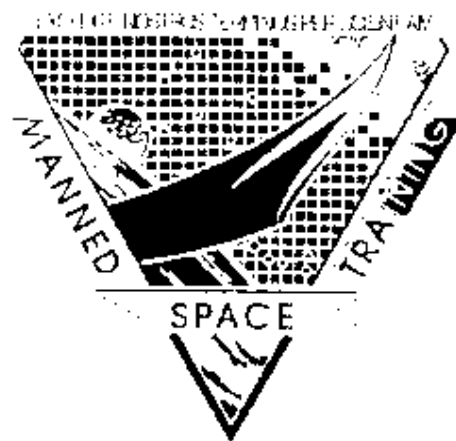


# **ATO/AOA/TAL Training Manual 2102**

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## **Mission Operations Directorate Space Flight Training Division Flight Training Branch**

**May 1995**

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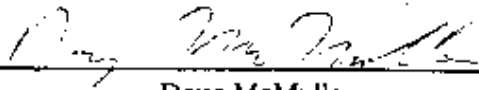
**Lyndon B. Johnson Space Center  
Houston, Texas**

# ATO/AOATL Training Manual

## 2102

May 1995

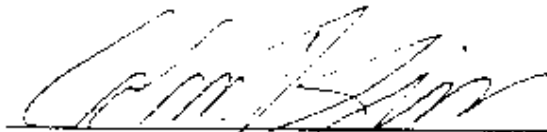
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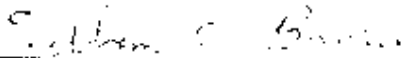
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## Foreword

The content of this document was provided by the Control/Propulsion Group, Flight Training Branch, Space Flight Training Division, Mission Operations Directorate (MOD), Lyndon B. Johnson Space Center (JSC), National Aeronautics and Space Administration (NASA). Technical documentation support was provided by Integrated Documentation Services (IDS), Hernandez Engineering, Inc. Any questions concerning this training manual or any recommendations should be directed to the training manual book manager, Cori Kerr, at DT66, 244-7015.

This material is for training purposes only and should not be used as a source of operational data. All numerical data, displays, and checklist references are intended as examples. To determine any prerequisites before using this document, consult the applicable Certification Plan. For shuttle manuals, consult the Flight Operations Support Personnel Training Guide (Blue Book) or the Crew Training Catalog. For Space Station manuals, consult the appropriate Space Station Certification Training Guide or Training Administration Management System (TAMS). The applicable training package should be studied before attending any classroom session or lesson for which this is a prerequisite.

A Training Materials Evaluation is included at the end of this document. Inputs on this sheet will be used to evaluate the lesson material. You do not need to sign the sheet.

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# Section 1

## Ascent and Abort Overview

### Objectives

Upon completing this section, the student should be able to:

- Distinguish between a standard insertion and a direct insertion mission
- State the definition of a main engine cutoff (MECO) underspeed
- Describe the four types of intact abort modes
- Describe how to initiate an Abort-to-Orbit (ATO) or Transoceanic Abort Landing (TAL)

### Nominal Ascent

The space shuttle ascent flight phase begins at launch with a vehicle composed of the orbiter, External Tank (ET), and two Solid Rocket Boosters (SRBs). The three Space Shuttle Main Engines (SSMEs) ignite about T-7 seconds. When the main engines are throttled to 100 percent of their rated thrust level, the two SRBs ignite, and lift-off occurs.

After lift-off, the space shuttle follows the ascent profile shown in Figure 1-1. The early part of ascent, when the SSMEs are burning in parallel with the SRBs, is often referred to as first stage. After about 2 minutes, the SRBs burn out, separate from the orbiter and ET, and are recovered for use on a later flight. Second-stage ascent begins after SRB separation and continues until MECO. The period from lift-off to MECO is known as the powered flight phase.

After MECO, the ET is jettisoned from the orbiter, and the Reaction Control System (RCS) jets are used to maneuver away from the tank. The ET enters the Earth's atmosphere, breaks up, impacts in a remote ocean area, and is not recovered.

At this point, the orbiter may or may not have achieved orbital velocity, depending on whether a direct or standard insertion was planned. A standard insertion uses the Orbital Maneuvering System (OMS) engines to supply the additional thrust needed to reach orbit. The first burn (OMS-1) occurs soon after MECO and results in an elliptical orbit. With a direct insertion ascent, the main engines are burned slightly longer to achieve the desired apogee altitude such that an OMS-1 maneuver is not required. Both insertion profiles require a circularization burn (OMS-2). This burn is performed at the apogee of the initial orbit.



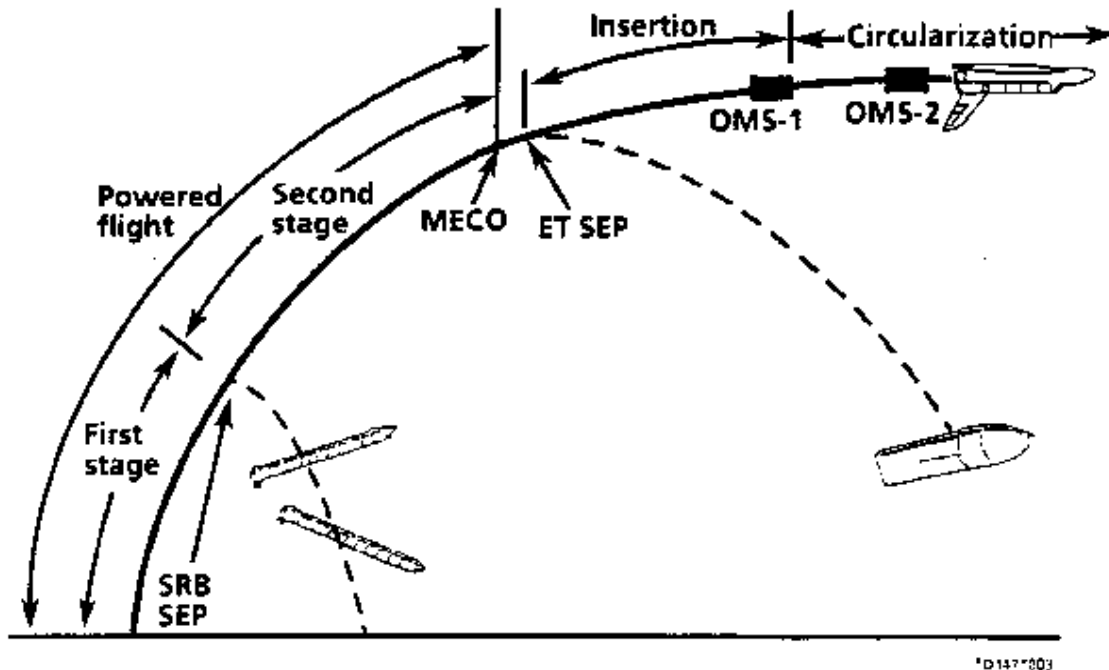


Figure 1-1. Nominal ascent profile

At the start of the Space Shuttle Program (SSP), standard insertion was the only type of insertion planned. STS 41-C was the first direct insertion flight and this type of insertion has been used since STS-30. Standard insertions were used on early flights when less information was available on SSME performance and targeting precision. Some of the other aspects considered for standard or direct insertion are mission objectives, ascent performance, ET impact, and orbital altitude. At present, a standard insertion would only be used for flights to low orbital altitudes where the ET impact point is outside of limits using direct insertion.

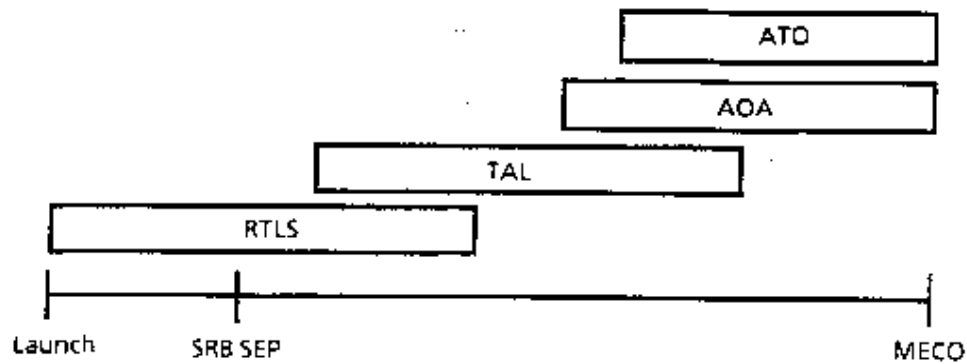
The main advantage of direct insertion is that higher orbital altitudes are possible because more OMS propellant is saved for orbital maneuvers.

## Performance

The performance capability of the shuttle is defined as the measure of the shuttle's ability to achieve a desired orbit. If shuttle performance is better than predicted, the desired MECO velocity is achieved with a surplus of propellant that is discarded. If, however, the shuttle does not perform as well as predicted, the desired MECO velocity may not be achieved.

A MECO velocity that is less than the target velocity is called an underspeed. The most probable cause of a MECO underspeed is a main engine failure. Underspeeds up to several hundred feet per second can be made up by increasing the  $\Delta V$  provided by the OMS-1 and OMS-2 burns. If the underspeed is too large to be made up using excess OMS propellant, the shuttle will not be able to reach the desired orbit, and an ATO or an Abort-Once-Around (AOA) will have to be

performed. If the engine fails early during ascent, orbit cannot be achieved at all, and a TAL or a Return to Launch Site (RTLS) abort will have to be performed. Figure 1-2 illustrates the availability of these aborts, depending on when the engine fails. The time period during which these aborts are available is approximate and varies with each flight.



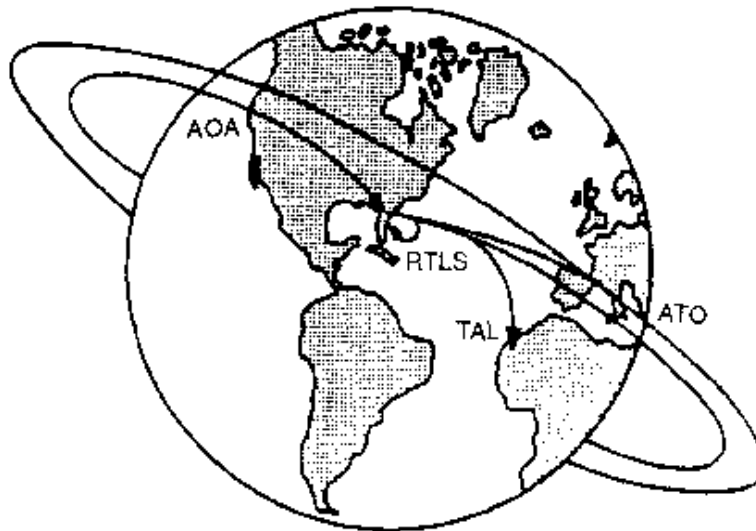
*Figure 1-2. Abort mode as a function of SSME failure time*

## Ascent Abort Modes

Selection of an ascent abort mode may become necessary if there is a failure that affects vehicle performance as described previously, or a vehicle system failure that jeopardizes crew safety, such as a cabin leak.

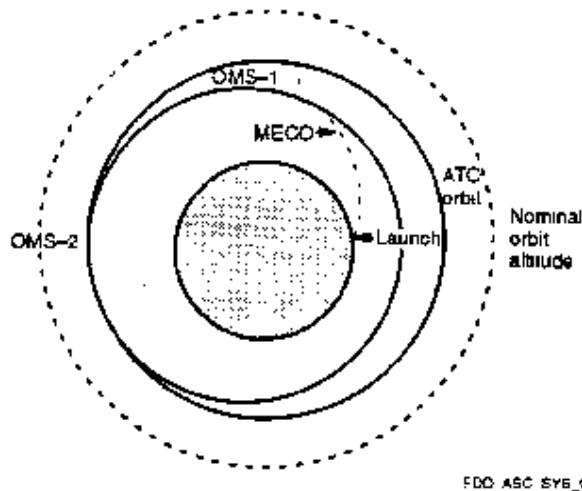
There are two basic types of ascent abort modes, intact and contingency. Intact aborts are designed to provide a safe return of the orbiter to a planned landing site. Contingency aborts are designed for crew survival and will probably result in loss of the vehicle. The type of abort required will depend on the severity and time of the failure.

There are four types of intact abort modes shown in Figure 1-3.



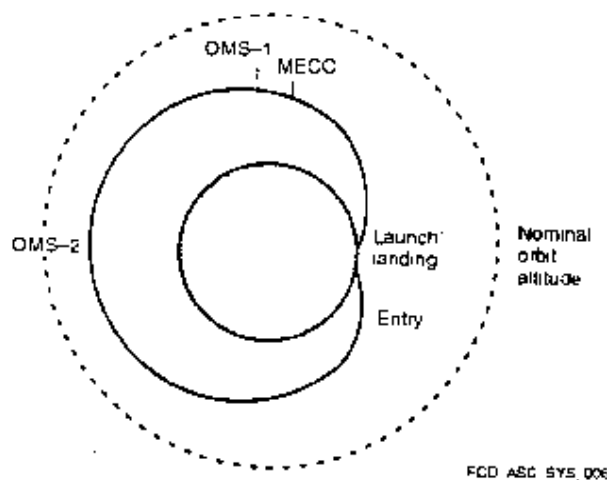
*Figure 1-3. Intact abort modes.*

**Abort-to-orbit** is designed to allow the vehicle to achieve a temporary orbit (typically 105 nautical miles (n. mi.)) that may be lower than the nominal orbit (Figure 1-4). This abort requires less performance and allows time to evaluate problems and then choose either an early deorbit burn or an OMS maneuver to raise the orbit and continue the mission.



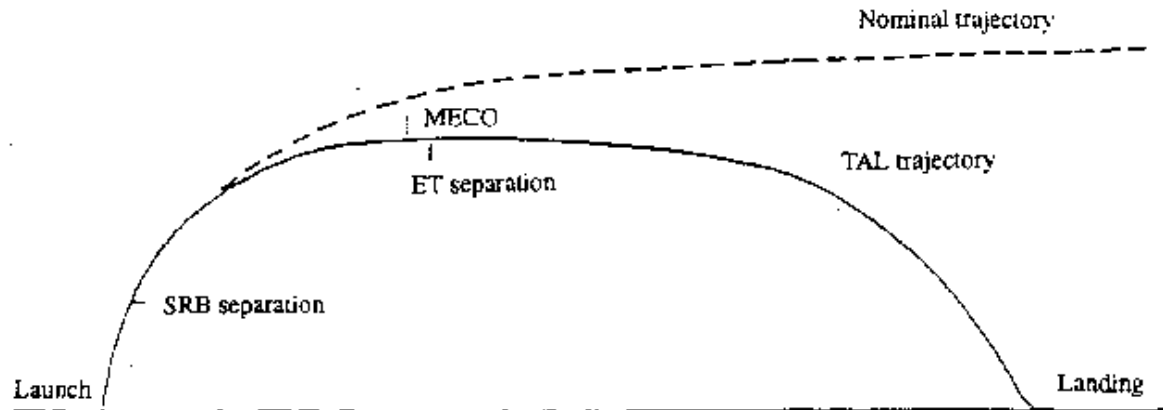
*Figure 1-4. Typical ATO profile*

**Abort-once-around** is performed when orbit cannot be achieved or maintained. This abort mode is designed to use the existing performance to make almost a complete revolution of the Earth and land at Edwards Air Force Base (EDW), Northrup Flight Strip (NOR), or Kennedy Space Center (KSC) (Figure 1-5). There are two types of AOA trajectories, AOA-steep and AOA-shallow. The entry trajectory for AOA steep is similar to the nominal End-of-Mission (EOM) entry trajectory. An AOA-shallow results in a flatter entry trajectory but uses less propellant in the OMS maneuvers. 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, the latter of which introduces a small risk of not obtaining aerocapture.



*Figure 1-5. Typical AOA profile*

**Transoceanic abort landing** is designed to allow the vehicle to achieve a suborbital trajectory that results in the orbiter landing on a runway in Europe or Africa, depending on the orbital inclination (Figure 1-6).



*Figure 1-6. Typical TAL profile*

**Return to launch site** is designed to allow the vehicle to fly downrange to dissipate propellant and then turn around during powered flight to return to a landing at a runway near the launch site. The RTLS abort is discussed in a separate book, RTLS Training Manual 2102.

