot{q}$  that occurs during pullout. Moving the c.g. forward reduces the elevon and bodyflap deflections required during pullout, which decreases the probability of aerosurface saturation or actuator stall.

A roll to heads-up is performed for some maneuvers during powered flight. This maneuver orients the bottom of the Orbiter/ET in the direction of the velocity vector. This orientation provides the proper attitude to start the ET SEP.

b. ET SEP

As the Shuttle falls during contingency abort powered flight, the  $\dot{q}$  increases. Safe ET SEP is a function of  $\alpha$  and  $\dot{q}$ . Rockwell analyses results for a successful ET SEP are shown in figure 3.3-22.

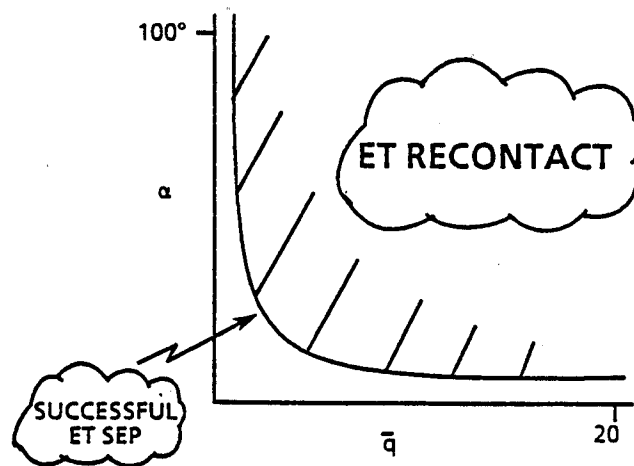


Figure 3.3-22.- Successful ET separation.

The ET may be safely separated at dynamic pressures up to 10 lb/ft<sup>2</sup> but the Orbiter angle of attack must be small (-4°). At less than 2 lb/ft<sup>2</sup>, large positive angles of attack are acceptable. But in such cases the time of -Z translation should be increased to at least 8 sec to prevent recontact.

The high sink rate during many contingency aborts results in a very rapid entry into the atmosphere and, thus, a very rapid increase in  $\bar{q}$ . In most cases, there is insufficient time for a pitchdown to a negative angle of attack and a normal 14-sec RTLS mated coast ET SEP sequence.

Therefore, a fast SEP is performed which takes only 5 sec. Instead of pitching to a negative angle of attack, which could take as much as 30 sec, the separation is commanded while at a high angle of attack and a -4 deg/s pitch rate. The fast SEP offers distinct advantages over normal separation techniques.

First, it allows the separation to be delayed as long as possible and extends the time available for powered flight. It is initiated when EAS is greater than 7 fps and increasing. This corresponds to a dynamic pressure of approximately 0.2 lb/ft<sup>2</sup>, which allows the ET SEP to occur before the 2 lb/ft<sup>2</sup> limit for high angle of attack separations. Analysis shows this is a safe technique.

Second, the Orbiter is already near the angle of attack that will be required for entry, and the -4 deg/s pitch rate need only be slowed as the proper angle of attack is reached. If the Orbiter were taken to a negative angle of attack for separation, it would require two pitch maneuvers, a negative pitch to the separation angle of attack followed by a pitch back up to the entry alpha.

The -4 deg/s pitch rate used for the fast SEP is a compromise between desiring a rapid pitchdown with the need to maintain control and slow

the pitch rate after separation. Simulations have shown the pitch rates exceeding -6 deg/s may result in loss of control.

The GPC's will automatically mode to MM 602 10 sec after structural release if the angle of attack is greater than 10°. At MM 602 Earth relative velocity (Mach) will be displayed.

### c. Entry

The goal of contingency abort powered flight and ET SEP is to deliver the Orbiter to acceptable entry conditions without loss of control. In general, reducing separation altitude and sink rate improves the entry. Any mistakes made in powered flight or separation will manifest themselves in entry. Entry phases include alpha recovery, Nz hold/pullout, and alpha-Mach.

#### (1) Alpha recovery

After separation is complete the Orbiter should be maneuvered to an angle of attack that maximizes lift and drag. This is called alpha recovery. This angle of attack is dependent on Mach and trim and can range from 20° to 60°. For the simplification of crew procedures, however, discrete angles of attack as a function of Mach are given in the procedures. The data reflect SES runs based on the AMES wind tunnel results (APR 1987:  $\alpha$  up to 60°).

| <u>M</u>    | <u>Alpha recovery</u> |
|-------------|-----------------------|
| ≤ 2.0       | 20°                   |
| > 2.0 ≤ 3.0 | 40°                   |
| > 3.0 ≤ 4.5 | 50°                   |
| > 4.5       | 58°                   |

In most cases, the alpha recovery will be reached by continuing the negative pitch rate initiated in the high rate separation. The alpha display tape will only show a maximum of 60°, so 58° is the maximum alpha used.

The speedbrake and bodyflap should also be set in the alpha-recovery phase before the critical Nz-hold phase begins. The speedbrake and bodyflap affect the maximum  $\dot{q}$  and the hinge moment loads on the elevon during the critical Nz-hold phase. The speedbrake can be opened to increase the vehicle drag, slow the Orbiter, and reduce dynamic pressure. Unfortunately, opening the speedbrake also induces a pitching moment that forces the elevon to a lower trim position and may result in elevon saturation or actuator stall during Nz hold. Also, the speedbrake should not be opened above Mach 10 because of thermal constraints. As a result, the procedures recommend manually closing the speedbrake unless the Mach is less than three, when it should be set to 65 percent.

The bodyflap can also be lowered to increase the drag. However, this induces a negative pitching moment that forces the elevon to a higher trim position. Lateral control problems may occur if the elevons are in an up (negative) position. As a result, the procedures recommend leaving the bodyflap in auto to trim the elevon to its schedule. The bodyflap should be driven manually only if control problems occur.

Large negative bodyflap deflections during alpha recovery should also be avoided. If the bodyflap is deflected upward when the Nz-hold phase begins, it may drive down too slowly to assist the elevon in decreasing the angle of attack. Without the bodyflap, the elevon may saturate or its actuator limits may be exceeded.

## (2) Nz-hold/pullout

The altitude sink rate ( $\dot{H}$ ) will continue to increase during alpha recovery until the Orbiter drops low enough in the atmosphere to develop sufficient  $\bar{q}$  and lift for equilibrium flight. As lift increases the Nz on the Orbiter will increase. When the normal load factor reaches one, the Orbiter is developing enough lift to support its own weight, and the sink rate will begin to decrease. The maximum negative  $\dot{H}$  is a good indicator of how severe the entry will be, and it is used to calculate the Nz required for pullout.

The Nz required for pullout has been found to provide a good balance between Nz structural limits and  $\bar{q}$ -limits. The structural limit is actually a function of Orbiter weight and wing root bending moment. The 240,000-pound Orbiter is certified to  $\bar{q} = 375$  and 2.5g with a 1.4 factor of safety. Rockwell structural engineers will only tell us the percent we exceed the certification limits. Rockwell will not provide an estimate of whether or not the Orbiter will survive to the bailout point. Nevertheless, procedures were developed to minimize  $\bar{q}$  and g to reduce exceedance percentages. JSC structural engineers have evaluated several cases. As of July 1, 1988, we know that the Orbiter will structurally survive all 2 engine out contingency aborts from lift-off to the Single Engine Droop boundary (2 ENG OUT BLUE and 2 ENG OUT GREEN).

The load factor will continue to increase as alpha recovery is maintained and  $\bar{q}$  increases. When the load factor approaches the Nz target (within approximately 0.4g) a pitchdown is initiated to converge to the hold the Nz target. This is called the Nz-hold phase. The actual load factor is shown on the AVVI acceleration scale which is scaled to show g's while in MM 602, with 10 = 1g, 20 = 2g, and 30 = 3g. As the Nz target is held by reducing alpha, the  $\bar{q}$  will continue to increase until the sink rate is stopped. When the magnitude of the sink rate is reduced to less than -250 fps the Orbiter is said to have achieved pullout from its descent.

It is during this phase that some contingency aborts will exceed vehicle structural, temperature, and flight control limits.



Holding a load factor below the  $N_z$  required for pullout will cause an increase in  $\bar{q}$  because the Orbiter achieves pullout at a lower altitude. It also requires the Orbiter to pitch to a lower angle of attack which can result in lateral control instability and increase the heating rate on the upper vehicle surface.

Most regions of contingency abort have adequate flight control. However, there are some contingency abort regions where even flying maximum structural load factor limit during  $N_z$  hold will not prevent the  $\bar{q}$  from exceeding 800 lb/ft<sup>2</sup>, having elevons stall, and then losing control of the vehicle. Analysis as of July 1, 1988, shows the Orbiter cannot be flown if three main engines fail between 8,000 fps and 12,000 fps (3 ENG OUT GREEN). Another region where control is lost is if an engine fails late (for example, 5000 fps and prior to 2 ENG TAL). In this case we abort RTLS at 2+30 and if a second and third main engine fail within 30 sec of powered pitcharound we execute the RTLS 3 ENG OUT BLUE procedure. Analysis and SES evaluations show we lose control of the Orbiter. Loss of control can result from a number of things. In some cases, the aerodynamic moments are so high that, even at maximum deflection and/or maximum jet firings, the vehicle rates cannot be controlled. Additionally, in some cases the aero-surface loads are so high that the aero-surface actuators cannot drive the control surfaces. This is often referred to as actuator stall. The flight control gains were designed for maximum dynamic pressure of 375 psf. Therefore, the system is often undergained and underdamped in these cases. Such cases require excellent piloting skills for successful completion. Often these control problems can be avoided by flying a higher g-level during pullout, thus lowering the dynamic pressure. Recent structural analysis indicates that these higher g-loads would be acceptable in some cases (see NASA memo DM3 88-54).

(3) Alpha-Mach

The contingency abort alpha-Mach entry phase is similar to other entry phases of flight.

(4) Bailout or ditching

Analysis has shown that the Orbiter will probably not survive a water ditch. Current recommendations are for the crew to place the Orbiter in an attitude hold and then bailout. For this purpose, an attitude hold mode was added to the MM 603 software. It is available when Mach is less than 1.0, and is activated by moving the abort rotary switch to ATO and pressing the abort PBI. When the crew switches from CSS to auto, guidance will snapshot the current airspeed and roll angle and attempt to hold both constant. If a new airspeed or roll is desired, control can be taken back to CSS. When auto is selected again a new snapshot will be taken.

After the attitude hold is established and an altitude of about 30,000 feet is reached, the crew should depressurize the cabin, blow the hatch, and bailout.

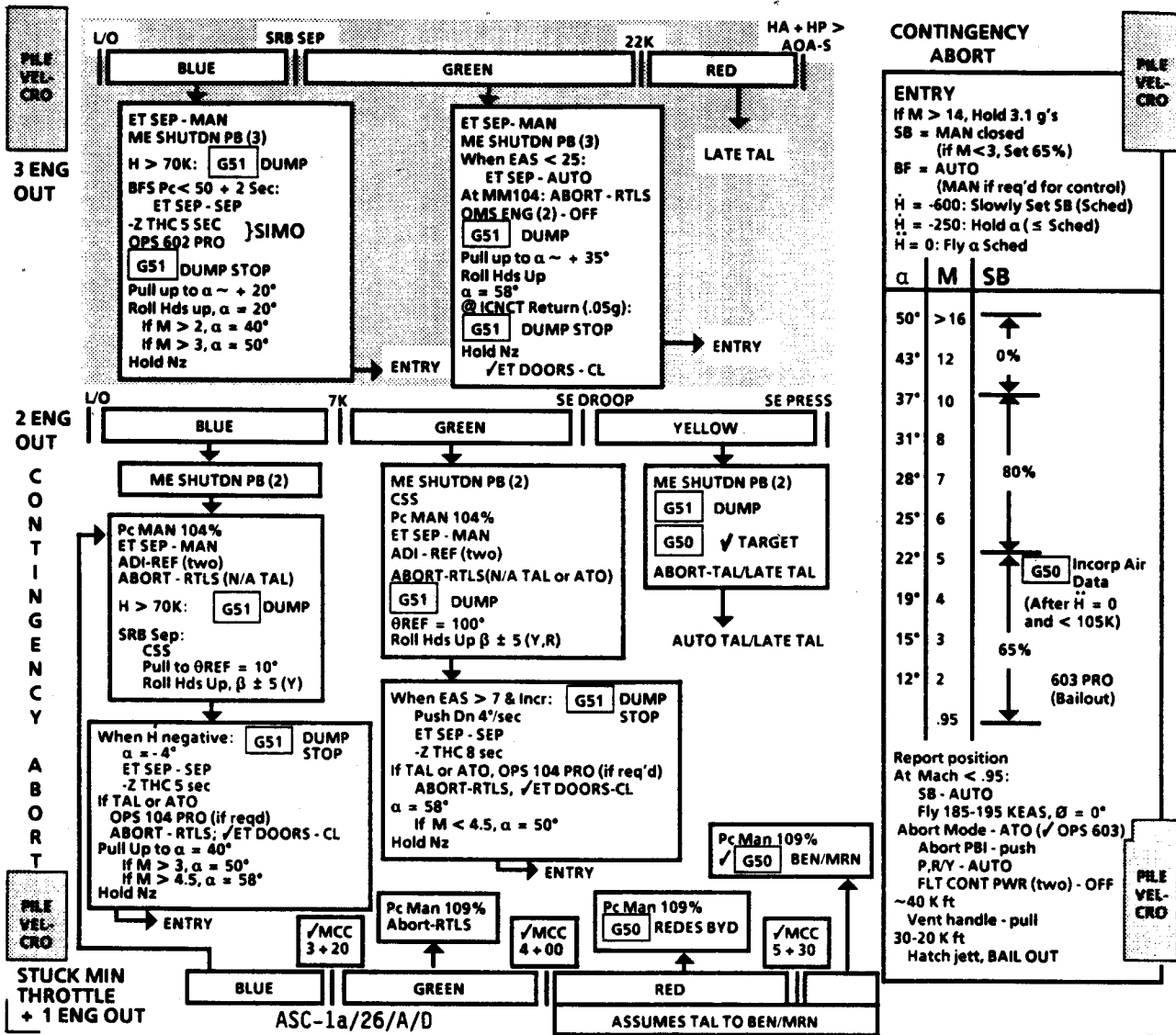


Figure 3.3-23.- Contingency abort.

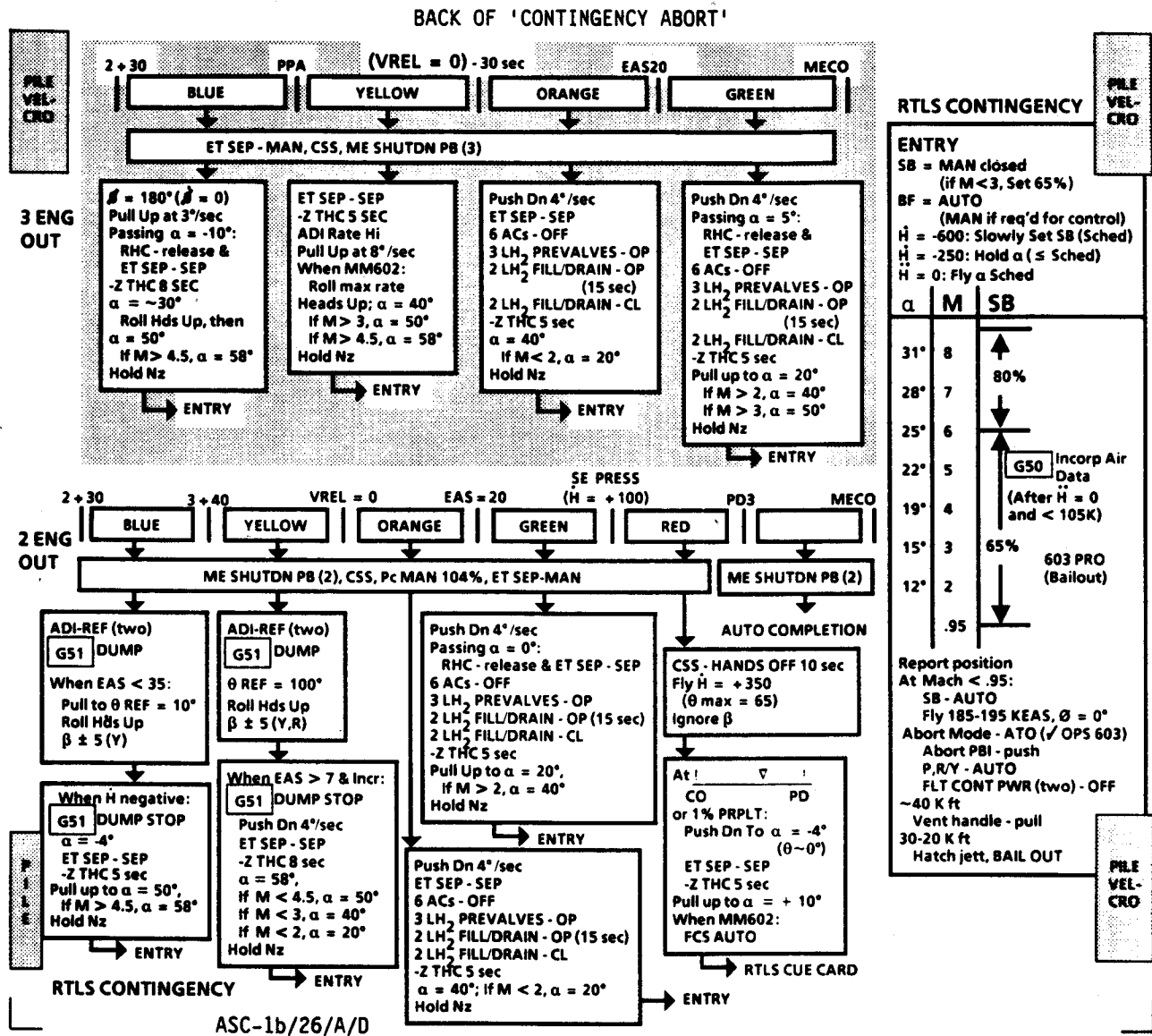


Figure 3.3-24.- RTLS contingency.

3.3.6.3 Contingency Abort Cue Card Rationale

The contingency abort procedures are shown in figures 3.3-23 and 3.3-24. Rationale for each procedure is explained in this section.

a. 2 ENG OUT BLUE

The two-SSME failure procedures between lift-off and  $V_I = 7000$  fps are shown in figure 3.3-25. The blue procedure is also used for  $1\frac{1}{2}$  ENG OUT resulting from one SSME stuck in the bucket plus another SSME failed.

