

FDO Console Handbook

Volume V Ascent

Mission Operations Directorate
Flight Design and Dynamics Division

Final, Rev A, PCN-2
6/23/2006

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**National Aeronautics
and Space Administration**

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

FDO CONSOLE HANDBOOK

VOLUME V
ASCENT

FINAL, Rev. A, PCN-2
6/23/2006

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**NATIONAL AERONAUTIC AND SPACE ADMINISTRATION
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Rev. A	5/14/03	Removes all TBD's from the book except the Displays Appendix. Removed partial document references. Also, applies new document # and format to all headers. The entire book is now available electronically. Closes CRs 2002-00 through 2002-10 and 2003-01 through 2003-05.	Remove and replace the entire book.

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PREFACE

This book has been prepared by the Ascent/Entry Flight Dynamics Group, Trajectory Operations Branch, Flight Design and Dynamics Division, Mission Operations Directorate, of the National Aeronautics and Space Administration's Lyndon B. Johnson Space Center in Houston, Texas. It documents Flight Dynamics Officer and Trajectory Officer console operations procedures and information for the Space Shuttle Program ascent flight phase.

This is a living document. Please direct any change requests, comments, or questions to DM46/J. Chris Edelen, Ascent/Entry Flight Dynamics Group, NASA JSC, Houston, TX 77058, telephone (281) 483-6541.

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1 INTRODUCTION

The purpose of this handbook is to provide basic understanding of Space Shuttle ascent and ascent abort targeting philosophy, methods, and procedures, and to document all console tools and procedures used by the ascent Flight Dynamics Officer (FDO) and Trajectory Officer (TRAJ). The book is intended to be generic and flight-independent. Variations and improvements for specific flights are to be addressed at the Ascent/Entry Flight Techniques Panel and documented in the flight rules and through special flight-specific procedures documents.

The information contained in this book is intended to serve as formal documentation of Flight Dynamics ascent operations, as a procedures and rationale reference for experienced operators, and as a learning guide for operators with little prior knowledge of the ascent phase.

1.1 How this Book is Organized

Two types of information are provided in this book. The first is a narrative overview, addressing a particular topic, and the second is a detailed procedure. Narrative sections generally document operating philosophy and rationale or define terms, flight control positions, or capabilities. A procedure always begins with its name and description, followed by the detailed procedure in either narrative or checklist form, or both. A background section then follows, describing rationale, history and/or references. In this way, procedures may be looked up quickly for use, while still providing readily available documentation.

1.2 Ascent Objectives

The ascent phase of Space Shuttle operations covers the period of time from Solid Rocket Booster (SRB) ignition through OMS-2 burn cutoff. It is intended to safely deliver the vehicle into orbit while maintaining capability to abort the ascent and return the orbiter and crew to the ground if systems or propulsion failures occur which preclude continuing the mission. In the event that multiple failures occur which prohibit a safe landing, the objective becomes one of guiding the vehicle safely to stable, gliding flight such that the crew can bail out.

1.2.1 FDO Ascent Operations

FDO Operations support the ascent objectives by providing a number of trajectory planning and assessment capabilities, generally in the form of analog plots of trajectory parameters and computational tools resident in the Trajectory Server (Traj Server). Some of these tools are used pre-launch to provide on-orbit trajectory planning data, to determine the proper planar targets for inertial plane launches (e.g., missions with a rendezvous or a planetary payload), and for preliminary abort maneuver planning.

During powered flight, the plots and the high-speed trajectory processors are used to provide continuous assessment of current and "hypothetical" (i.e., hypothesizing one or more performance-related failures) ascent abort capability. The primary processors are the Abort Region Determinator (ARD), the

Downrange Abort Evaluator (DAE), the External Tank Impact Point predictor (ETIP), and the Abort Maneuver Evaluator (AME). The ARD is used from liftoff through Main Engine Cutoff (MECO) to assess and predict nominal and abort performance. The DAE is used cyclically during powered flight and in a single-pass mode post-MECO to indicate sites within a landing capability "footprint". ETIP is used cyclically during powered flight to assess proximity to range safety limits, and can be used in a single-pass mode post-MECO. The AME is a post-MECO processor used to evaluate the highest priority mission mode available based on the actual MECO conditions and propellant available. Further details regarding these tools are contained in chapters 5 through 7 and in Appendix D.

1.2.2 Abort Modes

Ascent aborts consist of two general types -- intact and contingency. Intact aborts are those which support the Space Shuttle Program (SSP) design requirement of continuous single-Space Shuttle Main Engine (SSME)-out capability for safe return of the orbiter and crew. Specifically, these include Return To Launch Site (RTLs), Transoceanic Abort Landing (TAL), Abort To Orbit (ATO), and Abort Once Around using Steep targets (AOA-Steep). Other modes are considered contingency aborts, even when they result in a safe orbiter landing. These modes include AOA using Shallow targets (AOA-Shallow), uprange or downrange TAL aborts to Augmented Contingency Landing Sites (ACLS's) or Emergency landing Sites (ELS's), East Coast Abort Landings (ECAL's), Bermuda Contingency Abort Landings (BCAL's), any abort caused by multiple performance-related failures, and flight crew bailout.

1.2.3 Abort Landing Sites

Currently approved intact abort landing sites are as follows:

- RTLS: Kennedy Space Center, FL (KSC)
- TAL: Zaragoza, Spain (ZZA)
Moron NAS, Spain (MRN)
Istres, France (FMI)
- AOA: Edwards AFB, CA (EDW)
Kennedy Space Center, FL (KSC)
White Sands Space Harbor, Northrup Strip, NM (WSSH or NOR)

A representative list of currently approved Emergency Landing Sites follows. These sites are officially documented in STS-7700, Volume X, for both contingency ascent aborts and emergency deorbits:

- | | |
|----------------------------------|---------------------------------|
| Rota NAS, Spain (AOG) | King Khalid, Saudi Arabia (KKI) |
| Bermuda Island (BDA) | Diego Garcia (JDG) |
| Amilcar Cabral, Canary Is. (AML) | Amberley, Australia (AM) |
| Las Palmas, Cape Verde Is. (GDV) | Darwin, Australia (DDN) |
| Roberts Field, Monrovia (ROB) | Guam (GUA) |
| Kinshasa, Zaire (KIN) | Hao Atoll (HAO) |
| Hoedspruit, South Africa (HDS) | Honolulu, Hawaii (HNL) |
| Tamanrasset, Algeria (TMS) | Dyess AFB, TX (DYS) |

Souda Bay, Crete (SUD)
Orlando, FL (ORL)

Nassau, Bahamas (ZQA)

ECAL sites are airfields along the eastern U.S. coast. These include Cherry Point, NC (NKT), Dover, DE (DOV), Myrtle Beach, SC (MYR), Oceana, VA (NTU), Otis, MA (FMH), and Pease, NH (PSM).

Several other sites in the KSC, EDW, and NOR areas are carried by Guidance and Procedures Officers (GPO's) to provide coverage for extreme emergencies during entry. These sites have not been "approved" by the SSP. Their use is documented in the Deorbit and Entry FDO Console Handbook, (DM-CH-04, Volume IV).

1.3 Powered Flight Targeting

The ascent powered flight phase through MECO is divided into two distinct sub-phases, or stages. First stage, flight software Major Mode (MM) 102, begins at Solid Rocket Booster (SRB) ignition and continues until the SRBs separate. Second stage, MM 103, begins at SRB sep and continues through ET sep.

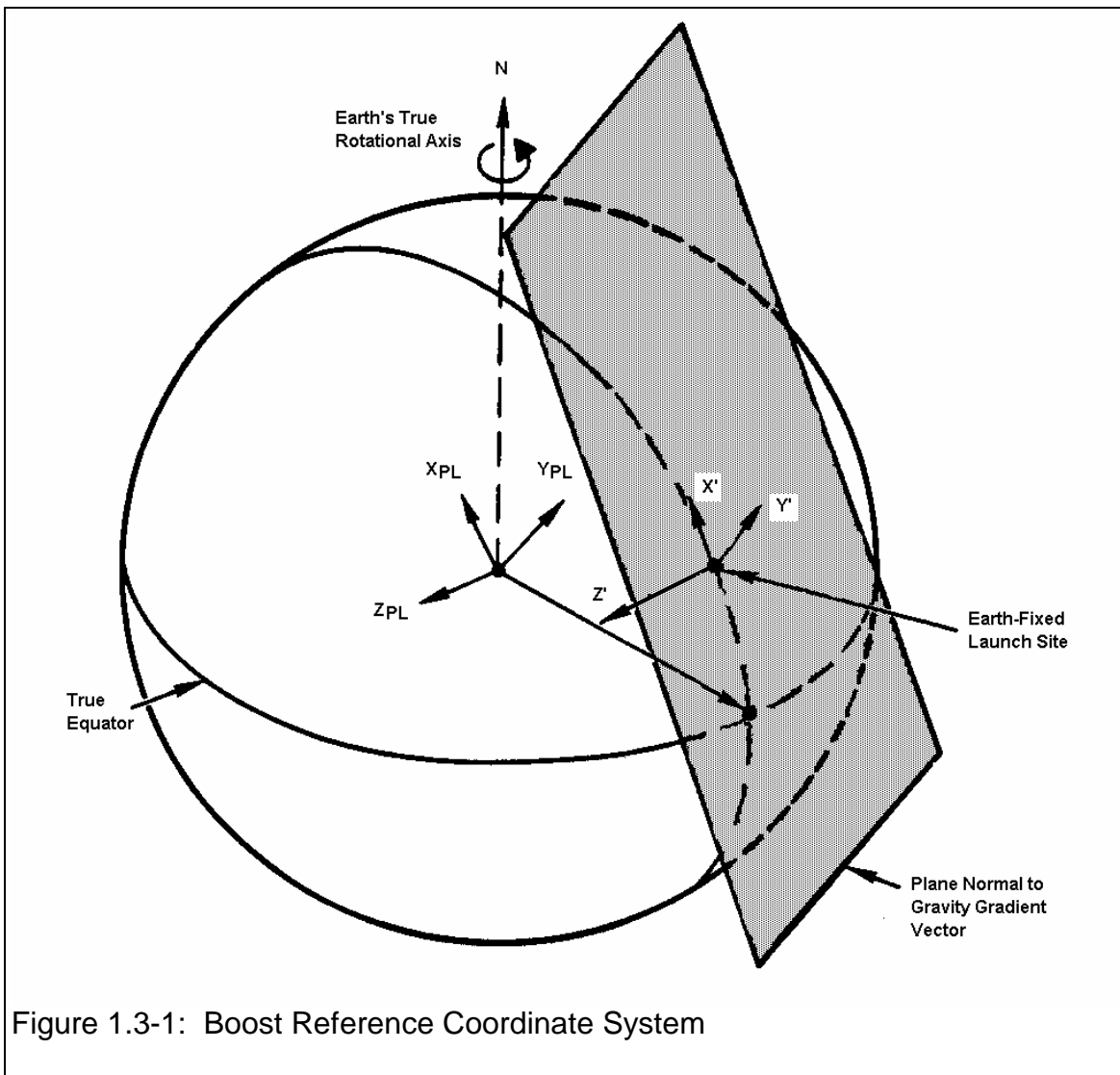
1.3.1 First Stage

First stage is intended to boost the stack through most of the sensible atmosphere using an open-loop guidance scheme. This technique must operate within a number of constraints, as follows:

1. **Launch Tower Clearance:** The initial portion of the flight is restricted to a brief period of vertical rise (no pitch profile) to ensure that the stack avoids recontact with the launch tower.
2. **Vehicle Performance Near Maximum:** After vertical rise to an altitude and velocity that ensures tower clearance, a tilt phase begins. This is a programmed series of velocity-referenced attitude commands designed to place the vehicle in a heads-down attitude and headed along an azimuth toward the desired orbital plane. The actual pitch and yaw commands are I-loaded and attempt to maximize vehicle performance consistent with the other constraints mentioned herein.
3. **Aerodynamic Loads Within Limits:** The nominal pitch and yaw commands attempt to maintain aerodynamic loads on the vehicle within specified limits. The initial attitude I-loads are designed based on a selected mean wind and atmosphere profile and protect structural margins for 3σ dispersions in wind, atmosphere, and SRB performance. On day-of-launch, these I-loads are redesigned, based on actual environment conditions and predicted SRB performance, and uplinked to the vehicle. This process is known as DOLILU (Day-Of-Launch I-Load Update).

4. Safe SRB Separation: The profile must be designed such that the vehicle's sideslip angle, angle of attack, and dynamic pressure (Q_{bar}) are all within acceptable limits to allow for successful separation of the SRBs.

The first stage attitude commands are defined in the Boost Reference coordinate system (figure 1.3-1), and the order of body rotations is yaw, pitch, roll. The I-loads themselves are stored as tangents of quarter-angles, which simplifies flight software computation of the associated attitude quaternion.



The origin of the Boost Reference coordinate system, a right-handed, cartesian coordinate system, is at the center of the earth. The Z_{pL} -axis is parallel to the gravity gradient (Z') which passes through the launch site and is positive in the direction of gravity. The Z_{pL} -axis is fixed at a specifically stated time. The X_{pL} -axis is parallel to X' , which is along the launch site meridian and is positive northward. The Y_{pL} -axis is parallel to the Y' axis, which completes a standard,

right handed system (i.e., positive east). The $X_{PL} - Y_{PL}$ plane is normal to the launch site gravity gradient vector.

1.3.2 Second Stage

After the SRB separation command is issued, the flight software modes to MM 103 and second stage begins. The orbiter maintains its last commanded attitude for four seconds while the SRBs fall away and a closed-loop guidance scheme converges on the required steering direction and rates. This scheme is called Powered Explicit Guidance, or PEG. Minor variation of the PEG algorithms are used to satisfy all post-SRB separation ascent and abort guidance requirements. PEG provides the flight control function with parameters defining the desired thrust direction to achieve an I-loaded set of target MECO conditions. For nominal ascent, these targets include a radius magnitude, inertial velocity magnitude, inertial flight path angle, and a unit vector normal to the desired orbital plane (referred to as the "IY" vector, or just "IY"). For TAL and RTLS aborts, the fixed velocity target is replaced with a velocity based on predicted MECO range to the selected abort site, and the planar target is recomputed by the software to minimize yaw steering requirements (TAL) or to assure that at MECO the vehicle is headed toward the HAC tangency point (RTLS). PEG is cycled by the flight software every 1.92 sec, to continually update the steering parameters based on current trajectory and propulsion system status until shortly before MECO.

Nominal second stage targets are designed for what is called the Direct Insertion (DI) ascent mode. This mode results in a sub-orbital trajectory at MECO to allow for controlled placement of the re-entering ET's debris footprint. The DI profile results in a MECO apogee that very nearly intercepts the initial nominal mission altitude, hence DI flights do not nominally require an Orbital Maneuvering System (OMS)-1 burn. The small difference in apogee between MECO and the desired orbit is made up in this case by a subsequent impulse from the Main Propulsion System purge operation (MPS Dump) conducted after ET separation. The MPS Dump is initiated manually by the crew at MECO+2 min, unless a MECO underspeed necessitates an OMS-1 prior to MECO+6 min, in which case the MPS dump is performed during the OMS-1 burn.

Location of the ET footprint is one criterion in the design of MECO targets, in conjunction with the desired initial mission altitude. Another insertion mode, Standard Insertion (SI), has been used in the past, but due to limitations on minimum performance capability for this profile caused by ET impact location, it is not currently planned for any future missions. SI targets result in a MECO apogee which is well short of the nominal mission altitude, requiring an OMS-1 burn to boost the trajectory the rest of the way to the initial nominal altitude.

As such, DI is the preferred insertion mode for all missions, though it can be limited for low-altitude designs by ET footprint concerns. The lack of an OMS-1 requirement also simplifies and relaxes the post-MECO timeline.

1.3.3 Transoceanic Abort Landing (TAL)

The TAL mode was developed to provide intact abort coverage between last RTLS and earliest uphill, or "press", capabilities. Since it was initially designed, however, it has become preferable to an RTLS abort. Generally, it is very similar to a nominal ascent and entry. The major ascent difference is that the MECO target velocity becomes a function of predicted range to the selected landing site at MECO, as is also the case with RTLS. In addition, depending on the number of engines running and the abort velocity, a pre-MECO throttle-down to minimum power level is commanded to ensure that a full OMS dump is completed. A maneuver to roll the vehicle to a heads-up attitude is also performed pre-MECO, to improve ET heating control and to help establish the orbiter in the proper entry attitude. Post-MECO entry differences are described in section 5.1.4.3, below.

1.3.4 Return to Launch Site (RTLS)

The RTLS abort provides intact abort capability for both 3-engine and 2-engine operation from liftoff through approximately four minutes MET. The powered flight portion consists of the following four phases. Post-MECO entry techniques are described in section 5.1.4.4, below:

1. Fuel Dissipation: The vehicle pitches to an attitude designed to control lofting while continuing downrange thrusting to deplete excess fuel. The fuel dissipation attitude is based on the velocity at SSME failure (at SRB separation if the engine fails in first stage), or at the abort selection velocity if all three engines are operating. A variation of launch PEG called PEG-5 is used to determine the proper time to begin thrusting back toward the landing site.
2. Powered Pitcharound (PPA): The vehicle pitches through vertical to a heads-up, PEG-commanded attitude to begin thrusting back toward the landing site. Cues for this event include velocity greater than a threshold value which protects against excessive downrange speed, and a guidance determination that the pitchdown phase target mass will be achieved with the currently projected flyback profile.
3. Flyback: During this phase, PEG-5 provides attitude and throttle commands which steer the vehicle to the target conditions of radius, flight path angle, range-dependent velocity, flight azimuth headed toward the HAC tangency point, and total mass at the start of pitchdown phase.
4. Powered Pitchdown (PPD): The vehicle is pitched down to an attitude designed to assure safe ET separation (an angle-of-attack of -4°) while continuing toward a range- and flight path angle-dependent velocity, at which MECO is commanded.

1.3.5 Abort to Orbit (ATO)

The ATO option allows the use of a pre-MECO OMS dump in order to decrease the vehicle weight to get the earliest “press” time for a single Space Shuttle Main Engine (SSME) failure. Also, it may involve the use of “variable IY” logic to freeze the current orbital plane to further reduce the MPS cost. On many missions, both the OMS dump and variable IY have been combined to yield the earliest possible Press-to-ATO time.

The RTLS, TAL and ATO aborts are the only intact abort modes that can be selected pre-MECO.

1.3.6 Contingency Aborts

All the above abort modes are defined as intact aborts. By definition, any abort with more than one SSME failed is classified as a contingency abort. There are various different contingency abort options, depending on the time of the SSME failures. Some of these aborts may result in the Orbiter reaching a landing site while others may result in a bailout.

Reference Ascent GPO Console Handbook for more on contingency aborts.

1.4 *Post-MECO Targeting*

After MECO and ET separation, the trajectory is sub-orbital, to allow for ET re-entry as described in section 1.3.2, and additional burns must be scheduled to achieve safe orbital conditions. The orbit insertion burns, OMS-1 and OMS-2, are performed in MM 104 and MM 105, respectively, and utilize another PEG algorithm known as PEG-4. In Operational Sequence (OPS)-1 (ascent) software, this mode targets for an altitude and flight path angle at a specified angular location measured from the inertial launch site position at liftoff. A number of these OMS target sets are carried in the flight software to perform these burns for a wide variety of possible MECO conditions. Figure 1.4-1 depicts this PEG-4 target geometry for OPS-1 applications.

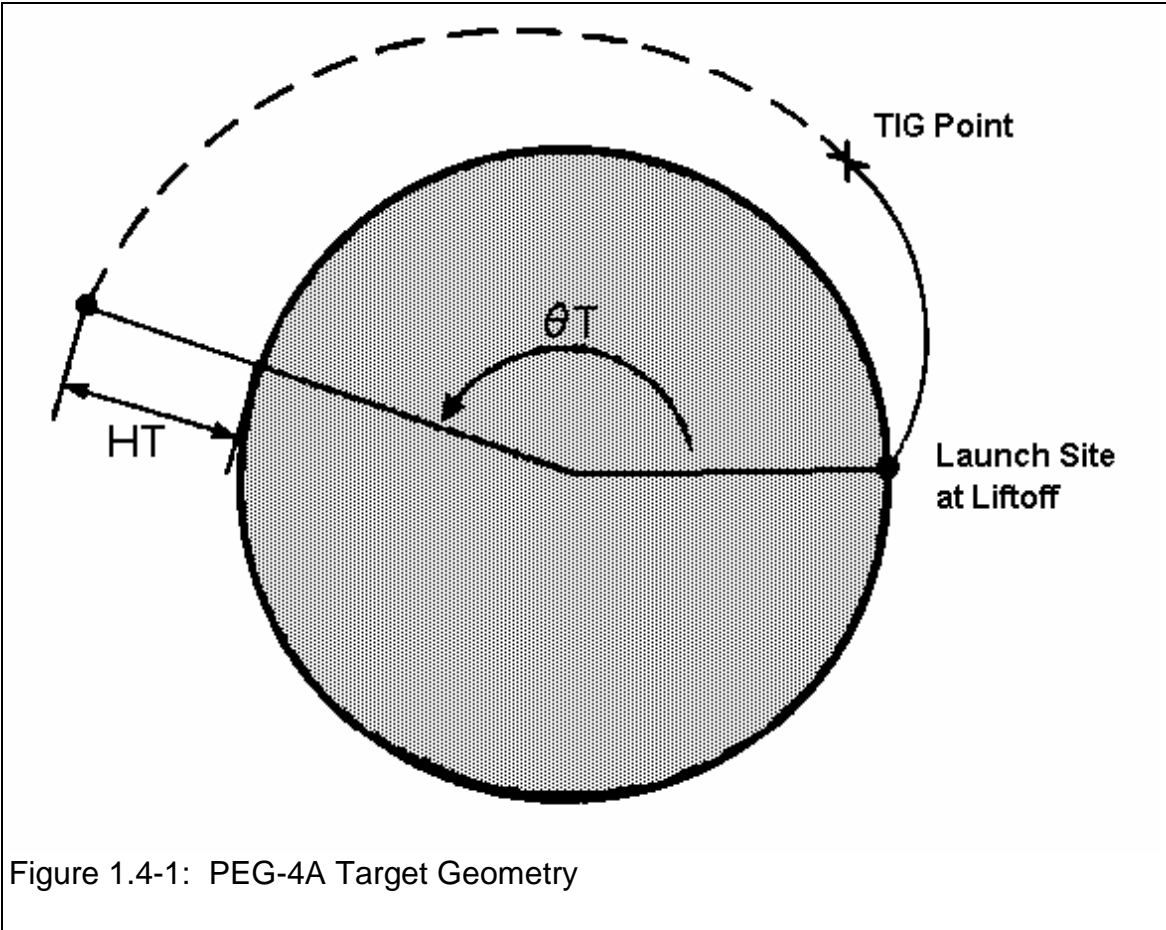


Figure 1.4-1: PEG-4A Target Geometry

1.4.1 OMS-1

Current flight design philosophy does not require an OMS-1 burn, since DI targeting is used exclusively.

Note:

Though the targeting scheme is currently unused, SI missions nominally require an OMS-1, designed to result in the desired apogee altitude with a minimum fuel expenditure. A number of corresponding OMS-2 target sets are designed specifically for execution after the nominal OMS-1. These targets will either raise perigee (Hp) to the nominal, safe, or minimum altitude, or will result in an AOA. Note that while AOA capability after the SI nominal OMS-1 is provided, the nominal OMS-1 targets are not specifically designed to protect that case. Flight Design Groundrules and Constraints did not require systems AOA protection after the SI nominal OMS-1 if providing such capability impacts the nominal mission.

For medium to large DI MECO underspeeds that result in a MECO apogee less than 95 nm, an OMS-1 is required. For most of these cases, the ATO/AOA OMS-1 target set is used, which does not commit the flight to either mode at OMS-1 ignition time (TIG). Hence, it is usually referred to as the "Common Target" or the "ATO OMS-1 Target." It is designed to raise apogee to 105 nm and to place the orbital line of apsides at a position to support a subsequent AOA OMS-2. The AOA may be to any of the three CONUS sites, EDW, KSC, or NOR, with separate AOA OMS-2 targets designed for each site (all of which may be executed off the common OMS-1 target). The AOA OMS-2 ΔV requirements for each site will generally not be identical. The differences may be small but are not necessarily negligible. The ATO OMS-2 burn simply raises Hp to a safe altitude or to 105 NM.

The common target's Tig is usually "floated" between MECO plus two minutes and two minutes prior to apogee (Time-to-Apogee = 2, or TTA=2), depending on MECO velocity and flight path angle. Floating the Tig to near apogee results in significant propellant savings over fixed Tigs since it usually reduces radial ΔV expenditures. The result is a post-OMS-1 orbit that is very nearly a Hohmann transfer to the OMS-2 point. Note that this only works due to the geometry of the MECO orbit and the OMS-1 target conditions, i.e., there is nothing that requires burning PEG-4 targets at apogee to be more efficient. Therefore, the use of the floating Tig technique is examined for applicability in the target design phase, and it may be specifically "no-go" for certain orbit geometries. In these cases fixed TIGs are used which are optimal for the design conditions, with the resulting target sets designated as "Optimum AOA."

For MECO underspeeds which exceed subsequent ATO/Minimum Hp or AOA-Steep capability, or which expose the orbiter to excessive atmospheric drag in the early post-MECO period, a special AOA-Shallow OMS-1 target is provided. This target requires less ΔV since it does not raise apogee as high as does the

common target, and it causes the trajectory to climb out of the low-altitude, high-drag region more quickly as well. It does this by employing a downrange target condition (the point at which the target altitude is to be met) which is somewhat closer to the burn location than is true for the common target. The resulting OMS-1 burn introduces a greater positive altitude rate in order to meet this condition.

A shallow AOA OMS-2 target is provided specifically for use after the Shallow OMS-1. The steep and shallow AOA targets designed for use with the common OMS-1 target are not compatible with the shallow OMS-1 target. This target set (both OMS-1 and OMS-2) is usually referred to as the "AOA Shallow/Shallow Target."

1.4.2 OMS-2

The post-MECO orbit (or post-OMS-1 orbit, for underspeed conditions or SI flights) is generally still sub-orbital, or at best provides an Hp that will support only a few orbits' lifetime. The OMS-2 burn is used to either raise Hp to the desired nominal mission insertion altitude, to establish a safe orbit if propellant problems exist, or to establish an AOA trajectory which returns the orbiter to a Continental U.S. (CONUS) landing site. OMS-2 normally uses PEG-4 guidance, exactly like OMS-1; however, on occasion a PEG-7 (external ΔV) burn is utilized.

For nominal MECO conditions (or after an SI nominal OMS-1), the nominal OMS-2 target may be used, raising Hp in the same manner as in an OMS-1. Although the targets are designed to provide an optimal burn for the design conditions, they may be executed with only a small ΔV penalty over a relatively wide range of perturbed "nominal" trajectories (in general, such perturbations arise only from small MECO underspeeds on DI flights). If the trajectory conditions are such that excessive radial ΔV exists, the TIG may be floated in the same manner as OMS-1 in order to improve efficiency. Beyond this region, the I-loaded PEG-4 target is abandoned in favor of ground-provided PEG-4 targets at apogee, with the target altitude usually selected such that the resultant orbit is circular. If the crew finds themselves in this region and is without communication with the MCC, their checklist directs them to perform a PEG-7 burn to circularize at apogee, raise Hp to the 105 NM, or raise Hp to minimum Hp.

The ATO OMS-2 target is only burned after the execution of the ATO OMS-1 (ATO-like OMS-2 targets to follow a nominal MECO are provided, though this maneuver is usually done as a ground-targeted PEG-4 burn). Performed at apogee of the post-OMS-1 trajectory, it results in a 105 nm circular orbit, providing reasonable orbital lifetime to assess the capability to raise the orbit or to plan a subsequent deorbit and entry. If serious propellant problems exist, the burn will be targeted to a minimum Hp, defined as 85 nm for low inclination missions or 90 nm for high-inclination, providing sufficient lifetime to support a flight day one (FD1) deorbit to the Primary Landing Site (PLS) on orbit 3 or orbit 7, respectively.

Several AOA OMS-2 target sets are provided, each designed to be burned off of a different post-MECO/OMS-1 trajectory. These targets are essentially canned deorbit burns which place the orbiter on a trajectory resulting in a CONUS landing at about one hour and fifty minutes Mission Elapsed Time (MET). The burns are performed using the OPS-3 (entry) version of PEG-4 guidance, which is similar to the OPS-1 version except that the downrange angular target is measured from the inertial vehicle position at the target TIG to the Entry Interface (EI) point. Because of this difference, once a TIG is chosen which provides the desired range to the landing site at EI (REI), **the TIG cannot be floated**. Doing so would directly affect the REI and seriously impact the capability to land at the targeted site.

Targets for both steep and shallow entries are available, although only a shallow OMS-2 can be executed after the AOA OMS-1 shallow target has been burned. In general, the shallow target is less expensive in terms of ΔV , however there are occasions (especially with DI missions) when the geometry results in a cheaper AOA-Steep. Steep entries are preferred for both technical and programmatic reasons. Technically, steep entries are less sensitive to the effects of trajectory and systems dispersions and are thermally less stressful. Programmatically, AOA-Steep is a certified intact abort mode, having been a program design requirement, while AOA-Shallow is considered uncertified and is therefore designated a contingency procedure.

The AOA entry is very similar to a nominal entry. For further details on deorbit and entry design and operations, see the Deorbit and Entry FDO Console Handbook, Volume IV.

1.4.3 TAL

Post-MECO on a TAL trajectory, an OMS burn is performed to help assure adequate separation from the ET when it ruptures on re-entry. The orbiter entry itself is unusual only in that it exposes the vehicle to higher thermal loads as it captures the drag-velocity profile than are present on a nominal entry. In addition, there are no high-speed tracking facilities available at any of the TAL sites, hence the abort must be performed with autonomous navigation after Bermuda tracking LOS. For this reason, flight rules specifically require redundant TACAN at the prime TAL site in order to be go for launch.

1.4.4 RTLS

The last phase of the RTLS trajectory is known as Glide RTLS, or GRTLS. This is the gliding portion of this abort mode, where the guidance establishes the vehicle on the entry profile. After ET separation, a phase called alpha recovery is begun where the vehicle pitches up to a fifty degree angle of attack. This is held as the orbiter drops into the atmosphere and the drag acceleration begins to build. At a normal acceleration (N_z) of 2g, an N_z hold phase begins during which the vehicle pitches down to maintain the 2g deceleration until the normal Mach-alpha profile is intercepted. Active crossrange control is not performed until Terminal Area Energy Management (TAEM) interface, at Mach 3.2. From there

on, the entry is very similar to a nominal approach and is handled as such from a crew and flight control perspective.

1.4.5 ATO

Post MECO an ATO option can be selected. This is done by the crew selecting an ATO target set to perform OMS-1. This would not usually be required unless there was a MECO underspeed, or a velocity shortfall. The FDO would make this recommendation once all the options had been evaluated after MECO.

1.4.6 Abort Once Around (AOA)

Another post MECO abort option is the AOA. This also can be done by the crew selecting an AOA target set to perform OMS-1 or OMS-2. The AOA may be required if the MECO underspeed was too large to not allow an ATO (a.k.a. performance AOA), or for multiple systems failures (a.k.a. systems AOA).

1.4.7 Contingency Aborts

Post MECO, contingency aborts may use either the RTLS software (OPS 6) or the nominal entry software (OPS 3) depending on the MECO velocity. Lower velocities require the RTLS software for the pullout to prevent over G'ing the vehicle. Depending on where MECO occurs, the FDO and GPO work together to determine which landing site to select. It may require evaluating which site has better weather and which is best from an energy standpoint.

Also reference Ascent GPO Console Handbook.

2 RESPONSIBILITIES AND INTERFACES

The Ascent FDO and Trajectory Officer (TRAJ) function as a team to perform tasks necessary to ensure a safe and successful Space Shuttle launch from the standpoint of trajectory management. This includes the prelaunch selection of abort sites, assurance that flight rules affecting MCC commit-to-launch are satisfied, computation of ascent targeting parameters, and verification of proper TRAJ SERVER database configuration. After liftoff, duties include trajectory monitoring and assessment of launch abort capability in the event of systems failures. After MECO, the FDO/TRAJ team assesses the mission capability in light of the actual vehicle state and selects appropriate OMS burn targets.