There is a definite order of preference for the various abort modes. The type of failure and the time of the failure determine which type of abort is selected. During powered flight, the abort priorities for loss of performance are ATO, TAL, RTLS, TAL to an Augmented Contingency Landing Site (ACLS), and AOA-shallow. These priorities were established to provide the highest probability of safe return of the orbiter and the crew. For specific systems failures, such as a cabin leak or loss of vehicle cooling capability, the abort priorities are RTLS, TAL, and AOA. These priorities were established to provide the earliest available landing time or to avoid continuing to orbit with a loss of capability. A contingency abort, which usually results in the crew bailing out, is never chosen if another abort option exists.

## **Abort Mode Selection**

Ascent aborts are initiated during powered flight by use of the abort rotary switch on panel F6 (Figure 1-7). The rotary switch is turned to the desired position and then the abort pushbutton next to the switch is pushed. The positions on the switch are RTLS, OFF, ATO, and TAL.

The abort pushbutton does not light up when it is depressed, but it can be illuminated by a signal from MCC. If the abort light is illuminated by MCC, it will be extinguished by MCC once the crew has received and executed the abort request. In the absence of voice communication, this light would indicate to the crew that an abort selection was required. It could not, of course, specify the appropriate abort mode.

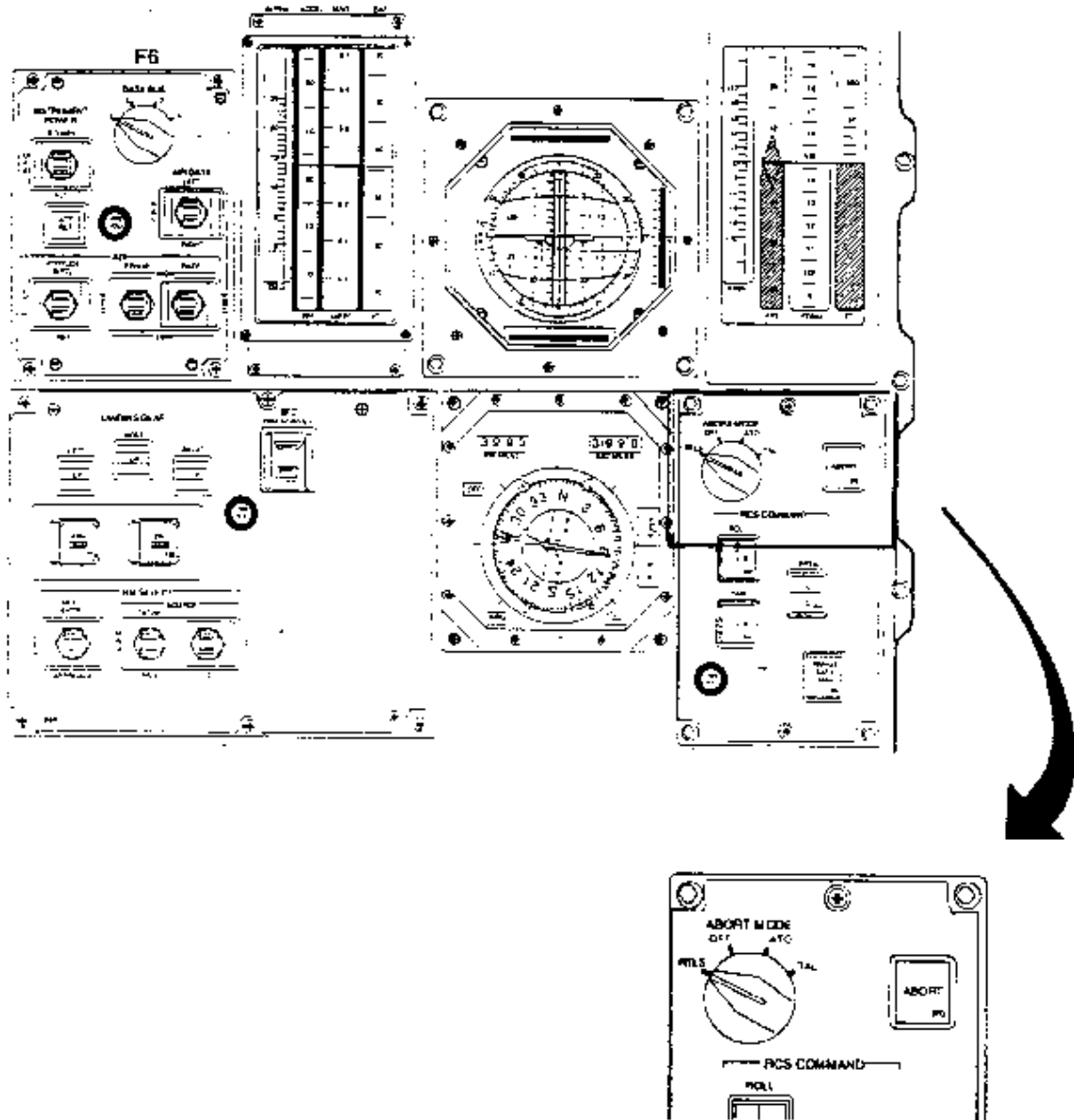


Figure 1-7. Abort rotary switch and pushbutton on panel F6

If the abort rotary switch fails, the crew can also initiate an abort by item entry on the OVERRIDE display (SPEC 51) shown in Figure 1-8. Items 1 and 2 allow the crew to select a TAL abort in MM103 and MM104 or an ATO abort in MM102, MM103, and MM104. These items are mutually exclusive and the selected mode is indicated by an "\*". The abort sequence is initiated by execution of item 3 and is indicated by an "\*". Execution of item 3 must be preceded by selection of item 1 or 2. Notice that no option exists for selecting an RTLS on this display. The crew can select RTLS by performing OPS 601 PRO. Specific abort requirements are described in more detail in their respective sections of this workbook.

XXXX'DS1:		OVERRIDE	XX X	DDD:HH:MM:SS	SS
				DDD:HH:MM:SS	SS
ABORT MODE		ENTRY FCS			
TAL	1X	ELEVON	FILTER	ATMOSPHERE	
ATO	2X	AUTO 17X	NOM 20X	NOM 22X	
ABORT	3X	FIXED 18X	ALT 21X	N POLE 23X	
MAX THROT	4X	SSME REPOS 19 XXX		S POLE 24X	
PROPLT DUMP		IMU STAT	ATT DES	PRL	
XXX ICNCT	5 XXXX	1S XXXX	X 25X	SYS AUT DES	
OVS DUMP		2S XXXX	XXX 26X	1S 28X 31X	
ARM	6X	3S XXXX	27X	2S 29X 32X	
START	7X			3S 30X 33X	
STOP	8X	ADTA	H	a	M DES
9 QUAN:SIDE	X1X	L 1S	XXXXXX	=XX X	X XX 34X
OVS DUMP	1TG XXX	3S	XXXXXX	=XX X	X XX 35X
		R 2S	XXXXXX	=XX X	X XX 36X
		4S	XXXXXX	=XX X	X XX 37X
AFT RCS 13	XXX	ET SEP		ROLL MODE	XXXXXXX
14 TIME	ΔΔΔ	AUTO	38X	AUTO SEL	42X
FWD RCS 15	XXX	SEP	39X	VENT DOOR CNTL	
16 TIME	ΔΔΔ	ET UMB DR		OPEN	43X
		CLOSE	40X	CLOSE	44X
		RCS RM MANF			
		CL OVRD	41		
					(XX)

Figure 1-8. OVERRIDE display (SPEC 51)

## Software Major Modes

The space shuttle is controlled by five computers that are usually referred to as General Purpose Computers (GPCs). The flight software in the computers is divided into several sections. Each section is called an Operational Sequence (OPS) and is tailored to a particular flight phase. For example, OPS 1 is software used during the ascent phase and OPS 3 is used for entry.

Each operational sequence is subdivided into Major Modes (MMs), which are used to denote incremental changes in flight phases. For instance, MM102 designates ascent flight between lift-off and SRB SEP. Immediately after SRB SEP occurs, MM103 is initiated. Table 1-1 lists the major modes relevant to ATO, AOA, and TAL aborts.

*Table 1-1. Major modes relevant to ATO, AOA, and TAL*

Operational Sequence	Major Mode	Mission Phase		
		ATO	AOA	TAL
OPS 1 (Ascent)	101	Prelaunch (T-20 min to lift-off)	Same as ATO	Same as ATO
	102	First stage (lift-off to SRB SEP)	Same as ATO	Same as ATO
	103	Second stage (SRB SEP to ET SEP)	Same as ATO	Same as ATO
	104	OMS-1 maneuver	Same as ATO	Transition coast
	105	OMS-2 maneuver	Transition coast	
	106	Post OMS-2 coast		
OPS 3 (Entry)	301		Pre-deorbit coast	
	302		Deorbit maneuver	
	303		Post-deorbit coast	
	304		Entry (early phase)	Same as AOA
	305		Entry (TAEM, A/L)	Same as AOA



## Questions

Answers to these questions are found in Appendix B.

1. What is the difference between a standard insertion and a direct insertion?
2. A MECO velocity that is less than the target velocity is called a(n) \_\_\_\_\_.
3. List the four types of intact aborts.
4. What is the typical orbital altitude for an ATO?
5. What are the consequences of an AOA-shallow?
6. Describe the primary and backup means of selecting an ATO or TAL.

## **Section 2**

### **Abort Mode Boundaries**

#### **Objectives**

Upon completing this section, the student should be able to:

- List the three types of abort mode boundary cues
- Define the seven boundary calls made to the crew by the MCC
- Determine the abort capability in a no-comm situation
- Define what the RTLS and GO tick marks represent on the ASCENT TRAJ display
- Determine which cue card to use and what abort is required for various system failures that occur pre-MECO
- Determine which cue card to use in the case of a MECO underspeed
- Determine which cue card to use in the case of various system failures that occur post-MECO

#### **Pre-MECO Performance Aborts**

During powered flight, it is important to know which abort modes are available in the event of an engine failure. There are three ways that the crew can determine abort capability:

- Voice calls to the orbiter from the Mission Control Center (MCC)
- Inertial velocity boundaries listed on a cue card
- Onboard trajectory displays

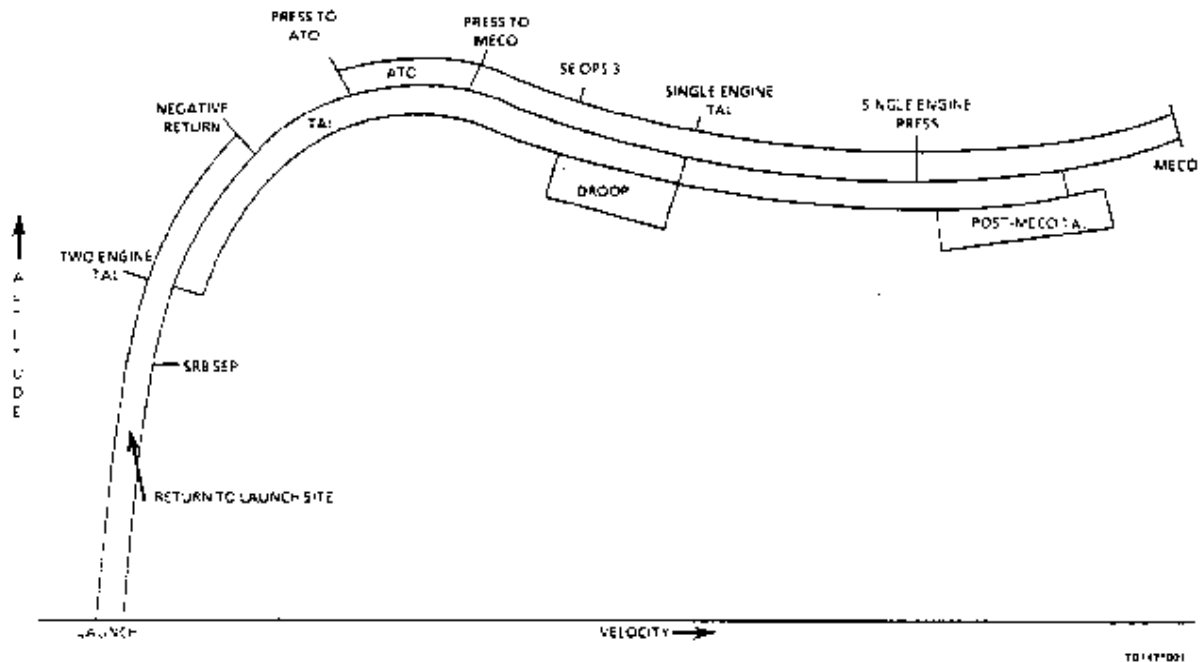
## Voice Calls

The primary indication of abort availability is the MCC voice calls. These calls essentially represent abort mode boundaries and vary from one flight to another, depending on the vehicle weight, predicted engine performance, and mission requirements. For example, high inclination flights will require different TAL sites than low inclination flights. Typically, the calls will include the following:

1. **TWO-ENGINE (PRIME TAL)** - The earliest inertial velocity ( $V_I$ ) or time a TAL can be accomplished to the primary TAL site if one main engine fails.
2. **NEGATIVE RETURN** - The latest  $V_I$  or time an RTLS abort can be successfully completed. Past this  $V_I$ , the orbiter will have too much downrange energy to successfully return to KSC.
3. **PRESS TO ATO** - The earliest  $V_I$  or time at least an AOA can be accomplished if one main engine fails and drop the ET in a safe area. Note: a pre-MECO OMS propellant dump is required.
4. **SINGLE ENGINE OPS 3 (TAL SITE) 109** - The first point after which, for two-engine procedures, the crew will abort downrange using OPS 3 (Droop procedure) software. Prior to this point, the loss of two engines requires a contingency abort using OPS 6 software.
5. **PRESS TO MECO** - The earliest  $V_I$  or time at least an AOA can be accomplished if one main engine fails. No pre-MECO abort selection is required.
6. **SINGLE-ENGINE (PRIME TAL)** - The earliest  $V_I$  or time a TAL can be accomplished to the primary TAL site if two main engines fail.
7. **SINGLE-ENGINE PRESS** - The earliest  $V_I$  or time at least an AOA can be accomplished if two main engines fail; however, no protection is made for ET impact. A pre-MECO abort selection is not required.

Figure 2-1 illustrates the approximate time the voice calls are made as a function of velocity and altitude.

- These abort regions overlap as follows:



*Figure 2-1. Abort calls as a function of velocity and altitude*

These boundaries can vary from prelaunch predictions because of changing atmospheric conditions and variations in SRB and main engine performance. Using this real-time information, a computer program called the Abort Region Determinator (ARD) allows MCC to predict what underspeed will result from a major loss of performance (engine failure, throttle lockup, degraded thrust, etc.). This information is then used to predict the actual abort mode boundaries on which the real-time voice calls are made.

## Inertial Velocity Boundaries

The preflight predicted abort boundaries are provided to the crew on a cue card in their overhead flipbooks that is shown in Figure 2-2. The cue card lists the boundaries and an inertial velocity in feet per second at which the abort mode is available. Inertial velocity can be monitored on tape meters on panels F6 and F8. The cue card is used by the crew to determine abort mode availability if voice communication with the ground is lost.