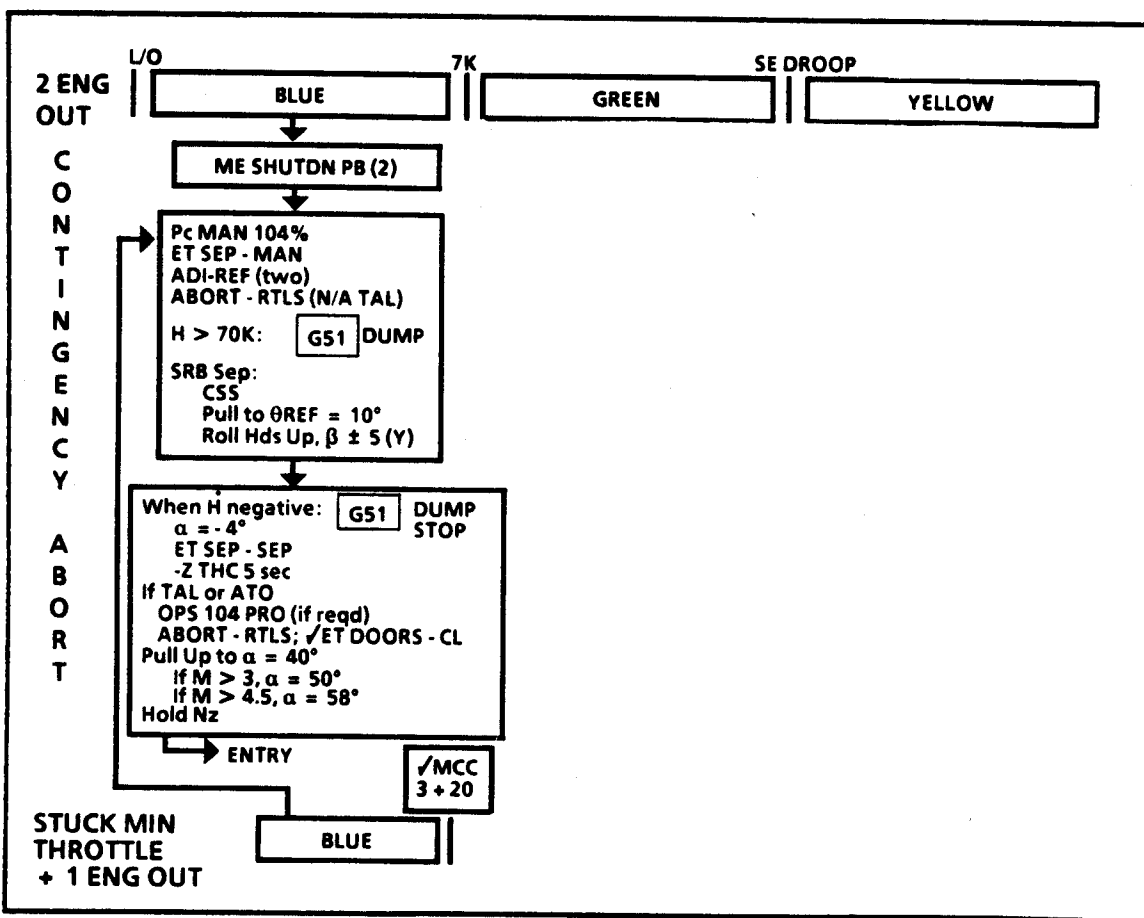


Figure 3.3-25.- 2 ENG OUT BLUE.

ME SHUTDN PB (2)

If one of the two failed SSME's has a data path fail, or if one SSME fails and then the second SSME fails when the main engine limits are in AUTO INHIBIT, the SSME pb's on panel C3 are required to tell the GPC's that a second engine has failed and to enable single engine roll control. This first step is crucial. Single engine roll control is required to maintain control.

Pc MAN 104%

Manual throttle control ensures that guidance will not issue a MECO command.

ET SEP - MAN

This step arms the ET separation system so that the fast SEP sequence can be accomplished later by one quick step with the ET SEP pb. It is not crucial to do this step at this point, but experience has proven that this is a good time to set the ET SEP switch on C3 to MAN, before the workload gets higher at a later point in the procedure.

ADI-REF (two)

The REF position of the ADI select switch makes the ADI a launch pad inertial, three-axis ball.

ABORT - RTLS (N/A TAL)

Select RTLS with the rotary and push the abort pb. This step takes the PASS and BFS to MM 601 after SRB SEP. This transition to MM 601 allows an automatic transition to MM 602 after ET SEP. If a TAL abort has been declared prior to the second SSME failure, do not select RTLS. For a TAL, RTLS will be selected after the ET SEP.

H > 70K: G51 DUMP

The objective of the contingency dump is to move the c.g. as far forward as possible within the time available. SPEC 51, item 6, item 7 EXEC will start a 2 OMS, four +X and 20 null jet OMS propellant dump. The dump needs to be started above 70,000 ft because analysis has shown that the OMS engine bells would collapse if the dump is started below 70,000 ft.

SRB SEP:CSSPull to  $\theta$  REF =  $10^\circ$ Roll Hds Up,  $\beta \pm 5$  (Y)

If two SSME's fail early in first stage, autoloft will loft the Orbiter at  $\theta \sim 80^\circ$ , to minimize the peak  $\dot{q}$  and also minimize the  $\dot{q}$  at SRB SEP. However, guidance needs to know two SSME's have failed in order to get autoloft. If guidance notification via the main engine pb's is delayed, the trajectory will be flatter and  $\dot{q}$  at ET SEP higher than desired. After SRB SEP, select CSS and pitch to  $\theta = 10^\circ$ . Pitching to  $\theta = 10^\circ$  and rolling to heads-up will place the thrust vector of the remaining engine along the local horizontal. This will increase apogee velocity while not increasing apogee altitude, and make the pullout less severe.

Beta ( $\beta$ ) can be trimmed up with yaw (Y) commands (using the RHC and observing the HSI).

When  $\dot{H}$  negative: G51 DUMP STOP

$\alpha = -4^\circ$   
ET SEP-SEP  
-Z THC 5 sec

When  $\dot{H}$  goes through zero, the flight path angle ( $\gamma$ ) is zero and the angle of attack will be  $-10^\circ$ . The pilot must stop the dump (G51 item 8) prior to the fast SEP. If not, when the software modes to 602 after the fast SEP, the dump will interconnect at MM 602 + 2 sec and the RCS jets will fire. The OMS screens will break down if the g's are  $< .02$  (most of the time in this region), and you will lose control of the Orbiter. OI-8c software does not automatically start the contingency dump post MECO. Therefore, this step will not be necessary with OI-8c software. After a small pitch maneuver to  $\alpha = -4^\circ$  a fast SEP is commanded. The ET SEP conditions will be similar to a normal RTLS ET SEP. Since in MM 601 the -Z jets will not fire until ET SEP occurs, the THC should be deflected prior to the engine status lights going out (ET SEP) and held for 5 sec from that event. The manual -Z command significantly improves ET/Orbiter clearance.

Typical ET separation conditions for this abort are:

Case 1

2 SSME's out at lift-off + 30 sec

$\bar{q} = .4$   
 $\alpha = -6^\circ$   
 $H = 238,000$  ft

Case 2

2 SSME's out at 6000 fps

$\bar{q} = .4$   
 $\alpha = -4.3^\circ$   
 $H = 268,000$  ft

Relative motion between the Orbiter and ET after separation for this abort is shown in figure 3.3-26.

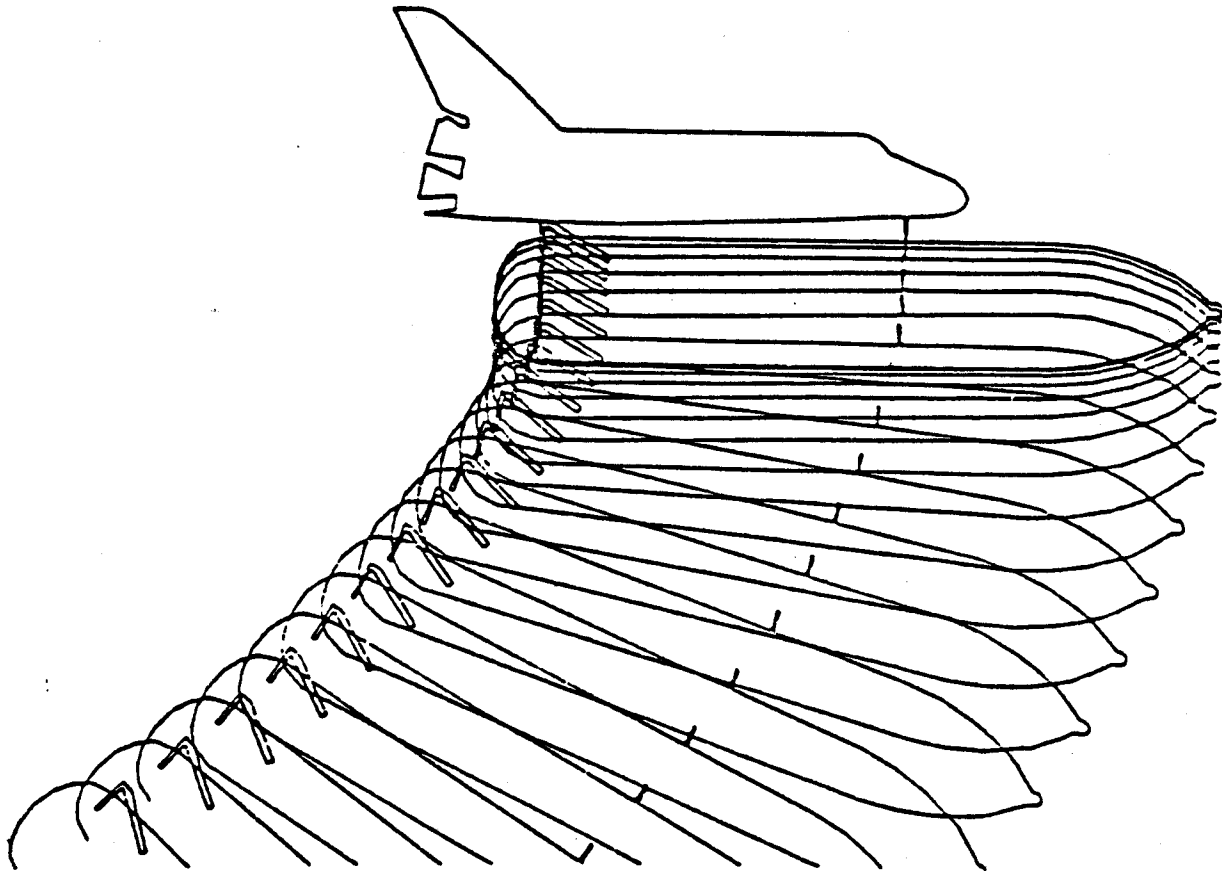


Figure 3.3-26.- Relative motion between the Orbiter and ET (2 ENG OUT BLUE).

If TAL or ATO, OPS 104 PRO (if req'd)  
ABORT RTLS, ✓ET DOORS - CL

If TAL or ATO, you are in MM 103 the -Z THC 5 sec should mode you to MM 104. However, if still in MM 103, do an OPS 104 PRO. MM 103 will not mode to MM 602. MM 104 will allow you to mode to MM 602. ABORT RTLS will mode you to MM 602. You need to be in MM 602 to adequately control the Orbiter. The PLT should verify that the ET door sequence automatically closes and latches the doors.

Pull Up to  $\alpha = 40^\circ$   
if  $M > 3$ ,  $\alpha = 50^\circ$   
if  $M > 4.5$ ,  $\alpha = 58^\circ$

After separation is complete, maneuver the Orbiter to an  $\alpha$  that maximizes lift and drag. This is dependent on Mach and trim and can range from  $20^\circ$  to  $60^\circ$ . For the simplification of crew procedures, however, discrete angles of attack as a function of Mach are used.

| <u>M</u>    | <u><math>\alpha</math></u> |
|-------------|----------------------------|
| < 2.0       | 20°                        |
| > 2.0 ≤ 3.0 | 40°                        |
| > 3.0 ≤ 4.5 | 50°                        |
| > 4.5       | 58°                        |

After ET SEP it is important to increase angle of attack. For this about the normal Mach regime results in an  $\alpha$  of 50°. Therefore the procedure is to pull up to  $\alpha = 50^\circ$ . If M is > 4.5, increase  $\alpha$  to 58°. This is a "fine tune" pitch maneuver to minimize  $N_z$  and  $\bar{q}$ .

### Hold $N_z$

The altitude sink rate ( $\dot{H}$ ) will continue to increase during alpha recovery until the Orbiter drops low enough in the atmosphere to develop insufficient  $\bar{q}$  and lift for equilibrium flight. As lift increases  $N_z$  on the Orbiter will increase. When the  $N_z$  reaches one, the Orbiter is developing enough lift to support its own weight, and the sink rate will begin to decrease. The maximum negative  $\dot{H}$  is a good indicator of how severe the entry will be, and it is used to calculate the  $N_z$  that will be required for pullout. The equation currently used is

$$N_z = -(\dot{H} \text{ max}/1000) + 0.5$$

The  $N_z$  is calculated and displayed on the VERT SIT display. This  $N_z$  provides a good balance between normal load factor structural limits and  $\bar{q}$  limits. The structural limit is actually a function of Orbiter weight and wing root bending moment. The  $\bar{q}$ -limit is a function of angle of attack, but an approximate limit of 800 lb/ft<sup>2</sup> is used.

$N_z$  will continue to increase as  $\bar{q}$  increases. When  $N_z$  approaches the calculated  $N_z$  (within approximately 0.3g) a pitchdown is initiated to converge to and hold the  $N_z$ . The actual load factor is shown on the AVVI acceleration scale which is scaled to show g's while in MM 602, with 10 = 1g, 20 = 2g, and 30 = 3g. As  $N_z$  is held by reducing alpha, the  $\bar{q}$  will continue to increase until the sink rate is stopped. Bodyflap/ speedbrake movements, aerodynamic forces, and the Orbiter rate command flight control system combine to make it difficult to manually fly  $N_z$  precisely.

It is during this phase that some contingencies will exceed vehicle structural, temperature, and flight control limits. Holding a load factor less than the desired  $N_z$  will cause an increase in  $\bar{q}$  because the Orbiter achieves pullout at a lower altitude. It also requires the Orbiter to pitch to a lower angle of attack which can result in lateral control instability and increase the heating rate on the upper vehicle surface.

This phase of flight must be flown well if you want to complete the maneuver. Margins are small. While the CDR is holding  $\alpha$  and  $N_z$  is



small, the PLT and MS2 must look at the ENTRY cue card (fig. 3.3-27).  
Some critical items may be required to perform or know prior to holding Nz.

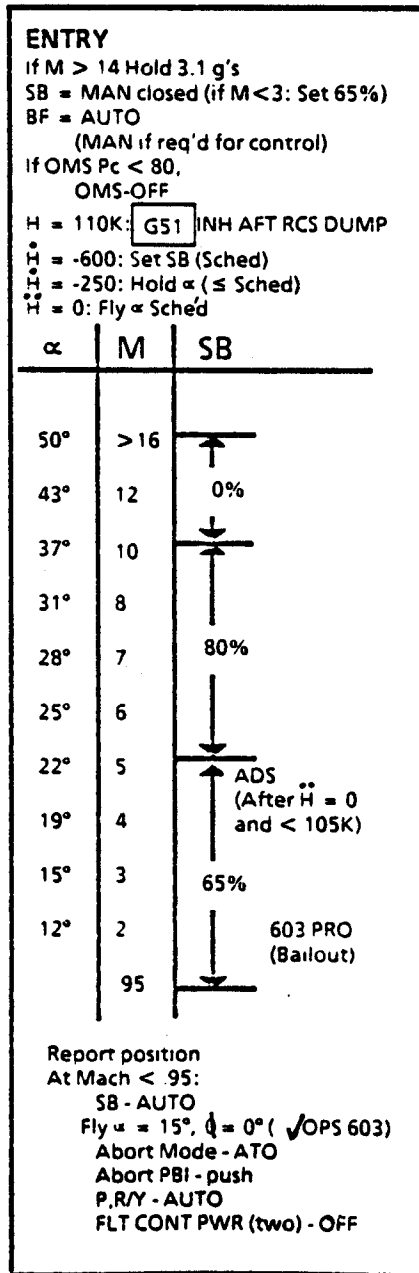


Figure 3.3-27.- ENTRY cue card.

If M > 14, you must hold Nz = 3.1 instead of the calculated Nz (explained later). The speedbrake must be placed in the proper position prior to Nz increasing. The speedbrake will not move after Nz ~2.5g.

The OMS engine Pc may drop to 80 at any time in the procedure. You must turn the OMS engines off when Pc drops to 80, or an OMS engine could blow up. A dropping OMS Pc (if quantity is greater than 15 percent) means that an OMS tank fuel screen has unwetted, and the OMS engine chamber is filling with N<sub>2</sub>O<sub>4</sub>. If the fuel screen should rewet and a slug of fuel goes into the OMS engine chamber, the OMS engine will have an uncontained explosion. Analysis cannot prove this would not be catastrophic. Therefore, a crew member must watch the OMS Pc during the OMS propellant dump.

The pullout phase for 2 OUT BLUE is  $N_z = 3.1$ ,  $\bar{q} = 728$  for case 1 and  $N_z = 28$ ,  $\bar{q} = 456$  for case 2. These pullouts are structurally survivable.

If M > 14 Hold 3.1g

In order to prevent greatly exceeding the single use heat load limits on the upper surface, hold 3.1g. This keeps the angle of attack as high as possible during the  $N_z$  hold and reduces the OMS pod and upper surface heating.

SB = MAN closed (if M < 3: Set 65%)

BF = AUTO

(MAN if required for control)

The speedbrake and bodyflap should be set in the alpha-recovery phase before the critical  $N_z$  hold phase begins. Both of these surfaces affect the maximum  $\bar{q}$  and the hinge moment loads on the elevon and bodyflap during the critical  $N_z$  hold phase. The speedbrake can be opened to increase the vehicle drag, slow the Orbiter, and reduce  $\bar{q}$ . Unfortunately, opening the speedbrake also induces a pitching movement that forces the elevon to a lower trim position, and may result in elevon saturation or actuator stall during  $N_z$  hold. Also, the speedbrake should not be opened above Mach 10 because of thermal constraints on the elevon and speedbrake. As a result, the procedures recommend manually closing the speedbrake unless the Mach is less than three, when it should be set to 65 percent. At Mach less than 3, you will lose control if the speedbrake is not opened to 65 percent.

The bodyflap can also be lowered to increase the drag; however, this induces a negative pitching moment that forces the elevon to a higher trim position. Lateral control problems may occur if the elevons are in an up (negative) position. As a result, the procedures recommend leaving the bodyflap in auto to trim the elevon to its schedule. The bodyflap should be driven manually only if control problems occur.

Large negative bodyflap deflections during alpha recovery should also be avoided. If the bodyflap is deflected upward when the  $N_z$  hold phase begins it may drive down too slowly to assist the elevon in decreasing the angle of attack. Without the bodyflap to assist it, the elevon may saturate or its actuator limits may be exceeded.

$\dot{H} = -600$ : Slowly set SB (Sched)

As the Orbiter begins to pullout from its fall, the altitude rate (HDOT or  $\dot{H}$ ) will begin to return toward zero. The speedbrake should be opened just before pullout (approximately -600 fps) to help the CDR maintain control. During some Nz pullouts the CDR is holding aft RHC to hold Nz and will lose control if the speedbrake is not opened at  $\dot{H} = -600$ . Opening the speedbrake lets the CDR move the RHC forward a bit, have some control margin, and helps maintain control. This speedbrake motion does not cause problems in other flight phases.

 $\dot{H} = -250$ : Hold  $\alpha$  ( $\leq$  Sched)

When the Orbiter has achieved pullout ( $\sim\dot{H} = -250$ ), the angle of attack is held constant. A pitch up would increase lift and worsen the phugoid that has been initiated with the pullout. A pitchdown would increase  $\dot{q}$  at a point where  $\dot{q}$  is at its maximum and may already be at or above structural limits.