This section provides an overview of the responsibilities of the Ascent FDO, TRAJ, and each of the positions which support or interface with them. Detailed procedures and techniques are contained in subsequent sections of this book.

2.1 *Ascent FDO Duties and Responsibilities*

The ascent FDO is ultimately responsible for all ascent trajectory processing, including initialization/QA of the MCC trajectory processors and updates to the Abort Region Determinator (ARD) and Abort Maneuver Evaluator (AME) based on actual OMS and ET loadings. The FDO is responsible for ensuring that the trajectory support team is ready for launch and that all Flight Rules which dictate mandatory MCC hardware and processing requirements are satisfied.

The following list briefly reviews some of the major responsibilities, actions and tasks performed by the ascent FDO and is intended for overview use only. Specific, detailed tasks are documented in subsequent sections of this handbook.

2.1.1 Pre-Launch

- Review trajectory-related Flight Rules (generic and flight-specific).
- Close (or negotiate interim agreements regarding) all open issues with the Flight Directors Office.
- Review updated propellant loading and vehicle weight data with the trajectory support team; update key parameters as required and document them completely in the flight rules annex.
- Verify the Mission Control Center (MCC) trajectory database.
- Review FD1 activities (off-nominal orbit raising plans, etc.) with the lead FDO (and the Orbit 2 FDO, if different).
- For ground-up rendezvous missions, assess potential launch targeting changes using the Launch Window/Launch Targeting processor. On launch day, the appropriate parameters are updated in the MCC and uplinked to the onboard computers under FDO and GPO supervision.
- Review Day-of-Launch (DOL) trajectory simulations to understand the effects of winds on the trajectory and propellant reserves.
- Interface with the Spaceflight Meteorology Group (SMG), Landing Support Officer (LSO), and Entry Support to assess the effects of

forecast and observed winds and weather conditions on ascent abort and FD1 PLS landing conditions. Based on this data, recommend landing sites, runways, aimpoints, and speedbrake logic settings for RTLS, TAL, AOA, and FD1 PLS landings.

- Interface with the Flight Control Officer (FCO) at the Eastern Range (ER) to obtain range safety collision avoidance (COLA) launch window cutouts and general status of the range safety processors and command systems.
- Review anticipated effects of DOL winds on the trajectory, and review significant changes to the nominal ascent events summary which is sent to the FCO by ARD Support during the week before launch.

2.1.2 **Powered Flight**

- Use the MCC trajectory processors to assess the vehicle's trajectory and performance and apply appropriate flight rules as needed.
- Make abort mode boundary calls and appropriate abort mode recommendations, as required, to the FD based upon current and hypothesized Orbiter performance.
- Interface with NAV and GPO to determine the best state vector source for use in trajectory assessments.
- Interface with the FCO to monitor range safety constraints and ensure that proper abort action is taken for impending range safety violations.
- Operate the Abort Light switch, either as a backup to the FD switch or upon coded verbal notification from the FCO of impending range safety destruct action.

2.1.3 **Post-MECO**

- Assess and recommend the highest priority mission mode based upon actual trajectory conditions and propellant available.
- Optimize OMS targets in real-time to reduce propellant costs and maximize the probability of mission success.
- Confirm maneuvers after their execution and assess the resultant orbit and future maneuver plans.
- Perform preliminary planning for orbit raising maneuvers and/or early payload deploy/jettison, if required.
- Evaluate AOA and FD1 PLS deorbit trajectories in the event either are needed.
- If an AOA is required, recommend the appropriate target set, alert the selected landing site via LSO, prepare and distribute maneuver and Deorbit/Entry/Landing (DEL) Preliminary Advisory Data (PAD's).
- If a TAL abort or downrange abort is required, evaluate energy and ranging capability and recommend the best landing site.
- For RTLS and TAL trajectories, evaluate the vehicle state with respect to the range-velocity target line and monitor the subsequent entry and landing.

2.2 Ascent Trajectory Officer Duties and Responsibilities

The primary responsibility of the ascent Trajectory Officer (TRAJ) is to support the FDO as required, although many specific tasks are delegated to the TRAJ. The following list briefly reviews specific TRAJ-related responsibilities, actions and tasks and is intended for overview use only. Specific task details are documented in subsequent sections of this handbook.

2.2.1 Pre-Launch

- Review trajectory-related Flight Rules (generic and flight-specific).
- Participate in resolution of all open issues with the Flight Directors Office.
- Review updated propellant loading and vehicle weight data with the trajectory support team; maintain cognizance of updates to key parameters as required.
- Verify the MCC trajectory database.
- Review FD1 activities (off-nominal orbit raising plans, etc.) with the Ascent FDO.
- Review FD1 activities (off-nominal orbit raising plans, expected handover actions, etc.) with the Orbit 2 TRAJ.
- For ground-up rendezvous missions, participate in assessment of potential launch targeting changes using the Launch Window/Launch Targeting processor.
- Review Day-of-Launch (DOL) trajectory simulations to understand the effects of winds on the trajectory and propellant reserves.
- As required, interface with the Spaceflight Meteorology Group (SMG), LSO, and Entry Support to help the FDO assess the effects of forecast and actual winds and weather conditions on ascent abort and FD1 PLS landing conditions.
- Interface with the Flight Control Officer (FCO) at the Eastern Range (ER) to obtain range safety collision avoidance (COLA) launch window cutouts and general status of the range safety processors and command systems. Review with FCO the anticipated effects of DOL winds on the trajectory, along with any significant changes to the nominal ascent events summary which is sent to the FCO by ARD Support during the week before launch.

NOTE:

The TRAJ, acting for the FDO, is the primary MCC point of contact with the FCO.

2.2.2 Powered Flight

- Maintain the accuracy of the ARD, ensuring that it is correctly modeling actual flight.

NOTE:

This is the primary task of the TRAJ during powered flight.

- Maintain the status of the ARD hypothetical modes allowing FDO to make accurate and appropriate abort mode boundary calls and abort mode recommendations, as required.
- Interface with the FCO to monitor range safety constraints and to ensure FCO and FDO awareness regarding trajectory and range safety status.

2.2.3 Post-MECO

- Configure AME and ephemeris weights based on abort dump status.
- Operate the AME at the direction of the FDO.
- Assist the FDO in optimization of OMS targets in real-time to reduce propellant costs and maximize the probability of mission success.
- Confirm maneuvers after their execution.
- Perform preliminary planning for orbit raising maneuvers and/or early payload deploy/jettison, if required, at the direction of the FDO.
- Model AOA and FD1 PLS deorbit trajectories for FDO evaluation in the event either are needed.
- If an AOA is required, assist the FDO in preparation, verification, and distribution of the maneuver and DEL PADs.
- If an RTLS, TAL, or downrange abort is required, assist FDO in monitoring the resultant entry.

2.3 Multi-Purpose Support Room Personnel

Multi-Purpose Support Room (MPSR) personnel occupy consoles in the Flight Dynamics MPSR. These specialists in various disciplines represent expertise in Flight Design and MCC processor operation, and provide immediate and timely support for the FDO in various ways during all mission operations phases.

2.3.1 ARD Support

The ARD Support position is staffed by an RSOC contractor and has the following duties:

1. Acts as a clearinghouse for flight-specific console operations data and flight design products (reconfiguration input listings, ARD support data for off-nominal engine performance, stuck throttle performance charts, etc.).
2. Represents appropriate FDO concerns and requirements with STSOC contractor support personnel.
3. Maintains and reconfigures off-line ascent computational tools (Ascent/Entry Trainer, Notebook computers, and the HP-41C).
4. Processes OMS, RCS, and day-of-launch ET loading updates for use in the ARD and AME.

5. Performs real-time assessment of ARD mass track quality and recommends thrust and/or mass updates as required.
6. Maintains expertise regarding ARD and AME theory, formulation and operation.

2.3.2 Landing Support Officer

The Landing Support Officer (LSO) is a representative of the Department of Defense Manager for Space Shuttle Contingency Support (DDMS) detailed to the Ascent/Entry Flight Dynamics Section. The LSO is responsible to the FDO for:

1. Pre-launch coordination of landing site configuration requirements and status.
2. Representation at the Landing Operations Support Panel (LOSP).
3. Real-time assessment of Orbiter landing performance margins for RTLS, TAL, AOA, and FD1 PLS landings.
4. Real-time coordination between MCC and the landing sites.
5. Point-of-contact for MCC operations with SAR forces.

Specific details regarding LSO duties and operations may be found in the LSO Console Handbook.

2.3.3 Abort Support

Abort Support is a specialist operator responsible to the FDO for:

1. Detailed knowledge of flight-specific flight design groundrules and constraints.
2. Expertise in abort maneuver theory, requirements, and design.
3. Expertise in assessment of performance penalties, sensitivities, and trades.
4. Assistance in real-time analysis and recommendations regarding all abort situations.

This position is staffed by a STSOC representative from the pre-mission analysis/design community and therefore provides a "conduit" for feedback and communications between the disciplines of flight design and real-time operations.

2.3.4 Targeting

Targeting is a specialist position responsible for providing expert support to FDO with respect to design and selection of OMS-1 and OMS-2 targets. This position is staffed by a STSOC representative from the pre-mission analysis/design

community and therefore provides a "conduit" for feedback and communications between the disciplines of flight design and real-time operations.

Targeting is expected to possess a comprehensive knowledge of the flight design process, MCC data base reconfiguration, OMS target design techniques and requirements, target parameter sensitivities, orbital mechanics, and the powered flight guidance/targeting software.

2.3.5 Entry Support

Entry Support is a specialist operator responsible to the FDO for precision assessment of Orbiter landing performance on the day-of-launch. Assessments are made using a 3-degree-of-freedom (DOF) simulation based on expected landing weight and both measured and forecast winds for each of the potential intact abort sites. This information, in conjunction with LSO analyses, Shuttle Training Aircraft reports, and remote site pilot reports, is factored into the MCC launch GO/NO-GO decision process. Flight rules dictate required landing performance margins.

In addition to the above duties, Entry Support provides an additional real-time source of expertise and assistance to the FDO in the event of an unplanned or unusual entry.

During launch operations, Entry Support also serves as a specialist responsible to the FDO for assessment of TAL aborts, downrange abort options in the event of premature MECO, or loss of post-MECO maneuvering capability (prior to orbit insertion). This assessment is made using the DAE.

Specific TAL support responsibilities include:

1. Flight-specific configuration of the DAE software.
2. Real-time operation and control of workstation-based DAE processing.
3. Recommendation to FDO for downrange abort site selection and OMS dump requirements.

2.3.6 Ground Navigation

Ground Navigation Support (NAV) is responsible to FDO for processing and control of the trajectory determination processor. Specific duties and responsibilities include:

1. Monitoring, control, and processing of incoming radar tracking data.
2. Maintaining the quality of the ground navigation vector.
3. Recommendation to FDO regarding the best state vector source.

Additional operators (known as ONAV and INDAT) are located at the NAV console and are responsible primarily to GPO and NAV, respectively, for maintenance of the quality of the onboard navigation state, incoming tracking data, and operation of the delta-state processor.

2.3.7 Winds

The Winds position is responsible for:

1. Coordination of Jimsphere, Windsonde, and Rawinsonde balloon schedules and releases.
2. Processing of measured winds and atmospheric data for use in day-of-launch ascent loads and landing performance assessments.

2.3.8 Ascent Support

Ascent Support is the lead operator in the computation, preparation, and dissemination of DOL loads and trajectory analysis packages. This data is used by the Launch Systems Evaluation Advisory Team (LSEAT) to verify that expected vehicle dynamics loads are within limits and to make DOLILU recommendations to the Mission Management Team (MMT).

2.3.9 External Tank Impact Predictor

External Tank Impact Point support (ETIP) is a specialist responsible for real-time computation and dissemination of information regarding the expected ET impact point. This data is transmitted to the FCO and the Space Defense Operations Center (SPADOC) of the U.S. Space Command.

2.3.10 Launch Window/Launch Targeting

For flights involving use of the Launch Window/Launch Targeting MCC processor, additional support is provided to ensure consistent and accurate targeting on DOL. This always occurs for ground-up rendezvous missions but may also include planetary payload flights and others requiring insertion to a specific inertial plane. This position will include Rendezvous FDO personnel (call sign "FDO Support"). Also, TARGETING will provide assistance in QAing the computations and will independently verify the IYs.

2.3.11 Dynamics

For ascent phase, there are two Dynamics supporting the FDO/TRAJ. This position is responsible for making many of the inputs required to update the Traj Server and TSA database and executing the processors. This includes loading in Init PAD data, building ephemerides, manually inputting maneuvers, entering throttle changes into the ARD, executing DMP, etc.

2.3.12 Trajectory Applications Officer (TAO)

The TAO is responsible for initializing the Traj Server and TSA, monitoring the health of the Traj Server hardware and software, creating Traj Server and TSA checkpoints and turning the system around to previous checkpoints.

2.3.13 FDO Management Support

In order to assure orderly conduct of operations within the Trajectory MPSR, the Trajectory Operations Manager or a designated representative is present to

enforce access restrictions, attend to any management-related matters, and to provide a central authority for overall MPSR activities. The call sign for this position is "FDO Management Support," or sometimes just "FDO Support."

2.4 Other Interfaces

The ascent FDO and TRAJ interface with several other positions which are non-ascent specific, such as DFE in the Operations Support Team (OST) MPSR; Pointing, in the Flight Activities MPSR; the Spaceflight Meteorology Group (SMG), callsign "Weather"; and the Space Control Center (SCC) of the U.S. Space Command (USSPACECOM) at Cheyenne Mountain Air Force Station in Colorado Springs, Colorado. Specific operations with these personnel, where peculiar to ascent phase, will be dealt with in the "procedures" sections.

In addition, the FCO deals extensively with the ascent FDO and TRAJ in matters regarding protection of critical land masses and population areas from a malfunctioning vehicle. Specifics on range operations and FCO interfaces are found in the "procedures" sections and in the Range Safety section (chapter 9).

3 CONSOLE CONFIGURATION

This section defines FDO console configurations to be used during prelaunch, launch, and post-MECO phases, the purpose and configuration of PBI's, the abort switch, and DDD . It is assumed that the reader is familiar with MCC console hardware and display functions.

3.1 Display Configuration

Display configurations are changed during ascent, depending on the mission mode being executed. Standard configurations are described below for each type of display, though real-time modifications to these configurations may be made at the descretion of the operators.

3.1.1 Console Displays

Four CRT display monitors are used by the FDO and TRAJ. Each person has 2 monitors. There are several auto configs set up on the workstation for calling up all the displays needed by FDO and TRAJ for each phase. In addition, the several choices for the ascent phase including; 1) Powered flight FDO, 2) Powered flight TRAJ and 3) Post-MECO FDO. The powered flight TRAJ has a couple of additional displays that are called up for the TRAJ to possibly use in maintaining the Abort Region Determinator (ARD).

3.1.2 Group Displays

The group displays are projected on the three 10x10 foot screens in the front of the White Flight Control Room (FCR). For the ascent and entry phases, the GC has to redirect the video servers outputs to the front screens. Once this has been done, TRAJ can then call up the group displays by selecting the appropriate menu item on the DNAV. Just one click on this button automatically calls up all the group displays. For ascent phase, the displays are:

<u>LEFT SCREEN</u>	<u>CENTER SCREEN</u>	<u>RIGHT SCREEN</u>
(Group) Launch Digitals	Outplane (ETIP/DAE)	Altitude vs Downrange

If a RTLS or TAL is done, post-MECO the entry group displays must be called up. This should be done by TRAJ immediately after MECO. The ascent group displays can be killed after the entry ones have been called up. For entry phase, the displays are:

<u>LEFT SCREEN</u>	<u>CENTER SCREEN</u>	<u>RIGHT SCREEN</u>
(Group) Entry Digitals	Groundtrack	Velocity or E/W vs Range

3.2 *Push-Button Indicators*

There are two PBI modules used by FDO and TRAJ for ascent. This section covers the use and configuration of PBIs for ascent. The **FDO Launch PBIs** panel is the prime one now used. The **FDO Backup Launch PBIs** panel is used as a backup method to the PBIs on the ARD display GUI.

FDO Launch PBIs - Below is a list of PBIs on this panel and a brief description of what each PBI does:

BFS / TGT V54 TLM11: toggle between “TGT VAT V54 TLM 11” and “BFS VAT V54 TLM 11”. The default is BFS.

CUR UPP / BFS V53 TLM12: toggle between “CUR UPP V53 TLM 12” and “BFS GND V53 TLM 12”. The default is CUR UPP.

DAE P MECO AM/HM/2HM: Toggles between the Actual mode (AM), Hypothetical (HM) and 2nd Hypothetical mode (2HM) as the driver for the DAE predicted MECO footprint. The default is 2HM.

ETIP DRAG ON / OFF: Toggles the drag in the ETIP processor on and off. DRAG OFF is the desired setting for ETIP so that the the output matches the Flight Control Officer’s (FCO) “vacuum” impact point.

CUR O/B / BFS V56 TLM10: toggle between “CUR O/B V56 TLM 10” and “BFS O/B V56 TLM 10”. The default is CUR O/B.

ARD HYD FAIL ON / OFF: Toggles the Hydraulic Fail flag in the ARD ON and OFF. The default is off. This flag should be turned on after any hydraulic system failure.

FDO Backup Launch PBIs - Below is a list of PBIs on this panel and a brief description of what each PBI does:

SEL SRC TLM: Selects the telemetry vector as the selected source vector

SEL SRC FLTR: Selects the filter vector as the selected source vector

LIFTOFF: starts the ARD, ETIP, and DAE and sets the Traj Server liftoff time to the O/B lift-off time.

VECTOR SAVE / PC<50 : Receipt of this PBI following a valid L/O PBI causes the next six HSTD filter and TLM10 vectors to be saved, labelled, and output to the Traj Server log in internal units of ER, (earth radii) and ER/HR.

MECO: Indicates if MECO has occurred in the onboard, MCC, or both. The first receipt of this PBI following a valid L/O PBI will:

- Turn on the MECO DDD
- Terminate ARD (after the current cycle), RTLS EP, DAE, and out-of-plane monitor processing.
- Set the selected source to TLM for the first AME execution.
- Transfer post-MECO selected source and TLM10 vectors to the VAT, and make them available to the AME.
- Call the AME after valid post-MECO vectors are obtained. NOTE: Vectors are obtained at MECO+6, 30, and 60 seconds from all sources. These vectors are also sent to the AIPC.

The second receipt of this PBI turns off the MECO DDD, restarts the ARD, RTLS EP, DAE and terminates vector selection or the AME, whichever is executing. Subsequent receipts of this PBI toggles between the two options above. This PBI is valid only in LAUNCH phase.

ARD TAL MAN/AUTO THROTTLE: Toggles the ARD TAL THROTTLES between manual and auto . Manual throttles is used to by pass the throttle down logic for TALs.

THRUST UPDATE FREEZE: The Freeze PBI snaps the current thrust value and computes a delta thrust to the I-loaded value.

ALL ENGINE THRUST UPDATE EXECUTE: Divides the delta-thrust value computed from the Freeze by three and applies it to the thrust of each engine.

LEFT ENGINE THRUST UPDATE EXECUTE: Applies the total delta-thrust computed from the Freeze to the left engine thrust value.

CENTER ENGINE THRUST UPDATE EXECUTE: Applies the total delta-thrust computed from the Freeze to the center engine thrust value.

RIGHT ENGINE THRUST UPDATE EXECUTE: Applies the total delta-thrust computed from the Freeze to the right engine thrust value.

THRUST UPDATE RESTORE: Restores the thrust of all engines to the original pre-update value stored in the Traj Server.

ATO: Indicates if ATO has been selected in the onboard (BFS), ARD, or both. The PBI aborts ATO in the ARD and stops the other abort mode computations except for TAL.

TAL: Indicates if TAL has been selected in the onboard (BFS), ARD, or both. The PBI aborts TAL in the ARD and stops the other abort mode computations.

RTLS: Indicates if RTLS has been selected in the onboard (BFS), ARD, or both. The PBI aborts RTLS in the ARD and stops the other abort mode computations.

LEFT ENG OUT: Indicates that guidance acknowledges the left engine out in the onboard, ARD, or both. The PBI turns the left engine off in the ARD.

NOTES:

- L/O PBI must precede an SSME out PBI.
- Subsequent receipts of this PBI are ignored.
- Time and velocity of engine out will be computed on receipt of the first SSME out PBI only. Subsequent entries of different engine-out PBIs will set the time and SSME OUT discrettes for the selected engine, but will not initiate new velocity comps.

CENTER ENG OUT: Indicates that guidance acknowledges the center engine out in the onboard, ARD, or both. The PBI turns the center engine off in the ARD.

RIGHT ENG OUT: Indicates that guidance acknowledges the right engine out in the onboard, ARD, or both. The PBI turns the right engine off in the ARD.

TAL ACT MODE: Upon selection of this PBI, the user can change the selected landing site in the TAL Actual Mode.

TAL HYP MODE: Upon selection of this PBI, the user can change the selected landing site in the TAL Hypothetical Mode.

TAL 2nd HYP MODE: Upon selection of this PBI, the user can change the selected landing site in the TAL 2nd Hypothetical Mode.

RTLS ACT MODE: Upon selection of this PBI, the user can change the selected landing site in the RTLS Actual Mode.

RTLS HYP MODE: Upon selection of this PBI, the user can change the selected landing site in the RTLS Hypothetical Mode.

RTLS 2nd HYP MODE: Upon selection of this PBI, the user can change the selected landing site in the RTLS 2nd Hypothetical Mode.

RTLS / TAL PRI: Changes the selected mode and channel to use the primary landing site.

RTLS / TAL SEC: Changes the selected mode and channel to use the secondary landing site.

RTLS / TAL ALT1: Changes the selected mode and channel to use the ALT1 landing site.

RTLS / TAL ALT2: Changes the selected mode and channel to use the ALT2 landing site.

RTLS / TAL ALT3: Changes the selected mode and channel to use the ALT3 landing site.

RTLS / TAL ALT4: Changes the selected mode and channel to use the ALT4 landing site.

DAE P MECO TAL CHANNEL: When selected the DAE predicted MECO footprint will reflect the TAL channel of the selected mode.

DAE P MECO AOA CHANNEL: When selected the DAE predicted MECO footprint will reflect the AOA channel of the selected mode.

DAE P MECO NOM CHANNEL: When selected the DAE predicted MECO footprint will reflect the NOM channel of the selected mode.

DAE P MECO ATO CHANNEL: When selected the DAE predicted MECO footprint will reflect the ATO channel of the selected mode.

3.3 Digital Display Drivers

For all powered-flight ascent operations, including nominal, ATO, TAL, and RTLS one DDD (launch) field is use. The list below shows the contents of the FDO Ascent DDD panel. The MSIDs of the parameters are in the test plan for this panel.

TRAJ SERVER PHASE: indicates if the Traj Server is in Launch, Ops, or Landing Phase.

LIFTOFF: indicates if LIFTOFF has occurred in the onboard, Traj Server, or both.

PC<50 / SRB SEP : indicates when the SRB Pc < 50, and shortly after when SRB separation occurs.

MECO: Indicates if MECO has occurred in the onboard, Traj Server, or both.

ET SEP: Telemetry flag that indicates when ET Separation occurs.

L HYD LOCK: indicates when the onboard controller has set the left engine hydraulic lock-up flag.

C HYD LOCK: indicates when the onboard controller has set the center engine hydraulic lock-up flag.

R HYD LOCK: indicates when the onboard controller has set the right engine hydraulic lock-up flag.

HIGH PRIORITY: during normal operations the Traj Server cycles between high priority and low priority. During high volume processing times, it is possible for the Traj Server to go into high priority lockout, where only high priority jobs will be processed.

DAE P MECO MODE: Indicates which mode the DAE predicted MECO footprint is displaying, Actual, Hyp, or 2nd Hyp.

DAE P MECO CHNL: Indicates which channel is being used to plot the DAE footprint: TAL, AOA, NOM, or ATO.

RTLS PPA: Indicates when the onboard has begun powered pitch around.

RTLS PPD: Indicates when the onboard has begun powered pitch down.

L ELEC LOCK: indicates when the onboard controller has set the left engine electric lock-up flag.

C ELEC LOCK: indicates when the onboard controller has set the center engine electric lock-up flag.

R ELEC LOCK: indicates when the onboard controller has set the right engine electric lock-up flag.

LOW PRIORITY: during normal operations the Traj Server cycles between high priority and low priority. During high volume processing times, it is possible for the Traj Server to go into high priority lockout, where only high priority jobs will be processed.

BFS ENGAGE: Indicates that the onboard has performed a BFS engage.

MANUAL THROTTLE: indicates when the onboard, Traj Server, or both have taken manual throttles.

CSS/AUTO PITCH: Indicates if the onboard is in CSS or AUTO PITCH control.

CSS/AUTO ROLL/YAW: Indicates if the onboard is in CSS or AUTO ROLL/YAW control.

L ARD LOCK: indicates when the left SSME lock flag has been set in the Traj Server ARD processor.

C ARD LOCK: indicates when the center SSME lock flag has been set in the Traj Server ARD processor.

R ARD LOCK: indicates when the right SSME lock flag has been set in the Traj Server ARD processor.

3.4 Abort Switch

There are two abort switches in the MCC, one on the FD console, and one on the FDO console between the 2 FDO monitors. When an abort switch is depressed, the ABORT A/B ON words flash on the switch and an abort request command is sent to the orbiter, illuminating the cockpit ABORT light. The switches are tested during the prelaunch planning shift at about L-8:45. More details are in chapter 9.0 of this handbook.

3.5 Handling Real-Time Console Failures

In general, console failures must be brought to the attention of the Ground Controller (GC) and Flight Director (FD). The GC is responsible for the ground systems, and will notify and dispatch Maintenance and Operations (M&O) personnel to repair or replace the defective equipment. During critical phases, of course, the FD must be made aware of any malfunctions which may degrade the FDO's capabilities. For the same reasons, the FD must be notified when capability is restored.

This section is intended to outline backup capabilities and procedures to handle various equipment failures while repairs are effected, such that critical calls and data remain available to the FDO and/or TRAJ.

3.5.1 DVIS

FDO Keypad: FDO moves to TRAJ keypad, TRAJ moves to second GPO keypad. If possible, have GPO move to the second GPO keypad such that TRAJ can use the primary GPO unit (closer to the TRAJ console).

TRAJ Keypad: TRAJ moves to second GPO keypad. If possible, have GPO move to the second GPO keypad such that TRAJ can use the primary GPO unit (closer to the TRAJ console).

Both FDO and TRAJ Keypads: FDO and TRAJ both plug into primary GPO keypad. GPO moves to secondary keypad.

3.5.2 Workstation, Including Monitors

If FDO's workstation fails during high-speed, the FDO will move over to share the TRAJ workstation. If time permits, TRAJ could go to the MPSR. If the TRAJ workstation fails, the TRAJ can either move over and share the FDO workstation or go to the MPSR.

If the failure occurs in the pre-launch timeframe and time allows, call and report the problem to WSS on the WSS Call loop.

3.5.3 Large Screen Displays

Notify the GC of any problems with the large screen displays. The video server that drives this displays is a non-flight-critical system, and launch will not be held to regain this capability.

The standard configuration of the large screen displays for ascent are Group Launch Digitals on the left, Group Outplane (DAE and ETIP output) on the center and Altitude versus Range on the right screen. TRAJ is responsible for calling up the large screen displays during high-speed.

3.5.4 PBI

All FDO PBIs that are always used during ascent (e.g. launch, vector save, MECO) are now automated in the ARD Output GUI, provided the AUTO/MAN MED PBI is set to AUTO. Several other PBIs can now be shipped from the ARD Output also (e.g. Selected Source, TAL MAN Throttles). Should the ARD Output not work to send one of these PBIs, the FDO/TRAJ can use the FDO_Backup_Launch PBI panel to ship any of those PBIs. All FDO PBIs also have MED backups. Call Dynamics to have the appropriate PBI backup MED entered.

4 INITIALIZATION FOR OPERATIONS

4.1 Initialization for Ascent

PURPOSE

This section documents the Traj Server initialization procedures during prelaunch for either ILC, sim or flight support.

PROCEDURE

1. Log into the workstation & PC; sign on to DVIS.
2. Log in to command manager & activate FCO abort switch interface (Traj only) / abort switch (FDO only). Ref SOP 9.5.8.
3. Initialize TSA (Local Trajectory)
4. Traj Server Database Initialization (✓TAO)
 - Traj Server brought up "cold":
 - DYNAMICS will initialize the TRAJECTORY application (P80), load the INIT PAD data provided by ARD Support, and build TDRS ephemerides after step 7 (below) is performed.

WARNING:

FOR FLIGHT SUPPORT, DO NOT MODIFY ANY PARAMETER NOT ON THE STANDARD, APPROVED LIST (SECTION 4.3) WITHOUT PRIOR APPROVAL FROM THE ASCENT/ ENTRY FLIGHT DYNAMICS SECTION HEAD. ANY NON-STANDARD PARAMETER THAT IS MODIFIED MUST BE TESTED IN A SIM PRIOR TO USE FOR FLIGHT.

5. FLIGHT ONLY: VERIFY TAO RESTORES TSA FROM BASELINE
6. Ephemeris and AME Initialization
 - A. Set both the Ephemeris and AME weight to be the "Orbiter Pre OMS-2 Burn" weight. (M51 Total Vehicle and K73 Vehicle). This weight will be used instead of the weight that is output from the ARD WEIGHTS program.
 - B. Set the weight loss rate to 0.1 lbs/sec for both the MEP and MZH thrusters.

- C. Set system parameters MCOMPSP and MCRSET to zero.
 - D. Increase ET jettison weight by 5073 lb. This weight is changed with the K67 MED (Weight loss from ET jettison) and is displayed on MSK 433. Late updates with ARDTOOLS also need to be adjusted appropriately. This allows the ARD to hand over the correct (post MPS dump) weight to the AME
 - E. TUP Eph 3 on FDO Support or Nav's latest target vector. Verify propagation characteristics.
7. TRAJ: Start AUTOMOC VAT mirror:
Select AUTOMOC UIF
AUTOMOC VAT – Start
 8. TRAJ: Perform Launch Window / Launch Targeting (SOP 5.3.15)
 9. TRAJ: Configure Eph 2 w/ OMS-2 mnvr (SOP 5.2.6). Notify FDO & FDO Support “LW/LT complete”.
 10. FDO: QA LW/LT solution & give GPO “Go” for launch & OMS
 11. TRAJ: Execute PMPwith baseline data file for ascent. Perform an OMS depletion w/AOA Δ OMS (from Prop). Under **DATA/ SYNC TSU**, perform **SYNC ALL**.
 12. TRAJ: Configure PSAT per SOP 3.4.3.1.2
PSAT: M1 STDN = ON Nets = B/C/D/P/S/U/T (eph)
M2 STDN = ON Nets = B/C/D/P/S/T (eph)
M3 STDN = ON Nets = C/R/S/T (eph)
M4 STDN = OFF Nets = B/C/D/P/S/T (eph)
R STDN = ON Nets = E/N/S/T (ehp)
 13. TRAJ: Start AUTOMOC eph mirrors for each ephemeris desired (E1 thru E4 recommended). When TUPs complete, notify DFE that PSAT is ready.
 14. FDO: Configure underspeed curves per SOP 5.3.23
 15. FDO: Activate MARGI (select file from /users/fdo/cwsfdo/margi/ and choose “spd” for single-pane day or “tpd” for two pane day)

16. QA all parameters in the database. The majority of this QA can be done automatically with DB Checker. TSA inputs must be manually checked. Below is a list of the tables and applicable MSKs:

TABLE	CONTENTS	Display
AME	AME Init: K71, K72, K73, K89	ARD-AME INIT (433), MISC PARAMETERS, AME/ETIP AGT MED INP (2446)
CNST	System Parameters	ENGINE CHAR TABLE, ASC SYS Parms 1, ASC SYS Parms 2 (2361)
GTT	RTLS/TAL WX Alt: K90, K91, K92	RTLS/TAL WX ALT 1-3
LTT	IYs, OMS TGTs, dump timers, etc: K81, K82, K86, K89, K87	IYD Vector Display, AGT OMS-1 and 2 TGTs, AME/ETIP AGT MED INP (2446), ARD CONTROL DATA (2454)
MIT	ARD Init, throttle tables: K61, K64, K65, K66, K67, K69, K88, K89	ARD-AME INIT (433), AME/ETIP AGT MED INP (2446), SSME1-C/L/R THRTL/ISP/MR
MPT	EPH Init: M49, M51	Trajectory Profile Status
SECD	Traj. Parameters: F02	TRAJ PARMS (F02)
TMTT	Traj. Parameters: F02	TRAJ PARMS (F02)
DCT	Deorbit Constraints	Deorbit Constraints Table
ECT	Ent. Constraints:	Entry Constraints Table
---	SSME Parameters: INIT PAD or ASCT47	ARD SSME Params 1 & 2
LTT	MECO Underspeed Curves: K94	MECO Underspeed Tables, MECO Underspeed Curves
---	Mass Properties: √ PMP	ENGINE CHAR TABLE, DMP Mass Props

17. √ Low-Crossrange targets in the TAL WX Alternate Table (ref. section 5.3.6).