SYS FLIGHT RULES		RTLS	TAL
OMS - 2 He TKs			X
- 1 OX & 1 FU TKs (diff pods)			X
- 2 OX or 2 FU TKs			X
APU/HYD - 2 ↓ & 1 failing		X	X
CABIN LEAK - (-EO dP/dT > .15)		X	X
CRYO - All O2(H2)		X	X
2 FREON LOOPS ↓ (Accum Qty ↓ and decr) and/or Flow ↓)		X	X
2 MAIN BUSES ↓		X	
THERMAL WINDOW PANE		X	
NO COMM MODE BOUNDARIES			
NEG RETURN (104)	8200	2 ENG ZZA (104)	5600
PRESS TO ATO (104)	9100	ABORT TAL ZZA (4)	
SE OPS 3 ZZA (109)	11600	EO VI	<input type="text"/>
SE ZZA (104)	13200	SE OPS 3 ZZA (109)(13)	<input type="text"/>
		SE ZZA (104) (4)	<input type="text"/>
PRESS TO MECO (104)	13200	2 ENG MRN (104)	5500
SE PRESS (104)	17200	ABORT TAL MRN (3)	
NEG BEN (104)	17900	EO VI	<input type="text"/>
NEG MRN (104)	20400	SE OPS 3 MRN (109)(12)	<input type="text"/>
		SE MRN (104) (3)	<input type="text"/>
LAST PRE MECO TAL	23000	2 ENG BEN (104)	5500
LAST TAL		ABORT TAL BEN (2)	
FFA	24200	EO VI	<input type="text"/>
KBC	24400	SE OPS 3 BEN (109)(11)	<input type="text"/>
ESN	24900	SE BEN (104) (2)	<input type="text"/>
KKLZZA	25000		
JDG	25200		

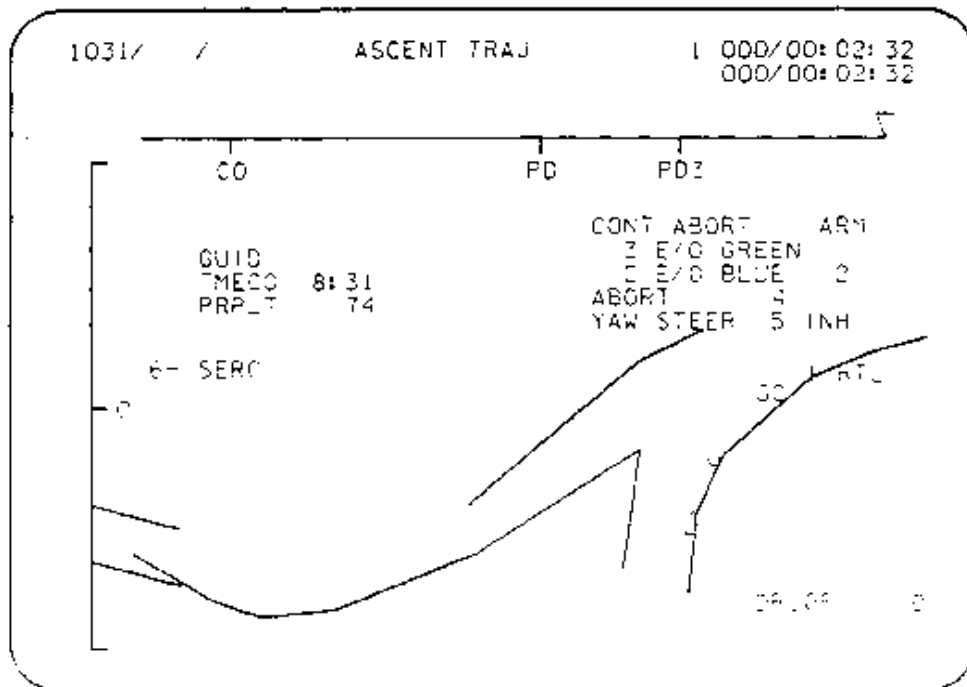
Figure 2-2. Predetermined abort boundaries given in terms of inertial velocity

The boundaries that are listed in bold are, typically, the ones voiced to the crew by MCC. Even though three 2 ENG (TAL) boundaries are given, only the flight day primary TAL site boundary is voiced to the crew. The boundaries that are not bold (i.e., NEG TAL site and LAST TAL site) give the crew the last inertial velocity at which the given TAL site can be reached. Past this  $V_t$ , the orbiter has too much downrange velocity to successfully reach the TAL site. The LAST PRE MECO TAL boundary is just as the name implies; it is the last opportunity to initiate a pre-MECO TAL abort.

This cue card does not reflect off-nominal performance, such as a stuck throttle. Only the ARD can calculate abort mode boundaries in real time, based on actual performance.

## Trajectory Display Boundaries

Another secondary indication of abort capability is the tick marks on the ascent trajectory displays shown on Figure 2-3. On the display, RTLS indicates the last point at which an RTLS abort should be selected. This tick mark usually corresponds to the Negative Return call from MCC. GO indicates the earliest point at which a main engine could fail and at least an AOA could still be accomplished. The GO tick mark usually corresponds to the Press to ATO call from MCC, or the Press to MECO call if there is no Press to ATO boundary on that flight. These tick marks are based on preflight analysis and may vary from the MCC voice calls.



T0:471273:091:1

Figure 2-3. ASCENT TRAJ display

## Pre-MECO Systems Aborts

The SYS FLIGHT RULES cue card (Figure 2-4) provides the crew with abort selection for critical systems failures that occur pre-MECO. In most cases, additional insight provided by MCC is necessary to accurately and fully diagnose a failure and select the best response. For loss of communication, however, only this cue card is available. Again, if both RTLS and TAL abort options are available, an RTLS abort will be selected if the vehicle has not exceeded the Negative Return boundary velocity.

SYS FLIGHT RULES		RTLS	TAL
OMS - 2 He TKs			X
- 1 OX & 1 FU TKs (diff pods)			X
- 2 OX or 2 FU TKs			X
APU/HYD - 2 ↓ & 1 failing		X	X
CABIN LEAK - (-EQ dP/dT > .15)		X	X
CRYO - A1 D2/H2		X	X
2 FREON LOOPS ↓ [Accum Qty (↓ and decr) and/or Flow (↓)]		X	X
2 MAIN BUSES ↓		X	
THERMAL WINDOW PANE		X	
NO COMM MODE BOUNDARIES			
NEG RETURN (104)	8200	2 ENG ZZA (104)	5600
PRESS TO ATO (104)	9100	ABORT TAL ZZA (4)	
SE OPS 3 ZZA (109)	11600	EO VI	<input type="checkbox"/>
SE ZZA (104)	13200	SE OPS 3 ZZA (109)(13)	<input type="checkbox"/>
		SE ZZA (104) (4)	<input type="checkbox"/>
PRESS TO MECO (104)	13200	2 ENG MRN (104) 5500	
SE PRESS (104)	17200	ABORT TAL MRN (3)	
NEG BEN (104)	17900	EO VI	<input type="checkbox"/>
NEG MRN (104)	20400	SE OPS 3 MRN (109)(12)	<input type="checkbox"/>
LAST PRE MECO TAL	23000	SE MRN (104) (3)	<input type="checkbox"/>
LAST TAL		2 ENG BEN (104) 5500	
FFA	24200	ABORT TAL BEN (2)	
KBO	24400	EO VI	<input type="checkbox"/>
ESN	24900	SE OPS 3 BEN (109)(11)	<input type="checkbox"/>
KKZZA	25000	SE BEN (104) (2)	<input type="checkbox"/>
JDG	25200		

Figure 2-4. SYS FLIGHT RULES cue card



### **OMS Capability**

A severe loss of OMS capability can make it impossible to continue uphill and deorbit. For example, loss of two propellant tanks results in insufficient propellant to get to orbit; therefore, a TAL is required.

### **APU/HYD**

With two APU/HYDs down and the third failing, a trajectory option with minimum time to the ground is desired. This enhances the potential to land prior to a complete loss of hydraulics.

### **Cabin Leak**

Loss of cabin pressure integrity impacts both breathing oxygen and equipment cooling. A minimum time to the ground option is required.

### **Cryo**

Loss of cryo O<sub>2</sub> and H<sub>2</sub> results in a loss of fuel cells and all electrical power. An RTLS or TAL is required.

### **Freon Loops**

Losing both Freon loops eventually results in loss of all three fuel cells because of a lack of cooling. Since this is time critical, RTLS is preferable over TAL.

### **Main Buses**

Two main bus failures preclude ET door closure. Since TAL entry trajectories are thermally severe, RTLS is preferred. If RTLS is no longer possible, pressing uphill is preferable to TAL.

### **Thermal Window Pane**

Heating during nominal TAL entries is severe. With a thermal window pane failure, RTLS is preferable because of its more benign heating characteristics.

## Post-MECO Performance Abort Boundaries

After MECO, a computer program called the Abort Maneuver Evaluator (AME) is used by MCC to determine what abort options are currently available. And, it also provides recommendations for the selection of a nominal, ATO, AOA, or AOA-shallow target for OMS-1 and OMS-2 maneuvers.

The crew also has insight into post-MECO abort options on their OMS 1/2 TGTING cue card, which is used for MECO underspeed cases. Figure 2-5 is an example of a direct insertion cue card. The card is based on preflight data and may vary from the AME.

The abort boundaries are given as a function of the current energy state (height of apogee (HA) plus height of perigee (HP)) and the percent of OMS propellant remaining. The smaller the value of HA + HP, the larger the underspeed. Depending on the magnitude of the underspeed, the cue card tells the crew what abort or OMS-1/OMS-2 targets are required. For example, if the MECO conditions fall between the two bold vertical lines, no OMS-1 burn is required, and a PEG 7 OMS-2 burn is performed 1 minute before apogee (TTA=1).

If the MECO conditions fall to the left of the bold vertical line, abort targets for OMS-1 and OMS-2 will be used. For example, ATO/MIN HP (85 NM) means that an ATO target will be used for OMS-1 and a target that raises HP to 85 n. mi. will be used for OMS-2. Above the target names, there are circled numbers indicating the target ID number that can be used to enter the targets with an Item 35 entry on the Maneuver display. This item entry will automatically bring up the abort target selected. However, the targets will still need to be loaded with an Item 22.

The only abort given on this card that does not require an OMS burn is a post-MECO TAL, which may be required for severely large underspeeds.

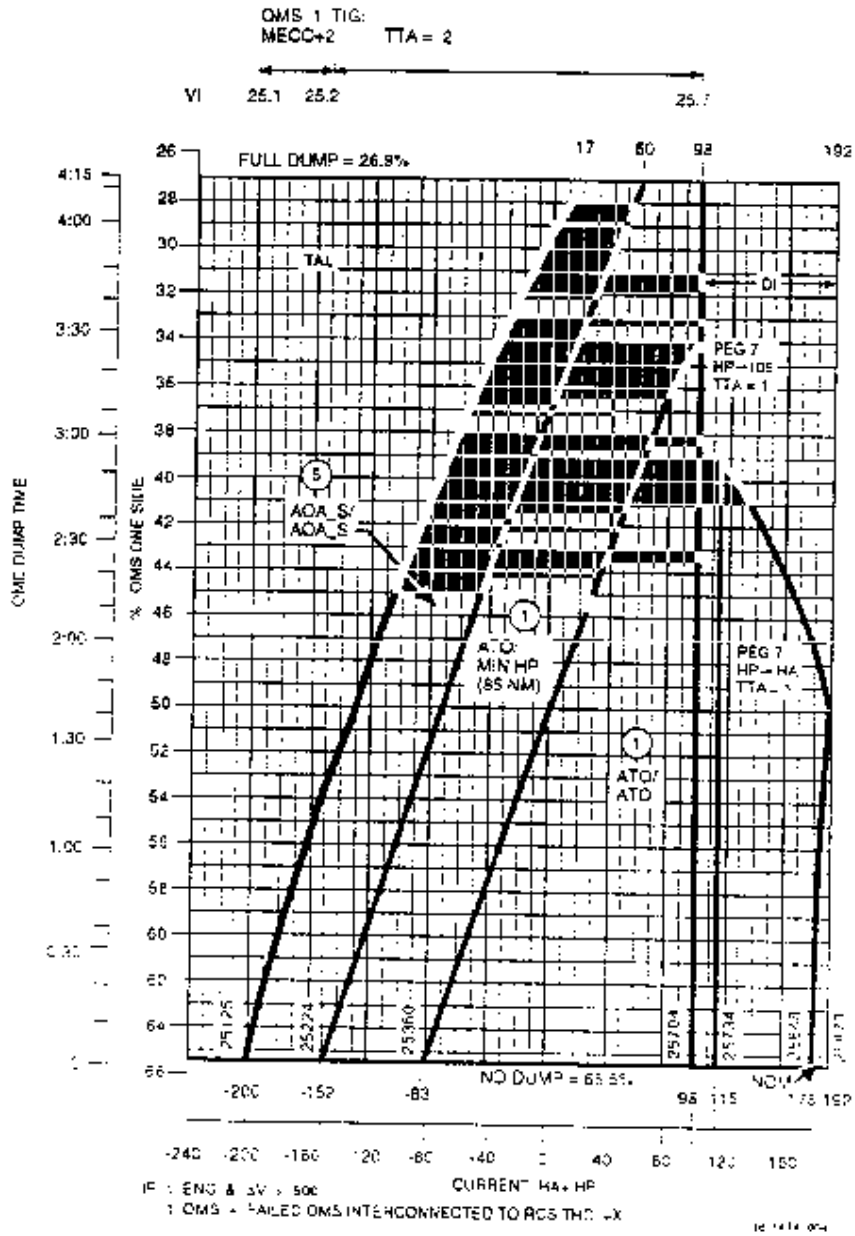


Figure 2-5. OMS 1/2 TGTING cue card

## Post-MECO Systems Aborts

Another cue card that provides the crew with abort options is the OMS 2 TARGETING cue card (Figure 2-6). This cue card is used for critical systems failures or OMS failures that occur before the OMS-2 burn. For the given systems failures, the capability to continue the mission or to reach the desired orbit has been lost; therefore, an abort is required.

In the case of a MECO underspeed and a systems failure, the worst case abort is performed. For example, if there is a MECO underspeed that requires an ATO, and there is a post-MECO cabin leak that requires AOA, then the AOA is performed.

### OMS 2 TARGETING (DIR INSERTION)

FAILURE	OMS 2 TARGET
OMS - 2 N2 TKs (Perform burn Single OMS Eng)	NOM
OMS - 1 PRFLT TK - 2 OMS ENGS - 1 or 2 He TKs EPS - MNA & B, MNB & C MNA & C ET SEP	PEG 7: T1A = 1 CUTOFF HP = 85
OMS - 2 OX or 2 FU TKs - 1 OX & 1 FU TK diff PODs	AOA-S
2 FREON LOOPS 2 H2O LOOPS CABIN LEAK (-EQ dP/dt: > .08)	AOA
APU/HYD - 2, & 1 failing	AOA
CRYO - ALL O2(H2)	AOA

### OMS

He	%	He	%
N/A	90	3270	50
N/A	80	2970	40
N/A	70	2670	30
3800	65.7	2390	20
3570	60	2100	10

MS147A\_000

Figure 2-6. OMS 2 TARGETING cue card

## Questions

Answers to these questions are found in Appendix B.

1. During powered flight, what three types of cues are normally available to provide the crew with information about abort mode boundaries?
2. Define the following MCC voice calls:
  - a. Two-Engine TAL
  - b. Negative Return
  - c. Press to ATO
  - d. Single-Engine OPS 3
  - e. Press to MECO
  - f. Single-Engine TAL
  - g. Single-Engine Press
3. Define the following boundaries listed on the NO COMM MODE BOUNDARIES cue card:
  - a. NEG TAL
  - b. LAST PRE MECO TAL
  - c. LAST TAL
4. What do the tick marks RTLS and GO represent on the TRAJ display?
5. List three systems failures that require an abort pre-MECO.
6. What is the OMS 1/2 TGTING cue card used for?
7. What is the OMS 2 TARGETING cue card used for?

## Section 3

# ATO/AOA Powered Flight Phase

### Objectives

Upon completing this section, the student should be able to:

- Name three software functions that can aid ascent performance and are consequences of ATO selection during powered flight
- Describe the difference between a nominal MECO target and an ATO MECO target
- Describe the benefit of abort shaping
- Given certain initial conditions, determine the resulting inclination due to variable IV steering
- List three reasons for performing an abort OMS dump during powered flight
- Describe the ATO OMS dump configuration
- Describe how to manually stop an ATO OMS dump
- Describe how to initiate an ATO pre-MECO

### ATO and AOA Abort Options

The implementation of the ATO and AOA abort options is highly dependent on specific flight planning. The payload weight, orbital inclination, orbital altitude, and propellant loading all have their effects on the performance capabilities and requirements for a flight. The flight software is designed to accommodate the varying mission requirements for guidance, navigation, and flight control.

One way this accommodation is made is by defining parameters that can be changed for specific flights. These variables are called initialization loads, or I-loads. Many of the ascent guidance parameters, including the MECO target, are examples of I-loads. Some software functions can be inhibited for a given flight by setting certain I-loads equal to zero. It is important to remember that not all of the capabilities designed into the software are used for all flights. Therefore, ATO selection does not always affect ascent guidance. Initiation of an ATO is only required for flights in which OMS propellant must be dumped pre-MECO to decrease overall vehicle weight, which in turn increases performance. This sequence is required in order to prevent disposing of the ET in populated areas.