 $\ddot{H} = 0$ : Fly Schedule

When H-DOUBLE-DOT ( $\ddot{H}$ ) reaches zero the Orbiter is beginning to accelerate downward to begin the next cycle of the phugoid. Fly the Mach/ $\alpha$  schedule. The schedule is very similar to the nominal entry alpha profile. The schedule also includes a speedbrake - Mach schedule which is also similar to the nominal entry profile.

G50 Incorporate Air Data

(After  $\dot{H} = 0$  and  $< 105k$ )

The air data probes should be deployed at approximately  $M = 4.5$  if the altitude is less than 105,000 ft and the Orbiter is descending. Then incorporate air data to GN&C and NAV.

603 PRO (Bailout)

Because guidance is not active, transition to MM 603 will not occur at Mach 3.2 as it does in a normal RTLS. The crew must manually select OPS 603 where the bailout guidance resides.

Report PositionAt Mach < .95:SB - AUTOFly 185-195 KEAS,  $\Phi = 0^\circ$ Abort Mode - ATO ( $\checkmark$  OPS 603)Abort PBI - pushP, R/Y - AUTOFLT CONT PWR (two) - OFF

Analysis has shown that the Orbiter will probably not survive a water ditch. Current recommendations are for the crew to place the Orbiter in an attitude hold and then bailout. For this purpose, an attitude hold mode was added to the MM 603 software. It is available when Mach is less than 1.0, and is activated by moving the abort rotary switch to ATO and pressing the abort PBI. When the crew switches from CSS to auto, guidance will snapshot the current airspeed and roll angle and attempt to hold both constant. If a new airspeed or roll is desired, control can be taken back to CSS. When auto is reselected a new snapshot will be taken.

The above procedures recommend taking the Orbiter to a wings level attitude and 185-195 KEAS airspeed before the attitude hold is initiated. This should result in a stable attitude for bailout. At an altitude of about 20,000 feet the crew will depressurize the cabin, blow the hatch, and commence bailout.

The auto engage needs to be flown precisely. Typically you will be @ 40,000 ft, EAS 165 K, sink rate 80 fps,  $\alpha \sim 12^\circ$ . Just hold attitude and the EAS will slowly increase. When EAS is >185 K, slightly increase pitch to stop the airspeed increase. Ensure the airspeed rate of change is small prior to:

Abort Mode - ATO

Abort PBI - push

P, R/Y - AUTO

If airspeed is changing quickly, you could lost control at auto engage.

## b. RTLS 2 ENG OUT BLUE

The rationale for this procedure (fig. 3.3-28) is the same as for 2 ENG OUT BLUE.

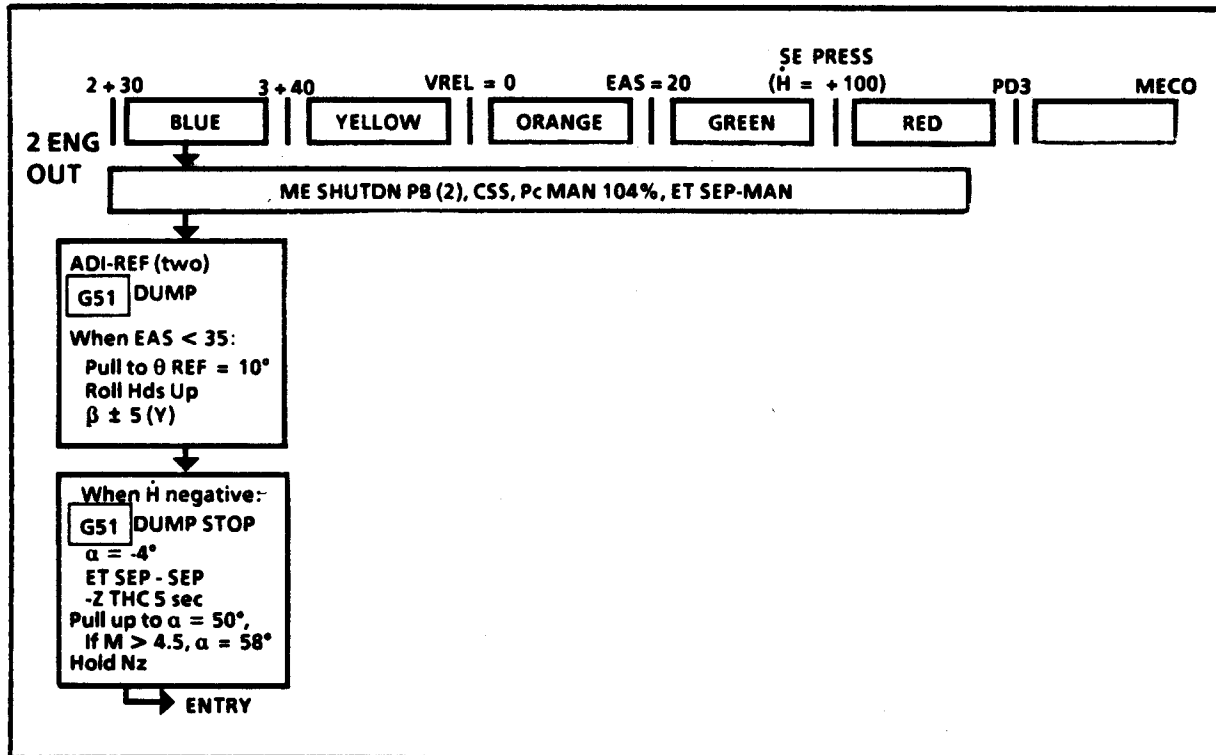


Figure 3.3-28.- RTLS 2 ENG OUT BLUE.

This procedure is bounded between 2 + 30 and 3 + 40 MET. The 2 + 30 MET is the first time that an RTLS abort would be declared. The 3 + 40 MET is a compromise that works safely for all cases. If the first SSME fails at lift-off, this procedure cannot be flown if the second SSME were to fail at 3 + 45 MET. The pullout phase is too severe. Typical ET separation conditions for this abort are:

## Case 1 (2 + 31)

$\bar{q} = 5.8$   
 $\alpha = -1.8^\circ$   
 $H = 200,000 \text{ ft}$

## Case 2 (3 + 40)

$\bar{q} = 1.5$   
 $\alpha = -4.8^\circ$   
 $H = 235,000 \text{ ft}$

Relative motion between the Orbiter and ET after separation for this case is shown in figure 3.3-29.

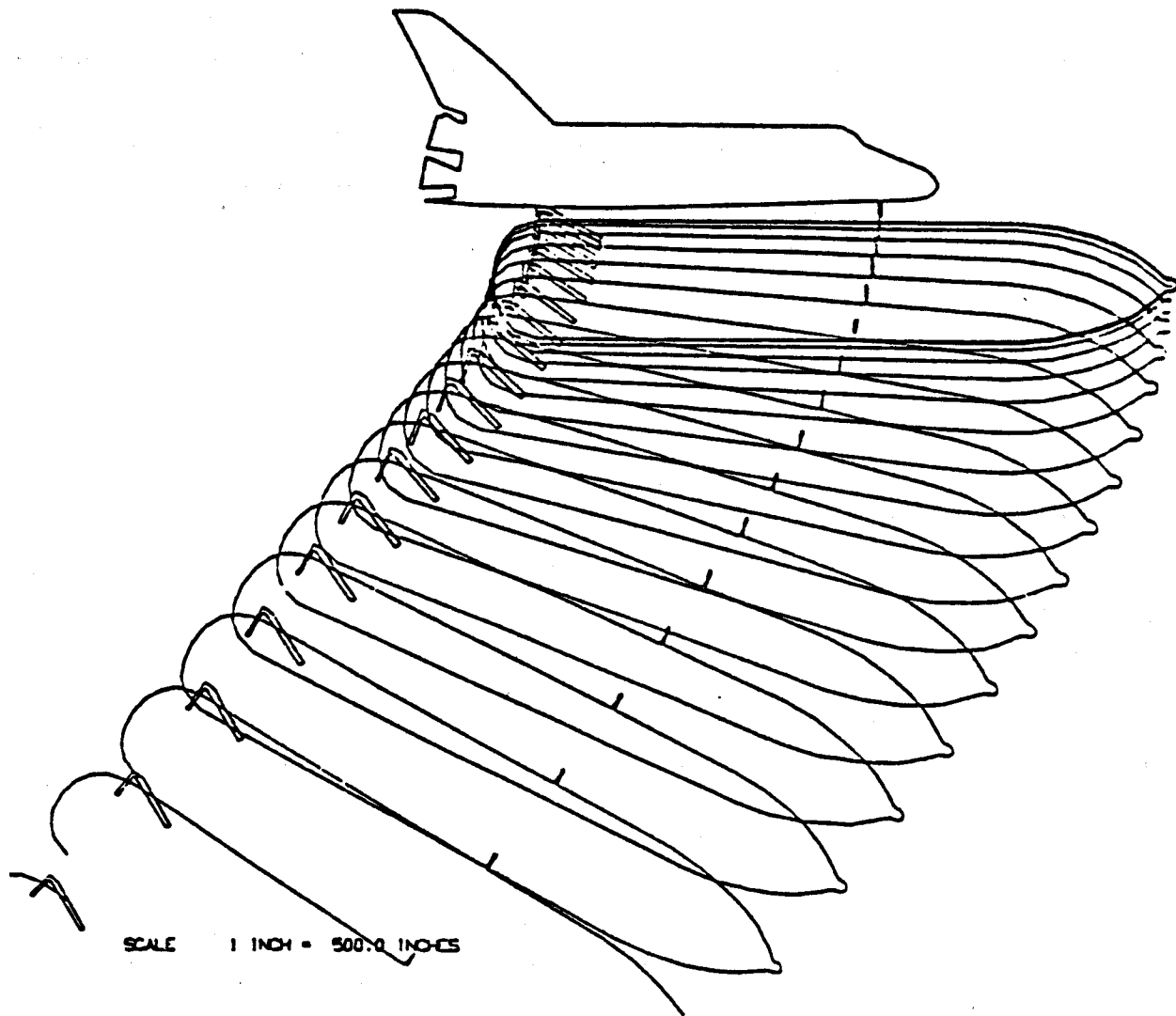


Figure 3.3-29.- Relative motion between the Orbiter and ET (RTLS 2 ENG OUT BLUE).

The pullout phase is  $N_z = 2.4$ ,  $\bar{q} = 353$  for case 1 and  $N_z = 2.9$ ,  $\bar{q} = 555$  for case 2. These pullouts are structurally survivable.

## c. 2 ENG OUT GREEN

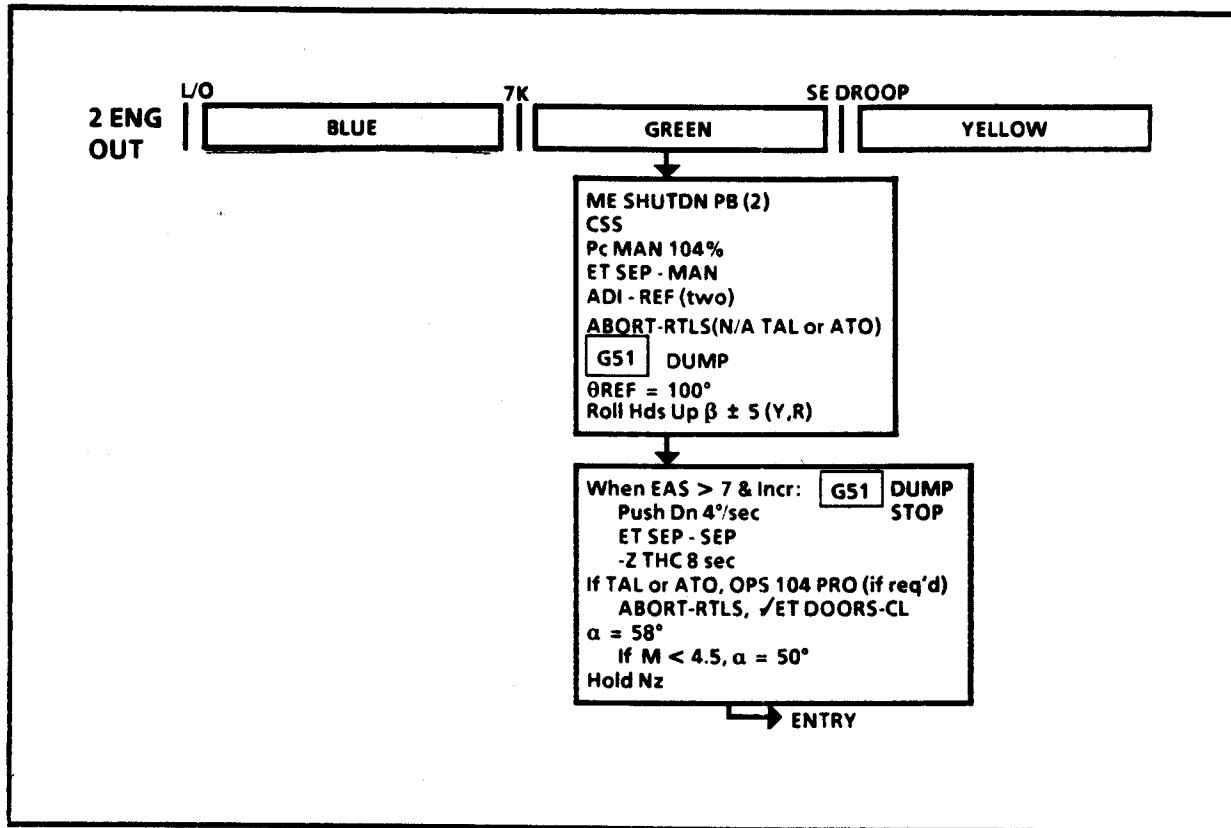


Figure 3.3-30.- 2 ENG OUT GREEN.

The 2 ENG OUT BLUE procedure will not work after 7000 fps because the trajectory is too high and EAS is too low. This results in a large sink rate (greater than 3000 fps), followed by an Nz hold phase with  $g > 3.5$ . Structural breakup would occur. Therefore, the 2 ENG OUT GREEN procedure (fig. 3.3-30) was developed. Basically, this procedure stands the Orbiter on its tail to reduce sink rate and reduce the  $g$  during the Nz hold phase.

ME SHUTDN PB (2)

Previously explained.

CSS

CSS puts the vehicle in attitude hold while you prepare to fly the Orbiter to  $\theta = 100^\circ$ .

Pc MAN 104%

Previously explained.

ET SEP - MAN

Previously explained.

ADI - REF (two)

This step is mandatory for this procedure. LVLH will cause an ADI ball flip later in the procedure when you maneuver to  $\theta = 100^\circ$ . The REF position will allow you to fly with a steady ADI ball during the maneuver to  $\theta = 100^\circ$ .

ABORT - RTLS (N/A TAL or ATO)

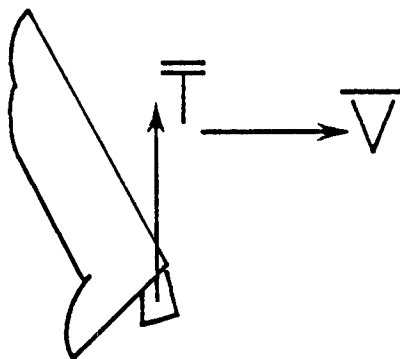
Select RTLS with the rotary and press the abort pb. This transition to MM 601 allows an automatic transition to MM 602 after ET SEP. Control authority is significantly improved in MM 602 versus MM 103.

G51 DUMP

Previously explained.

 $\theta$  REF = 100°ROLL Hds Up  $\beta \pm 5$  (Y,R)

This is a crucial step in successfully flying this maneuver. The purpose of the maneuver is to maintain the thrust vector ( $\vec{T}$ ) pointed up (to minimize sink rate) and have the bottom of the vehicle pointing in the direction of movement. Figure 3.3-31 shows the desired maneuver.



Final Attitude  
( $\theta_{ref} = 100^\circ$   
ROLLED HEADS UP)

Figure 3.3-31.- Vehicle thrust vector maneuver.



The heads-up attitude (final attitude in figure 3.3-31) provides the proper attitude to minimize sink rate (and hence minimize  $g$  during the  $N_z$  phase), and start the fast SEP maneuver.

The suggested flying technique is to pitch to  $\theta_{ref} = 100^\circ$ ; then roll the Orbiter  $180^\circ$  to  $\phi_{ref} = 0^\circ$ . If there is any roll angle, take time to get  $\phi_{ref} = 0^\circ$  before proceeding. After the roll is completed the HSI might look like figure 3.3-32. The suggested flying technique for  $\beta$  control is to first yaw to the tail of the course pointer. When the tail of the course pointer is on the lubber line, the X-axis is vertical. Then you roll (slightly) to the cause deviation indicator (CDI) to null  $\beta$ . Remember that at  $\theta = 90^\circ$ ,  $\beta$  is controlled totally by roll. A full scale CDI displacement on the HSI is  $5^\circ$ . Use pulses to maintain  $\beta = 0 \pm 5^\circ$ . When the CDI is centered, keep it there by adjusting roll attitude.

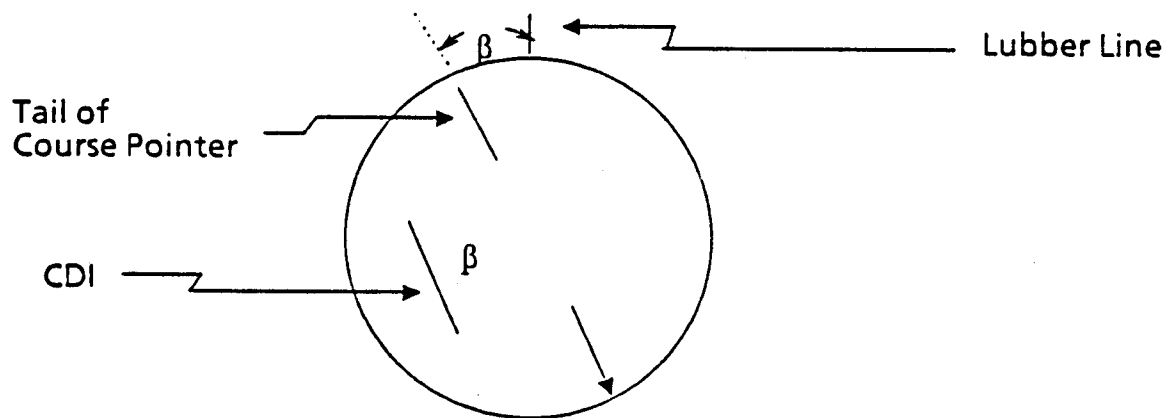


Figure 3.3-32.- Roll complete HSI.

Do not overcontrol. After your first adjustment to  $\beta = \pm 5^\circ$ , release the RHC. You will watch  $\beta$  increase to  $2^\circ$ ,  $3^\circ$ ,  $4^\circ$ . Then the auto trim integrator will automatically drive the thrust vector through the c.g. You will then watch  $\beta$  decrease back to  $4^\circ$ ,  $3^\circ$ ,  $2^\circ$ . With practice you will learn that it is easy to hold  $\theta_{ref} = 100^\circ$  and  $\beta = \pm 5^\circ$  with your hand off of the RHC. Let the auto trim integrator work for you.