NOTE: DO NOT load in sim throttle tables for the Traj Server Confidence run. Use the CTL Cycle tables loaded in the Traj Server.

18. TRAJ: EDS Init

- Configure each selections file (AOA, TAL AND FD1 PLS (ORB_NORMAL)).
 - √ Prime RWY
 - SELECT WINDS
 - NOTE: AOA & TAL must have "L-" file; ORB Normal is "TD-"
 - Have Dynamics fetch mass props for AOA & ORB_NORMAL files.
- VERIFY CTL UPDATES
 - Execute EDS w/ a TAL MECO vector
 - Verify proper EDS execution (plots, Entry Digitals, etc.)
 - CLEAN-UP: SET EPHR TO "NONE"

19. TRAJ: Configure DCT per FDO runway selections sheet & DSCT-30.
Configure K51 for RTLS

20. TRAJ: Review DB Check results w/ ARD Support. Poll team for "Go for checkpoint". Have TAO take checkpoint when team ready.

BACKGROUND

For both the ephemerides and the AME, use the post MPS dump weight as the initial vehicle weight. This is list in the Abbreviated Report as the "Orbiter Pre OMS-2 Burn" weight. This is done together with very small weight loss rate for the MEP and MZH thrusters for essentially zeroing out the Δ weight from the MPS dump. Doing this will simplify procedures post MECO and eliminate some extra steps required in configuring the AME for OMS-2 planning. Zeroing the two system parameters will allow the proper weight to be handed over from the ARD to the AME post MECO.

AUTOMOC VAT and EPHEMERIDES must be enabled to allow for TSA mirroring of these Traj Server tables. This allows the DOL Range Safety personnel electronic access to the MECO telemetry vector and GC access to ephemeris 1 for the groundtrack display. The control of the E3 ephemeris mirror is left to FDO Support. They cycle the update of E3 post liftoff to update the GMTR. Also, prelaunch initialization of the PSAT must be done for the data to be automatically updated following each trajectory update (TUP). E1 is initially set to a short duration to speed up processing during the busy OMS-1/2 planning timeframe. It is later lengthed to a longer duration to cover all of FD1 planning.

4.2 *Integrated Load Checkout*

4.2.1 ILC Overview

Ascent and Entry ILCs are usually combined into one 2 to 3 hour session, involving three to five ascents and an entry. Entry phase ILC details are covered in the Entry FDO Console Handbook. The general run sequence is as follows:

Run 1: Nominal Ascent:

This nominal run is used to check the ascent load in general and to get a handle on the magnitude of any gross mass errors between the Traj Server and SMS. This is done by comparing the trajectory to plot background nominal lines, by comparing the abort mode boundary times to the flight design products, and by observing the ARD nominal margin trend. **NOTE: If a good match is indicated, runs 1 and 2 may be combined.**

Run 2: Engine-Out at Press-to-MECO

This run is used to calibrate the distribution of propellant weight and dry, or inert, weight. An engine is failed at Press-to-MECO (PTM) and a predicted underspeed is obtained, once the ARD is updated correctly with the time and velocity of engine failure. This underspeed is compared to the actual underspeed achieved. The two should differ by the underspeed equivalent of the ARD FPR -- about 100 fps -- with the ARD having the greater underspeed magnitude. If this is the case, the SMS weights are correct. If not, ARD Support runs the ARD ILC program on the console notebook computer (reference ARD Support Console Handbook, section TBS), which computes the appropriate SMS weight updates. These updates are passed to the FDO Monitor in the Sim Control Area (SCA) for input into the SMS.

Run 3: Engine-Out at Press-to-MECO (if required)

This run is identical to Run 2, if necessary, to validate any required updates.

Run 4: TAL

This run is a "nominal" TAL abort, used to check out the TAL logic onboard and in the MCC. Any two or three engine case, to an inplane or out-of-plane TAL site, may be used, depending on the whims of the team and any other constraints or desired cases requested by any operator.

NOTE: Run 4 may be terminated early if time constraints are a factor. The recommended cutoff time is anytime after OPS-3 transition, assuming MECO occurred nominally on the R-V line.

Run 5: RTLS

This run is an RTLS, exercising the onboard and MCC logic paths for OPS-6. Again, there is no hard requirement for a two or three engine RTLS. Any special desire by any operator to see one over the other may be honored.

Run 6: Entry from EI-10 (or 200K)

The purpose of this run is to verify that the SMS reset points which will be used for integrated entry simulations are consistent with the entry profile which will be used by the FDO for those operations.

After the run, a checkout of the MCC processors used for deorbit targeting and entry planning is made. Reference the Entry FDO Console Handbook for more details.

4.2.2 Traj Server Initialization for ILC

PURPOSE

This section documents the procedure for Traj Server initialization for an Integrated Load Checkout (ILC).

PROCEDURE

1. Prior to the ILC, ARD SUPPORT provides desired database inputs and changes to DYNAMICS and the TOCSS GA, via INIT PADs. These inputs include those made using both D64s and those stored on DYNAMICS group MEDs.
2. FDO: Have DYNAMICS load the D64s and group MEDs.
3. FDO, ARD SUPPORT: Use the ILC Checklist (section 4.2.3) to QA the entire database. Ref. Entry FDOCH section 4.5.16 for the Entry ILC checklist.

BACKGROUND

In order to expedite the process and maximize use of the operators' time during the ILC, ARD SUPPORT provides known required updates to the Traj Server, TSA and EDS database prior to the ILC. These changes will be used for all simulations involving the load being checked out. These "standard" init pads included files that TOCSS GA will load in to properly configure the TSA database. For details on init pad preparation and a sample init pad, reference section 2.2.3, Dynamics Initialization Pad Preparation, in the ARD Support Console Handbook.

Standard items checked during the ILC are listed in the Ascent ILC checklist. Any deviations from standard procedures are to be noted in the Notes section of the checklist.

4.2.3 Ascent Phase ILC Checklist: STS- CYCLE

- Complete initialization steps (procedure 4.1)
- Visually check limit lines and nominal scribes below:

- ___ ΔV MARGINS
- ___ OUTPLANE (BOTH FDO AND GROUP)
- ___ ALT vs. RGO
- ___ INPLANE

- Integrated Ascent Runs

- Displays -- Ensure that the following displays are updating correctly:

- | | |
|-----------------------------------|----------------------------|
| ___ ΔV MARGINS | ___ FDO LAUNCH DDDs |
| ___ OUTPLANE (BOTH FDO AND GROUP) | ___ FDO LAUNCH PBlS |
| ___ ALT vs. RGO | ___ FDO B/U LAUNCH PBlS |
| ___ INPLANE | ___ ARD ADI |
| ___ FDO LAUNCH DIGITALS | Verify proper function of: |
| ___ ARD OUTPUT | ___ THRUST LIMITING |
| ___ GROUP LAUNCH DIGITALS | ___ ARD OMS |
| ___ AME PRIMARY | |
| ___ ARD MAINTANENCE | |
| ___ GROUP LAUNCH DIGITALS | |
| ___ RTLS DIGITALS (DURING A RTLS) | |
| ___ BAILOUT | |

- Processors -- Check the following processors for reasonable results. The ARD boundaries and the AME moding should closely match the flight design data:

- ___ ARD
- ___ AME -- Transfer the AME solution to ephemeris one. Verify a good transfer.
- ___ DAE
- ___ ETIP

- Integrated Ascent Runs (cont'd)
- Hardware -- Check the following hardware for proper functioning:

____ DVIS Keysets
____ Abort switch

- Traj Server/SMS performance match -- Note below any mass updates which were made:

_____ ΔETP _____ ΔDRY

4.2.4 S0044 Support

PURPOSE

This section documents procedures used to support S0044 launch simulations.

PROCEDURE

NOTE

NTD WILL PERFORM SIM PRE-BRIEF PRIOR TO EACH RUN. WINDOW OPEN AND CLOSE GMTs WILL BE PROVIDED ALONG WITH MAX DRAINBACK PERFORMANCE HOLD TIME. THESE MAY BE UPDATED PRIOR TO COMING OUT OF T-9 MIN HOLD.

- SELECT "MALTA" FROM DM46 DRIVE ON THE S:\ DIRECTORY
- LOAD DATA FILE (e.g. "110.RWD") AND SELECT "MALTA GRAPHICS"
- UNDER OPTIONS MENU, SELECT "ONE PANE DAY" OR "TWO PANE DAY" AS APPROPRIATE PER SIM BRIEF
- CLICK ON "PANE 1 INPLANE" AND ENTER PREFERRED L/O TIME
- CLICK ON "PANE 1 (or 2) ET CLOSE" AND ENTER WINDOW CLOSE
- UNDER COMPUTE MENU, SELECT DRAINBACK CURVE
- CLICK ON "DRAINBACK HOLD" AND ENTER MAX DRAINBACK HOLD TIME. IF TWO PANE DAY, ENTER "PANE SWITCH" TIME.
- UNDER "REAL-TIME" MENU, SELECT START BUG

MALTA IS NOW CONFIGURED TO SUPPORT LAUNCH HOLD OPERATIONS FOR THE S0044 RUN. ENTER LAUNCH HOLD DATA AS REQ'D, AND PROVIDE SCRUB AND SWITCH TIMES TO GC.

BACKGROUND

FDO's primary duty during a S0044 simulation is launch window clock management. MALTA is best suited for this effort, and is easily configured per instructions above. Note that when MALTA is first activated, GMT is calculated from computer clock time assuming CST. Whenever preferred launch time GMT is updated, MALTA checks the day to determine whether CST or CDT time bias should be applied to the CPU clock time. For this reason, you may notice MALTA's current GMT jump by one hour after preferred launch time is entered.

Prior to each S0044 run, it is vital that FDO pay close attention to the sim pre-brief, and again at T-9 min in order to make note of launch window information. This will be provided by NTD over the OIS 232 loop. Another important loop to monitor is OIS 161--issues and problems that may lead to a launch scrub are discussed here. Launch window data obtained over the loops is typed into MALTA, which in turn provides scrub and switch times to pass to GC who manages MCC clocks. A launch hold is usually announced verbally, but sometimes may come up quickly. The T-MINUS / T-HOLD clock in the MCC is tied directly to KSC and is the best indicator of whether a launch hold is active. In case of a hold, click on MALTA's "Launch Hold" PBI and select the "L-" time at which the hold was initiated. If holding inside drainback, pass MALTA's scrub GMT to GC. Always verify GC's clocks, and keep FD apprised of time remaining in the hold. Once the count has resumed (again, check the T-MINUS/T-HOLD clock), click on MALTA's "Resume Count" PBI and enter the resume GMT (it defaults to the time the PBI was selected). For launch holds prior to drainback, pass FD the new (reduced) max drainback time which MALTA computes, and pass GC the corresponding scrub GMT.

Refer also to SOP 5.4.4 "Clock Ops for Launch Holds".

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4.3 ARD/AME Database Procedures

Engineering and flight cycle MCC database deliveries for the ARD and AME are performed with products ASCT-22A (ARD) and ASCT-22B (AME). These are sorted into DATA-22A (system parameters) and DATA-22B (MEDCVs) by SDM; note that both products contain ARD and AME data. This data next goes to the SPF, which converts the system parameters to Traj Server internal units with the ICD processor. This conversion process can be verified by examining product DATA-41 (System Parameter Report). The above products consist of parameters that are normally expected to change for a flight design cycle (*standard delivery*). Occasionally, some parameters not on the standard delivery list will be manually added to either product. This may be due to some change in ARD operating procedures, or an improvement to modeling accuracy. The non-standard parameter may be a one-time change, or it may be manually added to subsequent products until it is put into the system parameter baseline, or incorporated into the standard delivery via a flight design processor SR. Regardless, *any manual addition to the standard delivery requires the parameter to be listed on the product cover page, and a Notice to Ascent Designer (NOTAD) must be sent to Ascent/Entry Flight Dynamics section head.* The section head should then coordinate notification of all ascent personnel of the impending change. This enables communication of the change, and encourages all parties to double-check that the change is necessary and correct.

Parameters that change from flight cycle to the close-to-launch delivery (ASCT-L47 & ASAB-32B) must be checked against the attached list. Parameters on the list are standard updates due to mass property tweaks, engine tag assignment, minor ILOAD changes, etc. ARD Support should determine why every change from flight cycle to the close-to-launch delivery has occurred, and check the new numbers for reasonableness and verify when possible. *Any parameter changed on a close-to-launch product, but not listed in this section should not be input into the Traj Server until FDO, TRAJ, ARD Support, ARD designer, ARD Supervisor, and the Ascent/Entry Flight Dynamics Section Head have approved.* These parameters should be submitted on a separate Dynamics Initialization Pad along with the initials from those listed above. If the same parameter changes on the close-to-launch delivery for two flights or more, then an MCC display update is required to get the parameter displayed if there is none currently available. *Furthermore, any non-standard parameter change must be verified in the MCC environment during either an integrated simulation, or dedicated database confidence run.* This should be completed by L-2 days and may require special coordination for the MCC and SMS. Advance planning should be used to identify any non-standard database change and verify it during a scheduled ascent simulation so that special support is not required.

The ASCT-L47 product includes Traj Server unit conversions for system parameters that require conversion. This is accomplished automatically for the

standard delivery and manually for non-standard updates. System parameters not requiring conversion are labeled "N/A". *When preparing an Initialization Pad, all system parameter changes should be listed with these Traj Server units.*

WARNING:

System parameters are typed directly into Traj Server memory. No limit checking or unit conversions are performed as is the case with MEDs. Therefore, if a system parameter is input in the wrong units and the error goes unnoticed, the ARD and/or AME may be no-go.

Special attention should be paid to the units for manual changes outlined on the separate Initialization Pad described above. Since the manual process is more subject to error, *proper Traj Server internal units should be verified for system parameters using DATA-41 or the system parameter baseline.* Manual MED additions should also have their units checked against the MED List.

All parameters that change from flight cycle should be verified during the database checkout to assure that the correct number has been input in proper units. To do this, hardcopy the Traj Server database prior to any D64 or system parameter floppy inputs, then make the changes, check each parameter for correctness, and then hardcopy again. *If a system parameter changes that is not displayed, have Dynamics call up the parameter prior to changing it, then hardcopy it, input the new value in proper units, verify that the updated number has gone in with correct units by comparison with the previous number, and finally hardcopy again before closing the display.*

Unless specified otherwise, the input units are the same as the display units.

System/Traj Parameters

Traj Server Name	Bench/Array	Source	MSK	Typical Value	Display Units	Traj Server Units	Description
MCWTET	WTETD	ASCT-L47	2360	7xxxx	lbf	lbf	ET weight loss at jettison
MCWTSD		ASCT-L47	2360	37xxxx	lbf	lbf	SRB jettison weight
MCWTDR	WTDRY	ASCT-L47	2360	21xxxx	lbf	lbf	Orbiter dry weight
MCTMST	TMSTG	ASCT-L47	2361	12x.xx	sec	hr	Staging MET
MCDBD1		ASCT-L47	2445	X.XXE-02	ft/sec ²	ER/hr ²	Thrust Update deadband coefficient
MCDBD2		ASCT-L47	2445	X.XXE-04	ft/sec ³	ft/sec ³	Thrust Update deadband coefficient
MCDBD3		ASCT-L47	2445	X.XXE-06	ft/sec ⁴	ft/sec ⁴	Thrust Update deadband coefficient
XDLSDD01	MDLSDD01	INIT PAD	2445	-80.6xxx	deg	rad	Launch Pad Longitude
XDLSDD02	MDLSDD02	INIT PAD	2445	28.6xxx	deg	rad	Launch Pad Latitude (geod)
XDLSDD03	MDLSDD03	INIT PAD	2445	.496xxx	ND	ND	Launch Pad comp.
XDLSDD04	MDLSDD04	INIT PAD	2445	.48	ND	ND	Launch Pad comp.
XDLSDD05	MDLSDD05	INIT PAD	2445	.88	ND	ND	Launch Pad comp.
XDLSDD06	MDLSDD06	INIT PAD	2445	-104.8885 (A) -99.0814 (B)	ft	ER	Launch Pad Longitude
XDLSDD07	MDLSDD07	INIT PAD	2445	.99	ND	ND	Launch Pad comp.
XDLSDD08	MDLSDD08	INIT PAD	2445	.88	ND	ND	Launch Pad comp.
XDLSDD09	MDLSDD09	INIT PAD	2445	.48	ND	ND	Launch Pad comp.
XDLSDD10	MDLSDD10	INIT PAD	2445	.99	ND	ND	Launch Pad comp.
XDLSDD11	MDLSDD11	INIT PAD	2445	.14	ND	ND	Launch Pad comp.

XDLSDD12	MDLSDD12	INIT PAD	2445	-.87	ND	ND	Launch Pad comp.
XDLSDD13	MDLSDD13	INIT PAD	2445	.48	ND	ND	Launch Pad comp.
MCC0DL	C0DLV	ASCT-L47	2360	1.3	ft/sec	ER/hr	ARD ΔV margin correction coefficient
MCC1DL	C1DLV	ASCT-L47	2360	-2.3E-03	ft/sec ²	ER/hr ²	"
MCC2DL	C2DLV	ASCT-L47	2360	-4.7E-04	ft/sec ³	ft/sec ³	"
MCC3DL	C3DLV	ASCT-L47	2360	1.6E-06	ft/sec ⁴	ft/sec ⁴	"
MC0DVT	C0DLVT	ASCT-L47	2360	-5.0	ft/sec	ER/hr	ARD TAL ΔV margin correction coefficient
MC1DVT	C1DLVT	ASCT-L47	2360	1.7E-01	ft/sec ²	ER/hr ²	"
MC2DVT	C2DLVT	ASCT-L47	2360	-9.2E-04	ft/sec ³	ft/sec ³	"
MC3DVT	C3DLVT	ASCT-L47	2360	2.1E-06	ft/sec ⁴	ft/sec ⁴	"
MCKMAX	XKMAX	ASCT-L47	2361	1.045	% RPL	% RPLND	Abort throttle
MCK2MN	EPSK2	ASCT-L47	2361	< 1	ND	ND	ATO ramp dump I-load that is used to protect the 15 sec min OMS on-time constraint
MCVKXU		ASCT-L47	2361	0 ≤ X ≤ 30000	ft/sec	ER/hr	Variable abort throttle up velocity
MCVKXD		ASCT-L47	2361	0 ≤ X ≤ 30000	ft/sec	ER/hr	Variable abort throttle down velocity

System/Traj Parameters: F02 (No unit conversions required)

Traj Server Name	Bench/Array	Source	MSK	Typical Value	Display Units	Traj Server Units	Description
MCXWTO		ASCT-L47	2363	21xxxx	lbf	lbf	Orbiter dry weight (equal to SP MCWTRD)
SECD003	MCTFLH	ASCT-L47	2363	7560.	%ft/sec ²	ER/hr ²	AG accel-to-throt factor for hot SRB perf.
SECD004	MCTFLC	ASCT-L47	2363	3120.	%ft/sec ²	%ER/hr ²	AG accel-to-throt factor for cold SRB perf.
SECD005	MCWTFH	ASCT-L47	2363	-450. to -800.	lbf/% pwr lvl	lbf/% pwr lvl	AG throttle-to-wt factor for hot SRB perf.
SECD006	MCWTFC	ASCT-L47	2363	-400. to -800.	lbf/% pwr lvl	lbf/% pwr lvl	AG throttle-to-wt factor for cold SRB perf.
SECD007	MCWF2H	ASCT-L47	2363	0	lbf/sec	lbf/hr	AG time-to-wt fctr: hot SRB
SECD008	MCWF2C	ASCT-L47	2363	0	lbf/sec	lbf/hr	AG time-to-wt fctr:cold SRB
MCDVN2	DVNOM2	ASCT-L47	2445	2.9E-02	ft/sec ²	ER/hr ²	Thrust update nom margin shape coefficient
MCDVN3	DVNOM3	ASCT-L47	2445	-5.3E-05	ft/sec ³	ft/sec ³	Thrust update nom margin shape coefficient
MDMBOD01	XMBOD	ASCT-44 ASCT-09	2363	11000	slugs	lbm	Desired mass at start of PPD for 2 engine RTLS
MDMBOD02	XMBOD	ASCT-44 ASCT-09	2363	11000	slugs	lbm	Desired mass at start of PPD for 3 engine RTLS

System/Traj Parameters: K89 (No units conversions required)

Traj Serve Name	Bench/Array	Source	MSK	Typical Value	Display Units	Traj Server Units	Description
NOMMXRT	FORNOM	ASCT-L47	433	6.0xxx	ND	ND	Nominal SSME mixture ratio
BLK2L		ASCT-L47	2360	1	ND	ND	Block II engine flag for L SSME
BLK2C		ASCT-L47	2360	1	ND	ND	Block II engine flag for C SSME
BLK2R		ASCT-L47	2360	1	ND	ND	Block II engine flag for R SSME
MASBIAS		ASCT-L47		-26xxx	LBS	LBS	

MEDCV: K61 (No unit conversions required)

Traj Server Name	Bench/Array	Source	MSK	Typical Value	Display Units	Traj Server Units	Description
SSME IGN	TMMEIG	ASCT-L47	433	-4.xxx	sec	hours	MET (neg) of SSME ignition, K61/1

NOTE: Confirm ARD Mass Recycle time on MSK 433 = SSME IGN time

MEDCV: K66 (No unit conversions required)

Traj Server Name	Source	MSK	Typical Value	Display Units	Traj Server Units	Description
RCS INT'CT ENABLE, ATO	ASCT-L47	2454	Y or N	none	none	RCS incnct'd to OMS for ATO, K66/4
RCS INT'CT ENABLE, TAL	ASCT-L47	2454	Y or N	none	none	RCS incnct'd to OMS for TAL, K66/5
RCS INT'CT ENABLE, RTLS	ASCT-L47	2454	Y or N	none	none	RCS incnct'd to OMS for RTLS, K66/6

MEDCV: K67 Vehicle Weights (No units conversions required)

Traj Server Name	Bench/ Array	Source	MSK	Typical Value	Display Units	Traj Server Units	Description
OMS	WTOMSI	ASCT-L47	433	24000.	lbm	lbf	OMS loaded, K67/7
RCS	WTRCSI	ASCT-L47	433	4970.	lbm	lbf	Aft RCS loaded, K67/8
MEP	WTETFI	ASCT-L47	433	1605800.	lbm	lbf	Usable MPS prop, K67/10
DRY	WTVDRY	ASCT-L47	433	660000.	lbm	lbf	Total Dry vehicle wt, K67/11
DWT SRB	WTLSSST	ASCT-L47	433	375500	lbm	lbf	Wt loss at SRB sep, K67/12 (= SP MCWTSD)
DWT ET	WTLSET	ASCT-L47	433	68900	lbm	lbf	Wt loss at ET sep, K67/13 (= SP MCWTET)
FWD RCS INIT	WFRCSI	ASCT-L47	433	2450	lbm	lbf	Fwd RCS prop loaded, K67/9
ARD FPR	ETFPFR	ASCT-L47	600	1880	lbm	lbf	Total ARD FPR, K67/6

MEDCV: K69 Throttle Tables (No units conversions required)

Traj Server Name	Bench/ Array	Source	MSK	Typical Value	Display Units	Traj Server Units	Description
ISP		ASCT-L47	2447-9	45x.xxx	sec	hours	SSME Specific Impulse, K69/2
ISP PET		ASCT-L47	2447-9		mm:ss	hours	SSME Specific Impulse time tags, K69/3
Mixture Ratio	VLFOR(1-3)	ASCT-L47	2447-9	6.0xx	ND	ND	SSME mixture ratio, K69/4
Mix. Ratio PET	VLTOR(1-3)	ASCT-L47	2447-9		mm:ss	hours	SSME mixture ratio time tags, K69/5
AM THRTL		ASCT-L47	2447-9	104	% RPL	ND	AM SSME power level, K69/7 (Item 9=A)
AM THRTL PET		ASCT-L47	2447-9		mm:ss	hours	AM SSME pwr lvl times, K69/8 (Item 9=A)
HM THRTL		ASCT-L47	2447-9	104	% RPL	ND	HM SSME power level, K69/7 (Item 9=H)
HM THRTL PET		ASCT-L47	2447-9		mm:ss	hours	HM SSME pwr lvl times, K69/8 (Item 9=H)
2HM THRTL		ASCT-L47	2447-9	104	% RPL	ND	2nd HM SSME power level, K69/7 (Item 9=S)
2HM THRTL PET		ASCT-L47	2447-9		mm:ss	hours	2nd HM SSME pwr lvl times, K69/8 (Item 9=S)

NOTE: Confirm "TL" flags off (blank) on ARD OUTPUT after throttle table data loaded

MEDCV: K73 AME Weights (No units conversions required)

Traj Server Name	Bench/Array	Source	MSK	Typical Value	Display Units	Traj Server Units	Description
VEHICLE		ASAB-32B	433	25xxxx	lbf	lbf	AME post-ET sep vehicle weight, K73/1
OMS		ASAB-32B	433	20000	lbf	lbf	AME Usable OMS, K73/2

RCS		ASAB-32B	433	4595	lbf	lbf	AME Usable RCS, K73/3
-----	--	----------	-----	------	-----	-----	-----------------------

MEDCV: K86 OMS-2 AGT Targets (No units conversions required)

Traj Server Name	Bench/Array	Source	MSK	Typical Value	Display Units	Traj Server Units	Description
WCG OMS		ASAB-32B	433	-2000 < X < 2000	lbf	lbf	AME OMS reserves (one per each target set)

MEDCV: K87 Abort Dump Timers

Traj Server Name	Bench/Array	Source	MSK	Typical Value	Display Units	Input Units	Traj Server Units	Description
CONT		ASCT-L47	2454	xxx	mm:ss	sec	hour	Contingency dump timer, K87/1
ATO		ASCT-L47	2454	xxx	mm:ss	sec	hour	ATO dump timer, K87/2
TAL		ASCT-L47	2454	xxx	mm:ss	sec	hour	TAL dump timer, K87/3
RTLS		ASCT-L47	2454	xxx	mm:ss	sec	hour	RTLS dump timer, K87/4
OMS ASSIST FLAG	OMSASS	ASCT-L47	2454	ON or OFF	ND	ND	ND	OMS Assist on/off flag, K87/5
OMS ASSIST TIME	NOMTM	ASCT-L47	2454	102	mm:ss	sec	hour	Dump timer for OMS Assist (NOM) dump, K87/6

MEDCV: K88 (No units conversion required)

Traj Server Name	Bench/Array	Source	MSK	Typical Value	Display Units	Traj Server Units	Description
FUEL BIAS		ASCT-L47	433,434	1015	lbf	lbf	AOA fuel bias
PROPLVL		ASCT-L47	600	=ARD FPR	lbf	lbf	Usable ET prop at fuel depletion cutoff
VLIN		ASCT-L47	2446	9000	ft/sec	ft/sec	Velocity at start of OMS dump ramp
VZERO		ASCT-L47	2446	10000	ft/sec	ft/sec	Velocity at end of OMS dump ramp
VMEOATO		ASCT-L47	2446	10300	ft/sec	ft/sec	Minimum velocity that an ATO can be performed

MEDCV: M10 (No units conversion required)

Traj Server Name	Bench/Array	Source	MSK	Typical Value	Display Units	Traj Server Units	Description
MCMEPW		ASAB-32B	2311	87.54	Lbs/sec	lbs/sec	MEP weight loss rate (MZH and MEP)
MCMEPT		ASAB-32B	2311	14xx	lbf	lbf	MEP thrust level (MZH and MEP)

MEDCV: K94 MECO Underspeed Curves (No units conversion required)

Traj Server Name	Bench/Array	Source	MSK	Typical Value	Display Units	Traj Server Units	Description
MUTCNUM		ASCT-L47	599	1-45	n/a	n/a	Curve number (1-45) K94/1
MUTDESCR	PMDISC	ASCT-L47	599	n/a	text	text	curve description K94/2
MUTSHLOW	SHFLG	ASCT-L47	599	ON/OFF	n/a	n/a	shallow availability flag K94/3
MUTSTEEP	STFLG	ASCT-L47	599	ON/OFF	n/a	n/a	steep availability flag K94/4
MUTDEORB	DODV	ASCT-L47	599	100-335	fps	fps	deorbit ΔV for this curve K94/5
MUTOMSEQ	OMSBAL	ASCT-L47	599	0-3000	lbm	lbs	OMS equivalent ballast K94/6
MUTUNOMS	WOADJ	ASCT-L47	599	± 3000	lbm	lbs	adjustment to usable OMS K94/7
		ASCT-L47	599	1-20	n/a	n/a	point number K94/9
MUTMECOU	DVMUS	ASCT-L47	599	0-1200	fps	fps	MECO underspeed for this point number
MUTDVREQ	DVPM	ASCT-L47	599	0-1500	fps	fps	ΔV required for this point number

TRAJ Parameters (F02) (No units conversion required)

Traj Server Name	Bench/Array	Source	MSK	Typical Value	Display Units	Traj Server Units	Description
MCWLOBC	WDLO2BC	ASCT-L47	2451	900	lbm/sec	lbm/hr	100% Center SSME LO2 flow rate
MCWLOBL	WDLO2DL	ASCT-L47	2451	900	lbm/sec	lbm/hr	100% Left SSME LO2 flow rate
MCWLOBR	WDLO2BR	ASCT-L47	2451	900	lbm/sec	lbm/hr	100% Right SSME LO2 flow rate
MCWLHBC	WDLH2BC	ASCT-L47	2451	150	lbm/sec	lbm/hr	100% Center SSME LH2 flow rate
MCWLHBL	WDLH2DL	ASCT-L47	2451	150	lbm/sec	lbm/hr	100% Left SSME LH2 flow rate
MCWLHBR	WDLH2BR	ASCT-L47	2451	150	lbm/sec	lbm/hr	100% Right SSME LH2 flow rate
MCWGOBC	WDGO2BC	ASCT-L47	2451	2	lbm/sec	lbm/hr	100% Center SSME GO2 flow rate
MCWGOBL	WDGO2BDG	ASCT-L47	2451	2	lbm/sec	lbm/hr	100% Left SSME GO2 flow rate
MCWGOBR	WDGO2BR	ASCT-L47	2451	2	lbm/sec	lbm/hr	100% Right SSME GO2 flow rate
MCWGHBC	WDGH2BC	ASCT-L47	2451	0.5	lbm/sec	lbm/hr	100% Center SSME GH2 flow rate
MCWGHBL	WDGH2DG	ASCT-L47	2451	0.5	lbm/sec	lbm/hr	100% Left SSME GH2 flow rate
MCWGHBR	WDGH2BR	ASCT-L47	2451	0.5	lbm/sec	lbm/hr	100% Right SSME GH2 flow rate
MCFTBC	FTBC	ASCT-L47	2451	470000	lbf	lbf	100% Center SSME thrust
MCILLMDT	ILLMDT	ASCT-L47	2451	6.0	lbm/sec	lbm/hr	OMS interconnect mixture ratio LOX loss flowrate
MCLXMDT	LXMDT	ASCT-L47	2451	0.3	lbm/sec	lbm/hr	OMS non-interconnected mixture ratio LOX loss flowrate
MCFTBL	FTBL	ASCT-L47	2451	470000	lbf	lbf	100% Left SSME thrust
MCFTBR	FTBR	ASCT-L47	2451	470000	lbf	lbf	100% Right SSME thrust
MCIFT1C	INFLCA(1,1,1)	ASCT-L47	2450	470000	lbf	lbf	Center SSME thrust influence coefficient # 1
MCIO1C	INFLCA(2,1,1)	ASCT-L47	2450	900	lbm/sec	lbm/hr	Center SSME LO2 influence coefficient # 1
MCILH1C	INFLCA(3,1,1)	ASCT-L47	2450	150	lbm/sec	lbm/hr	Center SSME LH2 influence coefficient # 1