A pre-MECO ATO can be selected for performance problems or critical systems failures. An AOA cannot be selected pre-MECO, but if it is known pre-MECO that an AOA is required, an ATO may be selected with a subsequent post-MECO downmode to AOA.

For systems failures, continuous ATO/AOA capability exists from lift-off to a short time (mission dependent) before OMS-2 ignition. However, for an abort situation other than performance problems, the crew does not select an ATO/AOA abort until post-MECO. There is nothing to be gained by selecting the abort pre-MECO.

Therefore, an ATO is usually initiated pre-MECO for a main engine failure or a known performance problem. If an ATO is selected, guidance may perform one or more of the following functions as well as the functions performed during a nominal ascent:

1. Select ATO MECO targets
2. Initiate variable IY steering
3. Initiate abort dump sequence

To achieve ATO capability for early SSME failures, a more favorable MECO target may be used. Also, to achieve earliest abort capability, a variable IY steering option is available, which changes the orbital plane target (unit vector normal to the orbital plane) at MECO from the nominal ascent value to a current, in-plane performance-optimum value for an ATO. In addition, the available OMS propellant may be burned pre-MECO, leaving only enough propellant for limited on-orbit and deorbit usage.

## **ATO MECO Targeting**

The ATO MECO target selection software determines whether the nominal or ATO MECO target will be used by the ascent second-stage guidance in the event of an ATO.

An ATO MECO target set is an I-loaded target, consisting of a velocity magnitude, radius magnitude, and flightpath angle. The current philosophy is to set the ATO I-loaded targets at the same values as the nominal MECO I-loads. The ATO OMS-1 and OMS-2 targets generate the ATO orbit, which typically is lower than the nominal orbit.

If an ATO has been requested, the software must decide whether the guidance should remain targeted for nominal MECO or be retargeted for the ATO MECO. The decision is based on the velocity when the main engine fails.

There is a maximum I-loaded velocity, called the ATO switch velocity, at which the ATO MECO target will no longer be used. If the velocity at engine fail is less than this switch velocity, guidance will be targeted for the ATO MECO. The nominal MECO target will be maintained if the velocity at engine fail is greater than or equal to the switch velocity. Currently, switch velocity is typically set well past nominal MECO velocity, so the ATO targets are always used.

## Variable IY Steering

Variable IY steering is another abort function that is intended to reduce performance requirements and to achieve earliest abort capability. This reduced performance is achieved by changing the orbital plane target at MECO from the nominal ascent value to a current, in-plane performance-optimum value for an ATO (Figure 3-1). By changing the orbital plane, the vehicle thrust is all in-plane, which optimizes fuel usage and performance. This function is used for orbit inclinations greater than  $28^\circ$ , where out-of-plane steering is done to achieve the required higher inclination and may also be used for  $28^\circ$  missions that use variable steering for ground-up rendezvous.

IY refers to a unit vector perpendicular to the desired orbital plane that implicitly specifies the inclination and node constraints. The most efficient way to launch a space vehicle is due east into an orbit with an inclination equal to the latitude of the launch site ( $28.5^\circ$  for KSC). However, that will not always be the inclination that is desired for a mission. To achieve an orbit with a different inclination, the vehicle must gradually steer its velocity vector toward the desired orbital plane.

If an ATO abort is declared and the variable IY steering option is selected, guidance changes the nominal IY target to the current in-plane value. In other words, no more steering is done so that downrange velocity can be gained as efficiently as possible. However, if the orbit inclination at the time of the abort is less than the minimum acceptable inclination that is defined pre-mission, then the IY target is set equal to a minimum IY value. This means that out-of-plane steering continues until this minimum inclination is reached.

Also, if the velocity at the time of the abort is greater than or equal to a premission stored mission continuation velocity criterion, the variable IY flag is set to OFF so that the nominal IY target is maintained, allowing mission continuation.

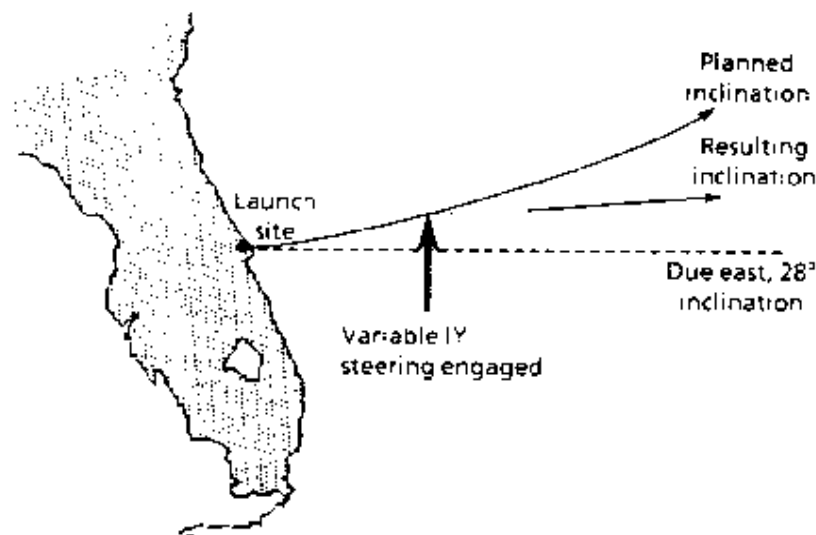


Figure 3-1. Result of variable IY steering

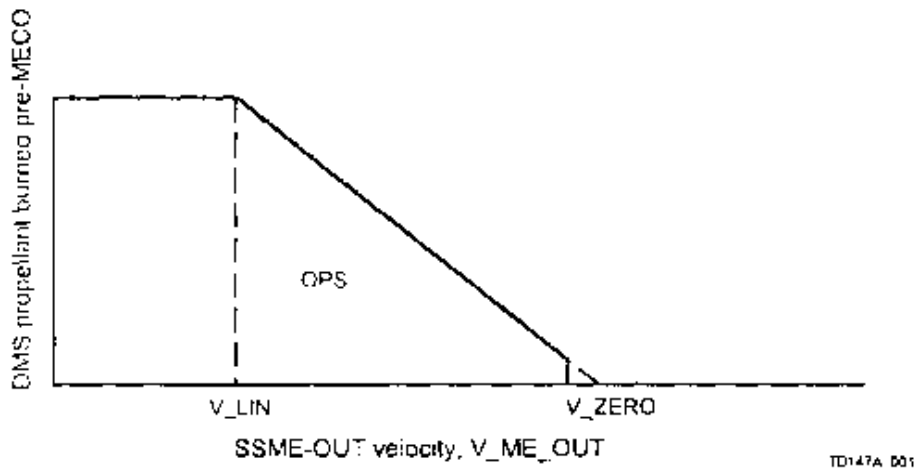


## Pre-MECO OMS Dump

The pre-MECO OMS dump initiates immediately upon ATO selection and terminates based on either a constant or ramp dump timer. There are three reasons for performing a dump: (1) to control the Center of Gravity (c.g.) of the vehicle, (2) to reduce overall weight for landing, and (3) to reduce overall weight in order to improve performance in powered flight. Since excess propellant can be burned during the deorbit burn to control the c.g. and reduce landing weight, the primary reason for a pre-MECO OMS dump is to increase uphill performance.

The dump is controlled by the abort control sequence as is the case for all dumps. The ATO dump configuration is flight specific and changes from flight to flight. As mentioned previously, the dump may be fixed in duration, variable, or a combination of the two. The software actually calculates the OMS dump time as a function of the main engine-out velocity.

Figure 3-2 shows an example of a typical ATO dump. As shown, for early ATO aborts (engine-out velocity less than or equal to a premission stored velocity), a constant burn duration sequence is performed. The OMS propellant burn time is decreased linearly as the engine-out velocity increases in an effort to conserve OMS propellant for on-orbit usage. If an ATO is selected with three main engines running, the OMS dump time is based on the vehicle's velocity at ATO abort deceleration (i.e., when the abort pushbutton is pushed).



*Figure 3-2. OMS burn duration scaling for ATO dump*

The dump is accomplished using the two OMS engines. If OMS propellant loading quantities require a higher burn rate than available through the OMS engines, an OMS/RCS interconnect is performed, and the 24 aft RCS jets can assist the dump. Interconnecting with the RCS jets is determined by an I-load specific for the ATO abort dump.

The ATO dump is based on a timer. At abort selection, the appropriate I-loads set the timer and determine whether an interconnect is to be executed. The dump through the OMS engines will occur almost immediately. If interconnected, the RCS jets begin to fire 3 seconds after the OMS engines fire.

The interconnected dump will normally select 24 RCS jets for the dump. However, if smart interconnect has detected a problem in configuring for the dump, 10 RCS jets or no jets may be selected. Smart interconnect is a software sequence that confirms the valve positions to ensure OMS propellant reaches the RCS jets. The RCS crossfeeds, RCS tank isols, OMS B crossfeeds, and jet availability are checked in that order. If one RCS leg is unavailable because of any of the above valve failures, that leg is unavailable on both pods to allow symmetric dumps. The affected manifolds are returned to feed from the RCS tanks, and the resulting OMS propellant burn rate is adjusted accordingly to provide an accurate value of propellant burned. Additionally, the interconnected dump is limited to just 10 jets if any one leg is unavailable. This is done to prevent unwanted pitching moments from asymmetrical jet firings. After the necessary burn has been accomplished, all propellant feed paths are returned to the normal configuration.

SPEC 51 is the crew interface to the abort dump software (Figure 3-3). This display shows the dump timer actively counting down as the dump is in progress (OMS DUMP TTG). The status of the interconnect is also shown and may be toggled from Enable (ENA) to Inhibit (INH) and vice versa while the dump is in progress with an ITEM 5 EXEC. Items 6 through 8 enable the crew to manually start and stop a SPEC 51 dump.

Whether interconnected or not, the dump continues until the expiration of the timer, as displayed on SPEC 51. As a precaution, the dump stops at MECO regardless of the time remaining. The crew is also provided with a cue card that gives the dump time for interconnected and non-interconnected dumps (Figure 3-4).

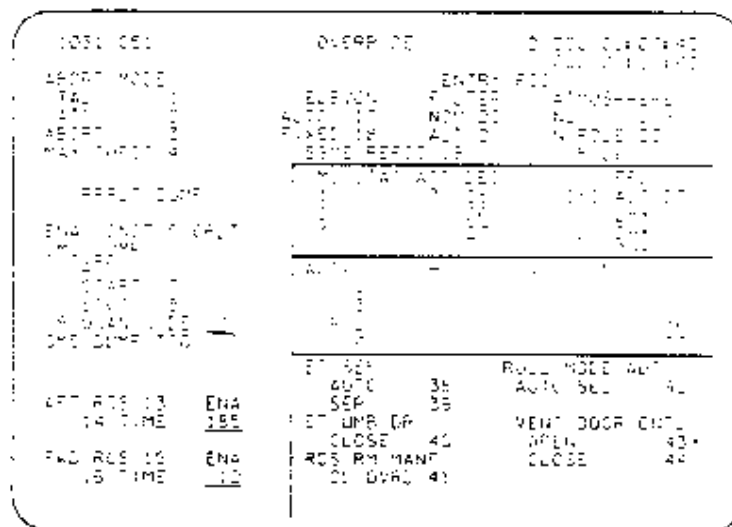
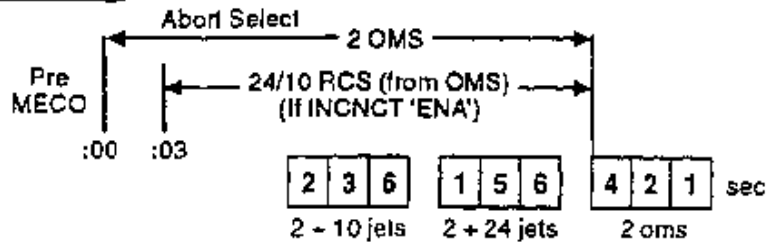


Figure 3-3. Crew interface to dump software on OVERRIDE display (SPEC 51)

# ATO/G51 DUMPS

## ATO\_DUMP



## G51\_DUMP

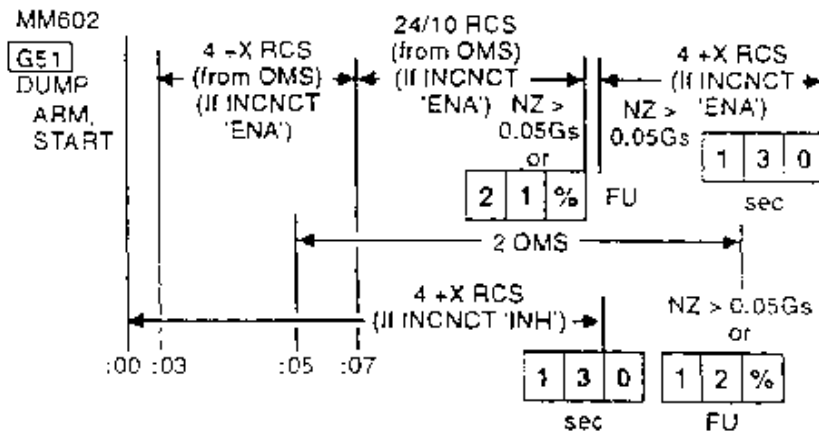
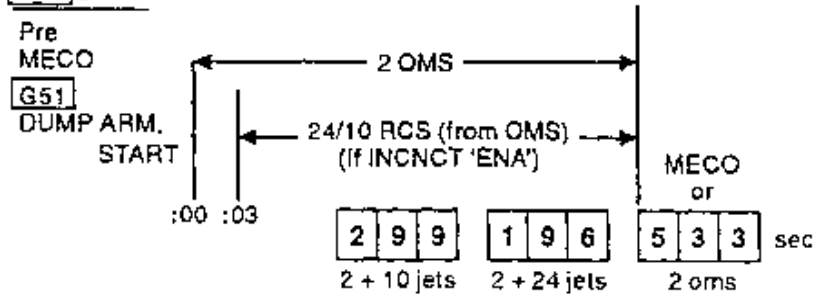


Figure 3-4. Dump cue card

## ATO Pre-MECO Abort Selection

The crew can request an ATO by setting the abort mode rotary switch to the ATO position and pressing the abort pushbutton or by item entries on the OVERRIDE display (SPEC 51) shown in Figure 3-5. Item 2 EXEC followed by Item 3 EXEC allows an ATO abort in MM102, MM103, and MM104. If an ATO is selected during MM102, guidance selects ATO targeting upon transition to MM103. ATO targeting is scheduled immediately if an ATO is selected during MM103.

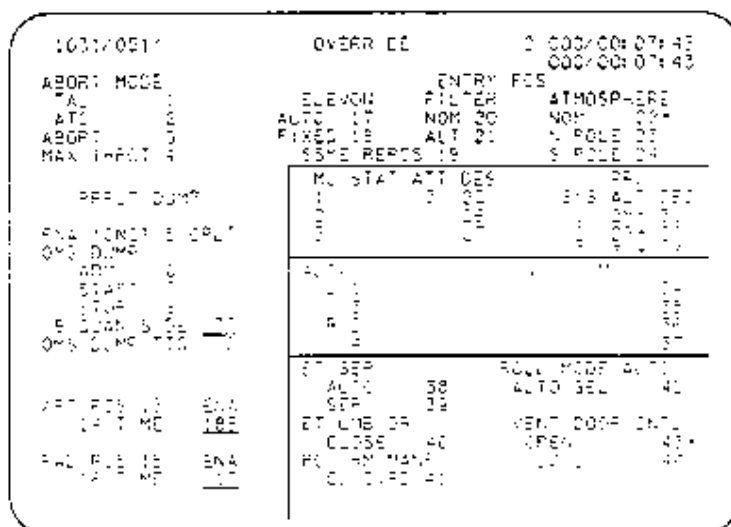


Figure 3-5. Abort selection on OVERRIDE display (SPEC 51)

## Questions

Answers to these questions are found in Appendix B.