When EAS > 7 and Incr: G51 dump stop

Pitch Dn  $4^\circ/\text{sec}$

ET SEP - SEP

-Z THC 8 sec

7 KEAS is just a cue. If you initiate the maneuver at 4 KEAS, you will not get as much OMS dumped, resulting in a further aft X c.g., and you will start the pullout at a higher altitude, resulting in higher  $g$  and  $\dot{q}$ . If you delay this maneuver to 10 KEAS, then you will be close to not getting the ET off before 25 KEAS, which could result in ET recontact.

**G51** dump stop was previously explained.

Analysis show that if you initiate pitchdown at 7 KEAS, pitch down at a 4 deg/s pitch rate, and then SEP the ET, you will not have ET recontact. The  $\theta$  ref at separation is approximately 85°. Note that pitch maneuvers at rates exceeding 6 deg/s may result in loss of control.

-Z THC 8 sec is to ensure all 10 down RCS jets keep firing. At SEP there is an automatic -Z translation, but not necessarily at full jet authority because of the 4 deg/s pitch rate. The THC command overrides the RHC inputs (CSS rate damping).

Figure 3.3-33 shows the fast SEP maneuver.

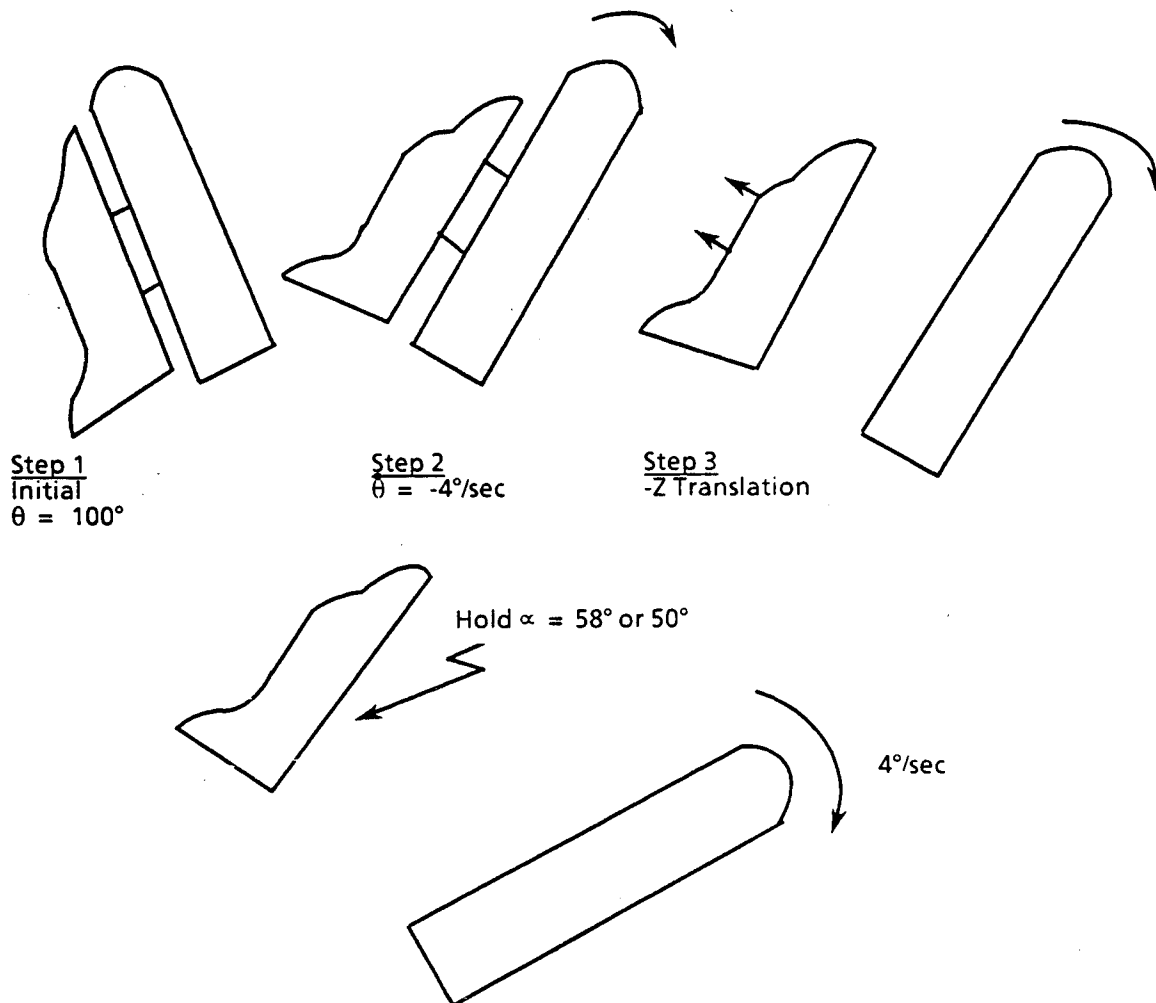


Figure 3.3-33.- Fast SEP maneuver.

Typical ET separation conditions for this abort are

Case 1 (7000 fps)

$\bar{q} = .2$   
 $\alpha = 74^\circ$   
 $H = 287,000 \text{ ft}$

Case 2 (11,700 fps)

$\bar{q} = .4$   
 $\alpha = 75^\circ$   
 $H = 302,000 \text{ ft}$

Relative motion between the Orbiter and ET for this case is shown in figure 3.3-34.

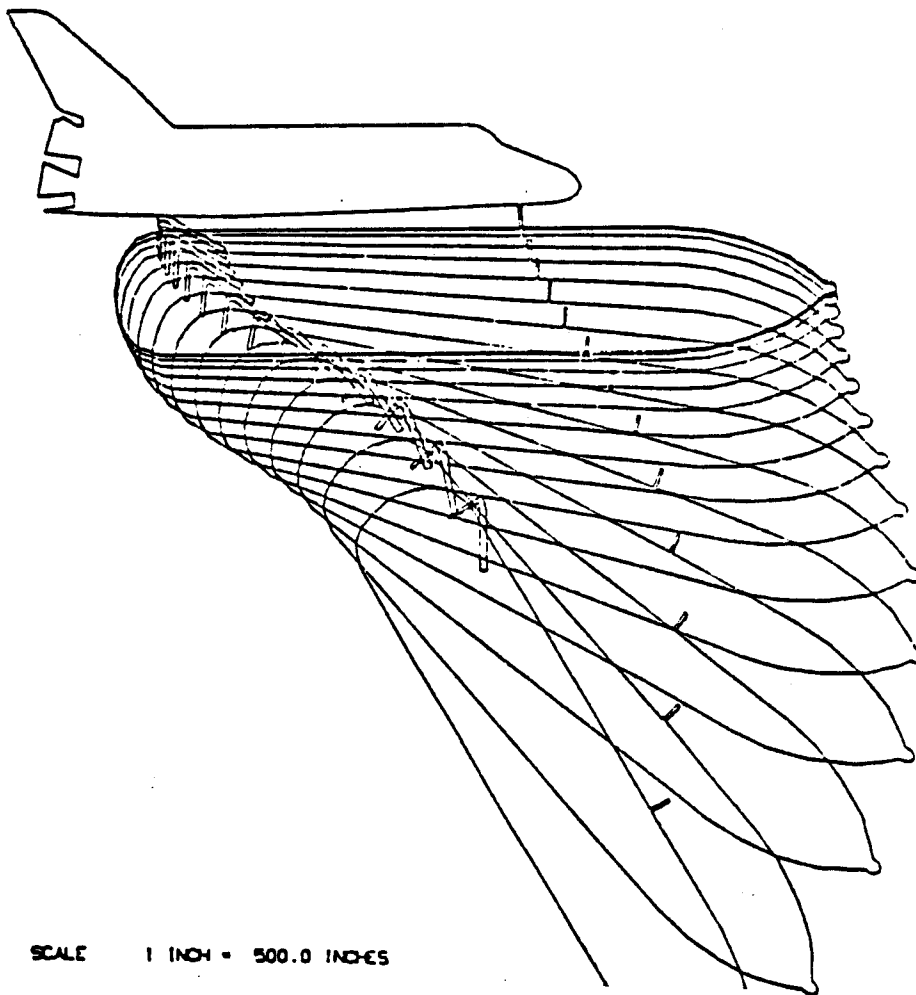


Figure 3.3-34.- Relative motion between the Orbiter and ET  
 (2 ENG OUT GREEN).

If TAL or ATO, OPS 104 PRO (if req'd)  
ABORT RTLS,  $\checkmark$  ET DOORS - CL

If TAL or ATO, you are in MM 103. The -Z THC 8 sec should mode you to MM 104. However, if still in MM 103, do an OPS 104 PRO. MM 103 will not mode to MM 602. MM 104 will allow you to mode to MM 602. ABORT RTLS will mode you to MM 602. You need to be in MM 602 to adequately control the Orbiter. The PLT should verify the ET door sequence automatically closes and latches the doors.

$\alpha = 58^\circ$

During the -Z THC 8 sec the  $\alpha$  will continue to decrease to a  $\sim 30^\circ$  to  $50^\circ$ . After releasing the THC, fly  $\alpha = 58^\circ$  or  $50^\circ$  depending on Mach number (previously explained).

Hold Nz  
ENTRY

Previously explained.

The pullout phase is  $Nz = 3.2$ ,  $\bar{q} = 693$  for case 1 and  $Nz = 2.9$ ,  $\bar{q} = 666$  for case 2. These cases are structurally survivable.

## d. RTLS 2 ENG OUT YELLOW

The rationale for the procedure shown in figure 3.3-35 is the same as previously covered in CONT 2 OUT GREEN.

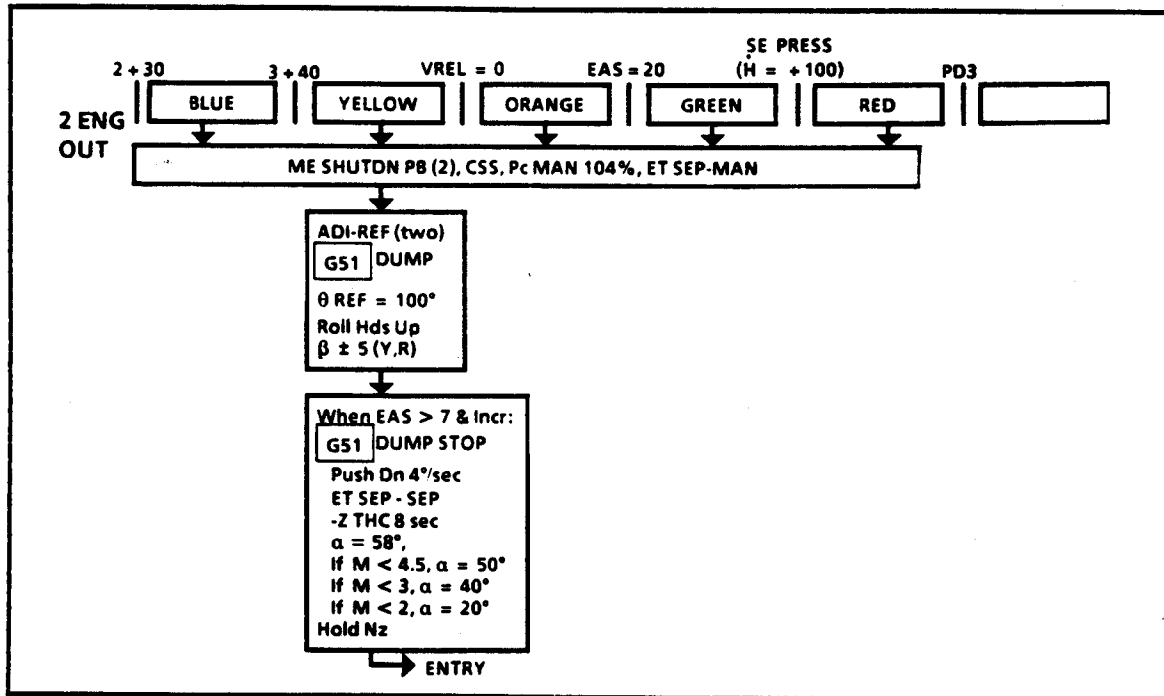


Figure 3.3-35.- RTLS 2 ENG OUT YELLOW.

Typical ET separation conditions for this abort are

## Case 1 (3 + 40)

$\bar{q} = .8$   
 $\alpha = 83^\circ$   
 $H = 240,000 \text{ ft}$

## Case 2 (PPA + 10 sec)

$\bar{q} = 1.2$   
 $\alpha = 79^\circ$   
 $H = 228,000 \text{ ft}$

## Case 3 (VREL = 0)

$\bar{q} = 1.7$   
 $\alpha = 139^\circ$   
 $H = 188,000 \text{ ft}$

Relative motion between the Orbiter and ET after separation for this case is shown in figure 3.3-36.

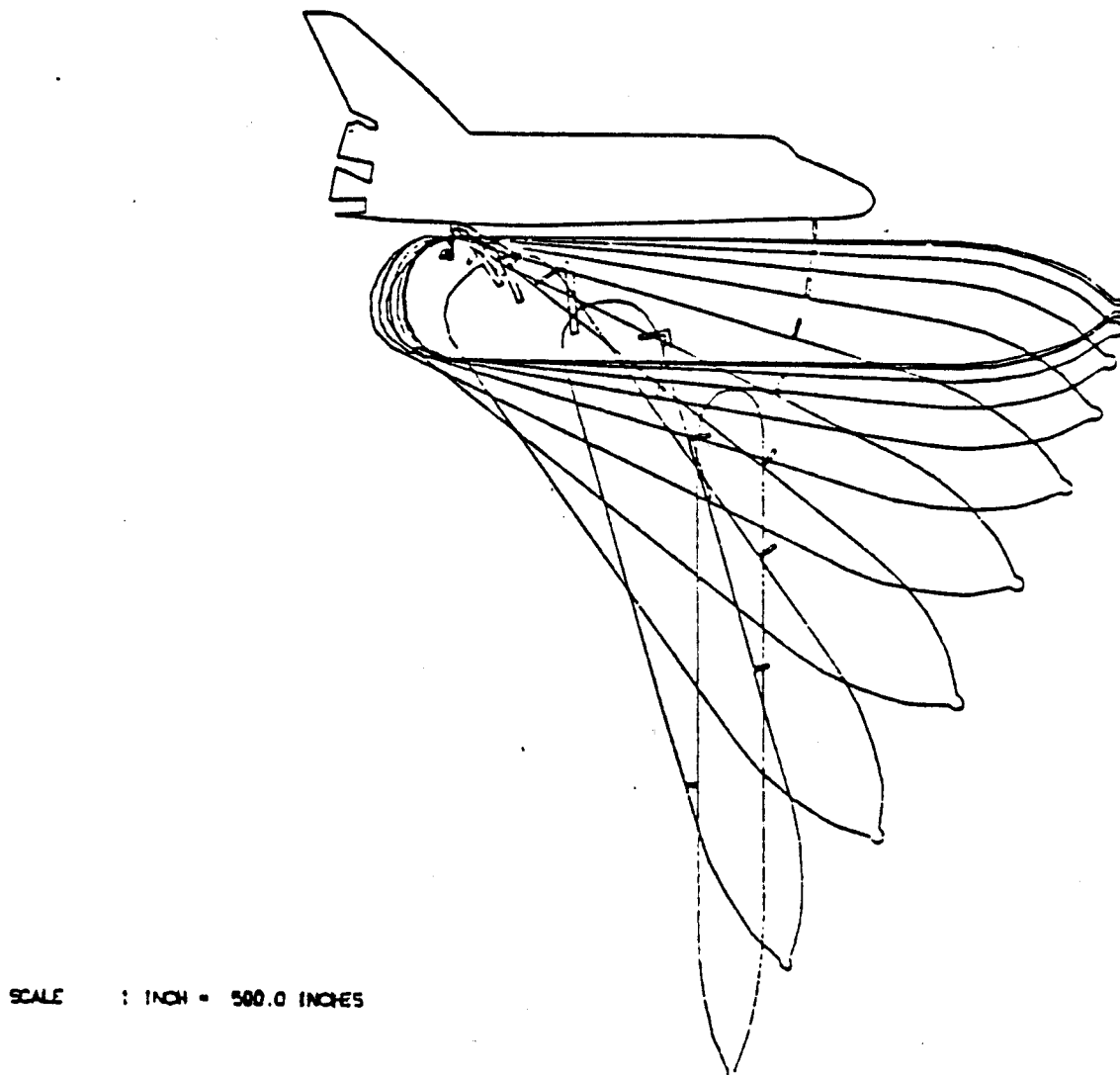


Figure 3.3-36.- Relative motion between the Orbiter and ET (RTLS 2 ENG OUT YELLOW).

The pullout phase is  $N_z = 2.8$ ,  $\bar{q} = 473$  for case 1 and  $N_z = 2.5$ ,  $\bar{q} = 790$  for case 3. These cases are structurally survivable.

## e. RTLS 2 ENG OUT ORANGE

The contingency procedure required from VREL = 0 to EAS 20 is shown in figure 3.3-37.

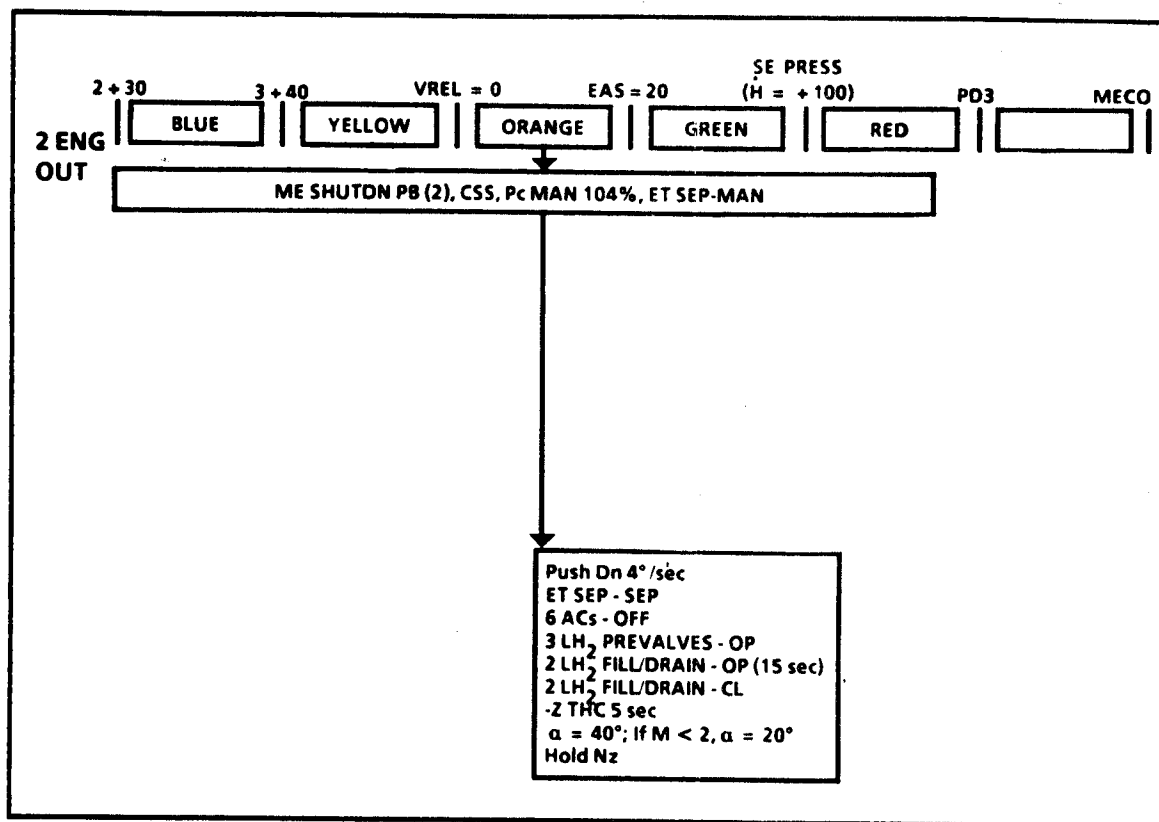


Figure 3.3-37.- RTLS 2 ENG OUT ORANGE.