MCIGO1C	INFLCA(4,1,1)	ASCT-L47	2450	17	lbm/sec	lbm/hr	Center SSME GO2 influence coefficient # 1
MCIGH1C	INFLCA(5,1,1)	ASCT-L47	2450	1	lbm/sec	lbm/hr	Center SSME GH2 influence coefficient # 1
MCIFT2C	INFLCA(1,2,1)	ASCT-L47	2450	-20000	lbf	lbf	Center SSME thrust influence coefficient # 2
MCILO2C	INFLCA(2,2,1)	ASCT-L47	2450	-60	lbm/sec	lbm/hr	Center SSME LO2 influence coefficient # 2
MCILH2C	INFLCA(3,2,1)	ASCT-L47	2450	-10	lbm/sec	lbm/hr	Center SSME LH2 influence coefficient # 2
MCIGO2C	INFLCA(4,2,1)	ASCT-L47	2450	-18	lbm/sec	lbm/hr	Center SSME GO2 influence coefficient # 2
MCIGH2C	INFLCA(5,2,1)	ASCT-L47	2450	0	lbm/sec	lbm/hr	Center SSME GH2 influence coefficient # 2
MCIFT3C	INFLCA(1,3,1)	ASCT-L47	2450	20000	lbf	lbf	Center SSME thrust influence coefficient # 3
MCILO3C	INFLCA(2,3,1)	ASCT-L47	2450	45	lbm/sec	lbm/hr	Center SSME LO2 influence coefficient # 3
MCILH3C	INFLCA(3,3,1)	ASCT-L47	2450	7.5	lbm/sec	lbm/hr	Center SSME LH2 influence coefficient # 3
MCIGO3C	INFLCA(4,3,1)	ASCT-L47	2450	7	lbm/sec	lbm/hr	Center SSME GO2 influence coefficient # 3
MCIGH3C	INFLCA(5,3,1)	ASCT-L47	2450	0	lbm/sec	lbm/hr	Center SSME GH2 influence coefficient # 3
MCIFT1L	INFLCA(1,1,2)	ASCT-L47	2450	470000	lbf	lbf	Left SSME thrust influence coefficient # 1
MCILO1L	INFLCA(2,1,2)	ASCT-L47	2450	900	lbm/sec	lbm/hr	Left SSME LO2 influence coefficient # 1
MCILH1L	INFLCA(3,1,2)	ASCT-L47	2450	150	lbm/sec	lbm/hr	Left SSME LH2 influence coefficient # 1
MCIGO1L	INFLCA(4,1,2)	ASCT-L47	2450	17	lbm/sec	lbm/hr	Left SSME GO2 influence coefficient # 1
MCIGH1L	INFLCA(5,1,2)	ASCT-L47	2450	1	lbm/sec	lbm/hr	Left SSME GH2 influence coefficient # 1
MCIFT2L	INFLCA(1,2,2)	ASCT-L47	2450	-20000	lbf	lbf	Left SSME thrust influence coefficient # 2
MCILO2L	INFLCA(2,2,2)	ASCT-L47	2450	-60	lbm/sec	lbm/hr	Left SSME LO2 influence coefficient # 2
MCILH2L	INFLCA(3,2,2)	ASCT-L47	2450	-10	lbm/sec	lbm/hr	Left SSME LH2 influence coefficient # 2
MCIGO2L	INFLCA(4,2,2)	ASCT-L47	2450	-18	lbm/sec	lbm/hr	Left SSME GO2 influence coefficient # 2
MCIGH2L	INFLCA(5,2,2)	ASCT-L47	2450	0	lbm/sec	lbm/hr	Left SSME GH2 influence coefficient # 2
MCIFT3L	INFLCA(1,3,2)	ASCT-L47	2450	20000	lbf	lbf	Left SSME thrust influence coefficient # 3
MCILO3L	INFLCA(2,3,2)	ASCT-L47	2450	45	lbm/sec	lbm/hr	Left SSME LO2 influence coefficient # 3
MCILH3L	INFLCA(3,3,2)	ASCT-L47	2450	7.5	lbm/sec	lbm/hr	Left SSME LH2 influence coefficient # 3
MCIGO3L	INFLCA(4,3,2)	ASCT-L47	2450	7	lbm/sec	lbm/hr	Left SSME GO2 influence coefficient # 3
MCIGH3L	INFLCA(5,3,2)	ASCT-L47	2450	0	lbm/sec	lbm/hr	Left SSME GH2 influence coefficient # 3
MCIFT1LR	INFLCA(1,1,3)	ASCT-L47	2450	470000	lbf	lbf	Right SSME thrust influence coefficient # 1
MCILO1R	INFLCA(2,1,3)	ASCT-L47	2450	900	lbm/sec	lbm/hr	Right SSME LO2 influence coefficient # 1
MCILH1R	INFLCA(3,1,3)	ASCT-L47	2450	150	lbm/sec	lbm/hr	Right SSME LH2 influence coefficient # 1
MCIGO1R	INFLCA(4,1,3)	ASCT-L47	2450	17	lbm/sec	lbm/hr	Right SSME GO2 influence coefficient # 1
MCIGH1R	INFLCA(5,1,3)	ASCT-L47	2450	1	lbm/sec	lbm/hr	Right SSME GH2 influence coefficient # 1
MCIFT2R	INFLCA(1,2,3)	ASCT-L47	2450	-20000	lbf	lbf	Right SSME thrust influence coefficient # 2

MCILO2R	INFLCA(2,2,3)	ASCT-L47	2450	-60	lbm/sec	lbm/hr	Right SSME LO2 influence coefficient # 2
MCILH2R	INFLCA(3,2,3)	ASCT-L47	2450	-10	lbm/sec	lbm/hr	Right SSME LH2 influence coefficient # 2
MCIGO2R	INFLCA(4,2,3)	ASCT-L47	2450	-18	lbm/sec	lbm/hr	Right SSME GO2 influence coefficient # 2
MCIGH2R	INFLCA(5,2,3)	ASCT-L47	2450	0	lbm/sec	lbm/hr	Right SSME GH2 influence coefficient # 2
MCIFT3R	INFLCA(1,3,3)	ASCT-L47	2450	20000	lbf	lbf	Right SSME thrust influence coefficient # 3
MCILO3R	INFLCA(2,3,3)	ASCT-L47	2450	45	lbm/sec	lbm/hr	Right SSME LO2 influence coefficient # 3
MCILH3R	INFLCA(3,3,3)	ASCT-L47	2450	7.5	lbm/sec	lbm/hr	Right SSME LH2 influence coefficient # 3
MCIGO3R	INFLCA(4,3,3)	ASCT-L47	2450	7	lbm/sec	lbm/hr	Right SSME GO2 influence coefficient # 3
MCIGH3R	INFLCA(5,3,3)	ASCT-L47	2450	0	lbm/sec	lbm/hr	Right SSME GH2 influence coefficient # 3

4.4 Flight Load Checkout

PURPOSE

This section documents the software checkout procedure for verifying all the ascent FDO software (processors, applications and displays) for mission use once the flight-specific load has been upgraded to MISSION CERT mode.

Trajectory Ops CCB Required Disclaimer

All applicable software items on the FDO DNAV pulldown menu should be verified using the Flight Load Checklist (FLC) between L-30 days and L-15 days. The FLC must be performed using a "CERT" ("MIS" or "SIM") activity for the flight of interest. If possible, applications should be used during a simulation run to verify functionality. It is the responsibility of the discipline to identify or arrange for an appropriate activity in which to perform the FLC. The objective of the FLC is to ensure that all required applications are available and properly configured in their flight support environment. This objective is met by actually running the applications on some representative input data and observing the results to be consistent within the context of available data and functions exercised. No qualitative or specific criteria are required to either prove or document success. There is no expectation to either execute or verify all of the functionality associated with each application. This check relies on the engineering judgement and training of the operator executing the FLC to select which functions to exercise and subsequently determine that the application appears to perform properly. As such, the operator executing the FLC must be a prime user from the responsible discipline. This checklist must minimally document each application on the FDO DNAV pulldown menu and exhibit a pass/fail indication. It is responsibility of discipline to reconcile incompletes or failures via waivers, workarounds or resolutions. Any such actions should be documented with the FLC. It is responsibility of the discipline to accept the results of the FLC and archive all the associated documentation for future reference (for at least 3 months after launch).

PROCEDURE

Verify that all the processors, applications and displays below function properly after logging onto the workstation with the flight-specific activity in CERT mode.

Use the checklist on the following page to check everything. Sign and date it and then turn in this checklist to the A/E FDO Group Lead.

STS-____
ASCENT FLIGHT LOAD C/O CHECKLIST

1. Software Modifications

Obtain a list of software modifications from TOCSS. List those modifications below or attach a summary sheet if necessary. Document how each modification was verified.

2. Display Modifications

Obtain a list of display modifications from TOCSS. List those modifications below or attach a summary sheet if necessary. Document how each modification was verified.

3. Limit lines and nominal scribes – Visually check the lines on the displays below.

- ___ ΔV MARGINS
- ___ OUTPLANE (BOTH FDO AND GROUP)
 Set Target Lines To: PAD A and PAD B
- ___ ALT vs. RGO
- ___ INPLANE

4. Verify that the DNAV scripts still work properly

- ___ Pre Launch (TRAJ)
- ___ Powered Flight (FDO)
- ___ Powered Flight (TRAJ)
- ___ Post MECO (TRAJ)
- ___ Large Screen Ascent Displays

5. Verify that PMP works properly

- ___ Load Ascent Baseline

6. During ascent runs, ensure that the displays are updating correctly.

- | | |
|--|--|
| <input type="checkbox"/> ΔV MARGINS | <input type="checkbox"/> FDO LAUNCH DDDs |
| <input type="checkbox"/> OUTPLANE (BOTH FDO AND GROUP) | <input type="checkbox"/> FDO LAUNCH PBIs |
| <input type="checkbox"/> ALT vs. RGO | <input type="checkbox"/> FDO B/U LAUNCH PBIs |
| <input type="checkbox"/> INPLANE | <input type="checkbox"/> ARD ADI |
| <input type="checkbox"/> FDO LAUNCH DIGITALS | Verify proper function of: |
| <input type="checkbox"/> ARD OUTPUT | <input type="checkbox"/> THRUST LIMITING |
| <input type="checkbox"/> GROUP LAUNCH DIGITALS | <input type="checkbox"/> ARD OMS |
| <input type="checkbox"/> AME PRIMARY | <input type="checkbox"/> ABORT SWITCH (including |
| <input type="checkbox"/> ARD MAINTANENCE | ROCC I/F) |
| <input type="checkbox"/> GROUP LAUNCH DIGITALS | |
| <input type="checkbox"/> RTLS DIGITALS (DURING A RTLS) | |
| <input type="checkbox"/> BAILOUT | |

7. On the PRELAUNCH and ASCENT DNAV pulldowns, call up all the displays once to verify that data acq connects properly.

_____ Is this load acceptable for use during the mission (yes or no)? If no, attach a separate sheet with reasons and copies of DR's.

Signature _____

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5 PRELAUNCH PROCEDURES

5.1 L-2 Week Timeframe

5.1.1 Weather Cadre Pre-Brief/TALCOM Meeting

PURPOSE

The purpose of this meeting is to familiarize the ascent FD, FDO, LSO, TALCOM, GOM and WX personnel with the prelaunch weather evaluation timeline, standard support requirements, and any unique flight-specific requirements.

PROCEDURE

TALCOM Meeting: This meeting is chaired by the lead LSO and is usually held within two weeks of launch, just before the TALCOM personnel depart for the TAL sites. TALCOMs are the Astronaut Office personnel who support each of the TAL sites for a given mission and fly weather reconnaissance aircraft to provide L-1 day and launch day observations. Depending on the experience of the TALCOMs and the number of mission-unique items, the meeting can last anywhere from ten to thirty minutes. The Ascent FDO's attendance is mandatory. The Entry FDO is usually represented by the Ascent FDO during the Entry Weather Cadre Pre-Brief, which follows immediately after the Ascent Pre-Brief. Trajectory Officers are not required, but they may attend if they wish.

The standard agenda, LSO TALCOM MEETING NOTES, is as follows:

1. PACKAGE AND CONTENTS
 - a. Key Players/Mission Control
 - b. TALCOM Schedule Highlights
 - c. TALCOM Schedule Notes
 - d. Digital Launch Window
 - e. Ascent Events Summary
 - f. Abort Mode Boundary Chart
 - g. LSO Shift Schedule
 - h. Sunrise/Sunset Tables
2. DOD SITE SUPPORT
3. Special Assignment Airlift Missions (SAAMs), if required
4. KSC DOD SUPPORT
5. EDW DOD SUPPORT
6. WSSH DOD SUPPORT
7. TAL SITES DOD SUPPORT

Ascent Weather Cadre Pre-Brief: This meeting is chaired by the Ascent Flight Director, and follows the agenda below:

- Pre-Launch Timeline, Weather Briefings, and Decision Points
- TALCOM Schedules and Data Review
 - Flight Times
 - Adding/Cancelling Flights
 - Abort Mode Boundary Charts
 - Pre-Launch Sequence of Events and Launch Window
 - Sunrise/Sunset Times (if Applicable)
 - Key Personnel at Each Site
 - Travel Schedules
- Site-Specific Weather Patterns and Issues
- RTLS Weather Recon Flight Schedules (T-38 and STA)
- Weather Rules and STA Cue Card (especially flight-specific items)
- Roles and Interfaces With Respect To Weather Evaluation
 - Weather Recon Aircraft
 - Weather Coordinator
 - Weather CAPCOM
 - Weather (SMG)
 - FDO
 - Other Personnel
 - MOD
 - Weather FD
 - Weather CAPCOM
 - Other Management/FD Personnel in FCR

FDO roles:

- Recommend specific runway/aimpoint/speedbrake selection based upon weather, landing and rollout evaluation
- Receive site/runway, NAV/Landing Aids status from LSO
- Track weather issues including rain/thunderstorm tracking for RTLS, TAL, AOA and FD1 PLS sites

FDO interfaces:

- FD
- Weather FD
- Weather
- Weather CAPCOM
- MPSR Personnel (Winds, LSO, Entry Support, etc.)

5.1.2 Final Trench Tag-up

PURPOSE

The Final Trench Tag-Up is held to ensure that all flight dynamics and guidance FCR and MPSR personnel are cognizant of all issues relating to the flight.

PROCEDURE

The Final Trench Tag-Up is held within L-2 weeks and is chaired by the Lead FDO. Attendance by the Ascent and Entry FDOs, or their designated representatives, is mandatory. Generally, no presentation materials are required, unless unique, flight-specific requirements warrant. For the Ascent FDO, some general topics which should be covered here, or in one-on-one meetings with the appropriate personnel, are:

- On-Console Times/Shift Schedules
- Handover Procedures
 - Pre-launch Planning Team to Ascent Team
 - Post-OMS-2 Ascent Team to Orbit 2 Team
- Database Changes made by the Planning Team
 - Make only necessary changes
 - Log all updates and changes
 - Restore all non-permanent changes
- Off-Nominal Orbit Recovery
 - Minimum payload altitude
- Timing of OMS-3/OMS-4, if required, relative to shift handover

5.1.3 Launch Window/Launch Targeting State Vector Req'ts

At about a week prior to launch for ground-up rendezvous missions, the Ascent FDO must coordinate with the Lead FDO and the Lead NAV to schedule times at which a target state vector is desired. Typically, the times used are L-24 hrs and L-3 hrs. The time at which the state vector for the L-1 day computations is required may be adjusted earlier or later depending on the scheduling of the L-1 day briefings. The L-1 day comps have been done lately using either a USSPACECOM state vector (propped to midnight of launch day) or TOPO supplied vector.

5.1.4 Traj Server Confidence Run Preparation

PURPOSE

The Traj Server Confidence Run is intended to provide an integrity check on the Traj Server processors and database. A run number is selected during the final, flight-specific ascent simulation for use during this run.

PROCEDURE

During the last flight specific ascent sim:

FDO: Following the completion of the sim, notify GC which run is to be saved for replay on L-1 day.

At approximately L-5 days:

FDO: Schedule the Traj Server Confidence Run. This is typically around L-24 hour timeframe. It must be completed prior to Comm Activation.

At approximately L-5 days:

FDO: Notify FD, TRAJ, ARD Support, DYN, TAO, GPO, Lead FDO and Lead Pointer of the scheduled time of the Traj Server Confidence Run.

BACKGROUND

Reference section 5.2.6, Traj Server Confidence Run, for details regarding the run itself. The tape selected is usually a nominal run, though any abort mode is acceptable provided that the ARD performed nominally. Only telemetry is necessary since a valid state vector source is the only requirement to exercise the critical processors. In the past, tracking data has not been available during the confidence run.

Since sim scripts and non-scripted facility problems can impact the "last" run of the day, it is recommended that *any* run which may potentially be used for the confidence run be used. This allows OST personnel to save the data for use on L-1 day.

The Ascent FDO is responsible for scheduling the Traj Server Confidence Run. The constraint is that it must be completed prior to Comm Activation since that requires that the Command Server and FEPs to be step-ahead to the current time vice sim time. The time of Comm Activation can be determined from either GC or FD. It is convenient to schedule it close to the L-1 day briefings. This is typically around L-24 hour timeframe. Once scheduled, FDO needs to inform the people listed above to let them know when it is scheduled. This is required to get the right people there to support the run and get the database loaded prior to the run.

5.1.5 L-1 Day Timeline Planning Considerations

PURPOSE

Provide a reference for FDO prelaunch activity scheduling. Since many L-1 day activities “float” depending on the proximity of nominal launch time to “normal” working hours, preliminary coordination is essential to ensure that all positions are able to accomplish their objectives.

PROCEDURE

- Coordinate the timeline for the following activities during the last ascent sim prior to launch with GC, GPO, ARD Support, and FD, to ensure that no schedule conflicts arise:
 - Traj Server Initialization
 - Prelaunch target tracking for ground-up rendezvous
 - ARD Support hardcopies of “clean” database
 - Traj Server database configuration inputs
 - Checkpoint
 - Traj Server Confidence run
 - L-1 Day Systems and Weather briefings
 - DOLILU Transfer test
 - Comm Activation
 - L-1 Day MMT meeting
- Notes:
 - Comm activation is usually scheduled to occur at L-24 hours and takes several hours to complete. The Traj Server Confidence run should be scheduled prior to this operation, if possible.
 - The Traj Server database configuration and the DOLILU transfer test can occur simultaneously.
 - GPO will coordinate the L-1 day balloon schedule and DOLILU transfer test timing with Ascent Support at the L-3 day transfer test (not supported by FDO).

BACKGROUND

Self-explanatory.

5.2 *L-1 Day Timeframe*

5.2.1 Traj Server Initialization

Follow procedures in section 4.1, Initialization for Ascent. The Traj Server will be brought up "cold" prior to the first launch attempt. For subsequent launch attempts, the Traj Server may be brought up from a checkpoint from the previous attempt (reference section 5.4.1, Post-Scrub/Pad Abort Actions).

5.2.2 Traj Server Database Check

Check the entire database per procedures in section 4.1, Initialization for Ascent. Section 4.3, ARD/AME Database Procedures, contains a convenient checklist of those parameters which are likely to have changed since the flight cycle.

NOTE:

Any parameter changed for flight on a close-to-launch product, but not listed in section 4.3 must not be input into the Traj Server until FDO, TRAJ, ARD Support, ARD Flight Design, ARD Flight Design Supervisor, and the Ascent FDO section head have approved.

In addition, Any non-standard parameter changed for flight must have been verified in the MCC environment during either an integrated simulation or dedicated database confidence run.

Parameters falling in this category must be submitted on a separate Dynamics Initialization Pad along with signatures from those listed above.

5.2.3 Shuttle Systems Briefing

The Systems Briefing is presented by KSC to the flight crew and the ground support team to identify all anomalies, problems, and other notes, along with their resolutions and workarounds, if any. The FDO has no responsibility for any of the data presented, but some items may be of interest from a situational awareness standpoint. The Systems Briefing is followed immediately by the Crew Weather Briefing (section 5.2.4).

5.2.4 L-1 day Crew Weather Briefing

PURPOSE

This section documents the support provided by FDO for the crew weather briefing on L-1 day.

PROCEDURE

- Review the weather sheets before they are faxed to the crew quarters, to verify that all flight rule violations are noted and circled appropriately.
 - Initialize TSA and run QUAC to check for crosswind and head/tailwind violations
 - TRAJ: Used as an additional QA source
- Once all the violations have been noted, have LSO fax the final version to KSC.
- No approach and landing simulations are performed on L-1 day, because so many things can change in the last 24 hours that this analysis is futile.

5.2.5 L-1 day Launch Window/Launch Targeting Computations

PURPOSE

This section documents the Launch Window / Launch Targeting computations done on L-1 day to determine the preliminary launch window open, close and preferred launch times. Once these times are computed, FD passes them on to the NTD for resetting of T-0.

PROCEDURE

- TOPO: Provides ISS target state vector (FDO Support may already obtained it).
- USSTRATCOM: Provides a target state vector (SP) based the latest tracking.
- Run Launch Window/Launch Targeting (reference section 5.3.15). First, generate the data for a one day late case.
- Generate the following data:
 - Planar window open and close times
 - Launch window opening times: These times are typically rounded up to the next minute unless launch window is very small (e.g., MIR or ISS rendezvous).
 - Launch window closing times: These times are always quoted to the second.
 - Phase angles at the above time.
 - Repeat the above times and phase angles for the second planar window, if applicable. Otherwise, mark this entire block as N/A.
 - The preliminary preferred launch time (ref. SOP 5.3.20).
- Document the results on a Launch Window Update form (next page). The form is available on the under s:/divisions/dm/private/dm46/forms/FD LW FORM.doc. Make 2 copies and put one in the FDO Logbook. Give the other copy to FD. These results will be passed immediately to NTD by the on-console FD if required.
 - Repeat the above steps for the planned launch day.

STS-__ LAUNCH WINDOW DATA

LIFTOFF ON __/__/__ (DAY __ GMT)

FIRST PLANAR WINDOW

	GMT	Phase Angle (deg)
WINDOW OPEN	__:__:__	__
WINDOW CLOSE	__:__:__	__

SECOND PLANAR WINDOW

	GMT	Phase Angle (deg)
WINDOW OPEN	__:__:__	__
WINDOW CLOSE	__:__:__	__

PRELIMINARY PREFERRED LAUNCH TIME:

__/__:__ GMT

ASCENT FDO

Generated: Liftoff - __ HR (__/__:__ GMT)

5.2.6 OMS-2 Optimization

PURPOSE

This procedure outlines the steps required to optimize the OMS-2 burn. This procedure should be done both prelaunch and again post-MECO.

PROCEDURE

PRELAUNCH:

- PREP TO MODEL OMS-2
 - VECTOR - USE LTP POST MPS DUMP VECTOR
 - ANCHOR EPH 2

- ITERATE TO FIND OPTIMUM TIG
 - HAVE DYN DIRECT INPUT OMS-2 INTO EPH 2 (PEG TGTs from LW/LT REF SET)
 - COMPUTE THE FIRST GUESS FOR THE OPTIMUM TIG
 - TIG = TIME OF APOGEE - 1/2 TGO
 - VARY OMS-2 TIG TO MINIMIZE ΔV_{TOT} :
 - PLUS AND MINUS Δt AROUND THE FIRST GUESS TIG
 - INCREMENTS OF 10 SECONDS
 - $\sqrt{\quad}$ OMS-2 Ha /Hp w/ OMP; ADJUST AS REQUIRED (Tolerance ± 0.1 Nm)
 - NOTE ΔV_{TOT}
 - IS ΔV_{TOT} MINIMIZED?
 - ONCE MIN ΔV_{TOT} IS FOUND:
 - ADJUST THE OMS-2 DTIG IN THE REF SET
 - ($\Delta t = \text{Opt TIG} - \text{LW/LT OMS-2 TIG}$)
 - RE-RUN LTP
 - $\sqrt{\quad}$ LTP COMPUTED OMS-2 TIG MATCHES OMS-2 TIG IN EPH2
 - RE-XFER SVs, IYs AND OMS TGTs

NOTE: ΔV_z should be positive

POST MECO:

- SET UP AME:
 - SINGLE PASS
 - $\sqrt{\quad}$ THRUSTER(S)
 - TGT SET 16 (VERIFY Ht IS CORRECT)
 - GRAB V53 POST MPS DUMP/OMS-1
 - VECTORS - USE V1/V53 (OR V2/V53 IF OMS-1 PERFORMED)

- ITERATE TO FIND OPTIMUM TIG
 - COMPUTE THE FIRST GUESS FOR THE OPTIMUM TIG
 - TIME OF APOGEE - 1/2 TGO
 - EXECUTE THE AME
 - NOTE OMS-2 TIG
 - COMPUTE Δt TO CHANGE TIG TO THE FIRST GUESS TIG
 - USE OMS-2 TIG SLIP
 - INPUT OMS-2 TIG SLIP (Δt FROM ABOVE)
 - VARY OMS-2 TIG SLIP AROUND THE FIRST GUESS TIG
 - INCREMENTS OF 10 SECONDS
 - $\sqrt{\quad}$ OMS-2 Ha /Hp w/ OMP; ADJUST AS REQUIRED (Tolerance $\pm .1Nm$)
 - NOTE ΔV_{TOT}
 - IS ΔV_{TOT} MINIMIZED?
 - ONCE MIN ΔV_{TOT} IS FOUND:
 - TRANSFER AME SOLUTION TO EPH 1

NOTE: ΔV_z should be positive

BACKGROUND

This procedure uses the AME to quickly iterate on the optimum TIG for OMS-2. It was found after STS-113 that the optimum TIG does not necessarily yield the smallest ΔV_z component. For an optimized burn, the ΔV_z component should be positive because the finite burn should have a slight downward component at TIG.

Although we can now easily execute the AME during the prelaunch timeframe, it was decided that this would not be done for a mission in order to preclude the (remote) possibility of corrupting the AME database. Therefore, the prelaunch steps were modified to have Dynamics manually input the OMS-2 maneuver.

The post MECO steps in the procedure are different because in that timeframe we are using the AME to model the OMS-2 instead of using the direct input into the ephemeris.

5.2.7 L-1 day DOLILU Transfer Test

PURPOSE

This section defines procedures and interfaces for the L-1 day DOLILU data transfer verification in the Traj Server.

PROCEDURE

- TRAJ:
 - Obtain H/C of throttle table changes (K69s)
 - When GPO is ready, give DYN a GO to do “K69 PREP”
 - Verify that all the times change to 16:40
 - After the “K69 PREP” is complete, have DYN execute DOLARD and transfer the throttle tables to the Traj Server.
 - Re-QA the throttle tables after the final DOLILU D64 data transfer.

BACKGROUND

This test is done on L-1 day after the completion of the Traj Server Confidence run to verify a good transfer of the DOLILU computed throttle tables from FADS to the Traj Server. This transfer test should not be done prior to the Traj Server confidence run.

|

5.2.8 Traj Server Confidence Run

PURPOSE

The Traj Server Confidence Run is intended to provide an overall integrity check on the Traj Server ascent processors and database.

PROCEDURE

Following Traj Server Database initialization:

- Take Traj Server checkpoint.
- Perform Confidence Run (reference FCOH SOP 11.2). Can be viewed online at http://mod.jsc.nasa.gov/da8/FCOH/ssp_fcoh/SSP_FCOH_TOC.htm:
 - Load in NOM, OMS-1, and OMS-2 sim IY's (if required). This may also require resetting the K83 L/O time. For RNDZ missions, change the K83 GMT L/O first before updating the IY's.
 - Update D65 reference time to sim launch time
 - Take Traj Server checkpoint.
 - Replay telemetry data from run chosen during final, flight-specific ascent sim (ref. section 5.1.4, Traj Server Confidence Run Selection).
 - Step Traj Server ahead to tape time as required.
 - Exercise processors as if a sim (L/O PBI, MEDs required).
 - Exercise ARD OMS, Thrust Limiting, and FPR W/S applications to verify that the actual flight data is loaded
 - Turn Traj Server around to **first** (pre-confidence run mods) checkpoint.
 - Step Traj Server ahead for flight support as required.

BACKGROUND

Between the last set of flight specific ascents and launch, over 500 parameters are updated in the Traj Server database. The Traj Server confidence run is intended to provide some level of confidence that the Traj Server database is properly configured and the Traj Server critical processors will perform as expected. This is intended to catch database errors that are outside the scope of the normal reconfiguration process.

The confidence run is not a constraint to launch. If anomalies are detected and corrected, it is desirable, but not required, to repeat the run. If the Traj Server remains up after a scrub following a confidence run, the run need not be repeated for subsequent launch attempts.

Since the Traj Server confidence run must be done with the Traj Server stepped ahead to the sim launch date, the Traj Server confidence run should be done prior to the Traj Server having to be stepped ahead to realtime for the Comm Activation.

- There are several “gotchas” that exist in doing a Traj Server confidence run. These include the following:
 - No BFS data
 - No tracking data
 - No AUTO L/O PBI due to no tracking data
 - MECO DDD indication “funny”*. This has led to entering a second MECO PBI which will cause the AME to not run.
 - AME may fail due to WCGNOM being set to the flight value

* If no MECO TM flag is available, the DDD never stops blinking red. This looks like the PBI was not sent when it actually has been if ARD OUTPUT AUTO MED is enabled. The AUTO MED logic will ship a MECO PBI to the Traj Server if either the MECO TM flag is set, BFS is engaged and all three engine-out flags are set or total onboard acceleration is zero.

5.2.9 L-1 day RNDZ Launch Window Data for ASCENT SUPPORT

PURPOSE

The purpose of this procedure is to document the data that needs to be computed and provided to ASCENT SUPPORT on L-1 day.

PROCEDURE

After the L-24 hour LW/LT comps, fill out the attached form with the following data:

- Planar window open and close times.
- Phase pane open and close times, if either planar window opens or closes on phasing. Otherwise these times are N/A.
- Repeat the above times for the second planar window, if applicable. Otherwise, mark this entire block as N/A.
- The preliminary preferred launch time.

Make 2 copies and put them in the FDO Logbook. ASCENT SUPPORT will pick up one copy at L-6 hours from the Planning Team FDO.

BACKGROUND

The data on this form is required by ASCENT SUPPORT to initialize the MARGINS Rendezvous Launch Window output. The MARGINS program determines launch window open and close times considering only performance-related items (ascent performance margin, yaw steering and LOX drainback). See the next page for an example of the ASCENT SUPPORT launch window data form. This form is available on the DM server under s:/divisions/dm/dm46/forms/ASCSUP LW FORM.doc. It is also available in the MCC on the U drive under u:/WORK/FDO/forms/ASCSUP LW FORM.doc.

STS-__ LAUNCH WINDOW DATA

FOR ASCENT SUPPORT

LIFTOFF ON __/__/__ (DAY __ GMT)

FIRST PLANAR WINDOW

	GMT
PLANAR WINDOW OPEN	__:__:__
PLANAR WINDOW CLOSE	__:__:__
PHASE PANE OPEN	__:__:__
PHASE PANE CLOSE	__:__:__

SECOND PLANAR WINDOW

	GMT
PLANAR WINDOW OPEN	__:__:__
PLANAR WINDOW CLOSE	__:__:__
PHASE PANE OPEN	__:__:__
PHASE PANE CLOSE	__:__:__

PRELIMINARY PREFERRED LAUNCH TIME:

__/__:__:__ GMT

ASCENT FDO

Generated: Liftoff - __ HR (__/__:__:__ GMT)

5.2.10 L-1 day State Vectors for Prelaunch COMBO Analysis

PURPOSE

This section documents the required data that must be provided to USSPACECOM on L-1 day.

PROCEDURE

On L-1 day after the nominal ephemeris has been built, execute the USSPACECOM Message application on TSA to generate the following:

Predicted post MPS dump state vector

Predicted post OMS-2 state vector

- Send state vectors to both USSPACECOM and ASCC (Alternate Space Control Center)

(ref. section 5.3.7, MECO State Vector for USSPACECOM Notification, for details on generation of the state vector for anchoring the nominal ephemeris).

BACKGROUND

The agreement with USSPACECOM is that a preliminary set of these state vectors would be sent for initial conjunction screening on L-1 day.

5.3 Day-of-Launch/Prior to Liftoff

5.3.1 Final Traj Server Database Check

PURPOSE

Documents the final database check procedure.

PROCEDURE

- **Final Database Check:** Follow procedures in section 4.1, Initialization for Ascent, step 7 for performing the final QA.