1. Name three software functions that can aid ascent performance and are consequences of ATO selection during powered flight.
2. What would you expect to be the major difference between the nominal MECO target and the ATO MECO target?
3. If the planned inclination for your flight is  $57^\circ$ , and the I-loaded minimum inclination is  $32^\circ$ , what inclination results if an ATO is selected because a main engine has failed at one of the following points?
  - a. Very early, when the current IY vector represents an inclination of  $28^\circ$ .
  - b. Later, when the current IY vector represents an inclination of  $40^\circ$ .
  - c. Near MECO, when the current IY vector represents an inclination of  $57^\circ$ .
4. List three reasons for performing an abort OMS dump during powered flight.
5. What normally stops an ATO OMS dump, a software timer or a quantity limit?
6. During an ATO OMS dump:
  - a. Is OMS propellant ever dumped through RCS jets?
  - b. Are OMS engines and RCS jets ever burning at the same time?
7. What is the simplest way to manually stop an ATO dump?
8. Describe how to select an ATO before MECO.
9. If the abort rotary switch does not work, how do you select an ATO before MECO?

# Section 4

## ATO/AOA Post-MECO Actions

### Objectives

Upon completing this section, the student should be able to:

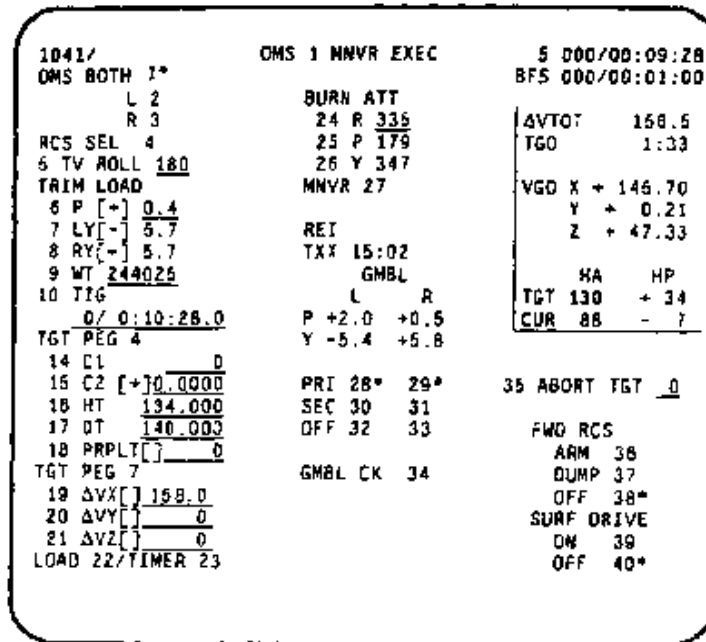
- Identify the cue card used for MECO underspeed situations
- Identify the most important parameters on the Maneuver (MNVR) display that are used in determining the target for an underspeed situation
- Given an underspeed scenario, determine the abort target required
- Describe the three OMS-1 burn target options on a direct insertion mission
- Describe the OMS-2 burn target options on a direct insertion mission

### Maneuver Display

The display that appears automatically at the transition to MM104 is the MNVR display (Figure 4-1). Several of the items that apply to abort targeting are described below. For more information on the display, see the DPS Dictionary.

#### Display Title

The MNVR title can have a variety of prefixes and suffixes, depending on major mode and abort mode, as shown in figure 4-2. The ATO and AOA prefixes will appear whenever the respective abort is selected.



103\*5A\*0536

Figure 4-1. MNVR display

Major Mode	Title	Mission Phase
104	OMS 1 MNVR EXEC	Nominal OMS-1 burn
104	ATO 1 MNVR EXEC	ATO OMS-1 burn
104	AOA 1 MNVR EXEC	AOA OMS-1 burn
105	OMS 2 MNVR EXEC	Nominal OMS-2 burn
105	ATO 2 MNVR EXEC	ATO OMS-2 burn
105	AOA MNVR TRANS	AOA transition (no burn)
106	OMS 2 MNVR COAST	Nominal after OMS-2
106	ATO 2 MNVR COAST	ATO after OMS-2
301	DEORB MNVR COAST	AOA pre-deorbit burn
302	DEORB MNVR EXEC	AOA deorbit burn
303	DEORB MNVR COAST	AOA post-deorbit burn

Figure 4-2. Maneuver display titles

## TIG

TIG is the time of ignition for the burn. It is displayed as "days, hours, minutes, seconds" in Mission Elapsed Time (MET).

## Target Parameters

There are two types of targets used by guidance, Powered Explicit Guidance (PEG) 4 and PEG 7. PEG 4 targets are stored in the software and are displayed automatically when the target ID is selected. PEG 4 targets can only be used in OPS 1 and OPS 3, and these targets are used unless the specific abort requires a PEG 7 target. PEG 4 targets consists of the following individual parameters:

C1 and C2 determine the relationship of vertical and horizontal velocity at the target point. The equation used by guidance is  $V_{\text{vert}} = C2 \times V_{\text{hor}} + C1$ . For OMS maneuvers in OPS 1, the target point is always an apogee or perigee point where the vertical velocity is zero; therefore, C1 and C2 are zero. For the deorbit burn in OPS 3, the target point is known as Entry Interface (EI). At EI, the vehicle must have a vertical velocity equal to some negative value, and the relationship of vertical velocity to horizontal velocity must be carefully controlled to permit a safe entry. For the deorbit burn, C1 is a large positive number with units of ft/sec and C2 will be a dimensionless number between 0 and -1.

HT is the altitude at the target point above the surface of the Earth in nautical miles. For the deorbit burn, the target point is EI, which is defined as an altitude of 400,000 feet (65.8 n. mi.)

$\Theta T$  is defined differently in OPS 1 and 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 the point of ignition to the EI target point. Figure 4-3 depicts  $\Theta T$  in OPS 1 and OPS 3.

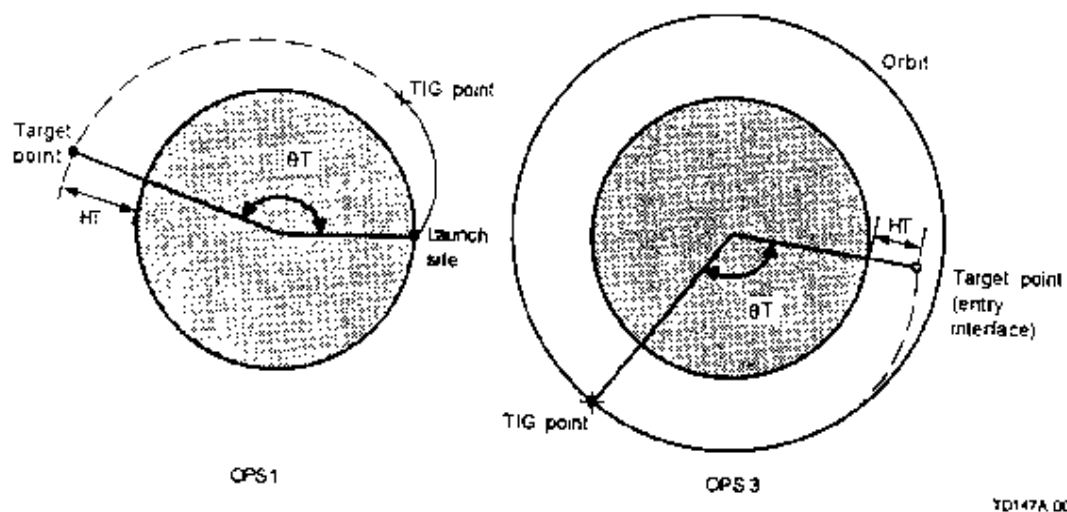


Figure 4-3. Definition of  $\Theta T$  in OPS 1 and OPS 3



PRPLT refers to propellant, and the value displayed is the total amount of OMS propellant in pounds that will be used for the OMS burn. This item entry is only supported in OPS 3. In some deorbit burns, it is desirable to burn excess propellant for e.g. control and weight reduction. Therefore, Item 18 is loaded with the number of pounds required for the burn plus the number of pounds to be wasted. When a zero is displayed for this item, only the amount of propellant required for the deorbit burn is used. If the value displayed is less than the amount required for the burn, there is no impact; the amount required is still used.

### **Load and Timer Items**

After a target is selected and displayed, it must also be loaded to determine a burn solution. A distinction should be made between "selecting" a target on the MNVR display and "loading" a target. Selecting a target is simply displaying the target parameters on the left side of the MNVR display. Loading a target causes guidance to calculate and display a burn solution on the right side of the MNVR display. Whenever an individual target parameter is changed, the target must be reloaded.

The targets for OMS-1 are loaded automatically, but in all other cases, the word LOAD flashes on the display, and an ITEM 22 EXEC is required to load the target. The word TIMER never flashes, but whenever a load entry is required, an ITEM 23 EXEC is also needed to start the Cathode-Ray Tube (CRT) timer, which counts down to TIG. The CRT timer is the second line from the top in the upper right corner of the display.

### **Burn Solution**

The burn solution includes  $\Delta VTOT$ , TGO, VGOX, VGOY, VGOZ, TGT HA, TGT HP (see acronyms list if necessary), the burn attitude (R, P, Y), and Range from Entry Interface (REI) to the landing site. These parameters are displayed when a target is loaded. When a target parameter is changed by item entry, the burn solution parameters goes blank until the new target is loaded.

Current (CUR) HA and CUR HP are the current apogee and perigee altitudes, they are displayed at all times. Below REI, there is a display field that in OPS 1 displays the Time to Apogee (TTA) or Time to Perigee (TTP), whichever is closer. If the difference between apogee and perigee is less than 5 n. mi., Time to Circularization (TCC) is displayed, and the time field is blanked. During OPS 3, Time of Free Fall (TFF) or time to EI is displayed.

### **Abort Target**

Item 35 is used to enter OMS targets using target ID numbers found in the checklist under OMS TGTS or on the OMS 1/2 TGTING cue card. This function is available only in OPS 1.

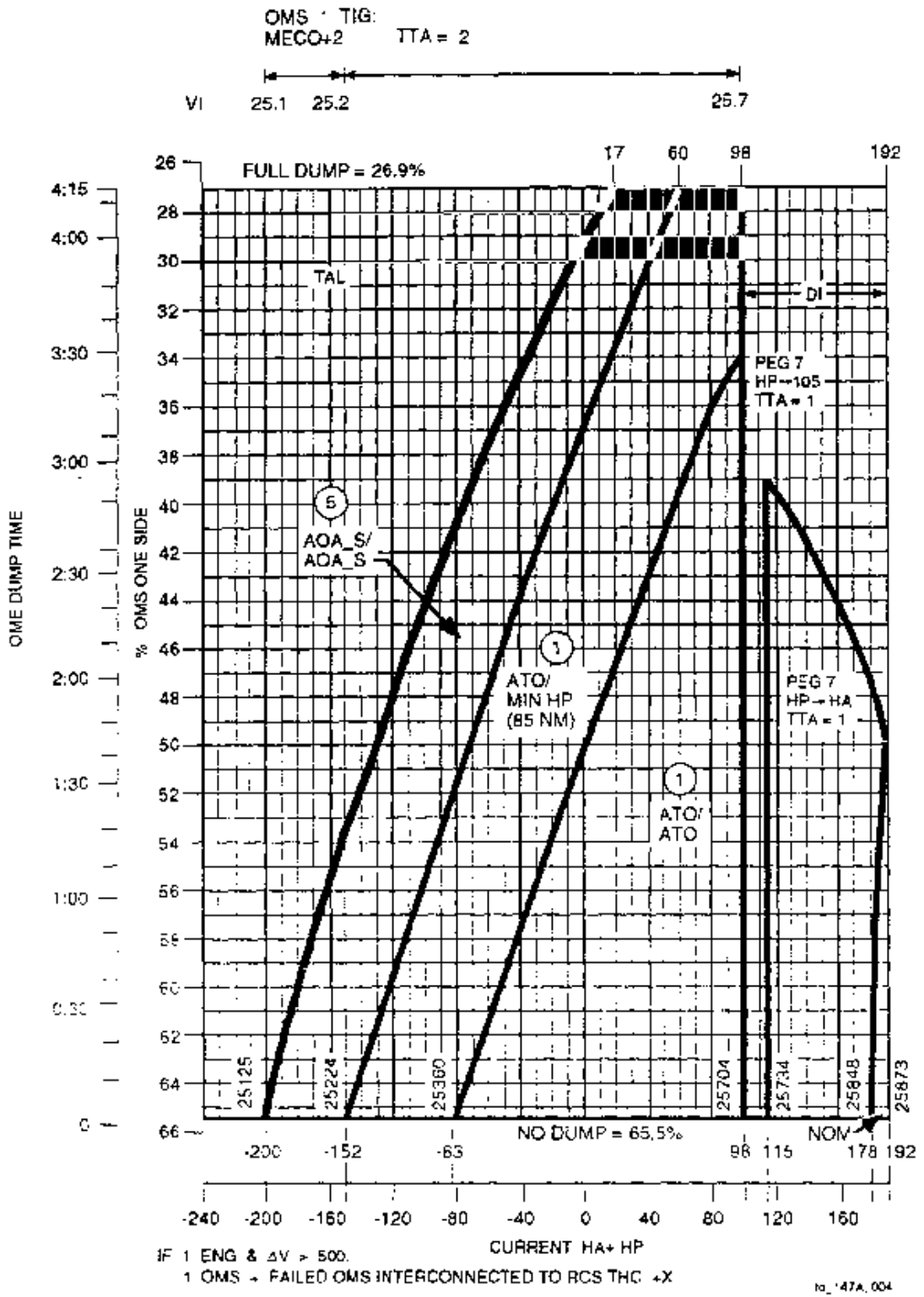
## Abort Mode Determination

Voice calls from MCC are the primary means of determining the proper abort mode. MCC uses the AME program to make this determination, based on the state vector and the OMS  $\Delta V$  available.

The crew can also determine the abort selection in the absence of a recommendation from MCC by using the OMS 1/2 TGTING cue card (Figure 4-4). The chart is designed to show abort mode boundaries as a function of the current HA and HP and the OMS propellant available. The following steps would be used to determine the required OMS targets, using the typical cue card shown:

1. Locate CUR HA and HP on the MNVR display and add the two numbers.
2. Note the ATO OMS dump time or the percent of OMS in one pod. Remember the ATO dump is ramped; therefore, the dump time depends on the time of SSME failure.
3. Find the intersecting point on the chart for CURRENT HA + HP and OMS dump time. The region where this point lies shows the abort targets required.
4. MECO VIs are shown on the chart as a cross-check for HA + HP. With extreme underspeeds, the HP display may be truncated.

If the point lies to the right of the bold vertical line (MECO HA = 95), no OMS-1 burn is required. If the point lies to the left of the bold vertical line, some type of OMS-1 abort target must be selected. In Figure 4-4, if the point lies to the left of the bold vertical line, either an ATO or AOA-shallow target is used for OMS-1. Each of these target sets are stored in the software and are identified by a target ID number that is the circled number located above the abort name. These target ID numbers are used to select the abort targets post-MECO.



*Figure 4-4. OMS 1/2 TGTING card*

## OMS Target Cue Cards

All of the available OMS targets are given on cue cards in the Ascent Checklist under OMS TGTS (Figure 4-5). Each card gives the specific values for TIG, C1, C2, HT,  $\Theta$ T, and REL. The card also provides a range for  $\Delta$ VTOT and a sign or a value for PRPLT. These cue cards can be used to verify targets and to follow the correct sequence of targets for OMS-1 (if applicable) and OMS-2. There are two cue cards provided in the checklist for each AOA site available. One card provides the OMS targets for direct insertion (no OMS-1 required), and one card provides the OMS targets if OMS-1 is required. For high inclination flights, there is usually only one set of cards, because NOR is typically the only AOA site available. For low inclination flights, three sets of cards are typically provided, one for KSC, one for EDW, and one for NOR.

## Target Selection

Any stored target set can be selected manually using the **ABORT TGT** item on the MNVR display. To select the targets, the crew performs an **ITEM 35 + (desired ID) EXEC**. The desired targets will appear on the MNVR display along with the new display title. If ATO was selected pre-MECO, then the ATO OMS-1 target set and ID will automatically appear after the MM104 transition. The crew can refer to the appropriate OMS TGTS cue card in the Ascent Checklist to verify the targets.