Push Dn 4°/sec  
ET SEP - SEP

From VREL = 0 to EAS 20 the  $\bar{q}$  is low (0.5 to 3.1). Therefore, we can obtain the best ET SEP conditions by establishing the 4 deg/s pitch rate and separating from the tank ASAP. The 5 sec -Z translation significantly improves ET separation. Typical ET separation conditions for this abort are

Case 1 (VREL = 0)

$\bar{q} = .5$   
 $\alpha = 105^\circ$   
 $H = 206,000$  ft

Case 2 (EAS 15)

$$\begin{aligned} \bar{q} &= 2 \\ \alpha &= 37^\circ \\ H &= 185,000 \text{ ft} \end{aligned}$$

Relative motion between the Orbiter and ET for this case is shown in figure 3.3-38.

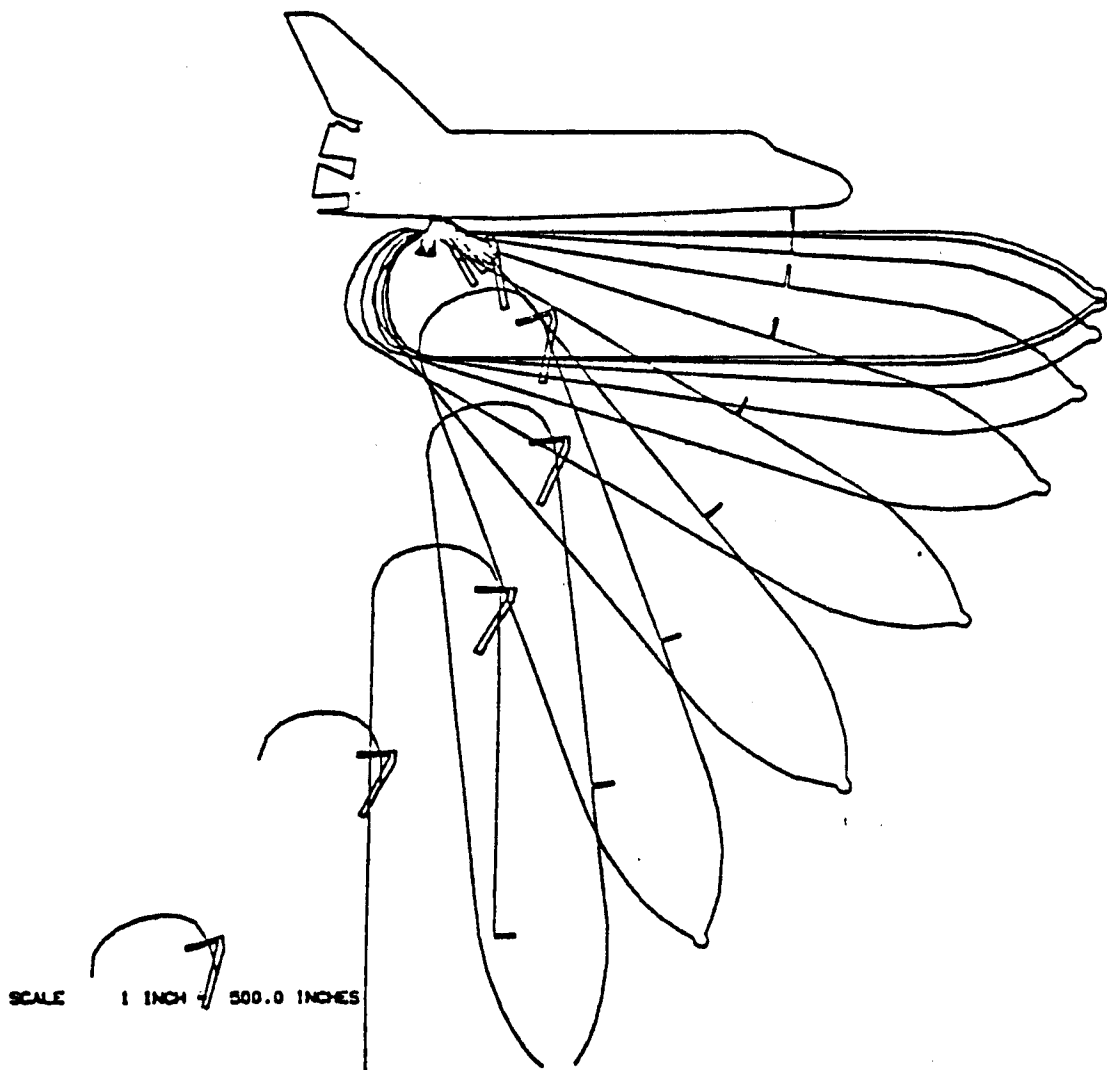


Figure 3.3-38.- Relative motion between the Orbiter and ET (RTLS 2 ENG OUT ORANGE).



Rockwell venting analysis shows that RTLS CONT two and three engine out cases between VREL = 0 and SE PRESS are not survivable. After the FAST SEP, a 2-in. LH<sub>2</sub> line fills many of the aft compartments with LH<sub>2</sub>. During entry (when the vent doors open) hot O<sub>2</sub> is mixed with the LH<sub>2</sub> causing many aft compartments to be on fire. A software change fixes the problem in OI-8C. Until then the following manual procedures must be accomplished or you will not survive.

6 ACs - OFF

Prevents the LO<sub>2</sub> dump.

3 LH, PREVALVES - OP  
2 LH<sub>2</sub> FILL/DRAINS - OP

Dumps LH<sub>2</sub> overboard within 15 seconds and prevents LH<sub>2</sub> from flooding into the Orbiter's aft compartments.

(15 SEC)  
2 LH<sub>2</sub> FILL/DRAINS - CL

Secures the LH<sub>2</sub> after the dump is complete.

When we have OI-8c software, the steps starting with 6 AC's - OFF in this step can be replaced with MPS PRPLT DUMP sequence-START.

$\alpha = 40^\circ$

It is important to raise the nose to  $\alpha = 40^\circ$  after the 5 sec -Z translation. In this zone  $\alpha$  is  $-7^\circ$  at completion of the -Z THC (if the procedure is started at EAS 20). If you do not raise the nose quickly,  $\bar{q}$  will build rapidly and you will lose control.

For cases where the procedure is started at VREL = 0, the  $\alpha$  is  $43^\circ$  and  $\bar{q}$  is .5 after the -Z THC; therefore, control is not a problem.

$40^\circ$  alpha for  $M > 2.0$  provides the best attitude to minimize  $\bar{q}$  during the pullout.

If  $M < 2.0$ ,  $\alpha = 20^\circ$

$20^\circ$  alpha for Mach  $< 2.0$  provides the best attitude to minimize  $\bar{q}$  during the pull out, and has the alpha as high as you want to maintain control.

Hold Nz

Previously explained. The pullout phase for case 1 is Nz = 2.9,  $\bar{q} = 536$ . The pullout for case 2 is Nz = 2.4,  $\bar{q} = 335$ .

## f. RTLS 3 ENG OUT ORANGE

The rationale for this procedure (fig. 3.3-39) is similar to RTLS 2 ENG OUT ORANGE. The zone starts at VREL 0-30 sec, because the fast rate separation procedure provides a survivable path to bailout. The procedure will not work earlier than VREL 0-30 sec.

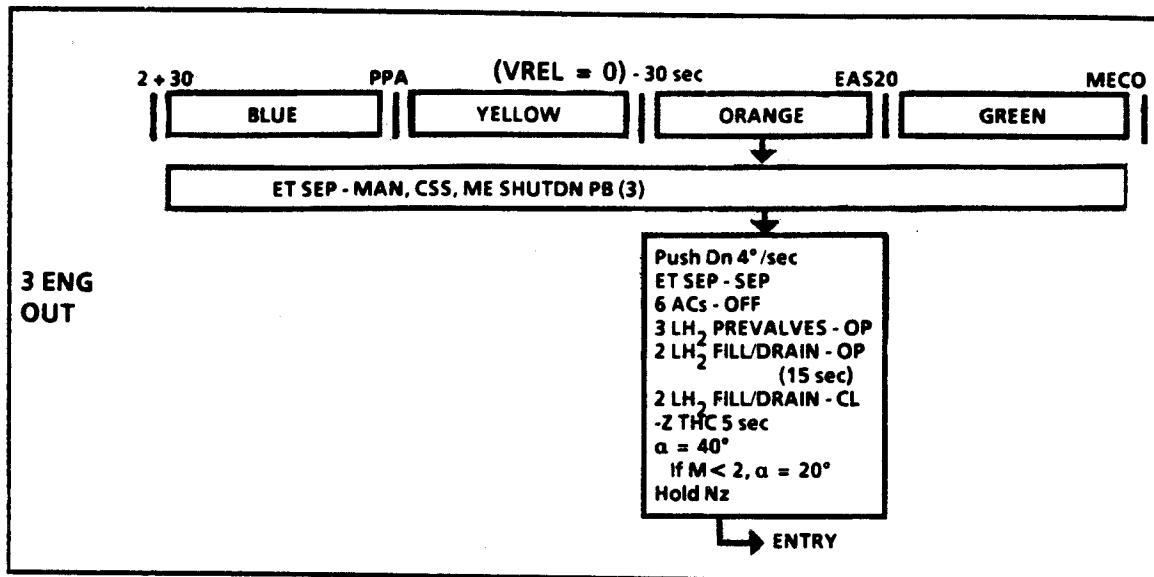


Figure 3.3-39.- RTLS 3 ENG OUT ORANGE.

Typical ET separation conditions for this abort are:

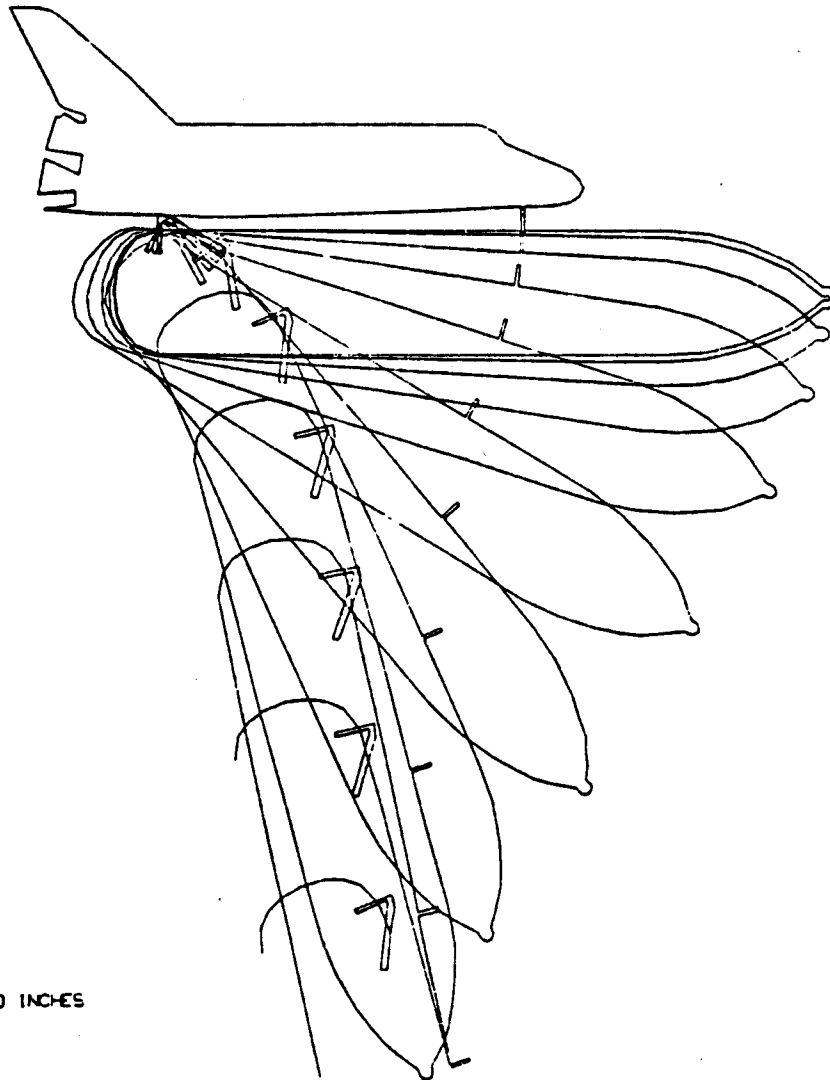
Case 1 (VREL = 0, -30 sec)

$\bar{q} = .3$   
 $\alpha = 147^\circ$   
 H = 223,000 ft

Case 2 (EAS 20)

$\bar{q} = 2.6$   
 $\alpha = 64^\circ$   
 H = 178,000 ft

Relative motion between the Orbiter and ET after separation for this abort is shown in figure 3.3-40.



SCALE 1 INCH = 500.0 INCHES

Figure 3.3-40.- Relative motion between the Orbiter and ET (RTLS 3 ENG OUT ORANGE).

The pullout phase is  $N_z = 2.9$ ,  $\bar{q} = 725$  for case 1 and  $N_z = 2.3$ ,  $\bar{q} = 229$  for case 2.

## g. RTLS 2 ENG OUT GREEN

At EAS 20 the  $\bar{q}$  is 1.3. This point marks the boundary between the orange and green regions (fig. 3.3-41). Beyond this point recontact will occur if the fast SEP technique is used. Therefore, a negative pitch rate is used to try to achieve an  $\alpha = -4^\circ$  for an acceptable separation. However,  $\bar{q}$  is building rapidly and loss of control after separation can occur if separation is delayed. Hence, the GREEN procedure (fig. 3.3-41), which maintains the pitch rate and commands separation when passing  $\alpha = 0^\circ$ , was developed as a compromise between acceptable ET separation and Orbiter control after separation.

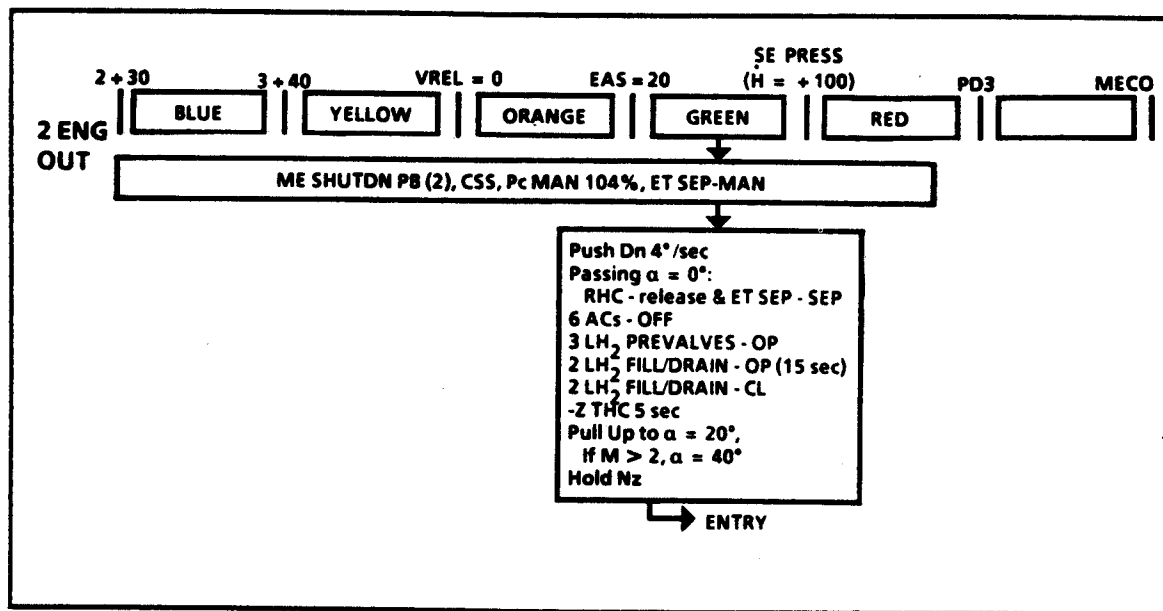


Figure 3.3-41.- RTLS 2 ENG OUT GREEN.

PUSH Dn 4°/sec

This rate provides a controllable rate to reduce  $\alpha$ .

Passing  $\alpha = 0^\circ$ 

RHC - release &  
ET SEP - SEP

This procedure provides the proper lead to arrive at the compromise attitude for ET separation and controllability. After releasing the RHC, immediately push the ET SEP pb. While the ET SEP sequence is running,  $\alpha$  will decrease to  $\sim -3^\circ$ , then stop, then start to increase. Typical ET separation conditions for this abort case are as follows:

**Case 1 (EAS 20)**

$$\begin{aligned}\bar{q} &= 12 \\ \alpha &= 1.5^\circ \\ H &= 158,000 \text{ ft}\end{aligned}$$

**Case 2 ( $\dot{H} = 0$ )**

$$\begin{aligned}\bar{q} &= 8.6 \\ \alpha &= -10^\circ \\ H &= 177,000 \text{ ft}\end{aligned}$$

Relative motion between the Orbiter and ET after separation for this case is shown in future 3.3-42.