BACKGROUND

The ascent team is responsible for the Traj Server ascent database. To ensure awareness of all Traj Server inputs (intentional and accidental) that may affect the database, DB Checker is executed. Any changes made between L-1 day and launch day will be flagged. The final database check completes the total QA of the flight database.

5.3.2 Weather Forecast Review

PURPOSE

This section documents the procedures for reviewing the weather forecast on launch day.

PROCEDURE

- Review the weather sheets before they are faxed to the crew quarters, to verify that all flight rule violations are noted and circled appropriately.
 - Initialize TSA to run QUAC to check for crosswind and head/tailwind violations
 - TRAJ: Used as an additional QA source
- Once all the violations have been noted, have LSO fax the final version to KSC.
- Determine the prime runway for RTLS, TAL, AOA, and FD1 PLS.
- Perform a quick QA of the upper level winds at each site to identify potential areas of concern due to strong winds, shears, or potential impacts to the first stage trajectory.

5.3.3 Prelaunch Runway Briefing

PURPOSE

This section documents the procedure for briefing the crew on launch day regarding the prime runways for RTLS, TAL, AOA, and FD1 PLS.

PROCEDURE

The prelaunch runway briefing immediately follows the launch day crew weather briefing (L-4:25 for 51.6° mission, L-3:55 all others). FDO prepares the briefing based on approach and landing sims using the forecast winds and weather.

- Tag up with both Entry Support and LSO regarding the priority needed on the forecast DDS and ALP runs, as well as any particular site priorities due to multiple TAL, AOA, or FD1 PLS sites being analyzed. Concentrate on the most likely prime sites first. The results for all the prime sites are needed by no later than 30 minutes prior to the briefing in order to prepare for it.
- Review DDS (Entry Support) and ALP (LSO) output for each site. The DDS is preferred due to its better fidelity, but ALP runs quicker and its results may be used if the DDS results are not available in time.
- For RTLS, TAL, AOA, and FD1 PLS:
 - prime site and runway
 - surface wind head/tail and crosswind components
 - HAC turn direction
 - Recommended aimpoint
 - Recommended speedbrake option
 - Altimeter setting
 - Predicted touchdown point
 - Predicted rollout margin
 - Predicted speedbrake setting at 3K ft
- Lakebed status for Edwards and Northrup
- Nav/landing aid status for all sites (note anomalies, if any)
- Blank Prelaunch Runway Briefing forms are available on the DM server under s:/divisions/dm/dm46/forms/Prelaunch runway briefing.doc. It can also be found in the MCC in the U drive under u:/WORK/FDO/forms/Prelaunch runway briefing.doc.
- About 15 minutes prior to the crew weather briefing, review the recommended site/runway and A/L sims results with FD. Any borderline

case should be discussed and the other options evaluated with FD prior to the briefing. During this review, FD may concur with FDO's recommendations or propose changes based on the review of the other options.

- Six copies of the Prelaunch Runway Briefing form should be made, one each for FD, CAPCOM, GPO, MMACS, GNC, and LSO. Ask LSO to fax it to the crew quarters. For sims, the LSO copy may be provided to FDO/GPO Monitor (FGMO) in the Sim Control Area (SCA).
- Immediately following the weather briefing, FDO briefs the crew from the Prelaunch Runway Briefing form.
- After the briefing, put the briefing form in the FDO Log Book.

BACKGROUND

Self-explanatory.

STS-_____ PRELAUNCH RUNWAY BRIEFING

RTLS: _____ WIND BREAKDOWN: _____ H/T _____ L/R
L / R OVHD NOM / CI AIMPOINT NOM / SFD SPEEDBRAKE ALTM _____
TD _____ FT ROLLOUT MARGIN _____ FT SB @ 3K _____%

TAL: _____ WIND BREAKDOWN: _____ H/T _____ L/R
L / R OVHD NOM / CI AIMPOINT NOM / SFD SPEEDBRAKE ALTM _____
TD _____ FT ROLLOUT MARGIN _____ FT SB @ 3K _____%

AOA: _____ WIND BREAKDOWN: _____ H/T _____ L/R
L / R OVHD NOM / CI AIMPOINT NOM / SFD SPEEDBRAKE ALTM _____
TD _____ FT ROLLOUT MARGIN _____ FT SB @ 3K _____%

FD1 PLS: _____ WIND BREAKDOWN: _____ H/T _____ L/R
L / R OVHD NOM / CI AIMPOINT NOM / SFD SPEEDBRAKE ALTM _____
TD _____ FT ROLLOUT MARGIN _____ FT SB @ 3K _____%

LAKEBED STATUS: EDW _____
NOR _____

NAV/LANDING AIDS STATUS: _____

FDO: _____ DATE: _____

5.3.4 Abort Entry Analysis

PURPOSE

This section documents the procedure for review of the entry analysis performed by Entry Support and LSO for all the intact abort sites and the timeline used to support that analysis.

PROCEDURE

In addition to the entry analysis performed to support the prelaunch runway briefing, both Entry Support and LSO run DDS and ALP Approach and Landing sims based on balloon data. Balloons are released at KSC for RTLS, at each TAL site, and at each AOA site. *FD1 PLS analysis is run for the forecast only.*

The standard balloon release times, with "data in" to MCC times in parentheses, are as follows:

RTLS	TAL	AOA
L-8.5 (6)	L-8.5 (6)	L-8.5 (6)
L-5.5 (4)	-	-
L-3.5 (2)	-	L-3.5 (2)*
-	-	L-3 (2)**
-	L-2.5 (1.5)	-
L-2 (1.25)	-	-
L-1 (45m)	L-1 (45m)	-

* KSC
 ** EDW & NOR

The Approach and Landing sims are typically completed about 30 minutes after the "data in" time. Entry Support delivers 2 copies of the DDS Approach and Landing Predictions (so called "trends" chart) to the FCR. FDO will receive one while FD or WX FD will get the other one.

Reference section 4.3.8.2d for an explanation of how to interpret the DDS Approach and Landing Predictions output.

BACKGROUND

Self-explanatory.

5.3.5 Weather Briefings

Three weather briefings are scheduled on launch day:

L-4:25 or L-3:55 Crew Weather Briefing: MCC patched through the AFD Conference loop. Followed immediately by the FDO Prelaunch Runway Briefing. L-4:25 is used on missions with short launch windows.

L-2:10 FD/FDO/WX Tag-Up (if required): Placeholder for forecast updates.

L-1:00 FD/FDO/WX Tag-Up (if required): Placeholder for forecast updates prior to Launch Director Weather Briefing at L-0:45.

5.3.6 ARD TAL WX Alternate Table Setup

PURPOSE

This procedure defines the setup of the ARD TAL WX alternate tables for use of low crossrange targets.

PROCEDURE

NOTE:

To avoid confusion, always coordinate with GPO before implementing this procedure, since it affects the configuration of the landing site table. Also, these steps are used to create D64 elements, thus avoiding manual inputs.

1. (R03) Add the desired low crossrange TAL site runway IDs in the Traj Server Landing Site Table. The source runway will be used for the all the data (i.e. latitude, longitude, etc.) for the LST with the exception of the runway ID.

INCLINATION	SOURCE	LOW XR ID
28.5°	BEN36	LBN36
	MRN20	LMN20
39°	ZZA30	LZA30
51.6° and 57° °	BEN36	LBN36
	MRN20	LMN20
	ZZA30	LZA30

2. (K91) Add the new areas into the TAL Guidance Target Table (GTT) using the GTT values for each original site, as follows:
 - 28.5°: Add LBN and LMN.
 - 39°: Add LZA only.
 - 51.6° and 57°: Add LZA, LMN and LBN .

NOTE: FMI does not have a low crossrange target line

3. (K91) Copy the TAL targets from the source runway to the low crossrange runway (e.g. BEN36 data for LBN36).
4. (K91) Overwrite the crossrange target (CRMAX) in each of the new target areas with the low crossrange value.
5. (K90) Load the new low crossrange runways into the WX alternate runway table (slots ALT2 thru ALT4) to make them available for the ARD, as follows:

- 28.5°: Add both LBN36 and MRN20.
- 39°: Add LZA30 only.
- 51.6° and 57°: Add LZA30, LMN20 and LBN36.

6. QA final configuration on Weather Alt 1 & 2 displays (MSKs 560 and 561).

BACKGROUND

Use of this procedure allows for quick and accurate configuration of the ARD for cases which require the low-crossrange targets. These cases, involving a second engine-out after droop and before single-engine TAL, sometimes require the low-crossrange target in order to ensure that the MECO underspeed conditions require a more benign downrange stretch, as compared to a crossrange stretch. If Droop guidance is invoked by the ARD, generally for cases between Droop and Single-Engine Limits and indicated by a "LOW-ENERGY TARGETS" ARD message, the low-crossrange targets are automatically implemented. If not, the low-crossrange targets must be manually selected. Use of the PBIs allows quick evaluation of both target sets without requiring Dynamics to modify them manually. The GTT was modified with ARD 3 to allow up to 10 landing areas (expanded from 5). This now allows all 3 TAL sites to be entered plus all 3 low crossrange areas to be stored in the GTT.

5.3.7 State Vectors for Prelaunch COMBO Analysis

PURPOSE

This procedure documents the steps required to update the nominal ephemeris. This ephemeris is the source of the predicted post MPS dump and post-OMS-2 state vectors which are sent to USSTRATCOM for prelaunch COMBO analysis at L-2 hr. The procedure assumes that a nominal ephemeris will be created, containing MPS dump and OMS-2 burn models.

For ground-up rendezvous missions, the MPS dump SV is obtained by execution of LTP. The MPS dump SV for the nominal ephemeris is computed by running LTP at the preferred launch time.

For non ground-up rendezvous missions, the MECO SV is obtained from the ASCT 06 product and is based on a specific liftoff date/time that is not necessarily the same as that which is actually planned. For this reason, the spherical elements SV are used.

PROCEDURE

For Ground-up Rendezvous Missions:

1. Use the LTP computed **MPS dump** state vector for a launch at the preferred launch time for use in anchoring the nominal ephemeris (EPH 2).

Model the MPS dump and nominal OMS-2 in EPH 2. Ref. SOP 5.2.6.

For Non Ground-up Rendezvous Missions:

1. Input the MECO SV from the ASCT 06 product:
 - Use the MET Timetag (Note: GMT may be inconsistent with planned launch time):
 - Use the spherical elements
 - Velocity = VI
 - FPA = GAMI
 - Azimuth = AZI
 - Latitude = LATC
 - Longitude = LONG
 - Height (Hs) = (RI / 6076.1155) - 3443.9 NM
2. QA the vector against the ASCT 06 product, **MECO** column orbital elements.

3. Anchor the nominal ephemeris (EPH 2) using the resultant SV.
4. Model the MPS dump and nominal OMS-2 in EPH 2. This may be done either with the AME and then transfer of by direct input.

BACKGROUND

In order to provide an accurate state vectors for prelaunch COMBO analysis, the best estimate of the predicted post MPS dump and post OMS-2 state vectors are required. This procedure provides the most accurate state vectors available in the prelaunch timeframe for this analysis.

5.3.8 Prelaunch SPADOC Coordination

PURPOSE

The purpose of this section is to identify the prelaunch interface procedures between the Ascent FDO and USSTRATCOM for prelaunch COMBO notification in support of Flight Rule A4.1.1-3, Orbit Conjunctions/Conflicts.

PROCEDURE

L-2 hr: FDO sends best estimated post MPS dump and post-OMS-2 state vectors (ref. section 5.3.7, State Vectors for Prelaunch COMBO Analysis).

L-1.5 hr: SPADOC sends COMBO analysis to FDO. If a conjunction is predicted within 2 hrs MET, COMBO runs will be made at one minute intervals until no conjunction is predicted.

Based on the L-2 hr analysis, FDO notifies FD of "Negative Conjunctions" or, if a slip is required, the new launch time for which no conjunctions occur.

Note: Currently, no COMBO analysis is done for launch slips due to weather or systems problems.

BACKGROUND

Reference flight rule A4.3 rationale for prelaunch conjunction analysis requirements background. Two COMBO runs, covering the period up to 0/2:00 MET, are performed by USSTRATCOM based on predicted post MPS dump and OMS-2 cutoff Orbiter state vectors issued at L - 2 hrs. Unplanned countdown holds do not justify additional COMBO runs. If a run reveals an Orbiter conjunction penetrating a 5 x 15 x 5 km ($\Delta U \times \Delta V \times \Delta W$) box centered on any cataloged object, launch GMT will be slipped to the next even minute until no such conjunction is obtained by a subsequent COMBO run. Under no circumstances will launch GMT be adjusted due to COMBO results reported after 5 min prior to resuming the count at T - 9 min

5.3.9 FCO Codewords

PURPOSE

Identify procedures for distribution and handling of FCO Codewords to FDO, FD and CAPCOM.

PROCEDURE

Caution:

FCO Codewords are for operational use only, and are to be viewed only by FDO, FD, CAPCOM and TRAJ. If concern exists that the Codewords have been compromised, a new set is to be requested from FCO.

- Codewords sent by 45th Space Wing/SEO to DM4/Chief, Ascent/Descent Dynamics Branch
- Ascent/Descent Dynamics Branch Chief passes Codeword letter to Ascent FDO
- FDO: Confirm Codeword letter date with FCO (L-2 hr)
- FDO: Open Codeword letter at L-1 hr. Make 2 copies. Distribute copies to FD and CAPCOM.
- In the event of a scrub:
 - FDO: Pick up copies from FD and CAPCOM. Re-seal Codeword letter for use on subsequent attempts, unless FD, FDO, or FCO have reason to suspect that the Codewords have been compromised. *Note that having the Codewords out on the FDO and FD console prior to launch does not constitute compromise of the words.*
- Post Launch:
 - FDO: Pick up copies from FD and CAPCOM. Dispose of all copies in the shredder.

BACKGROUND

Three FCO Codewords are used operationally: One used by FCO to notify the MCC that the Range Safety Destruct System ARM command has been sent, one used by FD to notify the FCO that the vehicle is out-of-control and the other one is used by FCO to request a manual MECO. A fourth Codeword, not documented in the Flight Rules at this time, cites an "FOA Breakup". The term

“FOA Breakup” indicates a vehicle breakup determined visually by personnel in the Forward Observer Area. The Codeword letter is not opened until L-3 hr to prevent unauthorized disclosure. In the MCC, sufficient security is maintained such that new codewords are not necessarily required following a launch scrub.

5.3.10 Deorbit/Entry Constraints Table Configuration

PURPOSE

Identify nominal DCT and ECT configuration for ascent.

PROCEDURE

DEORBIT CONSTRAINTS TABLE

INCL	COLUMN 1	COLUMN 2	COLUMN 3
LOW	2OMS/1OMS-STP, AT2	RCS-STP, AT2	2OMS/1OMS-SHL, AT2
MID	2OMS/1OMS-STP, AT2	RCS-STP, AT2	2OMS/1OMS-SHL, AT2
51.6°	2OMS/1OMS-STP	RCS-STP	2OMS/1OMS-SHL
57°	2OMS/1OMS- STP(ORB 7) NOM FD1 PLS *	2OMS/1OMS- SHL(ORB 7) NOM FD1 PLS *	2OMS/1OMS- SHL(ORB 3)

ALL Columns - **D23C** and **NCYC** set to ATO/MIN Hp VALUE for the FD1 PLS, except 57° missions. Also, ensure that the proper runway and atmosphere are selected for the appropriate FD1 PLS orbit/site.

ATMOSPHERE SELECTION TABLE

Atmosphere ID, name	Inclination	Season	Approaches
AT1, 62 STANDARD	All	All year	All
AT2, KSC39A-NOV	20 to ≤40	All year	Ascending
AT3, EDW39D-DEC	20 to ≤40	Oct – Feb	Descending
AT4, KSC39D-MAR	20 to ≤40	Mar - Sep	Descending
AT5, KSC57A-JUN	>40 to 57	All year	Ascending
AT6, KSC57D-DEC	>40 to 57	Oct – Mar	Descending
AT7, KSC57D-SEP	>40 to 57	Apr - Sep	Descending
AT8, 62 STANDARD	All	All year	All
AT9, 62 STANDARD	All	All year	All

ENTRY CONSTRAINTS TABLE

- VERIFY PROPER CONFIG FOR EACH SELECTION FILE (ref. SOP 4.1, step 11).

BACKGROUND

The DCT is set up to minimize real-time reconfiguration when time-critical evaluations must take place. For this reason, the **57°** inclination mission DCT is set up to allow quick analysis of nominal FD1 orbits (e.g., orbit 7 deorbit) and ATO/Min Hp "Press" orbits (orbit 3 deorbit).

5.3.11 ET Load and Launch Hold Capability Reporting (including Revert)

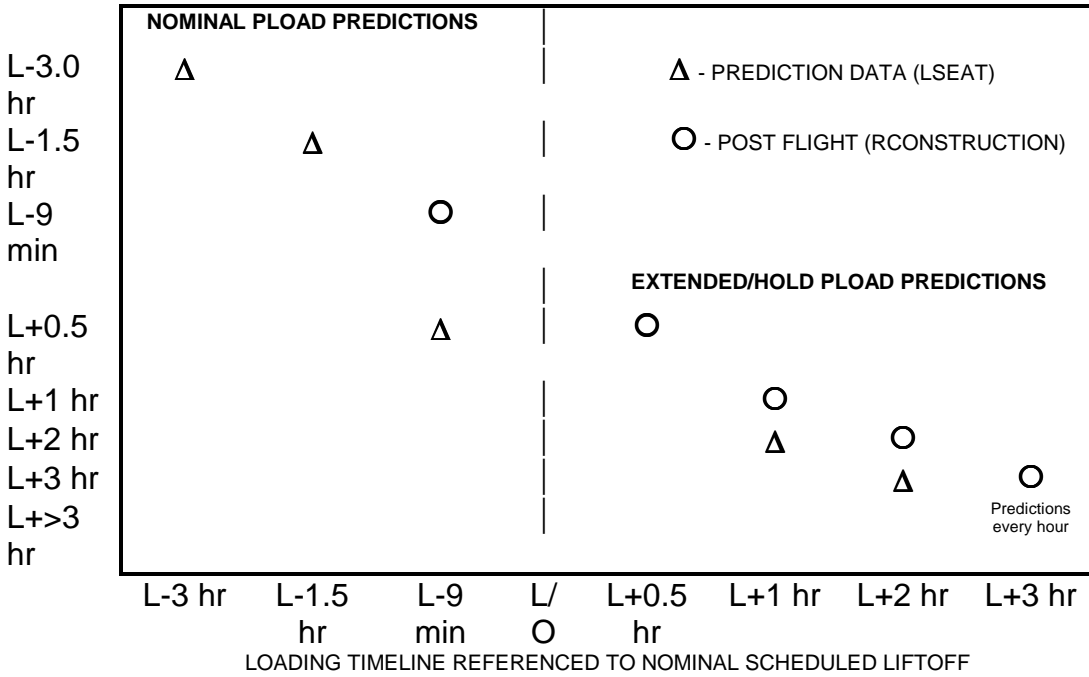
PURPOSE

This section defines procedures and interfaces for reporting and assessment of DOL ET propellant loadings.

PROCEDURE

- Reference attached timelines.
- Paper copy of the L-3:25 (H:M) loading data is given to ARD Support by Ascent Support in the TRAJ MPSR.
- Ascent Support provides the MARGINS data to FDO as soon as possible.
- FDO provides performance margin and launch hold capability to FD.
 - Nominal timeline: The report may be given at any convenient point between receipt of MARGINS data and L-20 min.
 - Revert timeline: Data is expected not later than 18 min after MCC receipt of PLOAD data.
- The MMT briefing, as well as the standard report to NTD, is performed by FD at approximately L-20 min.
- Notes:
 - In the event of a revert, LDO will assume a launch time of 1 hr from the time replenish is re-established. MMT and LDO will conference to establish the actual liftoff time, which will be determined by the LDO.

ET PROPELLANT LOAD (REPORT) TIMELINE



LO2 REVERT PROCEDURES	LH2 REVERT PROCEDURES
<p>USE WHEN THE 98% SENSOR GOES DRY; OTHERWISE USE OMRSD S00E000.125. (FROM STOP FLOW TO 98% (DRY) SENSOR IS APPROX. 25 MIN.)</p> <p>NOTE 1: LO2 REVERT LAUNCH TIME</p> <p>MSFC HOSC WILL ASSUME ONE (1) HOUR FROM START OF REPLENISH, UNLESS OTHERWISE NOTIFIED BY LSEAT.</p>	<p>LH2 HISTORY SHOWS FLAT ULLAGE PRESSURE DECAY.</p> <p>NOTE 2: LH2 DATA REQUIRED</p> <p>FIVE (5) MINUTES OF STABLE REPLENISH IS REQUIRED FOR FIRST OFFICIAL LH2 PLOAD DATA POINT.</p>

"STOP FLOW/LATE REVERT" PLOAD PREDICTIONS (WITHIN L-1.5 HRS)

Nominal LH2 Load	Nominal LO2 Load	
LH2 REVERT	LO2 REVERT	REVERT: 1. ON-LINE 2. MMT/LSEAT CHAIR: Verify launch time for MSFC PLOAD inputs 3. LSEAT Performance Representative 4. HOSC - MPS console (see NOTE 1)
0	0	START OF REPLENISH
See NOTE 2	20 min	1st PRELIMINARY PLOAD DATA POINT (LSEAT/MPS CONSOLE ONLY) - VERBAL/LOOP CALL
	25 min	2nd PRELIMINARY PLOAD DATA POINT (LSEAT/MPS CONSOLE ONLY) - VERBAL/LOOP CALL
5 min	30 min	OFFICIAL PLOAD DATA POINT: FIRST DATA POINT FOR LSEAT/PERFORMANCE LOAD PREDICTION PROCESS - VERBAL/LOOP CALL AND FAX
Continue with: JSC/MER (LSEAT) PERFORMANCE DATA DISTRIBUTION TIMELINE		

JSC/MER (LSEAT) PERFORMANCE DATA DISTRIBUTION TIMELINE

TYPICAL Receipt of data (min)	LH2 Revert Receipt of data (min)	LO2 Revert Receipt of data (min)	KSC	MSFC HOSC MPS Console	JSC
-	-	-	ET Data	ET Data in	ET Data in: LSEAT/MER MPS Console via "LSEAT Coord"
0	5	30		Official PLOAD Data Point	
3	8	33			FAX: From HOSC MPS Console to LSEAT/MER MPS Console via "LSEAT Coord"
5	10	35			Copies (5)
7	12	37			1. MPSR (ARD) 2. MPSR (Margins) 3. LSEAT/MER MPS Console PC Program and Calculations 4. Weights Console
12	17	42			
14	19	44			ARD, Margins: Data to FDO/TRAJ
16	21	46			LSEAT/Perf. Representative: Margin and hold time predictions from Margins and LSEAT/MER MPS Console
18	23	48			FDO: Results to FD LSEAT/Perf. Rep: Results to LSEAT Chair.
20	25	50			FD: Results to NTD & MMT
GO FOR LAUNCH					

BACKGROUND

Estimation of ET propellant masses (required for performance-related flight rules) is performed by Ascent Support using a program called PLOAD, which is run periodically beginning at L-6 hours. The outputs consist of LOX and LH2 predicted quantities at end of replenish (EOR) and at engine start command (ESC). These values are reported to the MER MPS console, and from there are passed to the Ascent Support operator for assessment of nominal performance and drainback hold time using the MARGINS program, and to ARD Support for preparation of MCC processor update values using ARD WEIGHTS. Abort Support evaluates impacts to mode boundaries using the bench ARD or mission-specific partials and the results of Ascent Support's analysis.

The technique used to estimate propellant load requires prediction of ET ullage pressures at T-0. The behavior of ullage pressure is a function of many factors; for LH2, however, it reaches a predictable value approximately 5 minutes after start of stable replenish. For LOX, ullage pressure changes significantly between start of stable replenish and T-0. Therefore, the PLOAD program performs a curve fit of the ullage pressure data in order to extrapolate to the T-0 value. Twenty minutes of stable replenish are needed before the ullage pressure behavior stabilizes to the point that the data are useful, and ten additional minutes of data are required to derive a reliable curve; therefore, at least thirty minutes are required between start of stable replenish and acquisition of sufficient data to perform a reliable prediction.

In a nominal countdown flow, stable replenish begins more than 3 hr before liftoff, and hence the time requirements are easily accommodated. However, during the replenish phase, if for any reason LOX is depleted to the point that the 98% sensors are uncovered, a "revert" is performed where the topping and/or fast fill phases of ET loading are resumed. This effectively destroys the ullage pressure curve established to that point, and the process must be re-started. It is assumed that thirty additional minutes are needed (beyond the PLOAD 30-minute data requirement) for transmission to JSC, distribution and analysis, briefings to MMT and FD, and count to T-0, thus leading to a 1-hr minimum time from start of stable replenish to T-0. Reverts occurring inside \approx L-1.5 hr (allowing for the additional time to actually fill the tank) will therefore likely require a launch slip such that required analysis may be performed.

These requirements are separate from LCC requirements which dictate ET loading criteria in terms of 98% and 100% quantity sensors indicating wet; these requirements only relate to the tank fill volume, and impose or imply nothing about the actual mass (i.e., performance capability) contained therein.

References: LCC, Booster Console Handbook, LSEAT Integrated Support Plan (NSTS 08211).

5.3.12 LSEAT Structural Loads Assessment

PURPOSE

This section defines FDO responsibilities regarding the Trajectory Packages produced by Ascent Support for use by the LSEAT to evaluate structural loads.

PROCEDURE

FDO is primarily an information-only customer regarding this data. While GPO is directly involved in the DOLILU uplink, only a few elements are used directly by the FDO:

- FCO Package: A delta file indicating expected trajectory performance with respect to design nominal lines is electronically provided to the FCO. FDO views this electronically using Netscape (via Ascent DOL Products) and should confirm with FCO that the electronic file has been received.
- Drainback Hold Time: Ascent Support informs FDO each time a new Margins Summary is available. FDO views this electronically using Netscape (via Ascent DOL Products). The drainback hold time is passed to FD and FCO.

NOTE: For ground-up rendezvous missions, the drainback hold time from MARGINS Summary is not used. Instead, the drainback hold time is obtained from the MARGI program output.

BACKGROUND

Self-explanatory.

5.3.13 DOLILU II Procedures

PURPOSE

This section defines procedures and interfaces for DOLILU II (Day of launch I-Load Update II) data verification in the Traj Server.

PROCEDURE

- L-3:15:
 - FDO: Review L-4:15 Trajectory & Loads packages
 - ABORT SUPPORT: Report status of ARDGEN QA to FDO
 - TRAJ:
 - Obtain H/C of DOLILU II MEDCV Inputs from ASCENT SUPPORT
 - FDO: When GPO is ready, have DYN load the “K69 Prep”
 - FDO, TRAJ, & ARD SUPPORT: Quickly QA throttle tables to verify that all lines have 16:40 times.
 - FDO: When above step complete, report to GPO: “K69 Prep” complete, GO for loading DOLILU II data
 - FDO, TRAJ, ARD SUPPORT: QA the following displays against DOLILU II MEDCV Inputs:
 - ___ TRAJ PARAMS (F02) (AGT & QPLOY/THROT I-loads, SECDs)
 - ___ SSME 2 - L THRTL/ISP/MR (ARD throttle table, L engine)
 - ___ SSME 1 - C THRTL/ISP/MR (ARD throttle table, C engine)
 - ___ SSME 3 - R THRTL/ISP/MR (ARD throttle table, R engine)
 - ___ 2454- ARD CONTROL DATA (ATO and OMS Assist dump timers)
 - ___ 2446- AME/ETIP AGT MED INP (VLIN and VZERO)
 - ___ ARD SYS PARAMS 2 (MCK2MN, input as K2MIN)

ARD SUPPORT and TRAJ must both verify a good transfer of ARD parameters

NOTE
IF A DISCREPANCY IS FOUND, PROCEED TO THE DISCREPANCY PROCEDURES BELOW IMMEDIATELY.

- UPON SUCCESSFUL QA COMPLETION:

FDO: Report to ASCENT SUPPORT on MPSR DYN A that the ARD data transferred from FADS has been QAed and that no discrepancies were found.
- ABORT SUPPORT: Provide to FDO, TRAJ, and ARD SUPPORT the new AGT table. Also, provide a plot for Δ Weight Override vs TDEL (if available).

DISCREPANCY PROCEDURES:

- A. Inputs Package vs. Traj Server Configuration:
 - 1. Conference w/ ASCENT SUP'T, ARD SUP'T, ABORT SUP'T; confirm problem not due to Traj Server units conversion
 - 2. No Joy: MCC NO-GO due to suspect electronic reconfiguration
 - Report to FD as required
 - Submit DR against DOLILU system
- B. MCC Input(s) Outside Expected Range:
 - 1. Conference w/ASCENT SUP'T, ARD SUP'T, ABORT SUP'T
 - Establish rationale
 - Review predicted/measured DOL conditions vs. groundrules for expected ranges
 - Request Bench ARD runs to validate inputs, eval impacts, etc.
 - 2. If rationale established: Document observation and rationale to FD via Flight Note.
 - 3. If unable to rationalize, MCC NO-GO for invalid ARD configuration
 - Report to FD as required
 - Initiate actions as req'd to analyze & resolve/correct problem.

BACKGROUND

DOLILU II implements day-of-launch uplink of the first stage steering parameters (nominal pitch and yaw tables) and an update of the throttle bucket as a function of Mach number. The command loads containing the information for uplink are built from corresponding Traj Server data tables which are updated on launch day based on off-line DOLILU II processing. The required values are normally transferred from the FADS to the Traj Server data tables via the DOLMOC and DOLARD applications on the workstations. When Command off the MOC (COTM) is used, the DOLCOM application will then be used for transferring the DOLILU II data to the Command server for building the commands.

ARD parameters are affected when the DOLILU II data is loaded into the Traj Server because the ARD data is part of the DOLILU II file transferred across from FADS. The ARD SSME throttle tables will be over-written when the

DOLILU data is loaded into the Traj Server. Also, the trajectory parameters that affect the ARD's modeling of AGT (SECD002 and SECD 005 thru SECD 016) are changed. ARD first stage trajectory modeling is also affected since the steering polynomials are updated, but accuracy of this prediction is not critical and is not a factor in the DOLILU II requirements.

Prior to loading the DOLILU II data, the "K69 prep" is executed. This is done to prepare the throttle tables for loading the new data from FADS. This is a precautionary measure to "clean the slate" before updating the the throttle tables.

The SECD parameters are now loaded using the K95 MED. Prior to STS-89, these parameters had to be loaded with the F02 MED. Loading F02s is troublesome because it requires taking the Traj Server to unlock Flight mode. The K95 MED gets away from the unlock Flight mode requirement for loading the SECDs.

Safety requirements on DOLILU II dictate that ARD parameters must be QA'ed by independent console positions. The procedure above defines specific steps and players in the QA process, and protocol for resolution of discrepancies.

If a DIVT rule A2 violation occurs during the generation of the DOLILU II I-loads, a plot will be generated to show Δ MPS (Δ Weight Override) versus TDEL. This allows the users to visually see how closely the curve fit routine fits through the data. This plot could be used instead of the new AGT table for determining the Δ Weight Override. A new AGT table is computed on launch day since DOLILU II adjusts the bucket to zero out the predicted TDEL.

ATO dump I-loads and the OMS assist dump timer may be changed on launch day. These parameters will be included in the DOLILU file that is electronically transferred to the Traj Server at around L-2:50 (L-2:20 for non-rendevzvous missions). These parameters are spread out on 3 different MSKs.

REFERENCES: GPO Console Handbook, LSEAT Integrated Support Plan (NSTS 08211, appendix F), FCOH section 3.2.6.3.

5.3.14 FDO/FCO L-30 min Tag-Up

PURPOSE

Identify the status items for the FDO/FCO Tag-Up at L-30 minutes.

PROCEDURE

- FCO-TO-FDO
 - GO/NO-GO STATUS OF:
 - CYBERS
 - RSDS
 - COMMAND SYSTEM
 - WX STATUS: CEILING AND VISIBILITY RESTRICTIONS
 - RF MONITORING RESULTS
 - COLA UPDATE
 - BLAST PROPAGATION ANALYSIS
 - FORWARD OBSERVER
 - ABORT SWITCH HEARTBEAT STATUS

- FDO-TO-FCO
 - DIVDT VIOLATIONS (LSEAT EVALUATION)
 - EXPECTED TRAJECTORY DEVIATIONS (CONFIRM ASCENT SUPPORT "FCO PACKAGE" WAS RECEIVED)
 - NO-COMM MODE BOUNDARY UPDATES
 - DRAINBACK HOLD TIME
 - RTL5 AND TAL RUNWAY SELECTION
 - WX STATUS
 - ✓ ABORT SWITCH HEARTBEAT STATUS

BACKGROUND

Ensures FDO and FCO situational awareness regarding GO/NO-GO status and procedures prior to launch, and provides a standard time for discussion of any issues which may affect launch operations.