If the crew is not satisfied with the planned burn targets, based on their evaluation or on ground advice, they can select another target set by executing another **ABORT TGT** item entry. Individual target parameters can also be manually entered or changed by keyboard entries (Items 10 through 17 on the MNVR display). This method can be used for planned targets (those not stored in the software) by referring to the OMS TGTS cue card for the target parameters. This method can also be used for new targets by using numbers provided by MCC. In addition, MCC has the ability to uplink targets directly to the display.

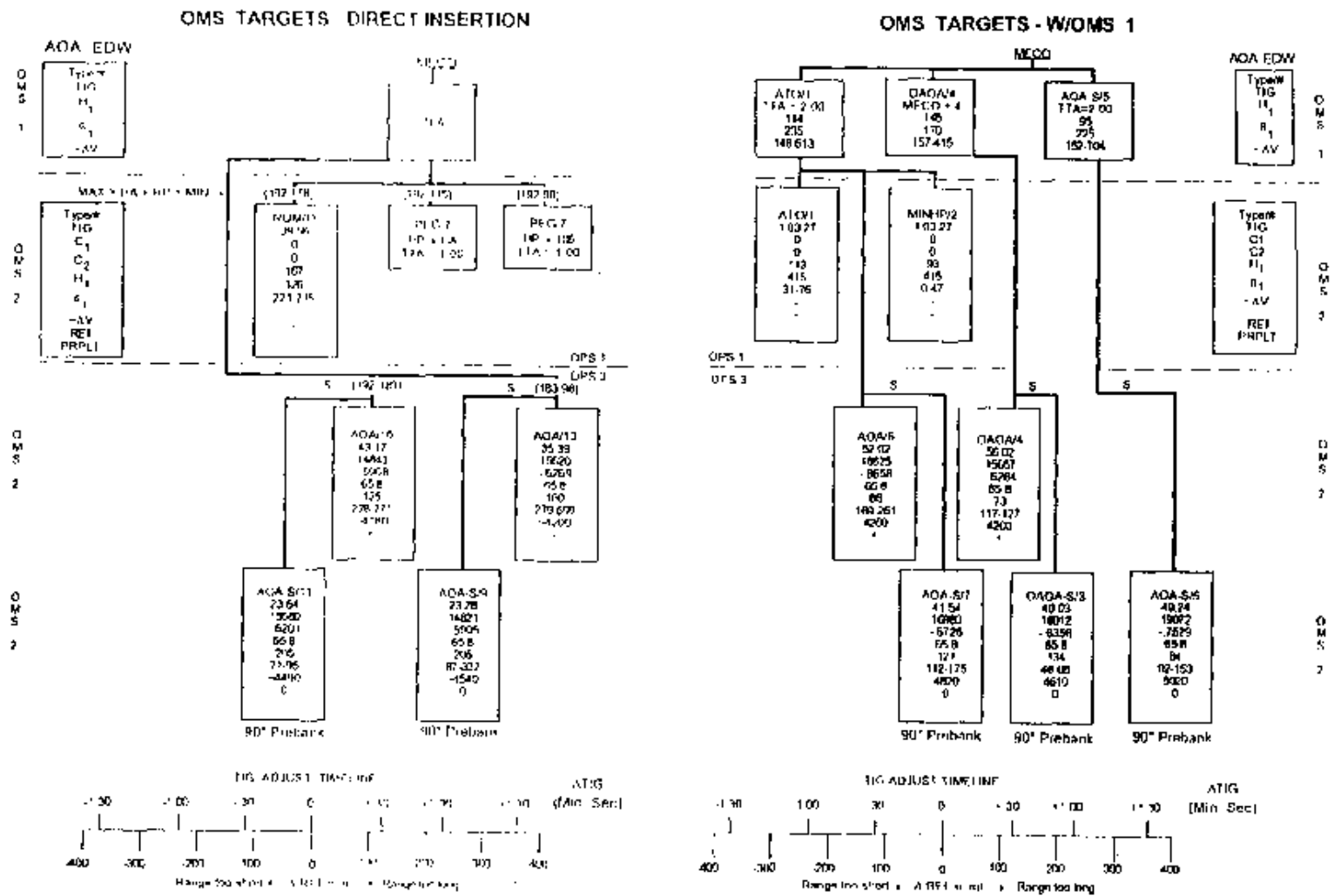


Figure 4-5. OMS target cue card

## OMS-1 Targeting Options

All flights since STS-30 have been direct insertion flights, therefore, our discussion of OMS-1 is in regard to aborts only.

On direct insertion flights, OMS-1 is required only for significant MECO underspeeds. The following are the OMS-1 target options

- ATO
- AOA
- AOA-shallow (AOA-S)

Not all of the target options will necessarily be available for all flights. Mission performance considerations and crew procedures will determine the specific set of target options for a particular flight.

The ATO and AOA-S targets are used for underspeed cases, depending on the magnitude of the underspeed

The stored targets are designed to provide the best possible performance for the most critical case in which the target is used. At the same time, the targets must result in a trajectory that preserves further downmode capability and maintains an orbital altitude that is high enough to avoid significant atmospheric drag.

Satisfying such a range of targeting requirements results in certain compromises. The orbit resulting from an ATO OMS-1 burn is designed to place the line of apsides in the best orientation for an AOA deorbit. Thus, OMS burn attitudes are not always horizontal in relation to the Earth's surface. The horizontal component of a burn increases the orbital altitude, but a radial component is necessary to shift the line of apsides. In some ATO cases, the radial component can be quite significant.

## OMS-2 Targeting Options

The following target options are available for the OMS-2 maneuver on a direct insertion mission.

- No OMS-1 burn required.
  - Nominal
  - PEG 7 HP→HA TTA=1
  - PEG 7 HP→105 TTA=1
  - AOA
  - AOA-S

- OMS-1 burn required (severe MECO underspeed):
  - ATO
  - MIN HP
  - AOA
  - AOA-S

Note that all AOA and AOA-shallow OMS-2 burns are performed in OPS 3. (On an AOA, the OMS-2 burn is the deorbit burn.)

The nominal OMS-2 targets are used following a nominal MECO (very slight MECO underspeeds are acceptable), and the targets will appear automatically on the MNVR display in MM105.

Slightly larger underspeeds may require a PEG 7 target in the X direction where the current perigee is raised to the same altitude as the current apogee or the current perigee is raised to an altitude of 105 n. mi.

For certain system failures that require immediate deorbit (identified on the OMS 2 TARGETING cue card, Figure 2-6), AOA or AOA-shallow targets are used for the OMS-2 burn

The OMS TARGETS-DIRECT INSERTION cue card (Figure 4-5) gives a flow diagram of the OMS-2 targeting options available when no OMS-1 is required. Remember not all of the target options are necessarily available for all flights.

The OMS TARGETS-W/O OMS 1 cue card (Figure 4-5) gives a similar flow diagram of the OMS-2 targeting options available following an OMS-1 burn. For example, if an ATO OMS-1 burn was performed, an ATO, MIN HP, AOA, or AOA-shallow OMS-2 burn can be performed. The ATO or MIN HP OMS-2 burn may be required for large MECO underspeed, and a down-mode to the AOA or AOA-shallow targets may be required for system failures that occur after the OMS-1 burn. For very large underspeeds, the AOA-shallow targets are used for the OMS-2 deorbit burn following an AOA-shallow OMS-1 burn

## ATO Procedures

The orbital insertion procedures for ATO are very similar to the nominal insertion procedures. After completing the OMS-2 burn, the shuttle will be in an orbit that is acceptable for several revolutions. In that time, a decision will be made either to increase the orbital altitude by means of OMS maneuvers and complete at least part of the mission or to deorbit on an early revolution.

There are special post insertion and deorbit preparation procedures for each of these possibilities. A deorbit and entry for an ATO would be very similar to a nominal deorbit and entry. The landing site for an ATO is most likely to be the same as the normal EOM landing site, however, the orbital ground track on some flights might necessitate landing at a different location.

## AOA Procedures

The procedures for AOA are quite different from those for nominal ascent. AOA OMS-2 targets should be selected (but not loaded) while in MM105. The target ID entry function, which allows the crew to select the AOA, must be performed in OPS 1 because that function is not available in OPS 3. When an AOA target is selected, the MNVR display shows a flashing OPS 301, as shown in Figure 4-6.

This message indicates that the guidance software is ready for an OPS transition, and it is safe to proceed to MM301 and then to MM302. AOA targets should be loaded only in OPS 3 because  $\theta$ T has different definitions in OPS 1 and in OPS 3, and a burn solution in OPS 1 is not correct for an AOA.

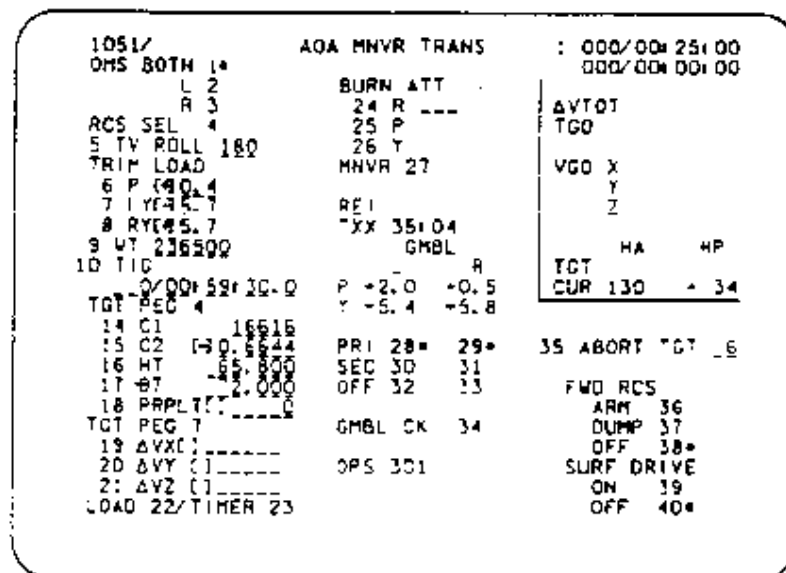


Figure 4-6. AOA MNVR TRANS display

The landing site for an AOA depends on the orbital ground track on the first revolution and the crossrange capability for a particular flight. On a low inclination mission, usually either EDW or KSC will be the landing site on an AOA. For a high inclination mission, typically NOR is the only landing site available because of ground track and crossrange constraints.

The AOA checklist procedures should be followed very closely because there are some significant differences from the nominal and ATO procedures. For example, the APUs are not turned off after OMS-1 if an AOA is in progress, and if an AOA decision is made later, then the APUs must be restarted. Also for certain underspeed cases, a special alpha (angle of attack) management procedure must be followed. This is because the underspeed may have caused a relatively low trajectory, and it is necessary to minimize the atmospheric drag by controlling the attitude of the orbiter in the coast phase between the OMS-1 and deorbit burns.



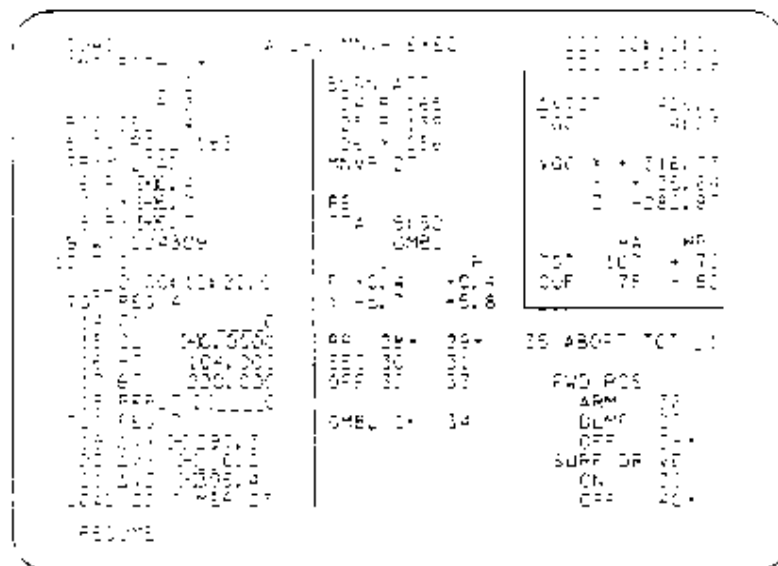
The OMS-2 burn is performed in OPS 3 and serves as the deorbit burn. If excess propellant must be burned to obtain the proper c.g. or to reach the OMS tank landing weight constraints, then propellant wasting is performed during the burn. However, for AOAs caused by OMS propellant failures, all of the available propellant may be required for the deorbit maneuver. If necessary, aft RCS and forward RCS propellant may also be used to complete the deorbit burn.

The entry and landing phase of an AOA is similar to a normal entry and landing.

## Questions

Answers to these questions are found in Appendix B.

1. Which cue card is used to help determine abort targets for underspeed situations?
2. What parameters on the MNVR display are most important for use in determining the target in an underspeed situation?
3. Using the MNVR display below, OMS 1/2 TGTING cue card (Figure 4-4), and OMS TARGETS (Figure 4-5), answer the following:
  - a. Is an OMS-1 required?
  - b. At MECO the left and right OMS has 45 percent a side, and the pre-MECO OMS dump lasted for 2 minutes 15 seconds. What target set should be selected?
  - c. At what TTA is the TIG (TTA=2 or TTA=1)?
  - d. What should the TIG (MET) be for this burn?
  - e. What is the  $\Delta V$  range expected for this burn?
  - f. What target set is loaded on this MNVR display?
4. Describe two ways that ATO or AOA targets can be selected post-MECO
5. What are the three OMS-1 burn target options on a direct insertion mission?



## Section 5

# Transoceanic Abort Landing

### Objectives

Upon completing this section, the student should be able to:

- List the most common TAL sites that are used for high inclination and low inclination missions
- With the aid of the No Comm Mode Boundaries cue card, determine which boundaries relate to TAL capability
- Describe two methods to initiate a TAL in the shuttle software
- Confirm that a TAL has been selected in the onboard software
- Define the purpose of variable IV steering
- Describe the actions for proceeding to OPS 3 in a normal TAL sequence
- List four reasons for the MM304 post-MECO dump
- Describe the requirements for TAL site redesignation

The TAL mode was developed during preparations for STS-1 and has evolved from a manual procedure into an automatic abort mode. The purpose of the TAL mode is to provide an intact abort option prior to the earliest Press to MECO boundary, for the loss of performance. TAL capability usually occurs prior to the last RTLS capability and is generally preferable to an RTLS abort.

The TAL mode is also useful for systems failures that occur after the last RTLS opportunity. If a cabin leak or vehicle-cooling problem is found to be too severe to support an AOA, then a TAL could be initiated to permit an early landing. OMS tank failures that occur during ascent, which reduce the  $\Delta V$  capabilities below that required to support an ATO or AOA, could be supported by a TAL abort. In this manner, TAL capability is any opportunity across the Atlantic ocean but before AOA capability is achieved. TAL aborts can be declared post-MECO.

## Landing Sites

Normally 10 TAL sites are carried in onboard software to support TAL aborts. Three of these sites typically are supported by NASA personnel for each flight. These are the pre-MECO sites as a general rule.

The TAL sites chosen are those closest to the ground track of the orbiter in order to limit cross range when flying the entry portion. Figure 5-1 shows the location of overseas landing sites and the orbiter ground track for various inclinations.



*Figure 5-1. Orbiter ground tracks for various inclinations*

High inclination flights will target Zaragoza Air Base (ZZA), Moron Air Base (MRN), and Ben Guerir (BEN). ZZA is usually the prime TAL site; only one TAL site is required to be go-for-launch.

Low inclination flights will target Banjul Gambia (BYD), BEN, and MRN. For low inclination, BYD is usually the prime TAL site.

Other landing sites are available for late or post-MECO TALs. The landing sites available in the software are listed in section 7 of the Ascent Checklist in the Landing Site Table.

## Abort Mode Boundaries

The TAL boundaries are relayed to the crew from MCC. Determination of the boundaries is based on real-time evaluation using the ARD operated by the Flight Dynamics Officer (FDO). If communication is lost with MCC, the crew can use the No Comm Boundaries cue card from the Ascent Flipbook (Figure 5-2). These boundaries are determined in the flight design phase. In addition an Abort Summary cue card is also carried onboard. Figure 5-3 shows the Abort Summary cue card for STS-67, a low inclination flight utilizing BYD, BEN, and MRN.