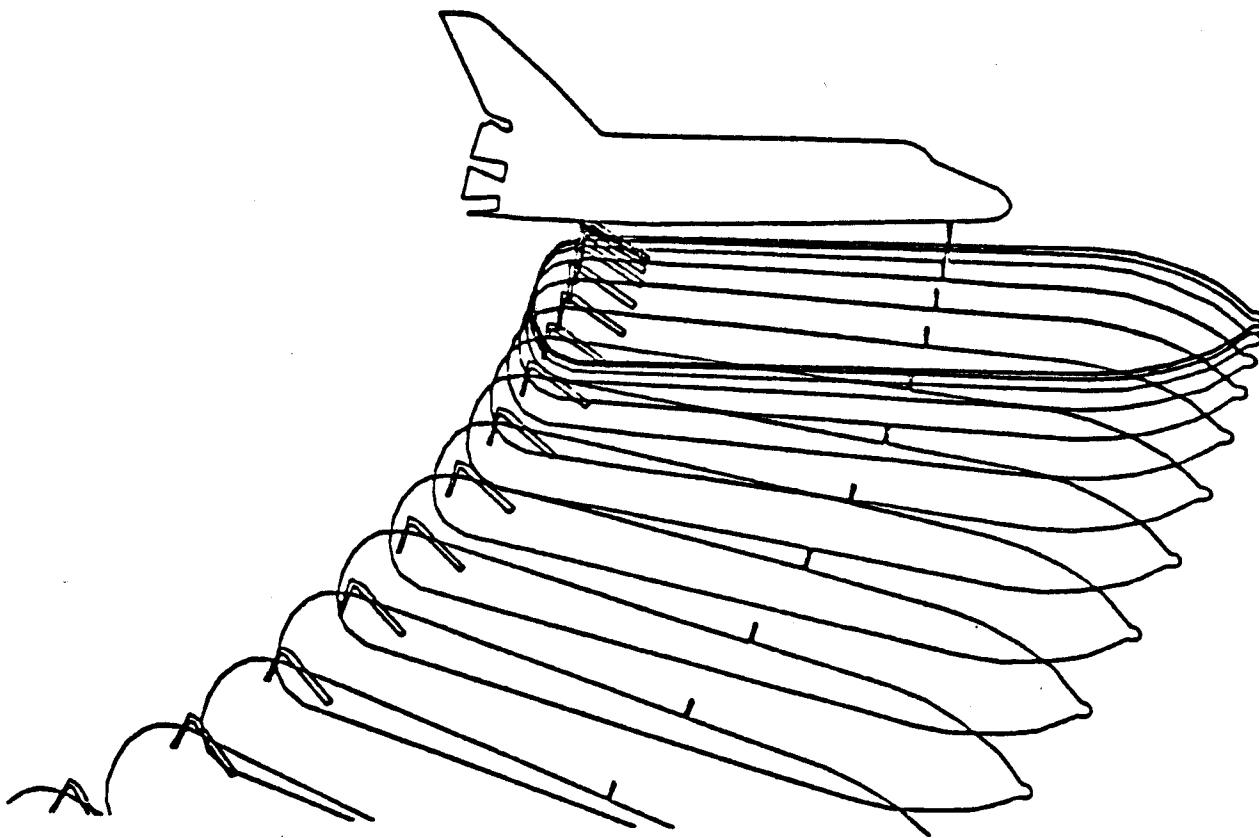


Figure 3.3-42.- Relative motion between the Orbiter and ET  
(RTLS 2 ENG OUT GREEN).

-Z THC 5 sec

The 5 sec -Z translation significantly improves ET separation.

Pull up to  $\alpha = 20^\circ$ 

One must pull the Orbiter's nose up as soon as possible or you will lose control. Do not delay pulling up to  $\alpha = 20^\circ$

If  $M > 2.0$ ,  $\alpha = 40^\circ$ 

This is a "fine tune" maneuver. After established at  $\alpha = 20^\circ$ , you can change your attitude if Mach is  $> 2.0$  to  $\alpha = 40^\circ$ . This attitude will minimize  $\bar{q}$  during the pullout phase, and keep alpha low enough to maintain control.

The pullout phase is  $Nz = 2.3$ ,  $\bar{q} = 212$  for case 1 and  $Nz = 1.9$ ,  $\bar{q} = 132$  for case 2. These cases are structurally survivable.

## h. RTLS 3 ENG OUT GREEN

The rationale for this procedure (fig. 3.3-43) is similar to RTLS 2 OUT GREEN. The  $\alpha$  are to release the RHC is  $5^\circ$  instead of  $0^\circ$ , because with 3 SSME down the Orbiter's flight path becomes steeper more quickly, and the  $\alpha = 0^\circ$  will lead to loss of control because you cannot pull the nose up. Therefore release the RHC at  $\alpha = 5^\circ$  for this abort.

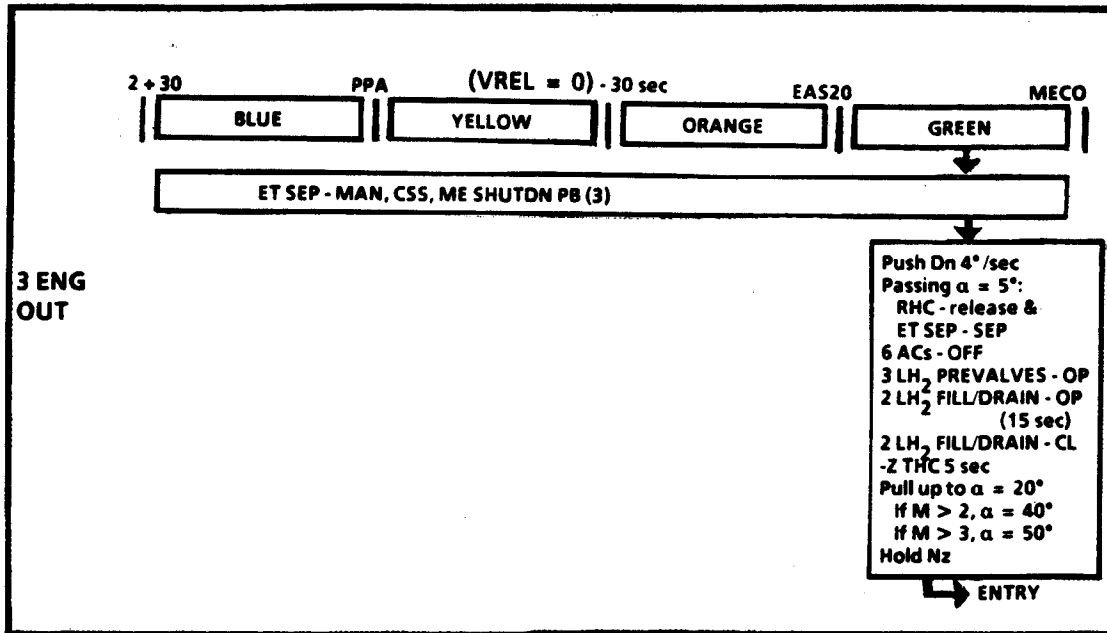


Figure 3.3-43.- RTLS 3 ENG OUT GREEN.

Typical ET separation conditions for the abort are

## Case 1 (EAS 20)

$\bar{q} = 4.1$   
 $\alpha = -6^\circ$   
 $H = 169,000 \text{ ft}$

## Case 2 (PPD)

$\bar{q} = 5.8$   
 $\alpha = -3^\circ$   
 $H = 207,000 \text{ ft}$

Relative motion between the Orbiter and ET after separation for this abort is shown in figure 3.3-44.

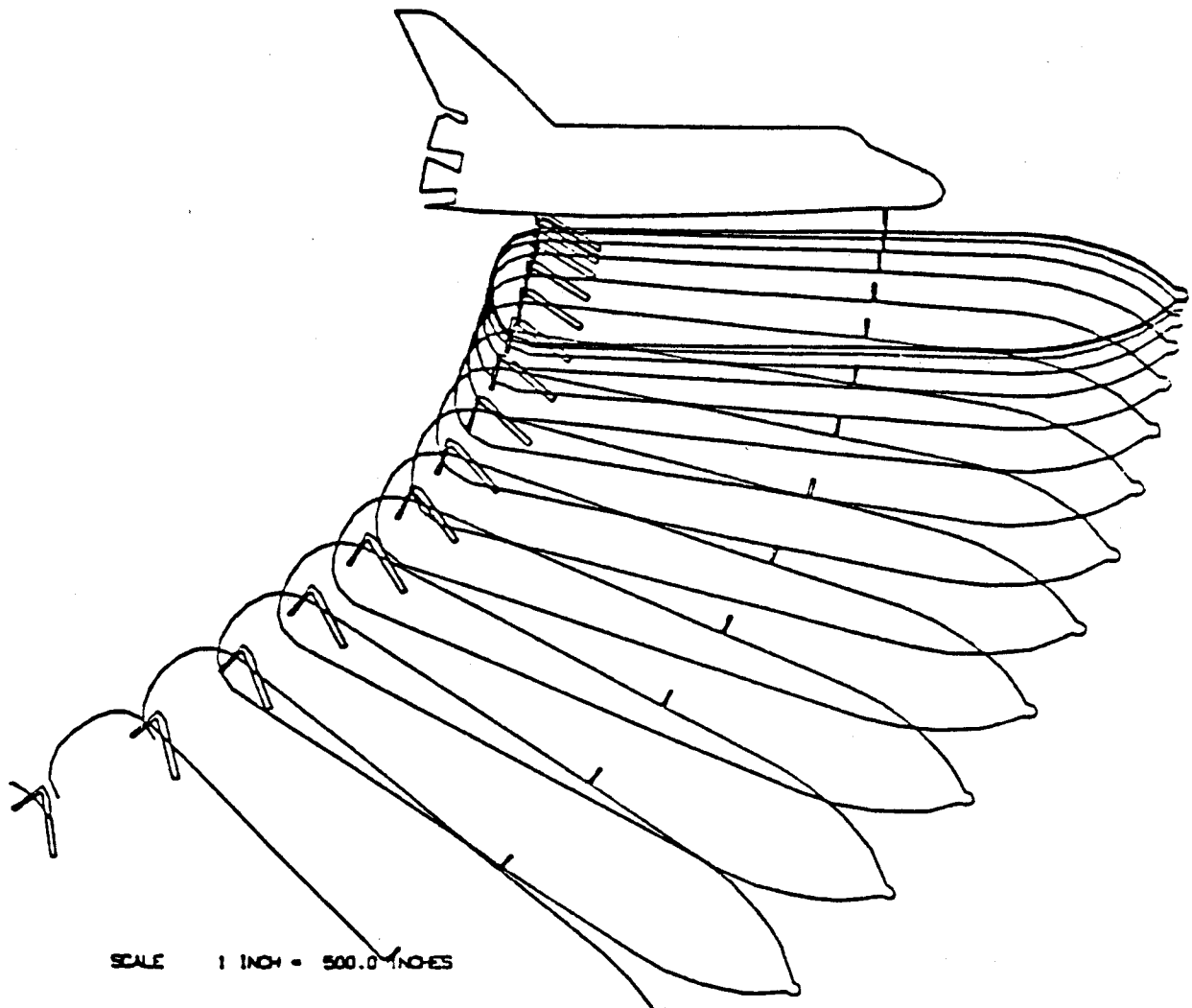


Figure 3.3-44.- Relative motion between the Orbiter and ET (RTLS 3 ENG OUT GREEN).

The pullout phase is  $N_z = 2.3$ ,  $\bar{q} = 262$  for case 1 and  $N_z = 2.0$ ,  $\bar{q} = 320$  for case 2. These cases are structurally survivable.



1. RTLS 3 ENG OUT BLUE

This procedure covers the case when the two remaining SSME's fail during RTLS fuel dissipation attitude (fig. 3.3-45).

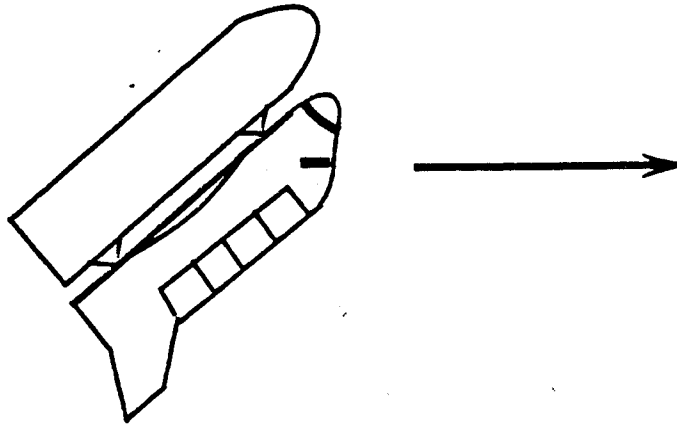


Figure 3.3-45.- RTLS fuel dissipation altitude.

The procedure for this contingency is in figure 3.3-46.

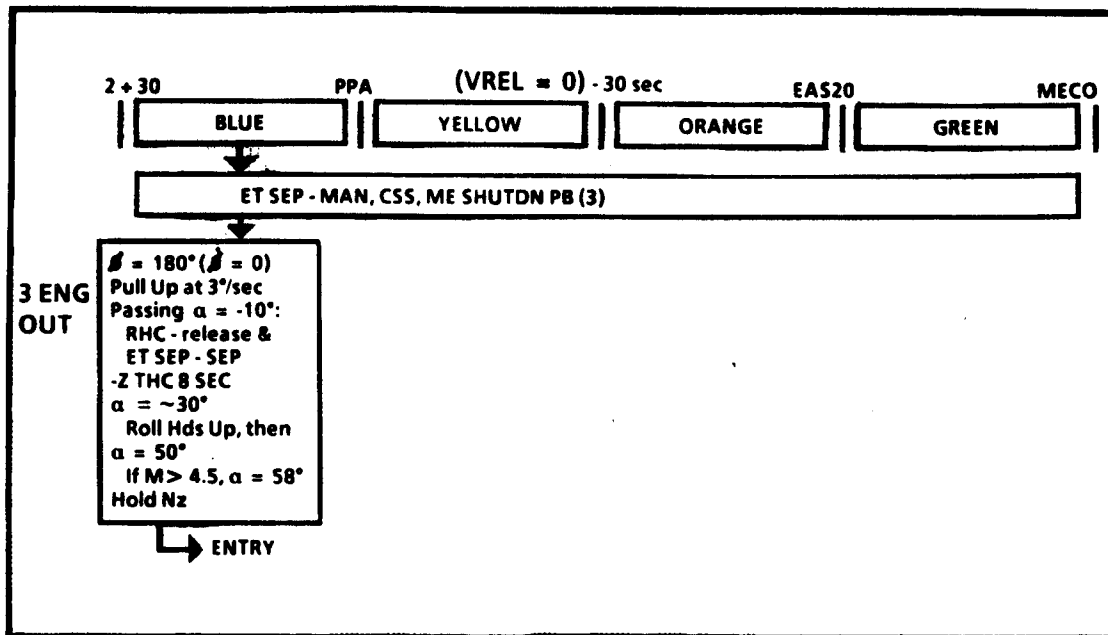


Figure 3.3-46.- RTLS 3 ENG OUT BLUE.

$\phi = 180^\circ$  ( $\dot{\phi} = 0$ )

Establishing roll ( $\phi$ ) =  $180^\circ$  and roll rate ( $\dot{\phi}$ ) = 0 will reduce workload during the procedure and ensure no roll rate during ET SEP. Take the time to get  $\phi = 180^\circ$  prior to the next step (a pitch maneuver).

Pull Up @  $3^\circ/\text{sec}$

Pull the Orbiter toward the horizon at  $\sim 3$  deg/s. Four deg/s is too high a pitch rate and will result in a positive  $\alpha$  for ET SEP. Two deg/s is too slow and will result in a higher  $\bar{q}$  for ET SEP. During this pitch maneuver continue to monitor  $\phi$ , and fly  $\phi = 180^\circ$  if required. At the start of this maneuver the Orbiter is typically at  $\alpha = -60^\circ$ .

Passing  $\alpha = -10^\circ$

RHC - release &  
ET SEP - SEP

The goal is to achieve an ET SEP at  $-5^\circ < \alpha < -2^\circ$  with no rates on the Orbiter. This procedure is a technique that will provide a good ET SEP. While pulling to the horizon at  $\sim 3$  deg/s, watch the  $\alpha$  tape. Remember  $\alpha$  is changing from  $-60^\circ$  toward  $\alpha = -10^\circ$ . The  $\alpha$  tape will show offscale white at the start of the pitch maneuver; it will start to move at  $\alpha = -15^\circ$ . At  $\alpha = -10^\circ$  (with a pitch rate of  $\sim 3$  deg/s) the CDR should release the RHC; the PLT should push the ET SEP pb.

Typical ET SEP conditions for this abort are

Case 1

L SSME + LIFTOFF  
ABORT RTLS 2 + 30 MET  
C, R SSME + 4 + 00 MET  
 $\bar{q} = .1$   
 $\alpha = -3$

Case 2

L SSME + 3 + 00 MET  
ABORT RTLS 3 + 05 MET  
C, R SSME + 3 + 10 MET  
 $\bar{q} = .2$   
 $\alpha = -3$

Relative motion between the Orbiter and ET after separation for this abort is shown in figure 3.3-47.

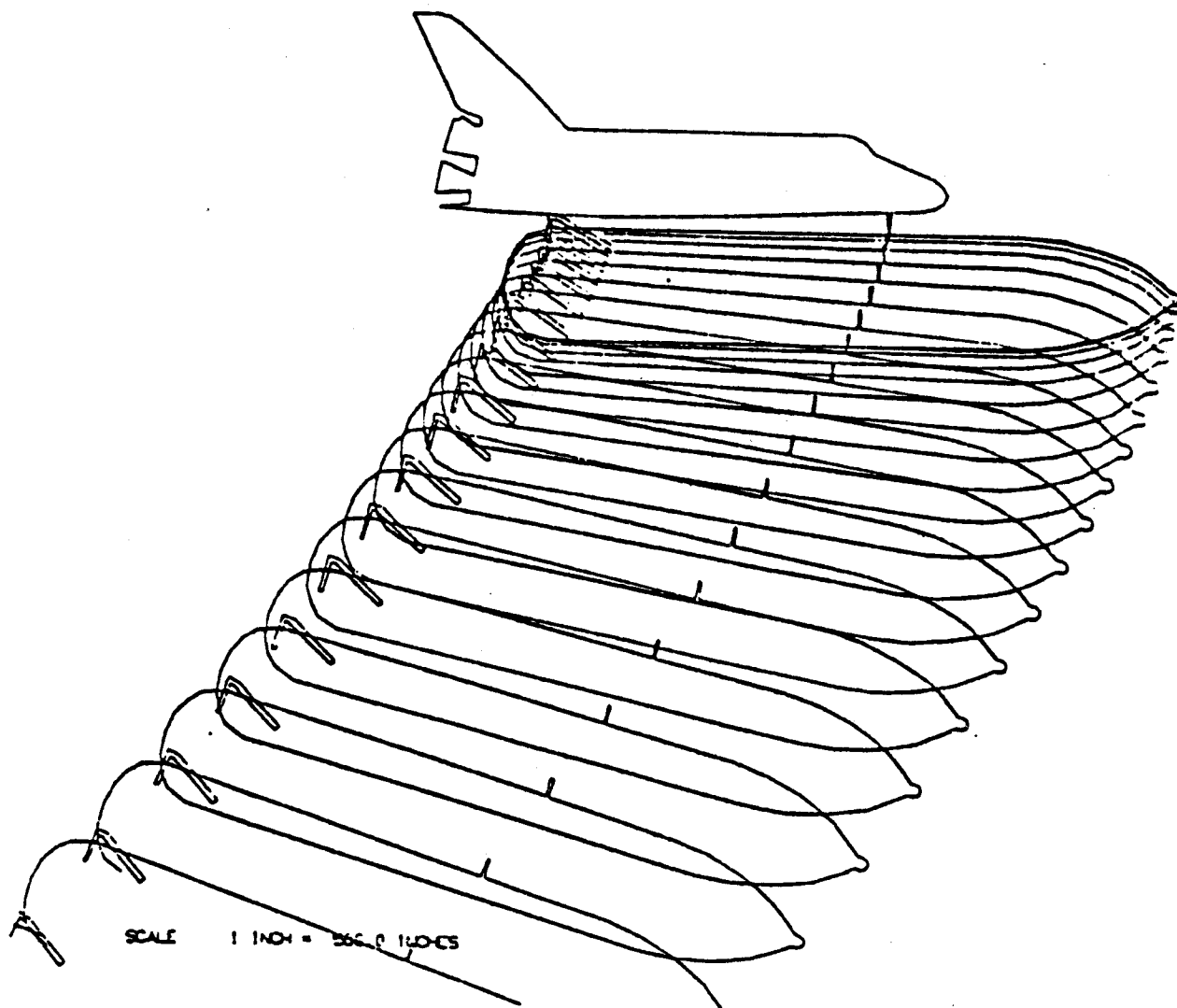


Figure 3.3-47.- Relative motion between the Orbiter and ET (RTLS 3 ENG OUT BLUE).