5.3.15 Launch Window/Launch Targeting Execution Procedures

PURPOSE

Define operational procedures for execution of the Launch Window Processor (LWP) and the Launch Targeting Processors (LTP). This checklist includes steps required for use with Auto Del-PSI.

PROCEDURE

Note: A detailed procedural narrative follows the checklist below.

SET-UP

- WORK LAST TO FIRST (DAY TO DAY AND PANE TO PANE)
- CONFIGURE TARGET EPHEMERIS (EPH 3)
- FETCH TARGET VECTOR (~1 HOUR PRIOR TO L/O; K12)
- DEFINE CHASER (EPH 1; K12)
- DISPLAY DESIRED REF SET
- QA LW/LT INIT DATA
- Launch W/T Init
- Launch Ref Tgt Sets
- Launch Window/Tgting
- SET MET RENDEZVOUS:

For 51.6 INC:

3/00:00 IF FD3 RNDZ (PHASE ANGLE ≤ 430).

5/12:00 IF FD4 RNDZ (PHASE ANGLE > 430).

LOW INC: ~ 2/00:00

- SET PHASE AND WRAP →
- BASED ON PHASE ANGLE AT INPLANE TIME. EACH REF SET HAS IT'S OWN WRAP FLAG.

EXPECTED OMS-2 PHASE ANGLE	PHASE CONTROL	WRAP
-90 to 90°	2	0
90 to 270°	0	0
270 to 450°	2	1
450 to 630°	0	1
630 to 720°	2	2

RUN LWP using desired Ref Set (K10)

- √ OPTIMUM LIFTOFF (INPLANE) TIME
 - √ MECO PHASE ANGLE
- IF LWP FAILS TO CONVERGE: →

√ PHASE CONTROL AND WRAP FLAGS IF CORRECT;
 1. RE-RUN LWP WITH FORCE CLOSE APPROACH SET TO YES.
 2. IF NO JOY, BIAS LAUNCH SITE LATITUDE DOWN AND RE-RUN UNTIL SOLUTION CONVERGES

A. GENERATE LW TIMES AND PHASE ANGLES

- √ DISPLAYED REF SET
- VERIFY MET RENDEZVOUS, PHASE AND WPAP FLAGS ARE CORRECT
- DETERMINE ET PLANAR OPEN, INPLANE AND CLOSE TIMES (LWP K10)

Refer to latest Generic Launch Targeting Parameters STF (SFOC TRANSMITTAL FORM) for descending node constraints (DSCN @ equatorial crossing).

The values below are from the 10/13/2004 STF.

For 51.63° (Pad Independent):

ΔT from opt	-5	-4.5	-4	-3.5	-3	-2.5	0	2.5	3	3.5	4	4.5	5
λ DN	66.267	66.149	66.031	65.913	65.795	65.676	65.087	64.496	64.378	64.260	64.142	64.024	63.905
mm:ss	16:01	08:56	01:52	54:47	47:42	40:34	05:13	29:46	22:46	15:36	08:31	01:26	54:18

NOTE
 FOR 28.5°, PHASE CONTROL/WRAP FLAGS MAY BE DIFFERENT FOR INPLANE AND WINDOW OPEN

For 28.5°	Open	Close	Inplane
<input type="checkbox"/> DN			
dd:mm:ss			

NOTE
 THESE COME FROM A FLIGHT-SPECIFIC PRODUCT.

- DETERMINE PHASE ANGLES @ OPEN, INPLANE AND CLOSE (LTP, OPTION B ON K15 MED)
- DETERMINE PHASE PANE CLOSE/ OPEN TIMES IF APPLICABLE (LWP WITH DESIRED PHASE ANGLE INPUT). FOR LOW INCLINATION, SET PHASE CONTROL/WRAP FLAGS BASED ON PHASE ANGLE AT **INPLANE TIME**)

IF PANE 2, REPEAT STEP A FOR PANE 1

B. DETERMINE KEY LAUNCH TIMES

- DETERMINE PREFERRED LAUNCH TIME (P.L.T.) (REF. SOP 5.3.20) AND PANE 2 OPEN (REF. SOP 5.3.22)

C. GENERATE VECTORS

- VERIFY MET RENDEZVOUS IS CORRECT
- √ DISPLAYED REF SET
- GENERATE LTP SOL'N (LTP, OPTION B ON K15 MED)
 - IF PANE 2: FOR PANE 2 OPEN
 - IF PANE 1: FOR P.L.T. (AND PANE 1 OPEN AND CLOSE IF REQUIRED)

- XFER SVs, IYs AND OMS TGTS

- UPDATE D65 LIFTOFF TIME AS REQUIRED (Checkout Monitor 1)

- RUN OMP (FDO SUPPORT/MARS)

EPH Mirrors ON (AUTO MOC)

USE MPS B/O SV FOR CHASER

To view OMP output: TSA → Rendezvous Processors → Orbit Maneuver Processor (OMP) → Maneuver Planning Status → select SSP

Then select the appropriate plan (NC1?, ask MARS). Next, right mouse button, START → VIEW EVALUATION TABLE

√ OMS-2 H_P (or H_A) (IF PHASING BURN)

√ NPC ΔV < 3 FPS: √ PHASE CONTROL/WRAP & MET RNDZ: RE-TARGET

- UPDATE REF SET OMS 2 Ht (per OMP output)

- ITERATE ON OMS-2 TIG TO MINIMIZE THE ΔV_{TOT} . **Ref. SOP 5.2.6.**
- OPTIONAL* XFER LTP SOL'N SET TO REF (K14) MAN UPDATE REF SET L/O (K18)

- IF PANE2: PLANAR WINDOW: —————▶
LOG SECOND PLANAR WINDOW DATA &
RETURN TO "SET-UP" TO FOR PANE 1

OMS-2 Ht	_____
OMS-2 Hp /Ha	_____
OMS-2 DTIG	_____
OMS-2 TIG	_____

D. GENERATE TARGETS AND COMMAND LOADS

FIRST PLANAR WINDOW ONLY

- RUN LTP, OPTION B, AT THE **PANE 1 INPLANE LAUNCH TIME** (K15)
 - √ L/O TIME = INPLANE TIME
 - √ MPS COST (PROP COMP (-) REF) ~ 0 LBS
 - √ PHASE ANGLES ARE IN THE EXPECTED REGION (FOR LOW INC, ~ OPEN PHASE + 220°)
 - √ MECO PHASE ANGLE > OMS-2 PHASE ANGLE BY ≈6-7° (NOT WRAPPED 360°)

- TRANSFER LTP SOLUTION IYs AND OMS TGTS (K16)

- OMS TARGETS TO THE AGT (AGT OMS-2 TGTS); USE "N" (NOMINAL) OPTION FOR AGT ITGT SLOT
 - √ IY VECTORS TO LTCT: (Launch Performance, IYD Vector Display MSK 2442)
 - √ CONFIRM K83 "RNDZ" OPTION USED (MSK 2442)

NOTE: DO NOT XFER MECO TGTS TO THE ARD

DO NOT XFER SVs TO THE VAT

DO NOT UPDATE THE D65 TIME. THE TRAJ SERVER REFERENCE TIME SHOULD REMAIN EQUAL TO THE PREFERRED L/O TIME (Checkout Monitor 1)

- MODIFY THE DEL NODE PHASE AND PANE SWITCH TIME AS REQUIRED (REFERENCE PROCEDURE 5.3.16)
- GIVE GPO A GO TO BUILD COMMAND LOADS (ASSUMES LAUNCH AT THE P.L.T.)

NOTE: PANE SWITCH TIME = GMT PHASE (425XX command load)

- √ NOM EPH (L/O AT P.L.T.) GIVE TRACK GO FOR ACQ DATA
- AFTER GPO COMMAND LOAD BUILD, PANE SWITCH TIME AND OMS-2 Ht (TGT 16) TO LAUNCH WINDOW OPEN VALUES.
- GIVE GPO A GO TO BUILD COMMAND LOAD FOR LW OPEN

- AFTER GPO COMMAND LOAD BUILD, RESET PANE SWITCH TIME AND OMS-2 Ht (TGT 16) TO P.L.T. VALUE
- QA COMMAND LOADS W/ GPO
- SIGN HARDCOPIES

E. FINAL QA

- K83 LIFTOFF TIME = **INPLANE TIME** FOR FIRST PANE
- K83 LIFTOFF TIME IS THE TIME TAG FOR THE IY's (IYD Vector Display and Launch Performance display)
- D65 LIFTOFF TIME = PLANNED LAUNCH TIME (Checkout Monitor 1)
- PANE SWITCH TIME:
FOR 2 PANE DAY: CONSISTENT WITH PLANNED LAUNCH TIME
FOR 1 PANE DAY = L/O + 30 DAYS (MUST BE IN THE FUTURE)

Procedure Details:

Build a target ephemeris in EPH 3. Reference the flight specific FDO Data Book for integration constants. In a realtime or near realtime mode, the target state vector will be provided by NAV. For sims, the TGT SV will be provided by either the Lead FDO or TARGETING, and should be propagated to a time that's prior to the expected window open time on the day of interest.

Using the K12 MED, fetch a TGT SV for LW/LT from the target ephemeris. The fetch time should be prior to the expected window open time, since LW uses the fetch time as the threshold to begin the inplane time search. The TGT SV may be fetched from the VAT rather than an ephemeris, but a TGT ephemeris must be specified in order to define integration constants.

Likewise, define a chaser ephemeris for accessing integration constants. This is usually EPH 1, and is also input on the K12 MED.

Check the LW/LT initialization data on the right sides of LAUNCH W/T INIT and LAUNCH WINDOW/TGTING displays and the REF SET data on LAUNCH REF TGT SETS. This data is delivered as part of the reconfiguration process and is unique to the flight/cycle combination of the Traj Server load. It may be checked against the ASCT 22B product. The K11, K12, K13, K18, and K19 MEDs are used to change the LW/LT inputs.

Run LWP with the K10 MED; do not reference a rendezvous plan for phase plane computations. A REF SET (normally set 2) must be specified. This LWP cycle computes planar window times and MECO phase angle for launch at the optimum time and fills out the top part of the LAUNCH WINDOW/TGTING display. Planar window open and close times are computed by simply adding premission-determined delta-t open and close parameters (DTO and DTC) to the inplane time. These times may change somewhat from the pre-mission values as phasing conditions change, and more precise times will be computed later using LWP. Check that the MECO phase angle is near the expected value; if it is not, the quadrant may be adjusted using an appropriate combination of the Phase Control and Wrap flags, which are input on the K13 and K18 MEDs, respectively. The Phase Control flag defines the initial phase interpretation, with choices of :1) 0 for phase angles from 0 to 360 degrees,2) 1 for phase angles form -360 to 0 degrees, and 3) 2 for phase angles from -180 to +180 degrees. The Wrap flag specifies an integer number of 360-degree increments to be added to the phase output under a given Phase Control setting.

WARNING

Proper settings of these flags is critical to both LWP and LTP. Consequences of improper settings range from difficulty in getting the processor to run (iterations fail as phantom plane offsets change discontinuously across phase quadrants) to generation of incorrect launch targeting uplink commands resulting in loss of mission.

NOTE: If the phase angle at the optimum liftoff time is close to the edge of the range specified by the phase control and wrap flags, the processor may fail to converge. Increasing the tolerance for the maximum iterations allowed may not solve the problem. If the processors fails to converge, change the phase control and wrap flags so that the optimum liftoff time's phase angle is in the middle of the range of phase angles. Trajectory parameters MCLWI3, MCLWI1, and MCLWI4 are the max iteration tolerances for time, longitude, and angle. In most cases these traj parameters should not have to be modified.

NOTE: For 28.5°missions, LWP may fail to converge even if the phase control and wrap flags are set correctly. This can happen because of a AR condition where the processor fails to find the inplane time. The first option to try is to re-execute LWP and force the close approach logic (K10 MED). If it still doesn't converge, then the old workaround must be used of biasing the launch site latitude down until the processor converges.

Launch times to meet ET disposal constraints may be computed by LWP. This is done via the K10 MED by specifying the longitude of the descending node for the ET IP limit as provided by TARGETING. Reference the latest STF for the generic descending node parameters. Notice that the nodes are inclination specific and may

also be launch pad dependant. Use the descending node at equatorial crossing values and not the instantaneous values.

LWP can also be used to compute launch time to satisfy a specific phase angle constraint. This is done by entering the desired OMS-2 phase angle on the K10 MED. The output of the launch time for a desired OMS-2 phase angle is displayed on the bottom of the Launch Targeting portion of the LAUNCH WINDOW/TGTING display.

For low inclination missions, the launch window open time is normally rounded up to the next minute. The launch window closing time should always be quoted to the second. For a launch slip scenario, these last few seconds may be the difference between a launch and a scrub.

For other inclination missions, the launch window open time is not rounded.

Execute the LTP on the K15 MED. The desired GMTLO must be specified as well as the REF SET. LAUNCH PERFORMANCE and the bottom of LAUNCH WINDOW/TGTING will fill out when execution is complete. The LAUNCH PERFORMANCE display shows the computed IYs, ΔV s, and prop usage Δ s between the computed data and the REF SET.

For OI-26 and subsequent Flight Software (FSW) revisions, the Auto Del Psi logic requires a change to procedures for high inclination missions. The IYs that are uplinked and the reference L/O time associated with those IYs must be computed at the inplane launch time. The Auto Del Psi logic uses the reference L/O time to compute an update to the first stage azimuth. The logic assumes that the reference L/O time is equal to the inplane time. Also, this FSW change also contained an I-load update to the node slope logic (del node phase) plus a time to switch to the second planar window (GMT Phase). For days without a 2nd planar window, the logic can be no-opted by uplinking a time well into the future. These two new parameters have been added to the Launch Targeting command load.

The Auto Del Psi logic is disabled for low inclination missions. In these cases, the IYs can be computed just prior to the window open time (5 seconds earlier) to avoid a FSW problem.

As a result of the above changes, LTP will have to be executed several times. The processor will need to be run at the window open, window close, preferred launch time and the inplane launch time.

After executing LTP at the preferred launch time, the LTP solution will can be transferred to set up assuming a launch at that time. On the LAUNCH PERFORMANCE display, check the MPS cost computed by LTP for reasonableness to insure a good solution. If the phase angle and performance computed by LTP are acceptable, the solution can be transferred using the K16 MED. The OMS-1/2

targets are sent to the AGT for use by the AME and COMMAND processors; the IYs are transferred to the LTCT for use by the ARD, AME, PFNI, and COMMAND processors; and the MECO targets can be transferred for use by the ARD, but usually are not due to biasing differences between actual MECO conditions needed for trajectory purposes and guidance targets used by the ARD (and onboard) PEG. The MECO, OMS-1/MPS dump cutoff, and/or OMS-2 cutoff state vectors can be transferred to the VAT for subsequent updating of the planning ephemeris. The OMS targets should be sent to the nominal AGT ITGT slot, normally ITGT 17 for OMS-1 and ITGT 16 for OMS-2. If MED option "N" (for "nominal") is used to specify the ITGT slot, the software searches the AGT for the ITGT slot with words "NOM" in the title. **NOTE: The "N" option should always be used instead of specifying the ITGT slot number.** Otherwise, the OMS-1 targets will be incorrectly set to ITGT 16. The GPO's command application is expecting to find the nominal OMS-1 targets in ITGT 17 and the OMS-2 targets in ITGT 16. When transferring the LTP solution, the vectors and IYs can be transferred alone. However, OMS targets to the AGT cannot be transferred alone as they require the IYs to be transferred as well.

When an LTP solution is transferred, if subsequent Traj Server operations are to be performed based on that solution (such as ephemeris update), it is also necessary to update Traj Server liftoff reference time via the D65 MED. All other transferred data should be carefully confirmed as well.

After targeting for the preferred liftoff time, the cost of the rendezvous plan can be evaluated. This is done by MARS and FDO Support executing the Orbital Maneuver Processor (OMP) on the workstation. Preflight analyses will determine the required rendezvous profile as a function of phase angle. NOTE: Verify that FDO Support has a pre-OMS-2 plan and a post OMS-2 plan ready to go prior to launch. These are both required immediately post MECO. The pre-OMS-2 plan will be used in evaluating the nominal OMS-2 target altitude and planar error. The post OMS-2 plan (with an NPC burn) is used in the evaluation of the onboard state vector prior to OMS-2.

MARS should queue the OMP using the MPS dump cutoff SV from the LTP solution. FDO can check the results on the RDVZ EVALUATION TABLE display. The NPC burn should not be larger than 8 fps; if it is, an adjustment should be made to the phase control and wrap flags and the targeting process should be re-executed until an acceptably small NPC results. The OMP solution will determine the desired post-OMS-2 H_p (or H_a). This perigee or apogee will be used to correct the OMS-2 HT in the REF SET. To compute HT, an empirical bias is added to H_p to compensate for J2 effects. Also, the ΔV for OMS-2 computed by the OMP can be used to update the OMS-2 ΔV in the REF SET. If desired, update the REF SET IYs and prop numbers with the latest LTP solution via the K14 MED. When this update is complete, re-execute LTP and re-transfer IYs and OMS targets. This will place the correct performance deltas on the LAUNCH PERFORMANCE display and the correct OMS targets into the AGT. Verify that the updated OMS-2 HT in the nominal ITGT slot is correct.

The final LTP solution is computed for launching at the inplane launch time. When the final LTP solution has been transferred, GPO can build the command loads to uplink the IYs and OMS targets. *FDO/GPO combined QA and signature concurrence on the resulting command loads is mandatory.* Refer to figures 5.3.16-1 and 5.3.16-2 for examples of the command load displays from the Command Server. The Launch Targeting command load has the planned launch time, min IYs, abort IYs, nominal IYs and the DEL PSI. The OMS Targeting command load has OMS-1 IYs and OMS-1 PEG 4 target from ITGT 17 and the OMS-2 IYs and OMS-2 PEG 4 targets from ITGT 16. The DTIGs uplinked, in seconds, are computed by taking the DTIGs in the AGT and subtracting the Δt ET Sep (typically 12).

If there are gaps or any phase discontinuities in the window due to limits in phasing capability or a second phase pane, LWP should be executed to determine the exact times at which the gap(s) or second phase pane opens and closes. These gaps/second phase pane are defined pre-mission in terms of limiting phase angles. The phasing requirement (wrap or phase more than 360 degrees) will normally be different after the gap or in the second phase pane. In this case, the Phase Control and/or Wrap Flags must be changed for the second part of the window. LWP is executed with the desired phase angles (K10 MED input) to compute the open and close times. LTP can then be executed at the gap close (second window open) time. In the execution checklist, the computation of this second phase pane data is performed prior to the first phase pane set in order to minimize the amount of Traj Server reconfiguration and re-computation necessary.

Although it has never been used, LTP provides the capability to intentionally target to an out-of-plane offset at MECO. This can be done with the Delta ROP and Delta VOP parameters, which specify the desired out-of-plane position and velocity, and the OMS OP flag, which allows LT OMS-1/2 computations to include planar steering. However, in order for the OMS-1/2 out-of-plane logic to be invoked, system parameters MCMAS1 and MCMAS2 must be set correctly. If the PEG-computed OMS-1 and OMS-2 burnout weights are less than MCMAS1 and MCMAS2 respectively, then the burn(s) will always be done in-plane. Therefore, these two parameters should be set to something less than the corresponding worst-case predicted burnout weights.

Command

Launch/OMS Targets (version 1.0)

Launch Targeting		MOC Input	42501	CMD HEX	GPC Dump HEX
GMT L/O ref for IYs	TL0	149:00:32:26	149:00:32:26	46C4771A 00000000	46CAED3C FFFFFFFF
Min IY (Earth Fixed)	IM1	0.59221076	0.59221076	40979B1F D68A0FD0	40979B1F D68A0FE4
	IM2	-0.30761573	-0.30761573	C04EBFE7 8C15CD74	C04EBFE7 8C15CD72
	IM3	-0.74475430	-0.74475430	C0BEA837 C20E2CF0	C0BEA837 C20E2CEA
Abort IYs	I1	-0.40444877	-0.40444873	C06789F3 A33E5E28	C0B144EA BC4F4FE9
	I2	-0.67363004	-0.67363006	C0AC7305 15988308	C05F9F49 49D99010
	I3	-0.61858206	-0.61858206	C09E5B64 D64E5710	C09E0341 DE6505C3
Nominal IYs	IN1	-0.40444877	-0.40444873	C06789F3 A33E5E28	C0B144EA BC4F4FE9
	IN2	-0.67363004	-0.67363006	C0AC7305 15988308	C05F9F49 49D99010
	IN3	-0.61858206	-0.61858206	C09E5B64 D64E5710	C09E0341 DE6505C3
D-psi	0.00000000	0.00000000	0000 0000	0000 0000	
Delta Node Phase	-0.77500000	-0.77500004	BF37 675B	BF37 675B	
GMT Phase	149:00:35:02	149:00:35:02	46C477B6 00000000	46F3E580 00000000	

Figure 5.3.16-1 - Launch Targeting Command Load

Command IDs		Launch/OMS Targets (version 1.0)			
OVS Targeting		MOC Input	42701	CMD HEX	GPC Dump HEX
OVS-1 Iy	I11	-0.40455010	-0.40455005	C0679097 97859E58	C0B145FE A4135378
	I12	-0.67349181	-0.67349184	C0AC69F6 1F0BED00	C05F941E 8066A3DF
	I13	-0.61866630	-0.61866630	C09E60EA 2FEE23C0	C09E08CD DAB86SEF
OVS-2 Iy	I21	-0.40635428	-0.40635423	C06806D4 C182B834	C0B19326 DCBC815C
	I22	-0.67279485	-0.67279488	C0AC3C49 0F092720	C05F2F2D AB80A57C
	I23	-0.61824209	-0.61824209	C09E451D 1AA20EE8	C09DEF18 47B187FA
OVS-1 TGT	DT 1	102.00	102.00	4266 0000	4266 0000
	HT 1	168.00	168.00	42A8 0000	42A8 0000
	Theta T1	154.00	154.00	429A 0000	429A 0000
	C1 1	0.00	0.00	0000 0000	0000 0000
	C2 1	0.00000	0.00000	0000 0000	0000 0000
	OVS-2 TGT	DT 2	2000.00	2000.00	437D 0000
	HT 2	178.20	178.20	42B2 3333	427C B333
	Theta T2	330.00	330.00	4314 A000	4314 A000
	C1 2	0.00	0.00	0000 0000	0000 0000
	C2 2	0.00000	0.00000	0000 0000	0000 0000

Figure 5.3.16-2 - OVS Targeting Command Load

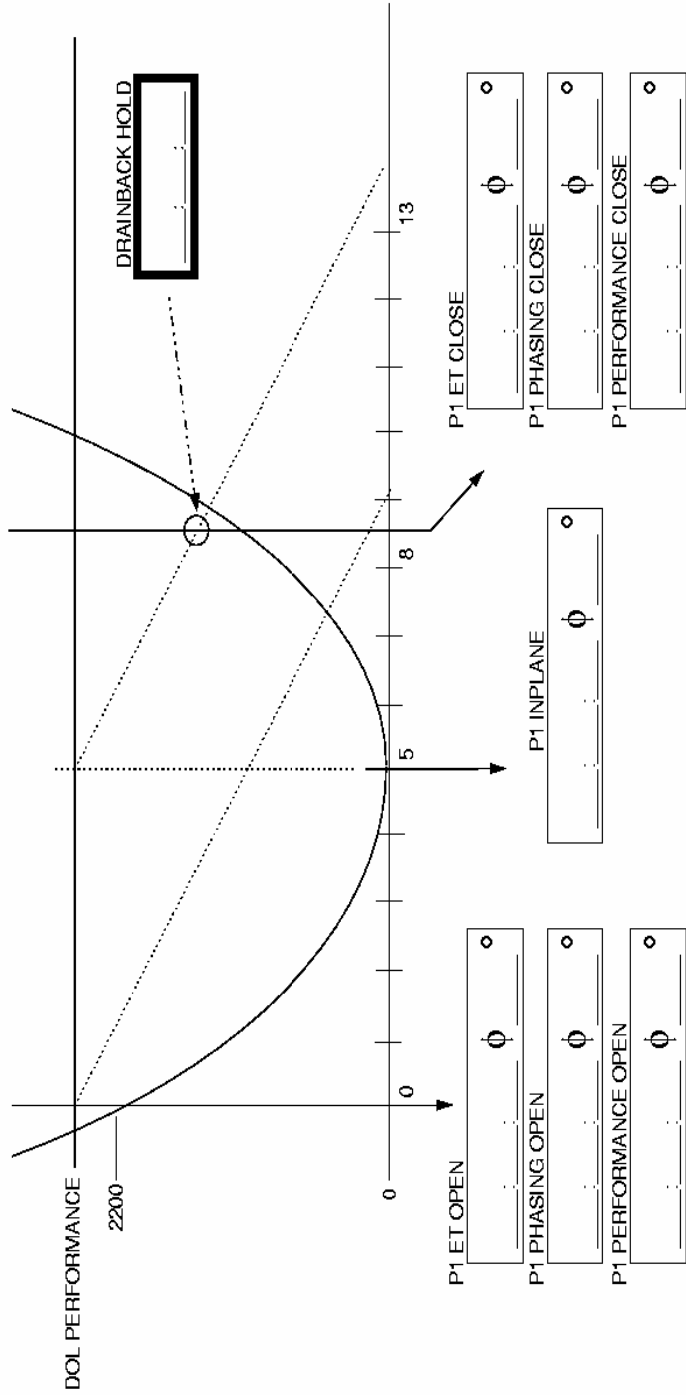
BACKGROUND

LW/LT is used to determine the launch window and launch targets for a rendezvous mission. Included in outputs of LWP are the planar window open and close times, optimum liftoff time, phase plane open and close times, associated phase angles, liftoff time to achieve a desired phase angle, and liftoff time to satisfy a descending node. Outputs of LTP include MECO SV, post-MPS dump or post-OVS-1 SV, post OVS-2 SV, IY vectors (nom, abort, OVS-1, and OVS-2), and phase angles at MECO and OVS-2 at a specified launch time. The Launch Targeting Performance Predictor (LTPP) is an extension of LTP which computes all normal LTP data plus the MPS and OVS performance required at the specified launch time. LTPP data may be used to define a reference launch condition (REF SET) and/or may be compared against another REF SET for determination of relative performance costs for changing launch times or phasing conditions.

The forms on the following two pages can be used for logging the results of the LW/LT comps. One form is for use on a 1 pane day while the other is for a 2 pane day. These can be found on the S drive in the Checklists folder (lw X pane.doc).

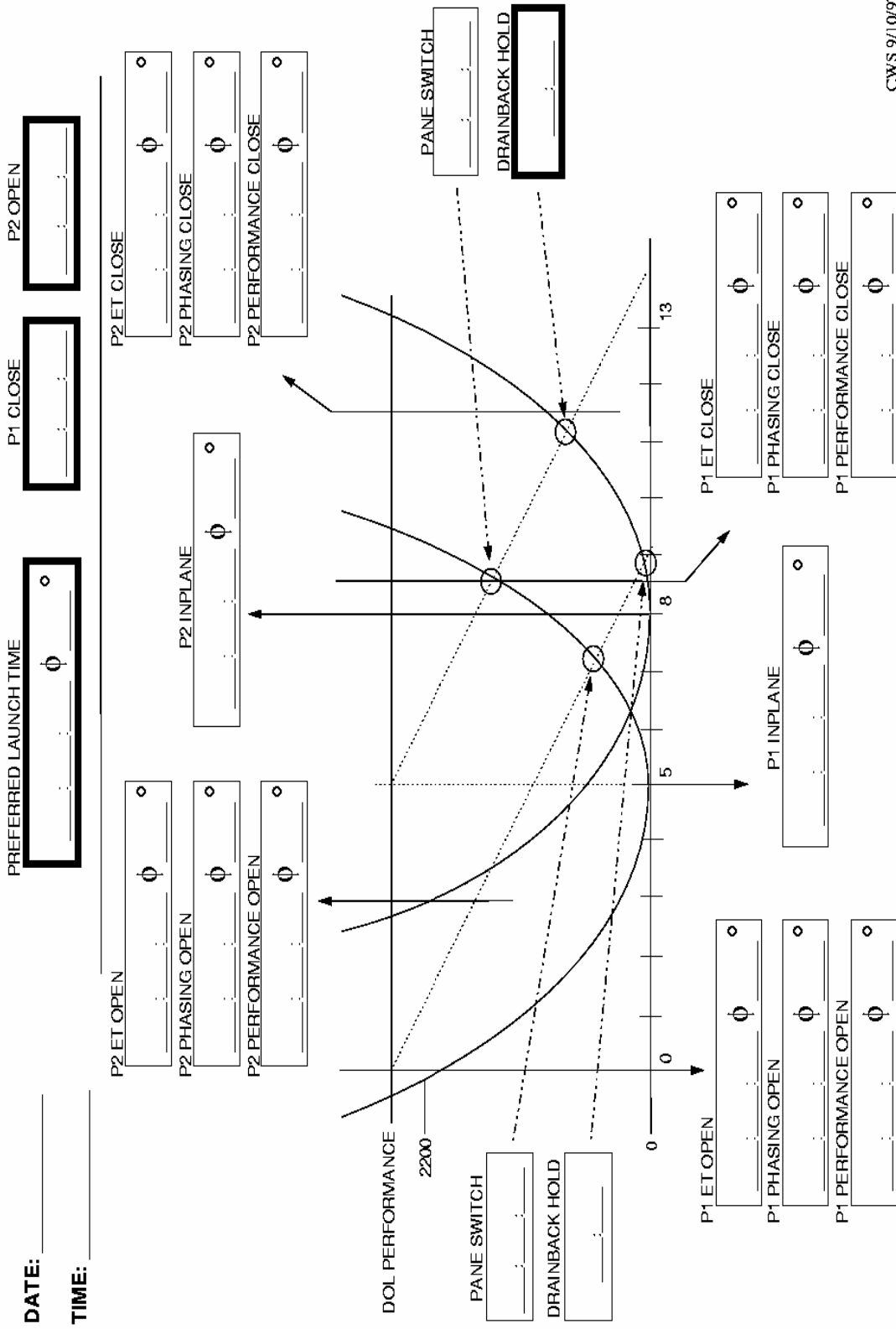
FLIGHT: STS- _____
 DATE: _____
 TIME: _____

PREFERRED LAUNCH TIME



CWS 9/6/97

FLIGHT: STS- _____
 DATE: _____
 TIME: _____



CWS 9/10/97

5.3.16 Adjustment of Node Slope Parameters

PURPOSE

This section defines steps for adjusting the node slope parameters. Only two of the three parameters will be modified in the close to launch timeframe (the NODE SLOPE parameter will not change).

PROCEDURE

TARGETING WILL PROVIDE AN UPDATE TO THE **DELTA NODE PHASE** N.L.T. L-1 DAY.

CHANGE **DELTA NODE PHASE** (K13 MED). QA THE CHANGE ON LW/LT INIT (**DEL NODE PHASE** PARAMETER)

IF THE FIRST LAUNCH ATTEMPT DOES NOT HAVE SECOND PHASE PANE, SET THE **PANE SWITCH TIME** PARAMETER (K13 MED) TO L/O + ~30 DAYS (NLT L/O + 180 DAYS).

IF THE FIRST LAUNCH ATTEMPT DOES HAVE SECOND PHASE PANE:

- DETERMINE THE EARLIEST TIME THAT THE SECOND PHASE PANE WOULD BE USED. THIS IS REFERRED TO AS THE **PANE SWITCH TIME. IT WILL PROBABLY BE AT THE END OF THE FIRST PANE.** HOWEVER, IT COULD BE AT THE OPENING OF THE SECOND PANE. THIS DEPENDS ON FLIGHT-SPECIFIC PRIORITIES (**CONSULT WITH THE LEAD FDO**).
- REFERENCE SECTION 5.3.22 FOR DETAILS ON DETERMINING THE END OF THE FIRST PANE OR THE OPENING OF THE SECOND PANE.
- ENTER THIS TIME INTO THE TRAJ SERVER AS THE **PANE SWITCH TIME** PARAMETER ON THE K13 MED. VERIFY THE CORRECT VALUE ON LW/LT INIT.