NO COMM MODE BOUNDARIES			
NEG RETURN (104)	8300	2 ENG BYD (104)	5700
PRESS TO ATD (104)	9100	ABORT TAL BYD (5)	
SE OPS 3 BYD (109)	11900	EO VI	<input type="text"/>
PRESS TO MECO (104)	12000	SE OPS 3 BYD (109)(5)	<input type="text"/>
NEG MRN (104)	12200	SE BYD (104) (5)	<input type="text"/>
SE BYD (104)	13200	2 ENG BEN (104)	6100
NEG BEN (104)	15200	ABORT TAL BEN (2)	
SE PRESS (109)	15700	EO VI	<input type="text"/>
SE PRESS (104)	16400	SE OPS 3 BYD (109)(12)	<input type="text"/>
LAST PRE MECO TAL	23000	SE OPS 3 BEN (109)(11)	<input type="text"/>
LAST TAL		SE BEN (109) (2)	<input type="text"/>
AVL	24100	2 ENG MRN (104)	5800
ROE	24600	ABORT TAL MRN (3)	
KIN, BYD	24900	EO VI	<input type="text"/>
HDS	25100	SE OPS 3 BEN (109)(11)	<input type="text"/>
		SE BEN (104) (2)	<input type="text"/>
		SE MRN (109) (3)	<input type="text"/>

Figure 5-2. No comm mode boundaries for STS-67

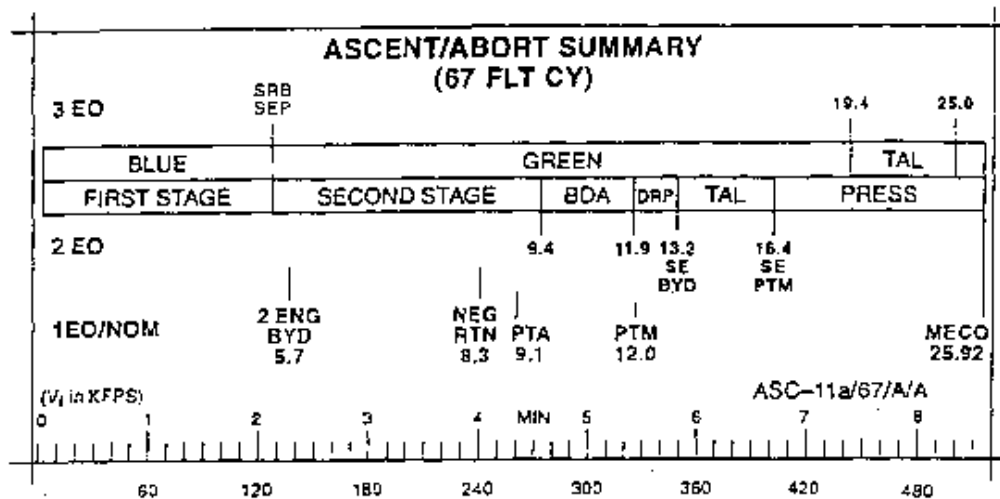


Figure 5-3. STS-67 ASCENT/ABORT SUMMARY cue card

TAL abort capability is available from the Two Engine (Prime TAL) through the NEG (TAL) boundaries. There will be overlapping of the availability of the sites, but because of the ground track, the sites may or may not have identical boundaries.

The SE OPS 3 (TAL site) 109 boundary represents the earliest point at which OPS 3 software will be used to execute an abort with only one engine running. This boundary also requires a maximum throttle setting of 109 percent, which is selected by item entry on SPEC 51. The Single Engine (TAL site) boundary is the point that guarantees the performance to reach the landing site. A throttle setting of 104 or 109 percent (inclination and site dependent) is required at this boundary.

For severe underspeeds, a TAL may be declared post-MECO. This capability is available beginning around a V<sub>i</sub> of 23k (flight specific) until AOA-shallow capability. Post-MECO TALs are usually declared using SPEC 51. An asterisk placed next to the item entry confirms that the TAL abort actually has been initiated.

## Abort Mode Selection

Pre-MECO abort selection is accomplished using the rotary switch on panel F6 to select TAL. The abort is actually executed when the pushbutton is pressed. If the abort rotary switch or the pushbutton is broken, a TAL still can be accomplished using SPEC 51 with an Item 1 and Item 3 entry. Verifying that TAL TRAJ replaces ASCENT TRAJ confirms that the TAL abort is being executed. Post-MECO TAL declarations would not bring up a TAL TRAJ; therefore, a SPEC 51 abort is preferred for the immediate confirmation.

# Procedures

Upon selection of TAL abort, the commander (CDR) and pilot (PLT) begin using the TAL cue cards from the Ascent Flipbook (Figure 5-4). Pre-MECO, the CDR verifies runway selection and TAL capability, based on velocity. The PLT monitors the OMS dump. Any actions associated with a second engine out are also executed by the PLT.

At MECO, the crew monitors ET SEP and software transitions to MM304. In addition, runway capability are reevaluated for site selection. After the transition some of the entry portion is similar to nominal EOM entry. The shortfield speedbrake is automatically selected for TAL.

**TAL CDR**

If  $V_1 > 23000$  manual MECO, go to Post MECO  
**ABORT TAL**  
 **G50** ✓SITE & RWY (PASS/BFS)

SITE	RWY	TACANS	ITEM 5	MLSI	LENGTH
2	BEN 36/18	BEN 108	CRA 118 (DME)	6-	13720/12720
3	MRN 2000	MRN 100	ACG 23	6-	12000/11800
4	ZZA 30/18P	ZZA 64	ZZA 77 (DME)	6-	12087/11977
11	BEN 36 FFA 27	BEN 108 -	BZN 56 -	6 -	13720 9996
12	MRN 20 KBO 32R	MRN 100 -	NDR 109 -	6 -	12000 11467
13	ZZA 30L ESN 01	ZZA 64 -	BAG 76 (DME) -	6 -	12397 11310
14	KIK 15P LDG 31	RY 92 -	NKW 57 -	6 -	12779 12003

\*C/O X/RNG

- If second eng fails:  **TRAJ** ✓SERC ON
- **G50** ✓SITE (✓Redes card)

$V_1 = 15.0K$  Roll to Heads Up (if  $V_1 < 20.3K$  at TAL select)

----- MECO BFS - C/O BUG ( $V_1 = 24.0K$ ) ----- MECO -----

MECO+18s ✓ET SEP, ✓AUTO -Z TRANS  
 MECO+35s ✓MM104

- If not previously selected,  **G51** ABORT TAL
- ✓SITE for high or Low Energy (TA- PLT)

✓P =  $10 \pm 30$ , Y =  $0 \pm 30$ ; RATES < .5"/sec  
 PASS, OPS 301 PRO (✓304)  
 • No joy in 68 sec: BFS - ENGAGE  
 • BFS, OPS 301 PRO

----- MM304 -----

✓Roll to Heads Up  
 BFS, OPS 301 PRO (✓304)  
 **G50** ✓SITE, RWY, TACAN  
 SPDBK & ALT (PASS/BFS)  
 ✓BUGS, HDG, RANGE,  $\alpha = 43^\circ$  50K

	WINDS
50K	/
38	/
28	/
20	/
12	/
7	/
SURF	/
SPDBK @ 3000 FT	
ALT	
AIMPT	
SPDBK	

RTLS

- Low energy:  **TRAJ** ITEM 3 (Lo Energy ENA)
- If MECO  $V_1 < 20.4K$ : Pitch - CSS,  $\alpha = 40^\circ$
- A/H = 400: AUTO
- If 42/man 37: Pitch - CSS at  $\alpha = 37^\circ$
- Pitch - AUTO at end of 2nd pullout

V = 10 ✓SPDBK → 81%  
 V = 7 Go to **ENTRY MANEUVERS** Cue Card

Figure 5-4. TAL flipbook procedures

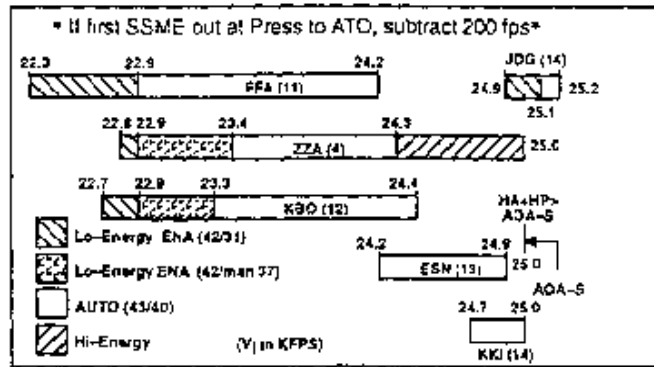
TAL PLT

✓OMS DUMP

- If second eng fail:
- [G51] MAX THROT (if reqd)
- DUMP ARM, START
- If OMS He PRESS < 2K: DUMP STOP
- Failed ME SHUTDN pb (two) - push
- When MPS PRPLT = 2%:
- MAN THROT, P<sub>C</sub> → 67%
- Man Shutdn at C/D mark

✓AUTO THROT

MECO --- BFS - C/D BUG (V<sub>1</sub> → 24.0K) --- MECO



MM304

✓OMS DUMP

✓ET DOORS - Closed and latched (MM304 +1:30)

- V = 19 HYD MPS/TVC ISOL VLV (three) - CL  
(hold 5 sec) ✓1b - CL
- V = 10
  - If RCS < [N/A] % either side:
  - [G51] AFT RCS INH, ITEM 13 EXEC
- V = 7 MLS (three) - ON (✓channels)  
I/O RESET  
Go to ENTRY MANEUVERS Cue Card

HI-ENER  
TAL

Figure 5-4. Concluded



## Guidance

After TAL is selected, the shuttle indicator and predictors on the BFS TAL TRAJ display begin following the upper TAL trajectory line. MECO is targeted about 2800 n. mi. from the landing site, depending on MECO velocity.

Variable Y steering is initiated at the time of abort to reduce the cross range or out-of-plane distances the shuttle is required to glide after MECO. The software attempts to bring cross range to within 500 n. mi. at MECO. The landing site is selected using SPEC 50, and should be selected prelaunch. A roll to heads up occurs at a velocity of 15.4k ft/sec (about 14.9k ft/sec for high inclination) to ensure a proper attitude for ET SEP and reentry and is performed at a 5 deg/sec rate. If TAL is selected after 19.0k ft/sec (20.2k ft/sec for high inclination), the roll is delayed until post-MECO (OPS 1 or 3). Between 15.4k and 19.0 k ft/sec a roll will occur immediately at abort selection.

Post-MECO, an OPS 3 PRO is performed and the software scrolls to MM304. A check to confirm that the Backup Flight System (BFS) moved to OPS 3 should also be performed. If the orbiter is not already heads up, a roll is performed automatically after the MM304 transition.

## Abort Dumps

Dumping of the OMS propellant begins almost immediately after TAL abort is selected. The dump is accomplished to meet landing weight constraints of the OMS tanks and the orbiter, as well as management of the c.g. for gliding entry.

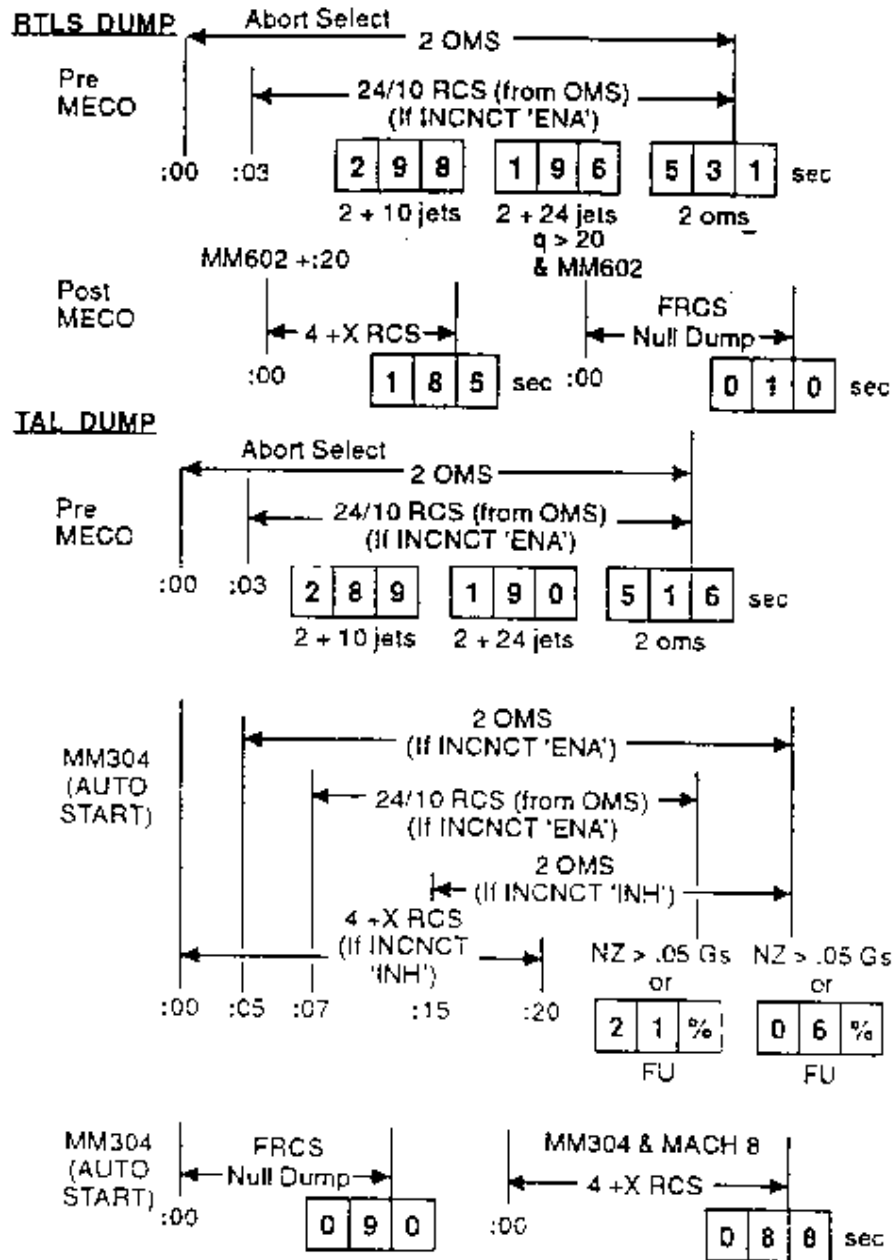
The dump is accomplished using the two OMS engines. The 24 aft RCS jets can assist the dump if required. Interconnecting with the RCS jets is determined by an I-load that is specific for the TAL abort. Once a TAL is declared, the interconnect may be toggled between ENA or INH. If the necessary dump cannot be completed pre-MECO, the engines throttle back to allow for more burn time. This point is determined by comparing abort declaration to an I-load velocity.

A good portion of the propellant is reserved for a post-MECO MM304 dump. This dump provides a separation from the external tank and helps reduce wing leading edge temperatures in addition to meeting weight and c.g. constraints cited earlier. Below Mach 8, an aft RCS dump is executed to further reduce weight and manage orbiter c.g. Figure 5-5 shows an abort dump cue card from the Ascent Flipbook.

TAL abort dumps, like all abort dumps, are based on a timer. At abort selection, the appropriate I-loads set the timer and determine whether an interconnect is to be executed. The dump through the OMS engines occurs almost immediately. If interconnected, the RCS jets begin to fire 3 seconds after the OMS engines fire.

Smart interconnect is available in all abort dumps and is described in section 3.

## RTLS/TAL DUMPS



*Figure 5-5. Abort dump cue card*

SPEC 51 is the crew interface with the abort dump software. This display shows the dump timer actively counting down as the dump is in progress. The status of the interconnect is also shown and may be toggled from ENA to INH and vice versa while the dump is in progress.

The MM304 dump is ENA or INH, based on the expected pre-MECO dump accomplished. If the total OMS quantity is greater than 36 percent, an interconnected dump is commanded. If the interconnect is enabled, the OMS engines are commanded to fire 5 seconds after dump start with the RCS jets beginning to fire 2 seconds later. Smart interconnect software performs the same steps post-MECO as it did pre-MECO. It is important to realize that the determination of 36 percent is not done with gauging, but by I-loads for what is expected to be accomplished pre-MECO.