The pullout phase is  $N_z = 2.9$ ,  $\bar{q} = 434$  for case 1 and  $N_z = 3.0$ ,  $\bar{q} = 490$  for case 2.

-Z THC 8 sec

An 8-sec separation burn with the THC will ensure good separation from the ET without sacrificing control. During the -Z translation  $\alpha$  will continue to increase from  $\sim -3^\circ$  to  $\alpha = 5^\circ$  to  $30^\circ$  depending on the sequence the SSME's failed.

 $\alpha \sim +30^\circ$ 

After the -Z translation increase  $\alpha$  to  $\sim 30^\circ$  (if necessary) prior to starting the next step (a roll maneuver).

Roll Hds Up, then

With  $\alpha \sim 30^\circ$  the Orbiter nose will be  $\sim 30^\circ$  to  $60^\circ$  below the horizon ( $\Theta_{ball} \sim 330^\circ$  to  $300^\circ$ ). Roll to heads up (control authority may be sluggish). Continue to monitor  $\alpha$  during roll maneuver and maintain  $\alpha$  between  $30^\circ$  and  $50^\circ$ .

 $\alpha = 50^\circ$ 

Previously explained.

## j. RTLS 3 ENG OUT YELLOW

This procedure (fig. 3.3-48) covers one of the most difficult of all contingency abort regions, and is the most challenging of all the procedures.

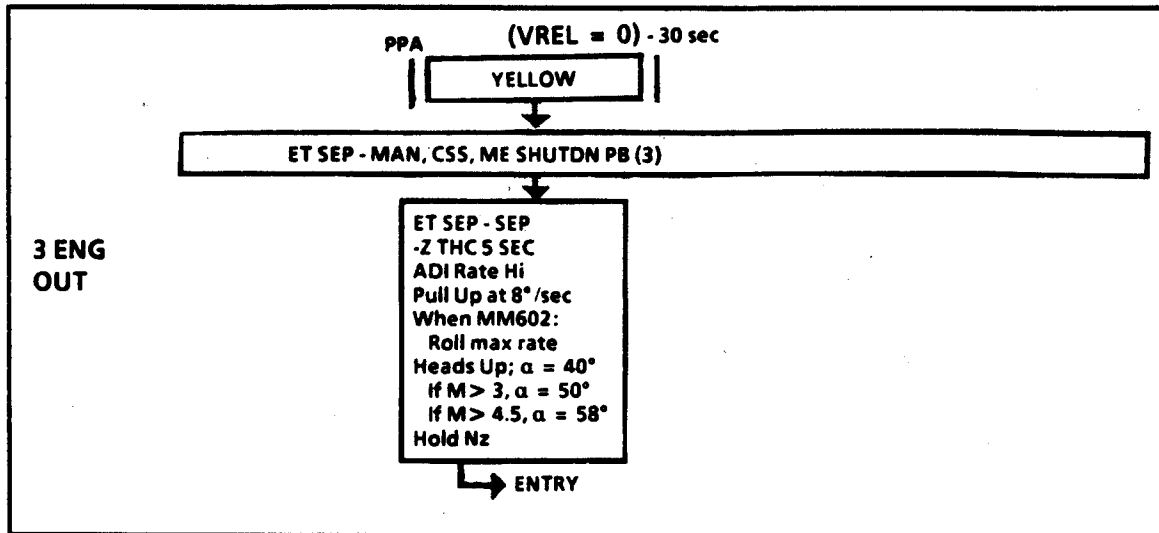


Figure 3.3-48.- RTLS 3 ENG OUT YELLOW.

Between PPA and VREL = 0, the Orbiter is flying backwards. If all three engines go out, the crew must both pitch and roll quickly through large angles to orient the vehicle downrange again before it hits the atmosphere. This yellow procedure does not need to be done all the way to VREL = 0; the velocity vector is close enough to straight down at 30 sec before VREL = 0 that the Orbiter can execute a pullout using the ORANGE procedure, and the drastic reorientation maneuver is not required within 30 sec of VREL = 0.

ET SEP-SEP  
-Z THC 5 Sec

Since it is time-critical to reorient the Orbiter before hitting the atmosphere, it is more efficient to jettison the ET and then maneuver the Orbiter alone.

ADI Rate Hi  
PULL UP AT 8°/Sec.

Both a 180° roll and a 180° pitch are required to reorient the Orbiter downrange. While a roll first (to heads down) is preferable, current software precludes this (since we mode to MM 602 halfway through the roll, when  $\alpha > 10^\circ$ , and control is lost). 0I-8c software will constrain

the MM 602 transition (to  $10^\circ < \alpha < 90^\circ$ ). For OI-8b software you must pitch first, then roll. 8 deg/s is critical to get the nose pointed downrange quickly. A slower rate will not allow you to subsequently complete the roll to heads up maneuver before hitting the atmosphere. Any faster rate causes you to overshoot and get the nose so low you cannot roll out and pull it back up soon enough. ADI rate high (Hi) lets you fly the 8 deg/s pitch rate.

WHEN MM 602:

ROLL MAX RATE

The DAP will mode to MM 602 automatically during the pitch maneuver (when  $\alpha > 10^\circ$ ). You should release the RHC in pitch and quickly start a max rate roll to heads up before you start building g's.

HEADS UP,  $\alpha = 40^\circ$

if  $M > 3$ ,  $\alpha = 50^\circ$

if  $M > 4.5$ ,  $\alpha = 58^\circ$

It is again time critical to get the nose up before you "dig" into the atmosphere.

k. 3 ENG OUT BLUE

The procedure in figure 3.3-49 is used if the three SSME's fail between lift-off and SRB separation.

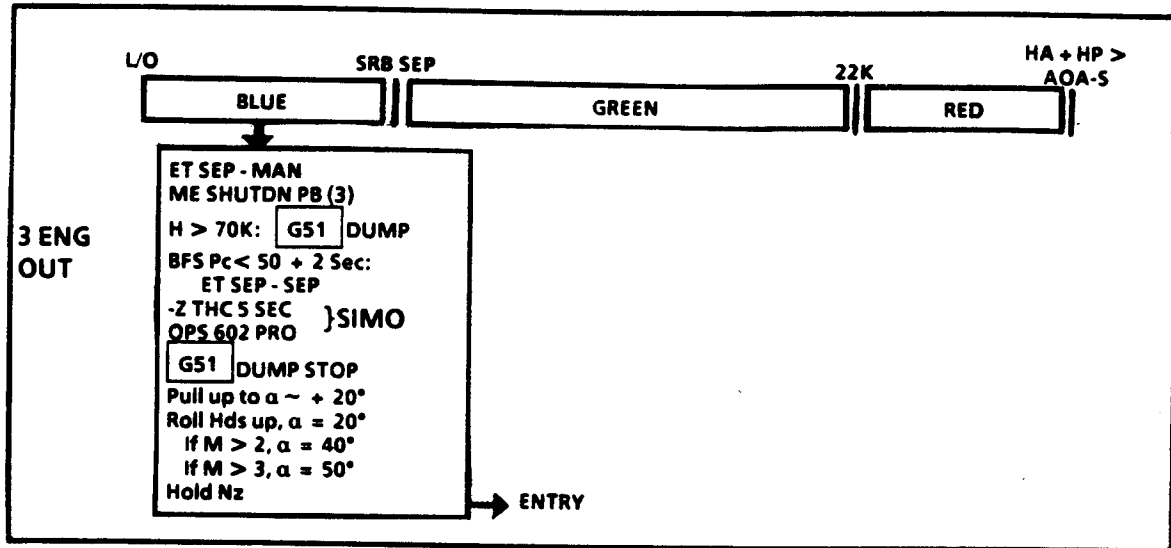


Figure 3.3-49.- 3 ENG OUT BLUE.

ET SEP - MAN

Previously explained.

ME SHUT DN PB (3)

Sets the MECO confirm flag.

H > 70K: G51 DUMP

Previously explained.

BFS Pc < 50 + 2 SEC:  
ET SEP - SEP

Fast SEP is not attempted until tailoff of the SRB's. If fast SEP is attempted while the SRB's are at full thrust, the Orbiter will hang up on the attach points and structural failure is likely to occur. The Pc < 50 cue must be monitored on the BFS TRAJ display because once MECO CONFIRM is set in the PASS, (as a result of three SSME's down), the SRB SEP sequence is no longer executed. The 2-sec wait will provide the ET from hanging up on the attach points. When the fast SEP sequence is

initiated in MM 102, an RTLS abort is automatically declared and the software will enter MM 601.

-Z THC 5 sec  
OPS 602 PRO } SIMO

The -Z THC has been discussed previously. The OPS 602 PRO is extremely time-critical in order to maintain control of the vehicle. The software will not transition to MM 602 automatically, and the PLT should perform this step immediately. A suggested technique is for the PLT to push the SEP pb, immediately focus on the software major mode, and prepare to type OPS 602 PRO as soon as you see MM 601. The CDR should ensure -Z THC the instant of ET SEP. This combined technique will ensure you get to MM 602 as soon as possible and maintain control.

Typical ET separation conditions for this abort are

Case 1 (3 SSME's + at lift-off)

$\bar{q} = 12$   
 $\alpha = -4.6^\circ$   
 $H = 126,000 \text{ ft.}$

Case 2 (3 SSME's + at SRB SEP)

$\bar{q} = 33$   
 $\alpha = 1.0^\circ$   
 $H = 152,000 \text{ ft}$

Relative motion between the Orbiter and ET after separation for this case is shown in figure 3.3-50.



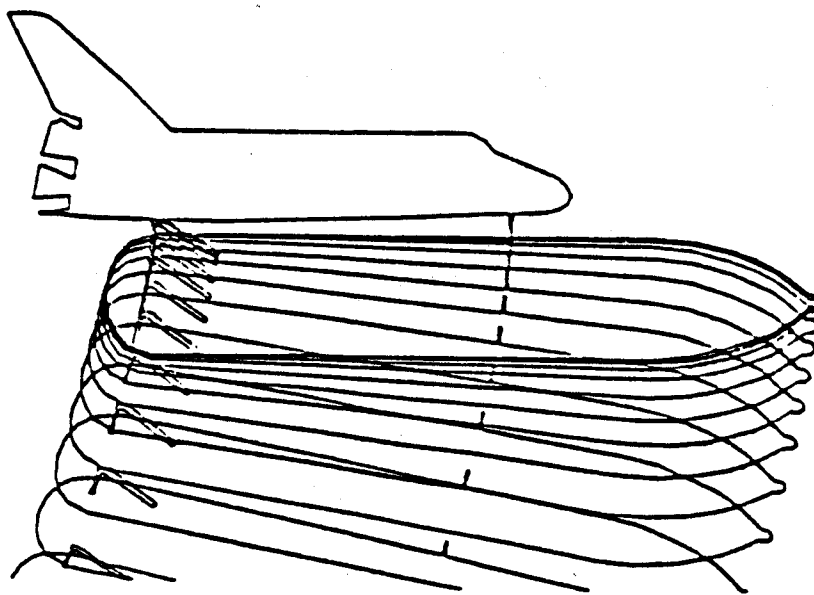


Figure 3.3-50.- Relative motion between the Orbiter and ET (3 ENG OUT BLUE).

**G51** DUMP STOP

When the OMS engines light up, the acceleration cancels the sensed drag on the vehicle. Orbiter navigation then thinks  $\dot{q}$  is zero. The zero  $\dot{q}$  prevents the ailerons from becoming active (aileron is not active until  $\dot{q} > 2$ ). The contingency dump will automatically start in MM 602, and the OMS engines will light up. Therefore, do a dump stop to ensure aerodynamic control capability. This dump stop will not be necessary with OI-8c software, because the dump will not restart automatically post MECO.

Pull Up To  $\alpha \sim +20^\circ$   
Roll Hds Up

In order to obtain roll authority in the GRTLS DAP,  $\alpha$  must be greater than  $10^\circ$ . Proceeding to  $\alpha = 20^\circ$  will allow for fluctuation in pitch attitude during the roll maneuver. At SRB SEP the angle of attack is approximately  $-4^\circ$ , and the Orbiter is upside down. Therefore, the maneuver to  $\alpha \sim +20^\circ$  results in pulling the nose towards the horizon (changing attitude approximately  $20^\circ$ ). Control is extremely sluggish during the roll to heads up.

If  $M > 2$ ,  $\alpha = 40^\circ$   
If  $M > 3$ ,  $\alpha = 50^\circ$

If Mach is high, increasing alpha will reduce pullout and still provide adequate control.

## 1. 3 ENG OUT GREEN

The procedure in figure 3.3-51 is used if three SSME's fail between SRB SEP and 22,000 fps.

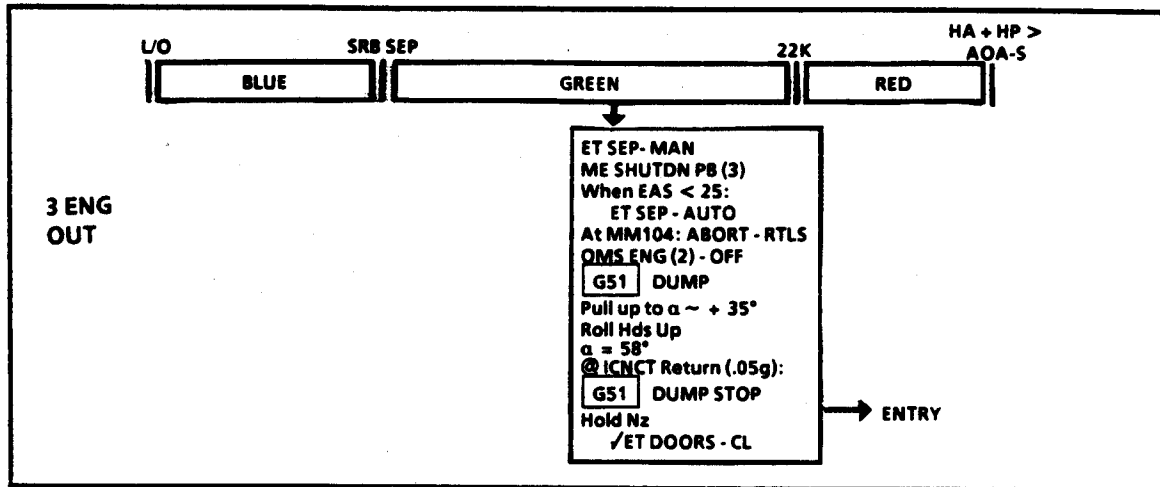


Figure 3.3-51.- 3 ENG OUT GREEN.

ET SEP - MAN  
ME SHUTDN PB (3)  
When EAS < 25:  
ET SEP-Auto

Previously explained.

For this case, the airspeed is allowed to bleed off while coasting to apogee. Since  $\dot{q}$  will remain low for an extended period of time, the more desirable automatic ET separation sequence is used in MM 103. Therefore, leave the Orbiter in auto flight control until MM 104.

A typical ET separation condition for three SSME's failed at 6000 fps is

$\dot{q} = .8$   
 $\alpha = -11$   
 $H = 248,000$  ft

Relative motion between the Orbiter and ET after separation for this case is shown in figure 3.3-52.

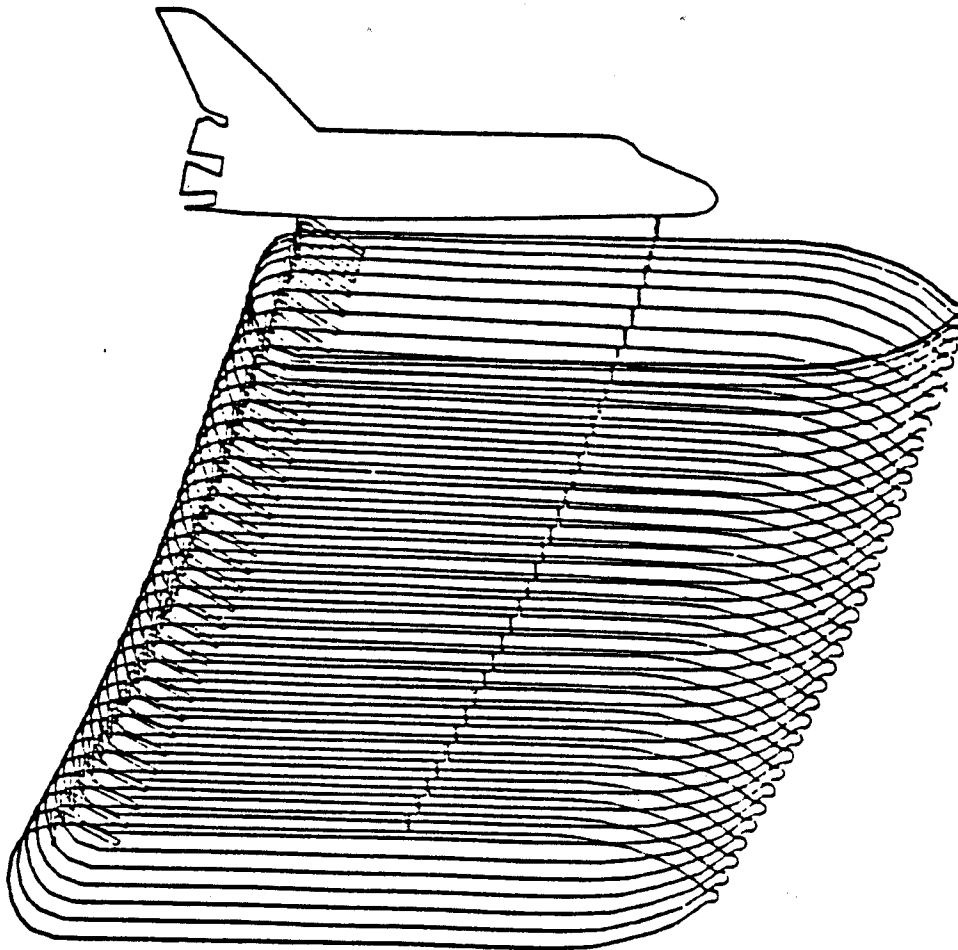


Figure 3.3-52.- Relative motion between the Orbiter and ET  
(3 ENG OUT GREEN).

At MM 104: ABORT-RTLS

Following ET separation, the automatic -Z burn and transition to MM 104 will occur. At this point abort RTLS to enter MM 602. The major mode 601 or 602 PRO is not allowed in MM 103.

OMS ENG-(2) - OFF

The OMS screens will only support either 2 OMS engines only or the RCS jets only with g's between .02g and .05g. This is where you are. The software will not let us turn the jets off. Therefore, we turn the OMS engines off (only option). At .05g the dump will automatically stop.

**G51** DUMP

Since the dump was not enabled pre-MECO and the fast SEP sequence was not invoked, the dump must be started manually in MM 602.

Pull up to  $\alpha \sim +35^\circ$   
Roll Hds Up

The rationale for increasing  $\alpha$  to  $+35^\circ$  is similar to increasing  $\alpha$  to  $+20^\circ$  for the 3 OUT BLUE procedure. Roll heads up to place the bottom of the Orbiter in the direction of the velocity vector (fig. 3.3-53).