BACKGROUND

The addition of the “node slope” equations to the MOC in the Spring of 1995 deleted the requirement to re-run LTP for launch slips into the launch window. The NODE SLOPE parameter is the slope of the differential nodal regression and is used to compute new M50 IYs for the actual launch time. The logic applies a delta to the nominal IYs on MSK 2442 using this slope and the Δ L/O time. The node slope logic is automatically executed to recompute Traj Server

IY vectors for all rendezvous missions to compensate for a launch slip past the nominal T-0.

The NODE SLOPE parameter should not be changed on launch day, otherwise the Traj Server and the onboard computed IYs will not match for a launch slip.

The **NODE ADJUST DUE TO PANE CHANGE** parameter (**DEL NODE PHASE** on MSK 466) may be modified slightly close to launch to optimize the IYs for a switch to the second phase pane. TARGETING is responsible for providing the updated value.

With the OI-26 FSW release, the O/B software automatically compensates for slips within a phase pane and can handle the switch in IYs if a switch to the second phase pane is required. This was part of the Auto Delta PSI CR. Currently, there is a 10 second cutout (pane switch ± 5 seconds) to prevent a DR condition where the PASS and BFS target for different planes. The **GMT PHASE** parameter, or pane switch time, is the time that the switch to the second phase pane occurs. This is parameter "PLO" on DSM 425 "Launch Targeting" command load. Any launch after this time will have a $\pm 360^\circ$ added to the phase angle and a new set of IYs computed to account for this change. Some missions may desire to remain on the first phase pane as long as possible (FD3 rndz higher priority than FD4 rndz). The new IYs are significantly different than the set for the first phase pane since the phantom plane is considerably different. This is a result of greater differential nodal regression as a result of the orbiter staying in a significantly lower orbit to "lap" the target prior to rendezvous. If the launch window supports only a single rendezvous pane (e.g. FD3 only), then the pane switch time must be set well into the future to prevent the O/B software from modifying the phase angle. Standard practice is to round up to the nearest day 30 days in the future. The command load processor will not accept a pane switch time greater than 180 days from the planned liftoff time.

During the training for STS-103, it was discovered that the MOC's node slope logic was incorrect if the inplane time was after the pane switch time. This would cause an incorrect pane switch for a launch after the pane switch time. The workaround used consisted of setting the ARD's IYs to the correct value for a launch at the window open. This was different than the IYs uplinked to the vehicle (based at the inplane time).

Also prior to STS-103, it was discovered that the node slope coefficient was sensitive to phase angle for low inclination missions. The result was that the node slope rotation from the inplane time back to the window open could produce errors from 1.25 to 6.7 feet/second. Due to this, the node slope coefficient was being evaluated as a candidate Flight Software change to make it uplinkable. All special mods to the LW/LT procedure for working around these problems were documented in the STS-103 Operations Supplement to the Ascent FDO Console Handbook.

5.3.17 No-COMM Mode Boundary Updates (including Rendezvous OMS-2)

PURPOSE

This section defines procedures used to update the crew's no comm abort mode boundaries and also the OMS-2 HT for a rendezvous flight prior to launch.

PROCEDURE

- UPDATE DUE TO DOL EFFECTS OR A LAUNCH SLIP IF BOUNDARY VELOCITIES CHANGE BY MORE THAN 200 FPS.
- CURRENT VALUES ARE IN THE ASCENT CHECKLIST ON PAGE 2-4.
- ABORT SUPPORT PROVIDES THE UPDATES BASED ON DOL RUNS WHICH TAKE INTO ACCOUNT THE DOL WINDS, ATMOSPHERE AND ACTUAL MPS LOADINGS. ALSO, LAUNCH SLIPS FOR INERTIALLY TARGETED FLIGHTS MAY HAVE SIGNIFICANT CHANGES AS LAUNCH SLIPS THROUGH THE LAUNCH WINDOW.
- UPDATES SHOULD BE WRITTEN ON A FLIGHT NOTE (E.G., "PRESS-TO-ATO: 10800") AND PASSED TO FD AND CAPCOM ASAP PRIOR TO COMING OUT OF THE T-9 MINUTE HOLD.

RNDZ ONLY: IF OMS-2 IS A PHASING BURN, THE **NOMINAL OMS-2 HT** AND **NO COMM HP** FOR THE PLANNED LAUNCH TIME ARE ALSO PASSED ON THE FLIGHT NOTE

- RNDZ ONLY: IF THE LAUNCH SLIPS INTO THE SECOND PLANAR WINDOW, INFORM FD AND THE CREW AFTER COMING OUT OF THE T-9 MIN HOLD.

BACKGROUND

Prior to STS-30, the need for providing pre-launch updates to the NO COMM MODE BOUNDARIES was realized. STS-30 was the first inertially targeted flight where the effects of a launch slip through the launch window was analyzed pre-flight. Several of the boundaries change significantly for these flights due to decreased yaw steering required as the launch time slips to the optimum liftoff time.

The threshold of ± 200 fps on the VI prior to update of a NO COMM MODE BOUNDARY was chosen by the Flight Director prior to STS-30. Since STS-30, non-rendezvous flights have used this same threshold to determine when to update these values. This covers any changes to the vehicle weight, atmosphere, winds, SSME performance parameters, etc., since the Flight Cycle analysis was performed.

ABORT SUPPORT provides the updates to all boundary predictions based on DOL runs which take into account the DOL winds and atmosphere and the actual MPS loadings. Again, launch slips for inertially targeted flights may have significant changes as launch slips through the launch window.

On STS 41-C, the predicted OMS-2 HT was passed to the crew just prior to launch. This allows the crew to perform OMS-2 to the correct target for the case of a loss of comm post MECO. Not doing so would result in the crew burning OMS-2 to the wrong altitude which could severely impact the rendezvous profile. Since the OMS-2 HT changes as the launch time slips through the launch window, the value of HT cannot be computed until the launch time is known. A preliminary value, which assumes a launch at the preferred launch time, is computed and passed to the crew. In the case of a launch hold, a new HT is not determined until the count is resumed after the T-9 minute hold. For short rendezvous launch windows (51.6° missions), one value of HT will usually work for an entire planar window. This is determined prelaunch and passed to the crew with the other NO COMM updates.

5.3.18 ARD Loading Updates

PURPOSE

This section defines procedures used to update the ARD based on Day-of-Launch ET loading data.

PROCEDURE

- ARD SUPPORT PROCESSES L-3:25 HR & MIN ET LOADING DATA (REF. Section 5.3.12, ET Load and Launch Hold Capability Reporting, and ARD SUPPORT Console handbook)
- ARD SUPPORT PROVIDES FDO AND TRAJ WITH:
 - HARDCOPY OF PLOAD LOADING DATA
 - ALL COMPUTED DELTAS TO ARD DATABASE PARAMETERS
 - UPDATED DOL ARD LAUNCH HOLD TABLE
- FDO, TRAJ, ARD DECIDE WHICH PARAMETERS REQUIRE UPDATING (WEIGHT CHANGE >50 LBS; 10 LBS FOR FUEL BIAS)
- TRAJ: PROVIDE DYNAMICS WITH UPDATES

PARAMETER	TYP. VALUE, lbs <i>(examples only)</i>	MED	MSK
ARD FPR	2823	K67	600
Initial ET (MEP)	1602063	K67	433
Dry Vehicle	689760	K67	433
ET Jettison	67930	K67	433
FBIAS	679	K88	433
PROPLVL	2823	K88	600

- HARDCOPY MSK 433 AND 600 TO DOCUMENT CHANGES

BACKGROUND

Use of this procedure ensures that the ARD has the most accurate values for ET usable and unusable propellant weights, based on the DOL loading data. In the past, a system parameter, MCWTET, was also updated. It was determined that this parameter is only used during first stage, where margin computations are meaningless. It is no longer updated.

5.3.19 FDO DOL Timeline

PURPOSE

Provide a convenient console reference for FDO prelaunch activities.

PROCEDURE

Use the attached timeline as a checklist and reference for all prelaunch activities.

BACKGROUND

Self-explanatory.

FDO DOL TIMELINE (page 1 of 2)

L-6:00	ON CONSOLE
	REVIEW WX FCST
L-5:40	FCO ABORT SWITCH TEST
L-05:15	HANDOVER COMPLETE
	REVIEW L-9 HR RTLS, TAL & AOA A&L ANALYSIS
	TRAJ: INITIALIZE TSA, THEN ENABLE AUTOMOC VAT AND AUTOMOC EPHEMERIDES (VERIFY AUTOMOC DISABLED BY FDO SUPPORT FIRST)
L-05:00	REVIEW FCST RTLS, TAL, AOA & FD1 PLS A&L ANALYSIS
L-04:40 for 51.6°	REVIEW RWY/AIMPOINT SELECTIONS WITH FD
L-04:10 for others	RWY BRIEFING SHEET → FD, CAPCOM, GPO, MMACS, GNC, LSO
	PASS RTLS LANDING WT/CG TO CAPCOM (CONFIRM LT/HVY WT)
L-04:25 (51.6°) L-03:55	CREW WX BRIEFING: RWYS, LKBDS, NAVAIDS THIS HAPPENS AT L-03:55 FOR NON-51.6° MISSIONS
L-04:00	REVIEW L-6.25 HR MARGINS OUTPUT. IF RNDZ MISSION, PICK THE PREFERRED LAUNCH TIME & REPORT TO FD AND ASC SUPT
L-03:30	REVIEW L-6 HR RTLS A&L AND TAEM ANALYSIS
L-03:15	FDO & ASC SUP'T: REVIEW L-4.5 HR MARGINS OUTPUT
	IF RNDZ MISSION, VIEW MARGI DATA FOR PERFORMANCE WINDOW OPEN AND CLOSE TIMES (IF APPLICABLE)
	DRAINBACK HOLD TIME → FD
L-03:00	FCO: COLA CUTOUPS
	FCO: COMM CHECKS
	FCO: CONTROLLABILITY LIGHT TEST
	RNDZ: FINAL LW/LT COMPS
L-02:50	RNDZ: DOLILU and DOLARD TRANSFER to TRAJ SERVER
L-02:30	FINAL DATABASE CHECK
	DOL ET LOAD DATA TO ARD SUP'T & ASC SUP'T; VERIFY TRAJ SERVER UPDATE
L-02:20	DOLILU and DOLARD TRANSFER to TRAJ SERVER
L-02:10	FD/SMG/FDO/WX CAPCOM TAG-UP (IF REQ'D)
	LAUNCH PHASE FOR HI-SPEED S-BAND √'s

FDO DOL TIMELINE (page 2 of 2)

L-02:00	ASC SUP'T: FCO PACKAGE
	PREDICTED POST MPS dump and OMS-2 SVs TO SPADOC (rndz mission, after LW/LT comps complete)
	RNDZ: DOL LAUNCH WINDOW DATA TO FD
	FCO: REVIEW OPERATING PROCEDURES
	DOLILU UPLINK
L-01:45	REVIEW FCO PKG FROM ASC SUP'T; CONFIRM FCO REC'D ΔFILE
L-01:30	ABORT SUP'T: NO-COMM MODE BDRY UPDATES
	REVIEW L-3.5 HR RTLS A&L ANALYSIS
	REVIEW L-3.5 HR AOA A&L ANALYSIS
L-01:00	FD/SMG/FDO/WX CAPCOM WX BRIEF
	DRAINBACK HOLD TIME → FD
	PREPARE/DISTRIB. NO-COMM MODE BDRY UPDATE FLT NOTE
	CODEWORDS TO FD
	RNDZ: PREP./DISTRIB. OMS-2 HT AND PHASE ANGLE FLT NOTE
	PRELAUNCH CHECKPOINT
	REVIEW L-2.5 HR TAL A&L ANALYSIS
L-00:50	WX: UPDATES TO RTLS & TAL ALTIMETER SETTINGS
L-00:45	LAUNCH DIRECTOR WX BRIEFING
	IF AOA OR FD1 PLS SITE CHANGED, MODIFY MECO U/S TABLES
	CREW: NO-COMM MODE BOUNDARY UPDATES
	CREW: RTLS & TAL ALTIMETER SETTING UPDATES
	CREW (RNDZ): OMS-2 HT AND PHASE ANGLE
	REVIEW L-2 HR RTLS A&L ANALYSIS
L-00:30	ASC SUP'T: FINAL MARGINS OUTPUT (L-2.25 HR DATA)
	RNDZ: FINAL LAUNCH WINDOW OPEN/CLOSE/DB HOLD → FD
	FCO/FDO PRELAUNCH TAG-UP √ ABORT HEARTBEAT: IF NO HEARTBEAT, TRY DEACTIVATING AND THEN RE-ACTIVATING THE ABORT SWITCH S/W
L-00:15	REVIEW L-1 HR RTLS AND TAL A&L ANALYSIS
L-00:09	LAUNCH PHASE AFTER COMING OUT OF HOLD
	FDO: UPDATE D65 L/O TIME IF REQ'D
	FINAL ABT LIGHT STATUS CHECK w/ FCO
L-00:05	FDO: UPDATE D65 L/O TIME IF REQ'D

5.3.20 Preferred Launch Time Determination

PURPOSE

Define operational procedures for determining the preferred launch time for all ground-up rendezvous missions.

PROCEDURE

PERFORMANCE LIMITED WINDOW OPEN AND CLOSE TIMES ARE BASED ON THE 4.5 HOUR MARGINS OUTPUT.

FOR A 51.6° MISSION:

FOR 2 PANE DAY:

THE OPTIMUM LAUNCH TIME FOR PANE 1 IS PREFERRED.

HOWEVER, IF FD3 RENDEZVOUS CAPABILITY DOES NOT EXIST AT THE OPTIMUM, THEN THE PREFERRED LAUNCH TIME MAY BE MOVED TO PICK UP THIS CAPABILITY.

FOR 1 PANE DAY:

LAUNCH AT THE LATER OF **OPTIMUM LAUNCH TIME** AND THE **RENDEZVOUS PHASE PANE OPEN**.

FOR A 28.5° MISSION:

LAUNCH AT THE LATER OF **PLANAR WINDOW OPEN** AND THE **RENDEZVOUS PHASE PANE OPEN**.

BACKGROUND

The groundrules for determining the preferred launch time was reviewed extensively in early 2002. The decision was made to always target to launch at the optimum launch time for all 51.6° missions in order to maximize the MPS performance margin available in case unforeseen in-flight performance problems occur. Another change that happened after this review was that the requirement for maintaining a minimum launch window duration of 5 minutes was dropped. Therefore, we will always target for the optimum (inplane) launch time unless the rendezvous phase pane open is later. For 28.5° rendezvous missions, the preferred launch time will be the opening of the composite window (planar and phase panes). Ref. Flight rule A2-8.D.2.

5.3.21 Day of Launch RNDZ Launch Window Data for Flight Director

PURPOSE

The purpose of this procedure is to document the data that needs to be computed and provided to the Flight Director on day of launch.

PROCEDURE

After the final DOL LW/LT comps, the attached form with the following data is provided to FD. The first column assumes a launch at the preferred launch time and the second (gray) column data assumes a launch at the window open:

- Window open time (the most constraining of performance, ET thermal and phasing)
- The preferred launch time
- If 2 pane day:
 - Pane 1 close time. This close time is the last time to launch in pane 1 (pane switch time - 5 sec). The pane switch time is obtained from the 4.5 hour MARGINS rendezvous launch summary.
 - Pane 2 open time. This is the pane switch time + 5 sec.
- Window close time (the most constraining of performance, ET thermal and phasing)
- Drainback hold time

Make 2 copies and put one in the FDO Logbook. Give the other copy to FD.

If during the T-9 hold the decision is made to launch at the window open, update the pane 1 close, pane 2 open and drainback hold time.

BACKGROUND

This data is required by FD to send to the NTD. This data will replace all previous launch window data. This data is now obtained from the MARGI program (Launch Window Data under the VIEW menu).

STS-XXX DOL Launch Window Data

Liftoff on 04/29/2003 (Day 119 GMT)

GMT

Window Open	09:17:01
Preferred Launch Time	09:22:01
Window Close	09:30:10
Launch T-0 at Preferred Launch Time:	
Pane 1 Close	09:26:45
Pane 2 Open	09:26:55
Pane 2 Inplane	09:25:10
Drainback Hold Time	07:04
Launch T-0 at Window Open Time:	
Pane 1 Close	09:25:20
Pane 2 Open	09:25:30
Pane 2 Inplane	09:25:10
Drainback Hold Time	10:20

(Ascent FDO)
Generated: L0+7 hr. (119/16:52:14)

5.3.22 MARGI Nominal Data

PURPOSE

The purpose of this procedure is to document the steps required to use MARGI for obtaining some nominal data.

PROCEDURE

CALL UP MARGI APPLICATION (PRELAUNCH MENU)

CLICK ON **FILE**

SELECT **OPEN** TO LOAD THE APPROPRIATE MARGI FILE

CLICK ON **EDIT**

EDIT PREFERRED (LAUNCH) TIME (IF REQUIRED)

√ BOTTOM RIGHT BOX (**LAUNCH WINDOW**)

- VERIFY PREFER TIME IS CORRECT
- OBTAIN PANE 2 OPEN TIME
- OBTAIN DRAINBACK HOLD TIME (MAX OF 5:00)

BACKGROUND

Following the L-2 day checkout as well as each balloon release on launch day, ASCENT SUPPORT will generate a MARGI file. The files are in flight-specific directories and are appropriately labeled. ASCENT SUPPORT will inform FDO when the file is available. The following nominal data are obtained from MARGI:

- Drainback hold time (SLWT is limited to a max of 5.0 minutes)
- Pane switch time
- Pane 2 open time (pane switch time + 5 seconds)

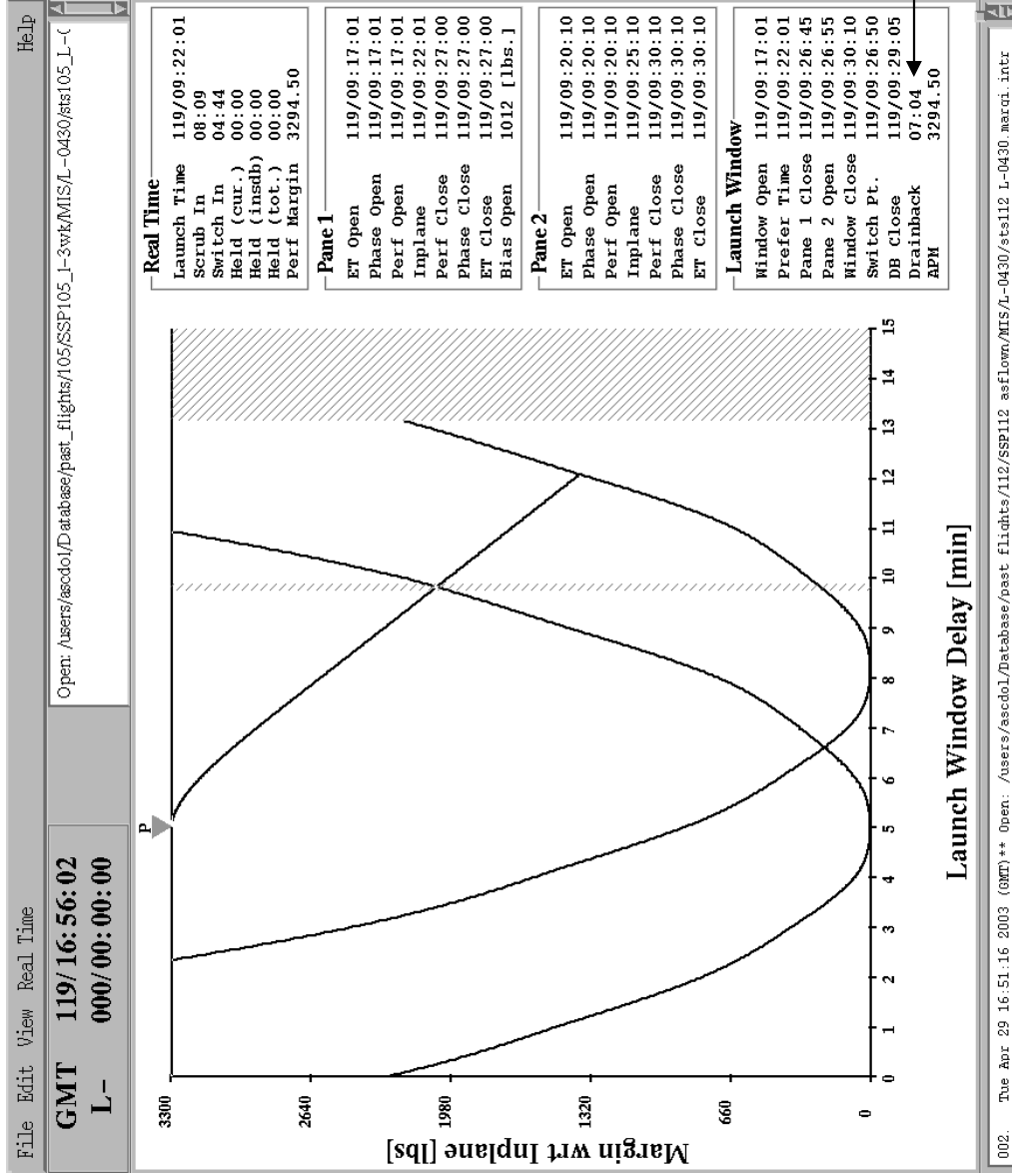


Figure 5.3.22-1 - Example MARGI output (2 pane day)

5.3.23 MECO Underspeed Curves Initialization

PURPOSE

The purpose of this procedure is to document the procedure to verify that the MECO underspeed curves used by the ARD are properly initialized for flight.

PROCEDURE

WARNING

Before making changes to any curve, tell MPSR support personnel not to make any inputs to the MECO UNDERSPEED CURVES display. If anyone changes the curve displayed it changes everyone's display.

1. QA the shallow and steep flags for the MECO underspeed curves. All curves should have the **Shallow Call Enable flags** turned on. Turn on all the AOA steep flags for each "GO" AOA site (WX acceptable, no critical equipment outages, site staffed, etc). Turn off the AOA steep flags for all "NO-GO" AOA sites:
 - Turn on the **Steep Call Enable flags** for all the AOA steep curves for all "GO" AOA sites (ATO_ST, DI_ST8, DI_ST10 and OPT_ST)
 - Turn off the **Steep Call Enable flags** for all the AOA steep curves for all "NO-GO" AOA sites (ATO_ST, DI_ST8, DI_ST10 and OPT_ST)
2. If rev 3 FD1 PLS is forecast NO-GO, but another FD1 site is GO then:
 - Reconfigure the ATO_MIN-SH-REV-3 for the alternate FD1 opportunity (modify usables & deorbit ΔV).
 - Note: pressing on cheaper of alternate ATO / Min Hp / FD1 shallow or AOA-ST
3. If all FD1 PLS sites are forecast NO-GO, but at least one AOA site is GO, then:
 - Turn off the **Steep Call Enable flags** for ATO_MIN-SH-REV-3 curve and ATO_ATO-ST-REV-7 curves.
 - Note: pressing on AOA-ST
4. If all FD1 PLS and all AOA sites are NO-GO, then:
 - If FRCS supports FD2 option, then
 - Reconfigure the ATO_MIN-SH-REV-3 for FD2 (modify usables for FD2; do not change deorbit ΔV).
 - Turn off the **Steep Call Enable flag** for ATO_ATO-ST-REV-7 and DI_HP=105-SH-REV-7

- Note: pressing on ATO / Min Hp / FD2 shallow deorbit assuming FRCS Hp adjust.
- Otherwise if FRCS does not support FD2 option:
 - Configure the ATO-ATO-SH-DAY-1 curve deorbit ΔV and unusables for FD2 opportunity.
 - Turn OFF the Steep Call Enable Flag for the DI_HP=105-SH-REV-7 curve.
 - Note: pressing on ATO / ATO / FD2 shallow deorbit.

WARNING

AT LEAST ONE CURVE MUST HAVE THE STEEP ENABLE CALL FLAG TURNED ON. FAILURE TO DO SO WILL RESULT IN THE ARD **PRODUCING PROGRAM CHECKS IN THE Traj Server.**

EXAMPLE

KSC is the prime AOA site
NOR is now also a "GO" AOA site

Curve 4 is KSC-ATO_ST-AOA_ST (KSC AOA site, ATO OMS-1 with Steep AOA D/O) and has shallow flag ON and steep flag ON.

Curve 14 is NOR-ATO_ST-AOA_ST (NOR AOA site, ATO OMS-1 with Steep AOA D/O) and has shallow flag ON and steep flag OFF.

Turn the steep flag **ON** for curve 14.

BACKGROUND

The MECO underspeed curves are used in computing XOMS. The curves represent the underspeed that can be supported as a function of ΔV available. The ΔV available is adjusted for any OMS ballast required, unusable OMS due to MR losses, any pre-MECO dump (if applicable), and deorbit requirements. The "delta to usables" accounts for additional ΔV available in the ARCS above entry redlines and on-orbit attitude control. The total ΔV available post MECO is then used to interpolate from the ΔV required table to compute the largest MECO underspeed to can be supported (XOMS).

When the ISHALW flag is OFF, all curves that have the steep call enabled flag turned ON are evaluated. The maximum underspeed that can be supported from all the curves that are evaluated is then set to the XOMS quantity for the ARD channel being computed.

When the ISHALW flag is ON, all curves that have the shallow call enabled flag turned ON are evaluated. Similar to above, the maximum underspeed that can be supported from all the curves that are evaluated is then set to the XOMS quantity for the ARD channel being computed. ISHALW is usually turned on only for gap closure.

The MECO underspeed curves are delivered with the steep call enable flags for the prime AOA site turned on. Prior to launch, steep call enable flags should be turned on for any other "GO" AOA site, since AOA to a "GO" site (even if it is not prime) is preferred over TAL.

All the curves should have the shallow call enable flags turned on. This is because all the curves should be considered when the ISHALW flag is turned on, even NO-GO sites. The flight rules allow an AOA to a NO-GO site for gap closure cases.

Step 2 is to configure the curves in the event the prime FD1 PLS (typically rev 3 to EDW) is not available. If another FD1 landing site is GO, then the ATO / Min Hp / Rev 3 shallow curve is modified to match the alternate opportunity (e.g. KSC rev 6). In this case, the deorbit DV is set based on DSCT-30, and Abort Support and Targeting supply the "delta to usables" to account for ballast and on-orbit RCS usage.

In step 3, if no FD1 PLS is available and at least one AOA site is GO, then FR A4-55 specifies that the press calls will be made based on AOA capability rather than FD2. In this case all FD1 curves will have their Steep Call Enable flags turned off (typically curves 1-3 & 11-13).

Step 4 is to configure the curves for cases where there is NO FD1 PLS available and all AOA sites are NO-GO. Here press is based on FD2 PLS. The use of FRCS for on-orbit is now allowed for FD2 PLS cases (ref Flight Rule A2-53). This typically means that the extra prop require to get to an HP of 95 to support the orbit lifetime through the FD2 PLS will be covered by the FRCS, along with the cost of lowering perigee back down to 85 nmi prior to deorbit prep. This change eliminated the Press hit when pressing on FD2. To reconfigure the ARD, the ATO / Min Hp / Rev 3 shallow "delta to usables" is modified to account for FD2 RCS usages. Any decrease in deorbit ΔV relative to rev 3 cost will not be credited, in order to honor FR A4-55 which specifies that pressing on FD2 PLS will not move press times any earlier than FD1.

If insufficient FRCS is loaded to support the FD2 option, then typically curve 2 is configured for ATO OMS-1/-2, with a shallow FD2 deorbit. This accounts for the aft propellant cost to insert into a 105 nmi circular orbit. Also, if pressing on FD2, the DI_HP=105-SH-REV-7 curve must also have its steep call enable flag turned off.

5.3.24 Dual 100% LO2 Fill Sensor Failure

PURPOSE

To describe the procedure for handling the failure of both of the 100% LO2 fill sensors.

PROCEDURE

- OBTAIN ADDITIONAL HOLD TIME X REQUIRED FROM LDO (TYPICALLY 61 SECONDS)
- INFORM FD THAT A HOLD OF X SECONDS WILL BE REQUIRED INSIDE OF DRAINBACK
- COMPUTE NEW TIME TO RESUME THE COUNT AT T-9 MINUTES (X SECONDS EARLY)
 - RESUME TIME = PLANNED L/O - 9:00 - X SECONDS
 - PASS TO FD
 - AFTER THE FINAL BALLOON DATA IS AVAILABLE:
- COMPUTE DRAINBACK HOLD TIME(S) (MARGINS TIME(S) + X SECONDS)
 - NOTE:** THE REPORTED DRAINBACK HOLD TIMES WILL HAVE TO BE INCREASED BY X SECONDS.
- CHANGE THE DRAINBACK TIME IN MaLTA AND LOCK IT
- CHANGE THE PREFERRED LAUNCH TIME IN MaLTA (X SECONDS EARLIER)

BACKGROUND

Should both of the 100% LO₂ fill sensors fail, KSC will fill the tank up to the 100.15% sensor. This will insure a full tank. However, the ET is not certified for flight with the extra .15% LO₂ onboard. Therefore, an intentional hold inside of drainback (probably at T-0:31) will be done to drain off the extra LO₂. The duration of the hold (X seconds) varies depend the propellant inventory documented in the SPAD. The T-9 minute hold will terminated X seconds early. This will preserve the option to still launch at the preferred launch time and not change the drainback hold time (assuming a launch at the preferred launch time). The drainback hold time computed by MARGINS is unaffected and is still corrected since is is computed with the ET loading at engine start command. In other words, drainback hold time assumes that the X seconds of hold inside of drainback has already occurred.

FDO shall compute the time to resume the count at T-9 minutes. This will be the planned launch time minus 9 minutes minus X seconds. So, if X is 61 seconds, then the resume time is just L/O minus 10:01.

After the L-2 hour balloon analysis is done, MARGINS and MARGI are executed with the final APM and load numbers to determine drainback hold and window close times. MARGINS does use the engine start command (ESC) loadings, so it assumes that the X seconds hold is done and the drainback hold times do not include the extra 0.15% LO₂. Therefore, the drainback hold times reported to FD will have to be biased by the X seconds. The computed drainback time for launching at the preferred time should be used to update the drainback time in MARGI. Once this is completed, the drainback hold time in MARGI should be locked. Then the preferred launch time in MARGI should be biased X seconds early so that the countdown clock in MARGI will be in sync. If an unplanned launch hold occurs outside of drainback, the drainback time in MARGI will again have to be updated manually (MARGINS time + X seconds).

5.4 Launch Hold/Launch Scrub Procedures

5.4.1 Post-Scrub/Pad Abort Actions

PURPOSE

The purpose of this procedure is to document the actions required of the FDO team following a scrub or pad abort.

PROCEDURE

- UPON SCRUB/PAD ABORT → **OPS PHASE**
- √ NO FURTHER ATTEMPTS TO BE MADE TODAY
- IF DOL LOADING ARD UPDATES HAVE BEEN MADE, RESET ALL UPDATED PARAMETERS TO THEIR ORIGINAL, TDDP-BASED VALUES:
 - (K67) ARD FPR
 - (K67) MEP
 - (K67) DRY VEHICLE
 - (K67) ET JETTISON
 - (K88) FBIAS
 - (K88) PROPLVL
- DISCARD THE UPDATED DOL LAUNCH HOLD TABLE
- EDS RESET: AOA, TAL and ORB Normal Selections files - Update winds selection to "NONE"
- NOTIFY **TAO**: "GO FOR CHECKPOINT" (WHEN CONVENIENT)
- THIS CHECKPOINT WILL BE USED FOR ATTEMPTS MADE WHEN THE TRAJ SERVER IS BROUGHT UP WITHIN A FEW DAYS OF THE SCRUB OR PAD ABORT; OTHERWISE, THE TRAJ SERVER WILL BE BROUGHT UP "COLD"
- COLLECT FCO CODEWORDS & RE-SEAL (SOP 5.3.9)

BACKGROUND

If another launch attempt is to be made within a reasonable amount of time, some work can be avoided by bringing the Traj Server up from a checkpoint taken after the previous scrub. The post-scrub checkpoint is used rather than

the L-1 hour checkpoint to ensure that the last checkpoint prior to bringing the Traj Server down will be used, as opposed to the second to last. In addition, this gives the FDO time to restore DOL loading update values to the TDDP values which are desired as a starting point for the next launch attempt. The Launch Hold Table computed based on the loading values is no longer valid, so it is discarded.