If the interconnect is inhibited, RCS jets begin firing at dump start for a duration of 20 seconds. The OMS engines will begin firing 15 seconds later, which allows a settling of the OMS propellant in the tanks.

Whether interconnected or not, both dumps will continue until the expiration of the timer, as displayed on SPEC 51. The cue card gives a percentage as a cue for dump stop, but this should only be used as a secondary cue. If the normal loads on the vehicle ( $N_z$ ) reach 0.05 times the acceleration of gravity, or 0.05g, the dump terminates, regardless of time remaining. The design of the tanks does not support operation under acceleration in axes other than the X-axis direction.

## Landing Site Selection

The possible TAL sites are listed on the No Comm Mode Boundaries cue card for each mission. The selection of which site to use on the day of launch is based on the earliest capability to a field that is available and within weather constraints. For example, a low inclination mission would normally use BYD as the prime TAL site. If, however, bad weather is observed at BYD on the day of launch, BEN would be chosen as the primary TAL site. During the flight, a call to reselect BYD would be made at the Press to ATO boundary. In this case, the performance capability would still allow the vehicle to make it to orbit, but the performance associated with two main engines down would not be enough to get within the required cross range to the out-of-plane site. Secondly, with two failures, the stringent weather constraints are waived. If a site is down for reasons other than weather, or if the weather is extremely intolerable, the redesignation is not called for. Only one good TAL site is required for launch constraints to be met.

Site selection for post-MECO TALs are also made real time. The MECO velocity will be the primary cue for the crew to determine site capability. This is directly related to gliding range to the field. Landing sites can be selected and reselected throughout OPS 3. Energy management is less efficient the later such selections are made. No-comm guidance for post-MECO TAL landing site selection is available in the form of a bar chart on the TAL PLT checklist.

## Questions

Answers to these questions are found in Appendix B.

1. What are the most common TAL sites used for high inclination and low inclination missions, respectively?
2. What capability does the SE OPS 3 \_\_\_\_\_ (109) boundary provide?
3. How does the crew select a TAL?
4. What confirming cues are available for the crew to determine that a TAL has been selected in the onboard software?
5. What is variable TY steering designed to accomplish?
6. In a normal TAL sequence, do you proceed to OPS 3 by doing an OPS 301 PRO or by an OPS 304 PRO?
7. Why is a post-MECO OMS dump executed on a TAL?
8. When is a TAL site redesignation required prelaunch? In flight?

## Appendix A

### Acronyms and Abbreviations

A/L	Approach/Landing
ACLS	Augmented Contingency Landing Site
AME	Abort Maneuver Evaluator
AOA	Abort-Once-Around
APU	Auxiliary Power Unit
ARD	Abort Region Determinator
ATO	Abort-to-Orbit
BEN	Ben Guerir
BFS	Backup Flight Software
BYD	Banjul Gambia
c.g.	center of gravity
CDR	Commander
CRT	Cathode-Ray Tube
CUR	current
$\Delta$ VTOT	total $\Delta V$ required for an OMS maneuver
DPS	Data Processing System
EDW	Edwards Air Force Base
EI	Entry Interface
ENA	Enable
EOM	End-of-Mission
ET	External Tank
FDO	Flight Dynamics Officer
GPC	General Purpose Computer
HA	Height of Apogee
HP	Height of Perigee

HT	altitude of target
HYD	Hydraulics
ID	Identification
INH	Inhibit
ISOL	Isolation
KSC	Kennedy Space Center
MCC	Mission Control Center
MECO	Main Engine Cutoff
MET	Mission Elapsed Time
MM	Major Mode
MNVR	Maneuver
MRN	Moron Air Base
n. mi.	nautical miles
NOR	Northrup Flight Strip
OMS	Orbital Maneuvering System
OPS	Operational Sequence
P	pitch
PASS	Primary Avionics Software System
PEG	Powered Explicit Guidance
PLT	Pilot
PRPLT	Propellant
R	roll
RCS	Reaction Control System
REI	Range from Entry Interface
RTLS	Return to Launch Site
SEP	Separation
SRB	Solid Rocket Booster

SSME	Space Shuttle Main Engine
SSP	Space Shuttle Program
TAEM	Terminal Area Energy Management
TAL	Transoceanic Abort Landing
TFF	Time of Free Fall
TGO	Time to Go, time left on OMS burn
TGT	Target
TIG	Time of Ignition
TRAJ	Trajectory
TTA	Time to Apogee
TTC	Time to circularization
TTG	Time to Go
TTP	Time to Perigee
$V_i$	Inertial Velocity
VG <sub>OX</sub>	velocity to go in X direction
VG <sub>OY</sub>	velocity to go in Y direction
VG <sub>OZ</sub>	velocity to go in Z direction
Y	Yaw
ZZA	Zaragoza Air Base

# Appendix B

## Answers

### Answers to Section 1

1. The difference between a standard insertion and a direct insertion is that a standard insertion has both an OMS-1 and an OMS-2 burn, and a direct insertion only has an OMS-2 burn.
2. A MECO velocity that is less than the target velocity is called an underspeed.
3. The four types of intact aborts are ATO, AOA, TAL, and RTLS.
4. The typical orbit for an ATO is 105 n. mi.
5. The consequences of an AOA-shallow are that the vehicle is exposed to a longer period of atmospheric heating and to less predictable aerodynamic drag forces.
6. The primary means to select an ATO or TAL is by turning the abort rotary switch to the desired position and then pushing the abort pushbutton.

The backup means of selecting an ATO or TAL abort is by performing an ITEM 1 EXEC or ITEM 2 EXEC, respectively, on SPEC 51 and then performing an ITEM 3 EXEC.

### Answers to Section 2

1. During powered flight, the three types of cues normally available to provide the crew with information about abort mode boundaries are voice calls from the MCC, velocity boundaries on the NO COMM BOUNDARIES cue card, and tick marks on the TRAJ display.
2. MCC voice calls are defined as follows:
  - a. Two-Engine TAL - Earliest point at which a TAL could be achieved with only two good main engines.
  - b. Negative Return - Last opportunity to achieve an RTLS.
  - c. Press to ATO - Earliest point at which at least an AOA could be achieved with only two good main engines. An OMS dump is required.
  - d. Single-Engine OPS 3 - The first point after which, for two engine failures, the crew will abort downrange using OPS 3 (Droop procedure) software. Prior to this point, the loss of two engines requires a contingency abort using OPS 6 software.
  - e. Press to MECO - Earliest point at which at least an AOA could be achieved with only two good main engines.



- f. Single-Engine TAL - Earliest point at which a TAL could be achieved with only one good main engine
  - g. Single-Engine Press - Earliest point at which at least an AOA could be achieved with only one good main engine.
3. The boundaries listed on the NO COMM MODE BOUNDARIES cue card are defined as follows:
- a. NEG TAL - Last opportunity to achieve a pre-MECO TAL to this site
  - b. LAST PRE MECO TAL - Last opportunity to select a pre-MECO TAL
  - c. LAST TAL - Last opportunity to achieve a post-MECO TAL to this site
4. RTLS on the TRAJ display indicates the last point at which an RTLS abort should be selected. This tick mark usually corresponds to the Negative Return call from MCC.
- GO on the TRAJ display indicates the earliest point at which a main engine could fail and an AOA could still be accomplished. This tick mark usually corresponds to the Press to ATO or the Press to MECO call from MCC.
5. The systems failures that require an abort pre-MECO are
- a. OMS helium or propellant tank failures
  - b. APU/HYD failures
  - c. A cabin leak
  - d. Loss of cryo
  - e. Freon loop failures
  - f. Main bus failures
  - g. A crack in the thermal window pane
6. The OMS 1 2 TGTING cue card is used to determine the type of abort required in the case of a MECO underspeed
7. The OMS 2 TARGETING cue card is used to determine the type of abort required for various system failures

## Answers to Section 3

1. The three software functions that can aid ascent performance and are consequences of ATO selection during powered flight are switching to the ATO MECO targets, enabling variable IY steering, and initiating an OMS/RCS dump.
2. The major difference between the nominal MECO target and the ATO MECO target is that the altitude for the abort target would be lower than the altitude for the nominal target.
3. If the planned inclination for your flight is  $57^\circ$ , and the I-loaded minimum inclination is  $32^\circ$ , the inclination that results if an ATO is selected because a main engine had failed is as follows:
  - a. Very early, when the current IY vector represents an inclination of  $28^\circ$ , the resultant inclination is  $32^\circ$ . The vehicle continues steering to the minimum inclination.
  - b. Later, when the current IY vector represents an inclination of  $40^\circ$ , the resultant inclination is  $40^\circ$ . The vehicle no longer steers toward the target inclination.
  - c. Near MECO, when the current IY vector represents an inclination of  $57^\circ$ , the resultant inclination is  $57^\circ$ . The target inclination has already been achieved.
4. Three reasons for performing an abort OMS dump during powered flight are to control the c.g. of the vehicle, to reduce the total vehicle weight for landing, and to reduce overall weight in order to improve performance in powered flight.
5. A software timer, which uses an I-loaded dump duration, normally stops an ATO OMS dump.
6. During an ATO OMS dump, OMS propellant may be dumped through both the OMS engines and RCS jets, all of which are burning at the same time.
7. The simplest way to manually stop an ATO dump is to call up SPEC 51 (OVERRIDE display) and type in "ITEM 8 EXEC" (OMS DUMP STOP).
8. To select an ATO before MECO, turn the abort rotary switch to ATO and push the abort pushbutton.
9. If the abort rotary switch does not work, select an ATO before MECO by calling up SPEC 51 and typing in ITEM 2 EXEC (selects ATO) and ITEM 3 EXEC (initiates the abort).

## Answers to Section 4

1. The OMS 1/2 TGTING cue card is used to help determine abort targets for underspeed situations.
2. CUR HA and CUR HP are the most important parameters on the MNVR display for use in determining the target in an underspeed situation.
3. Using the MNVR display, OMS 1/2 TGTING cue card, and OMS TARGETS, the following are true:
  - a. Since CUR HA + HP is equal to -4, you can determine from the OMS 1/2 TGTING cue card that an OMS-1 burn is required. Remember, also, that anything to the left of the bold vertical line (HA = 95) requires an OMS-1 burn.
  - b. By following the vertical line up from HA + HP = -4 until it intersects with a 2:15 minute dump time or 45 percent OMS quantity, you can determine that target set 1 must be selected (ATO/MIN HP).
  - c. The required TTA can be found on the OMS TARGETS - W/OMS 1 cue card (TTA = 2:00). The TTA can also be determined from the top of the OMS 1/2 TGTING chart. MECO underspeeds between 25.2 and 25.7k ft/sec require the OMS-1 TIG at a TTA of 2:00 minutes. Also note that MECO underspeeds between 25.1 and 25.2k ft/sec require the OMS-1 TIG at MECO + 2:00 minutes, which is worst case.
  - d. Since current TTA = 9:52, the TIG should be targeted for 7:52 minutes from the current MET. Add 7:52 to the current MET of 10:51, and you will get a TIG of 18:43 MET.
  - e. For this target set, the  $\Delta V$  range expected for this burn is 148 - 613 ft/sec. To get the range of  $\Delta V$ , look at the actual burn parameters from the target set on the OMS TARGETS cue card.
  - f. For an ATO abort, target set 1 comes up loaded automatically with a TIG of MECO + 2:00 minutes.
4. ATO or AOA targets can be selected manually using the ABORT TGT item on the MNVR display. To select the targets, the crew performs an ITEM 35 + (desired ID) EXEC. Individual target parameters can also be manually entered or changed by keyboard entries (Items 10 through 17 on the MNVR display).
5. ATO, AOA, and AOA-shallow are the OMS-1 burn target options on a direct insertion mission.

## Answers to Section 5

1. The most common TAL sites used for high inclination missions are Zaragoza, Moron, and Ben Guerir. The most common TAL sites used for low inclination missions are Banjul, Ben Guerir, and Moron.
2. The SE OPS 3 (TAL site) 109 boundary represents the earliest point at which OPS 3 software is used to execute an abort with only one engine running.
3. The crew can execute the abort by selecting TAL on the abort rotary switch and pushing the pushbutton on panel F6. A TAL may also be declared using SPEC 51 with an ITEM 2 EXEC to select TAL and an ITEM 3 EXEC to initiate the abort. SPEC 51 is preferred for post-MECO selection or if the abort rotary switch is inoperative.
4. The following confirming cues are available for the crew to determine that a TAL has been selected in the onboard software.
  - a. The ASCENT TRAJ display is replaced by the TAL TRAJ display on both the primary avionics software system (PASS) and the BFS machines.
  - b. SPEC 51 shows an "\*" next to Item 2 (when abort was initiated using SPEC 51).
5. Variable IY steering is designed to achieve a MECO target that is within a 500 n. mi. cross range of the landing site.
6. In a normal TAL sequence, an OPS 301 PRO is performed to proceed to OPS 3. The software scrolls to OPS 304. You should confirm that the BFS follows the PASS to OPS 301, and it may be necessary to manually PRO the BFS all the way to OPS 304.
7. The post-MECO OMS dump is executed on a TAL to do the following:
  - a. Provide additional velocity away from the ET
  - b. Provide additional velocity that helps to lessen wing leading edge temperature on the vehicle
  - c. Protect the landing weight constraint of the OMS tanks
  - d. Aid in overall vehicle c g management
8. Prelaunch, a TAL site redesignation is required if the primary TAL site has weather that is out of limits or has a navigation aid failure. On a high inclination flight, there is no TAL site redesignation during ascent. On a low inclination flight, a redesignation to the in-plane TAL site is required if the vehicle was launched with a secondary site selected. The redesignation is called for at the Press to ATO boundary.

## Training Materials Evaluation

Please answer the following questions regarding the lesson you just completed. Your feedback will allow us to produce more effective training materials. When complete, mail to: **Control/Propulsion Group, DT66.**

**TITLE/CODE OF LESSON:** ATO/AQA/TAL Training Manual

**SIZE OF AUDIENCES/CLASS:** \_\_\_\_\_

### 1. How well did this lesson meet its purpose?

For each statement below, mark one box on the scale:

- |  | Strongly<br>Disagree     |                          |                          |                          | Strongly<br>Agree        |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| a. <i>The lesson objectives are clearly stated.</i>              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| b. <i>The lesson objectives are clearly defined.</i>             | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| c. <i>The lesson effectively teaches skills and information.</i> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| d. <i>The lesson meets its purpose and objectives.</i>           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

### 2. How satisfying is the content of this lesson?

For each statement below, mark one box on the scale:

- |  | Strongly<br>Disagree     |                          |                          |                          | Strongly<br>Agree        |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| a. <i>The information is structured in a logical flow.</i>     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| b. <i>The content is clear.</i>                                | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| c. <i>The content is complete.</i>                             | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| d. <i>The level of detail is correct for this information.</i> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| e. <i>The amount of information is effective.</i>              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| f. <i>The graphics contribute to my understanding.</i>         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

### 3. How appealing was the presentation of this lesson?

For each statement below, mark one box on the scale:

- |  | Strongly<br>Disagree     |                          |                          |                          | Strongly<br>Agree        |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| a. <i>The overall presentation is appealing.</i>             | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| b. <i>The visuals chosen are appropriate for the lesson.</i> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| c. <i>The visuals make the information more interesting.</i> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| d. <i>The graphics are legibly reproduced.</i>               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| e. <i>The audio-visual or print quality is good.</i>         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

### 4. How valuable is this information?

For each statement below, mark one box on the scale:

- |   | Strongly<br>Disagree     |                          |                          |                          | Strongly<br>Agree        |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| a. <i>The lesson teaches skills and information I need.</i> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| b. <i>The lesson meets my expectations.</i>                 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| c. <i>This information is useful for later reference.</i>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| d. <i>I would recommend this lesson to others.</i>          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

**PLEASE WRITE YOUR COMMENTS/QUESTIONS ON THE BACK OF THIS FORM.  
EXPLAIN ANY NEGATIVE ANSWERS IN SPECIFIC TERMS  
THANK YOU IN ADVANCE FOR YOUR ASSISTANCE!**