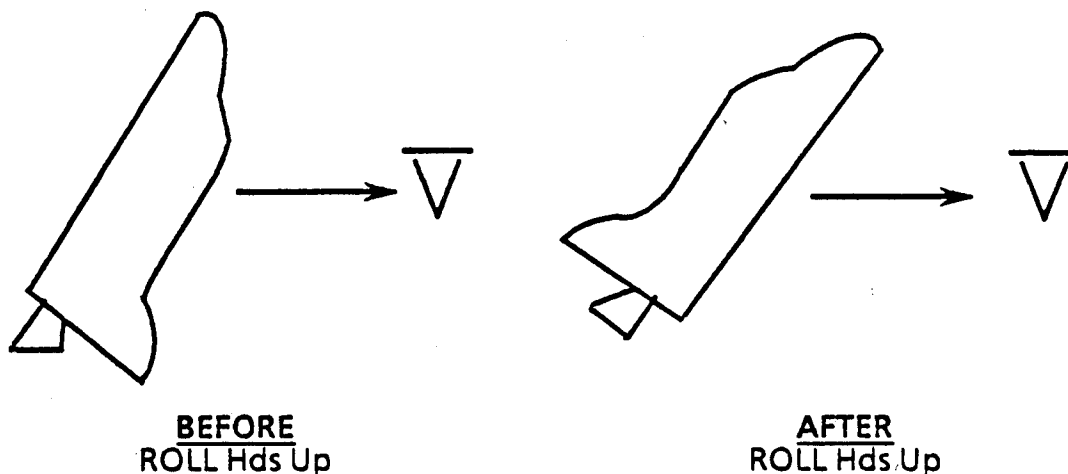


Figure 3.3-53.- Heads up roll maneuver.

@ ICNCT Return (.05g):

**G51** dump stop

This dump stop prevents the MM 602 4+X dump from occurring. The 4+X dump could cause a flammability hazard.

You have adequate control authority for the 3 ENG OUT GREEN contingency. However, this procedure is used for a wide range of Mach and attitudes. The pullouts are quite severe, but you can successfully maintain control if you fly the procedures precisely and hold  $N_z$  constant during the pullout phase. If the three SSME's fail between 8,000 and 12,000 fps, the Orbiter will not have adequate control authority and structural strength to survive the high  $\bar{q}$  ( $>800$ ) and 3.5g during the pullout phase.

The pullout phase for the SSME fail at 6000 fps is  $N_z = 2.8$ ,  $\bar{q} = 531$ . This case is structurally survivable.

## m. RTLS 2 ENG OUT RED

Figure 3.3-54 shows the manual technique to complete an RTLS if a second SSME fails after single engine performance capability (SE PRESS). The area begins at approximately 45 sec prior to MECO (H is typically +100 fps). The area ends at PD3, because auto guidance can successfully fly to the RTLS R-V line.

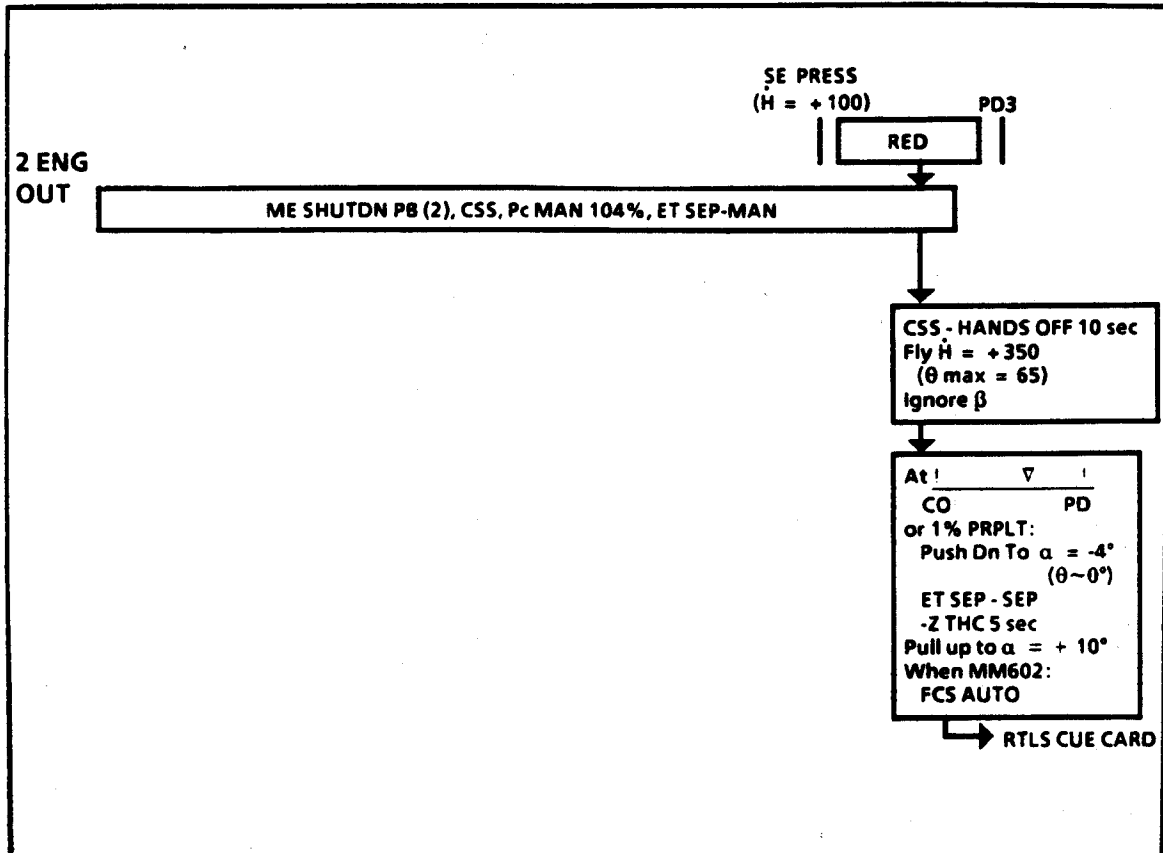


Figure 3.3-54.- RTLS 2 ENG OUT RED.

CSS - Hands OFF 10 sec  
ME SHUTDOWN PB (2) CSS

This step is critical. As soon as you ascertain that a second SSME has failed, the CDR should engage CSS with the two eyebrow pushbuttons. CSS will place the flight control in attitude hold. It is equally important to ensure the computers know two SSME's have failed so that flight control has single engine roll control. Therefore, the PLT should ensure single engine roll control by depressing the two pushbuttons for the failed engines. Do not push the wrong buttons. If the main engine limits are enabled, it is not necessary to push the pushbuttons. Flight

control will automatically have single engine roll control. If the main engine limits are inhibited, it is mandatory to push the two pushbuttons. If only one side main engine remains, the Orbiter initially will have a yawing moment. If flight control does not have single engine roll control, you will lose control within seconds.

Pc MAN 104%  
ET SEP-MAN

Previously explained.

It is very important to leave your hands off the RHC for 10 seconds. The auto trim integrator will move the remaining main engine thrust vector through the Orbiter c.g. if CSS and RHC are in detent. The Orbiter will yaw off  $\sim 5^\circ$ , then yaw back and hold  $\beta$  constant. If the RHC is out of detent, the auto trim integrator will not trim the remaining main engine. With the engine out of trim, you do not have adequate control authority. Therefore, go CSS, take your hand off the RHC, and let the vehicle rates damp out.

Fly  $\dot{H} = +350$   
( $\theta$  max =  $65^\circ$ )

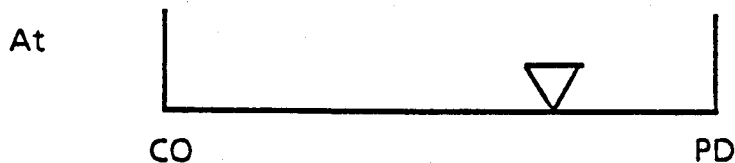
Do not let the pitch attitude exceed approximately  $65^\circ$ . You need to make the R-V line, and therefore need some horizontal thrust vector component. In this phase of flight, the pitch attitude prior to second SSME failure is approximately  $60^\circ$ .

If the second engine fails at  $\dot{H} = 100$  fps, and you are holding  $\theta = 65^\circ$ , the  $\dot{H}$  will start to increase. You must reduce  $\theta$  to hold  $\dot{H} = +350$  fps. This maneuver reduces  $\theta$  by  $\sim 30^\circ$  and puts you in the right place in the sky to reach MECO at  $\alpha = -4^\circ$ . If  $\dot{H}$  reaches +400 fps, and you start the pitchdown phase from +400 fps, a propellant depletion MECO probably will occur prior to settling down at  $\alpha = -4^\circ$ . Control will be lost, because the RCS jets will not be able to stop the pitch rate. If you hold  $\dot{H}$  too low at +300 fps, then pitch down to  $\alpha = -4^\circ$ , you will be lower in the atmosphere ( $\dot{q}$  will be high) and you will lose control during ET SEP. Therefore, fly  $\dot{H} = +350$  fps. This is very important!

Ignore  $\beta$

If you fly a pure pitch maneuver, the chances for success dramatically increase. Remember, everytime the RHC is out of detent, the auto trim integrator is cut out. The auto trim integrator will hold  $\beta$  better than you can trying to fly too much. Testing has shown that with a pure pitch flying task, you will be successful and the  $\beta$  at ET SEP will be satisfactory ( $\pm 5^\circ$ ). If you try to "sweeten up"  $\beta$ , it will be worse.

At the point shown on the RTLS TRAJ DISPLAY (fig. 3.3-55), reduce  $\alpha$  to  $-4^\circ$ . You are pitching down from  $\theta \sim 30^\circ$  to  $\theta \sim 0^\circ$ . Do not over control and get the nose down to  $\alpha = -10^\circ$ ; you will lose control. However, you must get to  $\alpha = -4^\circ$  for ET SEP. The important thing is to have no rates on the vehicle before a fuel depletion MECO. If a pitch rate is on the vehicle and a fuel depletion MECO occurs, you will lose control. The RCS system does not have enough muscle to fly the Orbiter and external tank at this  $\bar{q}$ . Therefore, accept  $\alpha = -5^\circ$ , or  $\alpha = -3^\circ$  and stable.



or 1% PRPLT:  
Push Down to  $\alpha = -4^\circ$

Figure 3.3-55.- RTLS 2 EO RED pitchdown cue.

#### ET SEP-SEP

When stable, the CDR should call ET SEP. The PLT should push the ET SEP pb. You could wait until the CO tic to MECO on the R-V line, but this technique is usually not as successful as that proposed. There is performance margin on the R-V line to command MECO prior to the R-V line and have a successful RTLS.

Typical ET separation conditions for this abort are

Case 1 (Second SSME +  $\dot{H} = +100$ )

$\bar{q} = 10$   
 $\alpha = -5.1^\circ$   
 $H = 201,000$  ft

Case 2 (Second SSME +  $\dot{H} = +350$ )

$\bar{q} = 5$   
 $\alpha = -2.4^\circ$   
 $H = 222,000$  ft

-Z THC 5 sec

Previously explained.

Pull up to  $\alpha = +10^\circ$

When you reach  $\alpha = 10^\circ$ , guidance will mode to MM 602 and improve control authority.

When MM 602  
FCS AUTO

When the guidance modes to MM 602, the CDR can engage auto for the GRTLS completion. Should you also have the case where guidance is unconverged after PD, the needles will stow and will not unstow in MM 602 (even though guidance is converged). This a flaw in the implementation of the guidance unconverge/needles stow software logic.

#### 3.3.6.4 Conclusion

The contingency abort analyses and procedures development have provided the Space Shuttle crew with a reasonable survivable flightpath to use the bailout system. There are some three main engine failure cases where the structural loads are too severe and survival unlikely. However, survival is possible in the majority of main engine failure scenarios in powered flight ascent.



## ACRONYMS

|               |   |
|---------------|---|
| ADI           | attitude direction indicator                  |
| ADTA          | air data transducer assembly                  |
| ALT           | alternate                                     |
| AMI           | alpha/Mach indicator                          |
| AOA           | abort once around                             |
| AOS           | acquisition of signal                         |
| APU           | auxiliary power unit                          |
| ARD           | abort region determinator                     |
| ASAP          | as soon as possible                           |
| ASC           | ascent  |
| ASP           | astronaut support personnel                   |
| ATO           | abort to orbit                                |
| AVVI          | altitude/vertical velocity indicator          |
|               |   |
| BDYFLP        | bodyflap                                      |
| BFC           | backup flight control                         |
| BFS           | backup flight system                          |
| BITE          | built-in test equipment                       |
| BOS           | backup operating system                       |
| BRK           | brake   |
|               |   |
| C&W           | caution and warning                           |
| C/L           | checklist                                     |
| CA            | contingency abort                             |
| CDI           | course deviation indicator                    |
| CDR           | commander                                     |
| c.g.          | center of gravity                             |
| CMD           | command                                       |
| CMDSOP        | Command Subsystem Operating Program           |
| CO            | cutoff  |
| COMM          | communication                                 |
| CR            | change request                                |
| CRT           | cathode ray tube                              |
| CSS           | control stick steering                        |
|               |   |
| DAP           | digital autopilot                             |
| DEL           | deorbit, entry, and landing                   |
| DI            | direct insertion                              |
| DIP           | display interface processing                  |
| DK            | display keyboard                              |
| DOF           | degree of freedom                             |
| dP/dT         | delta pressure/delta time                     |
| DPS           | data processing and software                  |
| $\Delta R$    | delta range                                   |
| $\Delta VTOT$ | total delta velocity                          |
|               |   |
| E/W           | energy-to-weight ratio                        |
| ECLSS         | environmental control and life support system |
| EAS           | equivalent airspeed                           |

|                 |                                    |
|-----------------|------------------------------------|
| EDW             | Edwards Air Force Base             |
| EI              | entry interface                    |
| EOM             | end of mission                     |
| ET              | external tank                      |
| ETR             | Eastern Test Range                 |
| FA              | flight aft                         |
| FCOS            | flight control operating system    |
| FCS             | flight control system              |
| FDI             | fault detection and identification |
| FDO             | flight dynamics officer            |
| FES             | flash evaporator system            |
| FPH             | Flight Procedures Handbook         |
| FRCS            | forward reaction control system    |
| FPR             | flight performance reserve         |
| FWD             | forward                            |
| GLS             | ground launch sequencer            |
| GMBL            | gimbal                             |
| GMT             | Greenwich mean time                |
| GN&C            | Guidance, Navigation, and Control  |
| GN <sub>2</sub> | gaseous nitrogen                   |
| GPC             | general purpose computer           |
| GRTLS           | glide return to launch site        |
| H               | altitude rate                      |
| HA              | apogee altitude                    |
| HAC             | heading alignment circle           |
| HP              | perigee altitude                   |
| HPOT            | high-pressure oxidizer turbo pump  |
| HSI             | horizontal situation indicator     |
| HSD             | horizontal situation display       |
| HUD             | head up display                    |
| ID              | identification                     |
| IMU             | inertial measurement unit          |
| INRTL           | inertial                           |
| ISP             | specific impulse                   |
| KEAS            | knots equivalent airspeed          |
| KSC             | Kennedy Space Center               |
| KYBD            | keyboard                           |
| LCC             | launch control center              |
| LG              | landing gear                       |
| LOS             | loss of signal                     |
| LOX             | liquid oxygen                      |
| LPS             | launch processing system           |
| LRU             | line replaceable unit              |
| LVIY            | local vertical inertial yaw        |
| LVLH            | local vertical/local horizontal    |

|           |                                  |
|-----------|----------------------------------|
| MA        | master alarm                     |
| MAN       | manual                           |
| MC        | mated coast                      |
| MCC       | mission control center           |
| MDM       | multiplexer/demultiplexer        |
| MECO      | main engine cutoff               |
| MET       | mission elapsed time             |
| MLS       | microwave landing system         |
| MM        | major mode                       |
| MMU       | mass memory unit                 |
| MOC       | mission operations computer      |
| MPS       | main propulsion system           |
| MSC       | master sequence controller       |
|           |                                  |
| NA        | not applicable                   |
| NAV       | navigation                       |
| NOM       | nominal                          |
| NOR       | Northrup Strip                   |
| NPSP      | net positive suction pressure    |
| Nz        | normal load factor               |
|           |                                  |
| OMS       | orbital maneuvering system       |
| OPS       | operations sequence              |
| OTC       | orbiter test conductor           |
|           |                                  |
| PA        | product assurance                |
| PAD       | preliminary advisory data        |
| PASS      | primary avionics software system |
| pb        | pushbutton                       |
| PBI       | pushbutton indicator             |
| Pc        | chamber pressure                 |
| PD        | pitchdown                        |
| PEG       | powered explicit guidance        |
| PFS       | primary flight system            |
| PIC       | pyro initiator controller        |
| PLT       | pilot                            |
| PNL       | panel                            |
| PPA       | powered pitcharound              |
| PPD       | powered pitchdown                |
| PRI       | primary                          |
| PRTL      | powered return to launch site    |
| PTI       | programmed test input            |
|           |                                  |
| $\bar{q}$ | dynamic pressure                 |
|           |                                  |
| RCS       | reaction control system          |
| REF       | reference                        |
| REI       | range at entry interface         |
| RGA       | rate gyro assembly               |
| RHC       | rotational hand controller       |
| RM        | redundancy management            |
| RPL       | rated power level                |

|       |  |
|-------|--|
| RS    | redundant set                                      |
| RSLS  | redundant set launch sequencer                     |
| RSS   | range safety system                                |
| RTLS  | return to launch site                              |
| R-V   | range-velocity                                     |
| RWY   | runway   |
| SBTC  | speedbrake thrust controller                       |
| SE    | single engine                                      |
|       | southeast  |
| SEC   | secondary  |
| SEP   | separation   |
| SERC  | single engine roll control                         |
| SI    | standard insertion                                 |
| SM    | systems management                                 |
| SORT  | simulation and optimization of rocket trajectories |
| SPD   | speed  |
| SPEC  | specialist function                                |
| SPI   | surface position indicator                         |
| SRB   | solid rocket booster                               |
| SRM   | solid rocket motor                                 |
| SSME  | Space Shuttle main engine                          |
| SSPO  | Space Shuttle Program Office                       |
| STG   | stage  |
| STS   | Space Transportation System                        |
| SVDS  | space vehicle dynamics simulation                  |
| sw    | switch   |
| SW    | southwest  |
| T     | thrust vector                                      |
| tacan | tactical air navigation                            |
| TAEM  | terminal area energy management                    |
| TAL   | transoceanic abort landing                         |
| TDDP  | trajectory design data package                     |
| TFF   | time to free fall                                  |
| TGO   | time to go   |
| THC   | translational hand controller                      |
| THROT | throttle   |
| TIG   | time of ignition                                   |
| TMECO | time of main engine cutoff                         |
| TTA   | time to apogee                                     |
| TTC   | time to circularize                                |
| TTG   | time to go   |
| TTP   | time to perigee                                    |
| TVC   | thrust vector control                              |
| θT    | target parameter                                   |
| UPP   | user parameter processing                          |

VI  
VHOR  
VREL  
VVER

inertial velocity  
horizontal velocity  
relative velocity  
vertical velocity

WONG  
WOW  
WSB  
WT  
WTR

weight on nose gear  
weight on wheels  
water spray boiler  
weight  
Western Test Range