Even if more than a few days have passed, the FDO may request the Flight Director to consider using the checkpoint if unique conditions warrant. However, if new TDDP data has been supplied or if any Traj Server software changes have been made, there is no choice but to come up cold.

The EDS winds selections are clear out by selecting the "NONE" option. This is a preventive measure in case Entry Support cleans out the Global winds directory.

|

5.4.2 Launch Hold Inside Drainback: Latest Time to Resume the Count

PURPOSE

This procedure is used to manually compute the latest GMT at which the countdown may be resumed following a launch hold inside of drainback.

PROCEDURE

1. Performance Hold Time Inside Drainback

(Ascent Support): _____:_____ (MN:SC)

ET Ullage Pressure Hold Time: _____:_____ (MN:SC)

(SLWT 5:00, LWT 6:42, LWT w/OV-102, 6:00)

Hold Time (smaller of the two times above) = _____:_____ (MN:SC)

2. Upon start of LOX drainback (T-4:55), compute the latest liftoff time for a hold inside drainback:

Planned Liftoff Time: _____:_____ Z (HR:MN:SC)

Hold Time: + _____:_____ (MN:SC)

Latest Liftoff Time: _____:_____ Z (HR:MN:SC)
--

3. If a launch hold inside drainback begins, compute the latest time to resume the count:

Latest Liftoff Time: _____:_____ Z (HR:MN:SC)

MET of Hold - _____:_____ (MN:SC)

Latest Count Resume Time: _____:_____ Z (HR:MN:SC)

4. Pass the Latest Count Resume Time to FD.

BACKGROUND

Once LOX drainback begins at approximately T-4 min 55 sec, the performance hold capability of the vehicle is extremely limited. If a hold is initiated in this timeframe, the launch team is under extreme pressure to resolve the problems which caused the hold and resume the count in a very short period of time. Once this situation is encountered, in order to maintain the team's level of situational awareness, FDO provides FD with the latest time at which the count may be resumed, based on the hold time inside of drainback and the actual MET at which the hold began. The hold time is based on the most constraining of the performance hold time and the ET GO₂ ullage pressure generic cert hold time. The LCC documents this generic ET cert limit and it varies depending on the tank and orbiter combination. The generic limits are: a) for the super lightweight tank (SLWT), 5.0 minutes; b) lightweight tank (LWT), 6.7 minutes; c) lightweight tank (LWT) with OV-102, 6.0 minutes.

Note that this time is based only on either performance capability or the ET generic cert limit, not the SSME start box limit. The SSME start box limit is a temperature constraint ($T_{\geq} -289.2^{\circ} \text{ F}$) which is monitored in real-time at KSC, and varies between 4.5 min and 6.5 min. The hold time to protect this constraint cannot be accurately predicted, and as such it is a real-time call by KSC.

Prior to this dynamic timeframe, FDO notes the maximum hold time based on performance, supplied by Ascent Support. Once LOX drainback has begun, this delta hold time is added to the current planned liftoff time to arrive at the latest possible launch time. If a hold subsequently occurs, this latest launch time is backed off by an amount equal to the hold MET (typically T-31 sec), resulting in the latest time at which the count can be resumed and still protect ascent performance or generic ET constraints. As soon as it is computed, this time is passed to the FD. This entire procedure is available as a crosscheck of the **Scrub** at time computed by the MARGI application.

5.4.3 Launch Hold Inside Drainback: ARD Updates

PURPOSE

Document procedure for updating ARD loading quantities and the liftoff time following a launch hold after the start of LOX drainback.

PROCEDURE

- FDO: ONCE COUNT RESUMES, VERIFY THE HOLD TIME

GMT Resume Count: ____:____:____ Z (HR:MN:SC)
GMT Begin Hold: - ____:____:____ (HR:MN:SC)

HOLD TIME: ____:____ (MIN:SEC)

FDO: HAVE DYNAMICS Δ THE LIFTOFF TIME (Δ = HOLD TIME)

- TRAJ, ARD SUPPORT: DETERMINE LINE ON ARD LAUNCH HOLD UPDATES CHART CLOSEST TO ACTUAL **HOLD TIME** (nearest 15 sec)
 - TRAJ: PASS THE APPROPRIATE TIME TO DYNAMICS TO LOAD THE UPDATES
- TRAJ AND ARD SUPPORT: CONFIRM UPDATED VALUES ON ARD OUTPUT and ARD MAINTANENCE (MSK 600)
 - ARD FPR
 - Δ ETP
 - Δ ETD
 - FBIAS
 - PROPLVL

<p style="text-align: center;"><u>NOTE</u></p> <p>Holds at T-31 sec are likely in this case, so it is not unusual for the updates to be made during powered flight . They must be complete prior to staging.</p>

BACKGROUND

Upon start of LOX drainback, the amount of usable ET LOX decreases with time. The result is a decrease in the amount of total usable propellant, an increase in Fuel Bias, and an increase in "dry" weight (unusable LH2). In addition, FPR decreases due to the increased Fuel Bias.

To ensure that Traj Server displays are counting properly and that MET-based events are correctly recorded, FDO resets the D65 liftoff time upon resumption of the count. This can be easily done by just putting in a delta time. For example, an entry of 2:20 on the D65 MED will automatically compute the new GMT of liftoff to account for a 2 minute and 20 second launch hold.

5.4.4 Clock Ops for Launch Holds

PURPOSE

This procedure is used to define which times (GMT) are provided to GC for counting to the end of the launch window.

PROCEDURE

IF RNDZ Mission:

After the L-2 hour analysis is complete, view the results of the MARGI application. After verifying a good set of data, give GC a copy of the MARGI output.

- **PANE 1 CLOSE** time is the close of pane 1 (pane switch time minus 5 seconds). N/A if single pane day.
- GC will use the **Window Close** time for setting up the window close clock:
- If the count is held outside of drainback (either at T-9 or T-5 minutes):
 - Pass GC the **Scrub at** time on MARGI. This is the latest time to resume the count. (Latest L/O GMT – Holding at Time). GC uses it to set the **HOLD TIME LEFT** clock.
 - Verify the **HOLD TIME LEFT** clock. This should match the **Scrub in** time on MARGI. Once verified, notify FD.
 - Once the count is resumed the **HOLD TIME LEFT** clock should be dropped.
 - After drainback start:
 - MARGI will compute new a **drainback hold time**. Pass to FD.
 - Pass new **DB Close** GMT to GC.
- Report drainback start to GC for displaying **DB Close** clock which will replace the **Window Close** clock.

- If the count is held inside of drainback:
 - Pass GC the **Scrub at** time on MARGI. This is the latest time to resume the count. (Latest L/O GMT – Holding at Time). GC uses it to set the **HOLD TIME LEFT** clock.
 - Verify the **HOLD TIME LEFT** clock. This should match the **Scrub in** time on MARGI. Once verified, notify FD.
 - Once the count is resumed the **HOLD TIME LEFT** clock should be dropped.
- yes →
- Another launch hold inside of drainback?

If Non-RDNZ mission:

- Give GC a preliminary GMT for setting up the **WINDOW CLOSE** clock and a **DB Close** clock (assuming drainback starts on time).
- If the count is held outside of drainback (either at T-9 or T-5 minutes):
- Compute new **HOLD TIME LEFT** time. This is the latest time to resume the count. (Latest L/O GMT – Holding at time)
- Insure that GC updates the **HOLD TIME LEFT** clock based on the new **Latest L/O GMT**.
- After the countdown is resumed, GC should drop the **HOLD TIME LEFT** clock.
- If the count is held inside of drainback:
 - Determine the new **latest count resume time** (Scrub at time from MARGI). Immediately pass this time to FD.
 - Insure that GC updates the **HOLD TIME LEFT** clock based on the latest resume time.
 - Once the count is resumed the **HOLD TIME LEFT** clock should be dropped.
- yes →
- Another launch hold inside of drainback?

BACKGROUND

The launch scrub on the first launch attempt for STS-88 showed that most of the FCR had poor insight into the time remaining in the count. The post flight reviews between JSC's FCT and the KSC Launch Control Team confirmed that KSC is responsible for insuring that liftoff occurs within the launch window. However, JSC's FCT will act as a backup to verify that liftoff doesn't occur outside the window or during launch window cutouts. These clocks will provide the better situational awareness in the MCC.

The **HOLD TIME LEFT** clock is used for cases with unplanned holds at either T-9 or T-5 minutes. This clock is counting down to the latest time that the countdown can be resumed and still launched within the launch window. Therefore, it is simply the GMT of the window close minus either 9 or 5 minutes.

On a ground-up rendezvous mission, the amount of drainback hold time is a function of where drainback starts within the launch window. Therefore, once drainback has begun the drainback time is know at the latest liftoff time can be computed. This window close GMT based on drainback is used to set-up the **DB CLOSE** clock. The initial DB close time is obtained from MARGI and it assumes that drainback starts on time (4 minutes and 55 seconds prior to the preferred launch time).

For any launch holds inside of drainback, it is desirable to have a clock counting down to the latest time to resume the count. This GMT is the GMT of drainback close minus the time of the hold. This GMT is used for set-up of the **HOLD TIME LEFT** clock. For example, if the window close is at 12:05:00 and the hold is at T-0:31 the GMT would be 12:04:29. MARGI automatically computes this time and displays it as the "Scrub at" time.

FDO or TRAJ will pass the appropriate GMT to GC on GC CALL 1. The GC will read back the time to verify a good copy. GC will then display the clock on the wall clock display in the FCR. This procedure is also documented in the FCOH (SOP 8.5).

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6 POWERED FLIGHT

6.1 General Procedures and Calls

6.1.1 Terminal Count Through SRB Separation

PURPOSE

Documents procedures for the final countdown phase through SRB separation.

PROCEDURE

TIME	RESP	ACTION
-9:00	FDO	√ BFS/TGT→BFS; ETIP→DRAG OFF
		GO TO LAUNCH PHASE; √ TAL/RTLS RWY SEL
-0:15	FDO	SELECTED SOURCE → TLM
	TRAJ	AUTO MED PBI →"ON"
L/O	TRAJ	√ ARD L/O TIME = O/B L/O TIME
		√ ARD CYCLING, VERIFY "TL" FLAGS OFF
0:10	FDO	√ HM AND 2HM THROTTLES
0:15	TRAJ	COPY FCO: IP MOVING OUT; ENSURE FDO COPIES
0:20	FDO	SS → FILTER ON NAV CALL
	TRAJ	COPY ARD SUP'T: BUCKET CALL; √ΔWT_OVERRIDE
0:30	F/T	MONITOR THROTTLE DOWN
	FDO	EVAL TRAJ/WINDS: REPORT OFF-NOM TO FD
	TRAJ	√ BUCKET: COMPARE W/TDEL_ADJUST
1:00	F/T	MONITOR THROTTLE UP
		IF STUCK → STUCK IN BUCKET PROCEDURES
	TRAJ	TO FCO: "MCC GO AT THROTTLE UP"
1:40	TRAJ	COPY FCO: SRB NLE; ENSURE FDO COPIES
1:50	FDO	NAV: FILTER STATUS
Pc<50	TRAJ	√VECTOR SAVE PBI (at 2:05 MET for Loss-of-Comm)
SEP	F/T	√ HDOT, VREL AT STAGING
	TRAJ	TO FCO: "MCC GO AT SRB SEP"

BACKGROUND

Prior to liftoff (L/O), FDO selects telemetry as the selected source for trajectory processing until the tracking filter is deemed "good" by NAV at approximately 25 sec MET. This also prevents spurious data points on plot displays as the radars lock up on the vehicle post-L/O. Also prior to L/O, TRAJ (and ARD Support) ensure that the ARD thrust limiting flags are off and the ARD mass track recycle time is correct to account for the pre-launch SSME throttle up from zero to 100%. Having these values set improperly can cause the ARD to begin decrementing the mass track at T-0, and results in the ARD carrying an extra 11,700 lbs of MPS propellant.

TRAJ pushes the MAN MED PBI to turn on "AUTO MED". One of the functions performed by "AUTO MED" is to automatically ship the L/O PBI to initiate Traj Server trajectory processing, upon confirmation that L/O has occurred. Once the L/O PBI has been entered, the Traj Server automatically updates the L/O time with a D65 MED to match the downlisted L/O time. TRAJ checks that the two are the same on FDO Launch Digitals (MSK 430). If the ARD doesn't start cycling, then the L/O PBI must be entered manually. TRAJ and ARD Support again ensure that the ARD thrust limiting flags are off and the ARD mass track recycle time is correct after the ARD begins cycling.

The FCO informs TRAJ as the vehicle's impact point (IP) begins moving downrange. TRAJ must ensure that FDO copies this (and all) FCO calls. A similar call is made by the FCO at the SRB NLE time, after which free-flying SRBs can **No Longer Endanger** populated land areas.

FDO and TRAJ both monitor throttle down, and TRAJ compares the actual throttles with those expected based on the Tdel_adjust (Tdel). This downlisted parameter indicates the difference between the time the vehicle reached a reference velocity and the time at which it was "expected". The difference is used to adjust the throttle bucket to account for hot or cold SRBs, with the idea being that only the SRBs can significantly affect the expected time and velocity this early in the flight. In the ARD, which does not modify the throttle bucket, the difference is accounted for with a ET propellant adjustment (delta-weight override). If Tdel is within the deadband for no throttle change (from the nominal), the delta-weight override is automatically set to zero. Also during this timeframe the software automatically rotates the ARD IYs based on the actual L/O time. FDO notifies FD of any lofting/depression or lateral deviation due to the winds. Throttle up is monitored, and special procedures apply for an SSME stuck in the bucket.

Just before staging, FDO statuses. The ARD Output GUI (if AUTO MED enabled) will automatically ship the Vector Save PBI at SRB PC<50, which initiates output of the next five telemetry and filter state vectors to the online. These state vectors may be retrieved at a later time if required for analysis. For loss of TM, the Vector Save PBI should be manually shipped at 2:05 MET.

6.1.2 ARD Biases

PURPOSE

Documents the general use of ARD biases.

PROCEDURE

N/A

BACKGROUND

ARD biases are required for all calls made out of the ARD, and are supplied in Flight Design product ASAB-25, ARD Bias Tables. The biases are used to account for differences between the ARD model and desired MPS Flight Performance Reserve (FPR) protection levels, 6-DOF effects, unusable propellant, SSME tailoff, and underspeeds. The bias product contains data for the following calls, all of which are described in more detail individually in the subsequent sections:

- Uphill capability, based on design underspeed
- Uphill capability, based on critical underspeed
- Two-Engine TAL
- Negative Return
- Press-to-ATO, including gap closure
- Press-to-MECO, including gap closure
- Droop (altitude)
- Negative <out-of-plane TAL site>
- Single-Engine TAL
- Single-Engine Press (nominal or post-ATO select), including gap closure

6.1.3 Gap Closure Techniques

PURPOSE

Documents the general use of gap closure techniques used for abort mode boundary calls.

PROCEDURE

Turn **Shallow Press Flag** On (aka Ishallow flag)

BACKGROUND

Flight rule A4-1D states that launch will not be attempted if a single-engine out abort gap is predicted to exist. However, rule A2-56 states that once liftoff has occurred, single-engine out abort gaps will be accepted as long as three-engine uphill capability still exists. Note that once an engine fails, the vehicle is almost always in a gap with respect to the next engine failure.

In order to minimize exposure to gaps which open up on the fly, a prioritized list of criteria which will be relaxed was developed. These criteria are reflected on the ARD bias product and may be used as required to "close" gaps. The gap closure techniques, and their priorities in applicable situations, are defined in detail in the flight rule A4-56I and are summarized below:

REQUIRED PRE-MECO ACTION

- Accept critical underspeed
- Accept ACLS
- Maximum throttles
- Accept Late TAL
- Accept AOA Shallow U/S
- Accept AOA/PLS to NO-GO site
- Accept 0 sigma

EVALUATED POST-MECO

- Maximum ranging using low-energy guidance to the Prime TAL or ACLS
- Commit OMS Ballast to Contingency CG Limit
- Accept Critical Underspeed
- Accept AOA Shallow

Rule Reference: A4-56I, A2-56.

6.1.4 Two-Engine TAL

PURPOSE

Documents the procedure used to make the 2-engine TAL call.

PROCEDURE

NOTE

THIS CALL OCCURS EARLY IN SECOND STAGE. THERE MAY BE VERY LITTLE TIME TO CONFIRM ARD HEALTH PRIOR TO MAKING THE CALL.

- USE HM TAL Σ CHANNEL AND THE "2E" BIAS FOR THE PRIME SITE
- \checkmark PROPER SITE SELECTED IN HM.
- MENTALLY NOTE MARGIN RATE OF CHANGE TO ANTICIPATE CALL
- \approx ONE ARD CYCLE PRIOR TO THE BIAS BEING REACHED:
CALL: "STAND BY FOR TWO-ENGINE <site>"
- WHEN TAL HM $\Sigma \geq$ "2E <site>" BIAS:
CALL: "MARK...TWO-ENGINE <site>"
- GAP CLOSURE WITH 3-SSME UPHILL CAPABILITY AND APPROACHING NEGATIVE RETURN, IN PRIORITY ORDER:

<u>ACLS UP</u> 1. ACLS AT ABORT THROTTLE 2. MAX THROTTLE 3. MAX RANGING USING LOW-ENERGY GUIDANCE 4. NOMINAL PERF. (0σ)	<u>ACLS DOWN</u> 1. MAX THROTTLE 2. MAX RANGING USING LOW-ENERGY GUIDANCE (PRIME SITE) 3. NOMINAL PERF. (0σ)
--	--
- GAP CLOSURE WITHOUT UPHILL CAPABILITY (3-SSMEs ON)
 - IF ONE SSME STUCK IN BUCKET OR MULTIPLE SUSPECT, ABORT TAL ON THE EARLIER OF THE FOLLOWING:
 - 2-ENG PRIME TAL AND (1-2/3 ACLS OR 1-2/3 NEG RETURN)
 - 2-ENG NEG RETURN - 10 SEC
 - ALL OTHER CASES, IF 2-ENG PRIME TAL NOT AVAILABLE BY NEG RETURN - 10 SEC \rightarrow RTLS; OTHERWISE \rightarrow TAL @ 2-ENG TAL

BACKGROUND

Call indicates when one SSME can fail and a TAL abort to the prime site can be performed to the desired MECO range-velocity targets, assuming protection of 2σ MPS FPR, 3σ entry dispersions, abort throttles, and a 15 second abort decision delay.

This call is considered a "critical" call, and therefore is made using a "stand by..." and "mark" to provide as accurate a boundary to the crew as possible.

For gap closure, note that all abort options are maintained as long as possible.

Rule Reference: A-56B, A4-56I (Gap Closure)

6.1.5 Negative Return

PURPOSE

Documents the procedure used to make the Negative Return call.

PROCEDURE

- USE HM RTLS Σ CHANNEL AND THE "Negative Return" BIAS
- WHEN RTLS HM $\Sigma \leq$ "Negative Return" BIAS:

CALL: "NEGATIVE RETURN"

BACKGROUND

Call indicates the latest time one SSME can fail and an RTLS abort can still be performed to the desired MECO range-velocity targets, assuming protection of 3 σ MPS FPR, 3 σ entry dispersions, abort throttles, and a 15 second abort decision delay.

This call is not considered "critical", since TAL is preferred over RTLS. A "stand by..." is not made prior to the call. If critical systems or other failures are being discussed, it may be delayed slightly until a break in FD loop traffic occurs (unless, of course, those failures may dictate RTLS over TAL).

Rule Reference: A4.-56C.1

6.1.6 Press-to-ATO

PURPOSE

Documents the procedure used to make the Press-to-ATO call.

PROCEDURE

- USE HM ATO MPROP CHANNEL AND THE "Press-to-ATO" BIAS
- MENTALLY NOTE MARGIN RATE OF CHANGE TO ANTICIPATE CALL
- \approx ONE ARD CYCLE PRIOR TO THE BIAS BEING REACHED:

CALL: "STAND BY FOR PRESS-TO-ATO"

- WHEN HM ATO MPROP \geq "Press-to-ATO" BIAS:

CALL: "MARK...PRESS-TO-ATO"

- IF PERFORMANCE INDICATES THAT PRESS-TO-ATO IS DELAYED INTO THE RAMP, PROVIDE A HEADS-UP CALL TO FD:
- FDO: CALL "EXPECT DELAYED PRESS BOUNDARIES"
- WHEN HM ATO $\Sigma \geq$ "Item 9 Press-to-ATO" BIAS
- FDO: CALL "ITEM 9 PRESS-TO-ATO"
- GAP CLOSURE (LAST RTLS OR LAST PRIME TAL TO FIRST PRESS):

ACLS UP

1. ACCEPT CRITICAL UNDERSPEED
(**USE BIAS**)
2. COMMIT OMS BALLAST TO CONTINGENCY CG LIMIT
3. ACCEPT ACLS
4. MAX THROTTLES
5. ACCEPT AOA SHALLOW
(ISHALW FLAG ON, and **USE BIAS**)
6. MAX RANGING USING LOW-ENERGY GUIDANCE (ACLS OR PRIME)
7. NOMINAL PERF. (0σ)

ACLS DOWN

1. ACCEPT CRITICAL UNDERSPEED
(**USE BIAS**)
2. COMMIT OMS BALLAST TO CONTINGENCY CG LIMIT
3. MAX THROTTLES
4. ACCEPT AOA SHALLOW (ISHALW FLAG ON, and **USE BIAS**)
5. MAX RANGING USING LOW-ENERGY GUIDANCE TO PRIME SITE
6. NOMINAL PERF. (0σ)

BACKGROUND

Call indicates when the design underspeed can be achieved assuming one engine out, 2σ MPS FPR, abort throttles, pre-MECO ATO selection (may invoke a pre-MECO OMS dump, abort MECO targets, and/or variable ly steering), and a 15 second abort decision delay.

The ARD MPROP margin is used rather than the Σ margin, since the Σ channel does not necessarily guarantee protection of the design underspeed for delayed press cases. If the boundary is delayed past the velocity at which the OMS dump begins to ramp down (VLIN), the increase in the ARD XOMS channel can inflate the Σ channel to the degree that it appears the boundary has been reached, when in reality the design underspeed is not being protected. Uphill capability does exist here, but the ET impact location is not (critical underspeed capability exists). Using the MPROP channel ensures that the design underspeed is the real constraint, per the definition of the press-to-ATO boundary.

This call is considered a "critical" call, and therefore is made using a "stand by..." and "mark" to provide as accurate a boundary to the crew as possible.

The "item 9 press-to-ATO" bias is that value which, in the indicated ARD channel, satisfies the design underspeed constraint with a full dump, regardless of the current velocity with respect to the ramp. That is, a manual override to a full dump quantity would be required per this procedure. This bias is provided by the flight design ARD group in the ARD bias product (ASAB-25). the call made by FDO when this bias is satisfied is "Item 9 Press-to-ATO." Procedures for the actual ATO abort with item 9 are covered in section 6.1.8.

Rule Reference: A4-56D, I (gap closure), A-55 (design and critical underspeed definitions)

6.1.7 ATO With Item 9 Dump

PURPOSE

This section defines the procedure for performing an ATO with an item 9 dump quantity override. It is may be used if any of the following are true:

- a) Critical underspeed (or better) can be achieved without a dump, and Design underspeed must be protected.
- b) I-loaded ramp dump will not dump enough (performance hit)
- c) I-loaded ramp dump will dump too much

PROCEDURE

- FOR ENG OUT AFTER "ITEM 9 PTA" AND PRIOR TO "PRESS-TO-MECO":
 - FDO: CALL "ABORT ATO WITH ITEM 9 + XX"; \sqrt ATO SELECTED IN ARD
 - NOTE: $\text{MAX QTY} \leq \text{ATO DUMP} - 3\%$ IF ATO DUMP IS I/C
 - TRAJ:
 - Current Item 9 = XX% on **ARD OUTPUT GUI**
- IF AM ATO MPROP PREDICTED U/S < DESIGN U/S
 - TRAJ: ADJUST Current Item 9 = YY% AS REQ'D TO GET WITHIN ≈ 10 FPS OF DESIGN U/S (NOT > DESIGN U/S): $1\% \cong 10$ FPS (Note: Use Eval Item 9 = YY% if dump has not started yet. Must specify dump type [11 for ATO].)
 - FDO: PASS NEW QTY: CALL "UPDATE ITEM 9 + YY"
 - FOR THREE-ENGINE ATO:
 - GET ITEM 9 QUANTITY (XX%) FROM ABORT SUPPORT
 - AFTER NEGATIVE RETURN:
 - FDO: CALL "ABORT ATO WITH ITEM 9 + XX"
 - TRAJ:
 - Current Item 9 = XX% on **ARD OUTPUT GUI**

BACKGROUND

The ramped dump that is utilized by the ATO software is designed for a specific performance level. There is a built-in pad (about 10 sec) to allow for some performance loss from Flight Cycle to launch day. If the performance loss leading up to and including launch day delays Press-to-ATO beyond this margin and into the ramp, a relatively small performance hit that has a small impact on Press-to-MECO can significantly delay or eliminate Press-to-ATO. This is because the ATO propellant dump quantity will not be sufficient to satisfy the design underspeed (typically the ET impact point constraint) even though critical underspeed (limited by performance) is satisfied.

There are only a few specific instances where violating the design underspeed is acceptable (ref. Flight Rule A2.1.2-13E). If the failure(s) do not allow ETIP constraints to be waived, then TAL is required.

By using item 9 on SPEC 51, the ramp dump can be over-written to effect a different ATO dump quantity. This procedure can be used in any case where a dump quantity larger than the automatic ATO dump amount will satisfy design underspeed.

The target underspeed is the design underspeed. If the predicted underspeed with a full dump is significantly less than the design underspeed, then the item 9 quantity will be adjusted to increase the underspeed (to within about 10 fps of design without exceeding design) and thus help avoid a nominal MECO. A nominal MECO following an ATO OMS dump is undesirable since this means that usable MPS propellant remained in the ET at MECO.

The ARD has two Item 9 inputs, the "Current Item 9" and the "Evaluation Item 9". The current (cur) item 9 can be applied to any dump that is already in progress. The evaluation (eval) item 9 must be used to evaluate the effect of the item 9 if the dump hasn't started yet. The **CUR Item 9** and **EVAL Item 9** may be input on the Manual EO/Abort Update menu on the ARD Output GUI. Whenever the Eval Item 9 is used, the user must specify which dump timer to override (ie. N = Nominal [or OMS Assist], I1 = Intact 1, I2 = Intact 2, C = Contingency). However, on the ARD Output GUI, an input of the Eval Item 9 will default to an I1 dump type and will turn ON the Eval Item 9 flag. If an Eval Item 9 flag is desired for a dump other than the I1 dump, the user must specify the dump type. In most situations the Cur Item 9 will be used. If an Eval Item 9 is entered and later the abort is started, the Cur Item 9 should then be used to update the dump quantity. On the MED, this requires entering the quantity in the Cur Item 9 field **and** turning off the I1 Eval Item 9 flag. On the ARD Output GUI, any Cur Item 9 entry will automatically turn off the Eval Item 9 flag.

If a downmode to TAL is declared after the ATO with item 9, the dump quantity onboard will be reset to the appropriate TAL dump timer. If the AUTO MED flag

is on, the ARD will automatically transition to TAL and the TAL dump timer, otherwise the TAL PBI must be clicked twice. The TAL dump timer can then be seen as the Intact 2 (I2) dump on the ARD Maintenance display.

If a downmode to a contingency abort is declared after the ATO with item 9, the dump quantity onboard must be reset manually to the contingency timer, both on the ground (using the K64 MED) and onboard.

For three-engine ATOs where a dump is required to protect the design underspeed, Abort Support provides the appropriate dump quantity to achieve the design underspeed (or smaller underspeed, if desired). The ATO selection is performed after Negative Return, and for ground-up rendezvous missions it may be delayed until after V_mission_continue to ensure that the nominal planar target is retained, thus keeping post-MECO rendezvous options open.

6.1.8 Press-to-MECO

PURPOSE

Documents the procedure used to make the Press-to-MECO call.

PROCEDURE

- USE HM NOM MPROP CHANNEL AND THE "Press-to-MECO" BIAS
- WHEN BIAS IS REACHED:

CALL: "PRESS-TO-MECO"
- GAP CLOSURE (LAST RTLS OR LAST PRIME TAL TO FIRST PRESS):
 - USE APPROPRIATE GAP CLOSURE BIAS (FUNCTION OF ACLS STATUS)

ACLS UP

1. ACCEPT CRITICAL
UNDERSPEED (**USE BIAS**)
2. COMMIT OMS BALLAST TO
CONTINGENCY CG LIMIT
3. ACCEPT ACLS
4. MAX THROTTLES
5. ACCEPT AOA SHALLOW
(ISHALW FLAG ON **and USE BIAS**)
6. MAX RANGING USING LOW-
ENERGY GUIDANCE (ACLS
OR PRIME)
7. NOMINAL PERF. (0σ)

ACLS DOWN

1. ACCEPT CRITICAL
UNDERSPEED (**USE BIAS**)
2. COMMIT OMS BALLAST TO
CONTINGENCY CG LIMIT
3. MAX THROTTLES
4. ACCEPT AOA SHALLOW
(ISHALW FLAG ON, **and USE BIAS**)
5. MAX RANGING USING LOW-
ENERGY GUIDANCE TO
PRIME SITE
6. NOMINAL PERF. (0σ)

BACKGROUND

Call indicates when the design underspeed can be achieved assuming one engine out, 2σ MPS FPR, and abort throttles.

This call is usually made from the NOM MPROP channel.

This call is not considered "critical", since Press-to-ATO precedes it and defines initial uphill capability. If for some reason the Press-to-ATO call is not made (e.g., OMS engine failure, etc.), then this call becomes "critical".

Rule Reference: A4-56E, I (gap closure), A4-55 (design and critical underspeed definitions)

6.1.9 Droop TAL/ACLS 109

PURPOSE

Documents the procedure used to make the Droop call, with no prior TAL abort declared. Reference section 6.3.1 for Droop TAL/ACLS 109 post-TAL selection.

PROCEDURE

- CONFIGURE THE ARD 2HM FOR ONE ENGINE AT 109%
- WHEN 2HM DROOP ALTITUDE ON ARD OUTPUT REACHES 265 K FT:

CALL ON **MOCR DYN**: "DROOP <site> 109"; WHERE SITE IS:
 - BEN GUERIR, for Low-Inclination
 - ZARAGOZA for High-Inclination
 - <Prime TAL> for Mid-Inclination
- IF ARD 2HM IS CONFIGURED FOR A HIGHER PRIORITY CALL, USE:
 - **INERTIAL VELOCITY** FROM ARD BIAS TABLE

BACKGROUND

Call indicates the earliest time after which a two-engine out trajectory will not fall below 265,000 feet, at which point ET heating becomes excessive, and TAL guidance will converge to the selected site's MECO targets prior to MECO. Assumes max throttles and a 15-second abort decision delay, and does not ensure the capability to reach any runway. The weather at the site is not considered in making this call. This call is now only used by the GPO so it is now made on the MOCR DYN loop instead of the FD loop.

For low- and high-inclination missions, the droop call on the uphill leg is always made to the "inplane" site (Banjul or Zaragoza, respectively) regardless of it's status. For mid-inclination missions, the Droop call is always made to the prime TAL site, since all three TAL sites (Ben Guerir, Moron, and Zaragoza) are inplane.

Rule Reference: A4-56F.1

6.1.10 Single-Engine TAL/ACLS 104

PURPOSE

Documents the procedure used to make this call for a nominal uphill or a Press-to-MECO case. For a post ATO selection case, reference 6.2.2.

PROCEDURE

- USE 2HM TAL Σ CHANNEL AND THE "1E" BIAS FOR THE DESIRED SITE:
 - TBD site, for Low-Inclination
 - ZARAGOZA for High-Inclination
 - <Prime TAL> for Mid-Inclination

- ✓ PROPER SITE SELECTED IN 2HM

- ✓ 1 ENGINE AT 104% IN 2HM

- **CALL:** "SINGLE-ENGINE <site> 104" when the earlier of following is satisfied:
 - SELECT THE "1E <site>" BIAS BASED ON SITUATION:
 - "SIMO" BIAS (if available) FOR 3-SSME ON
 - "SEQ" FOR 2-SSME ON OR "SIMO" NOT AVAILABLE

 - TAL 2HM $\Sigma \geq$ "1E <site>" BIAS AND LOW ENERGY LOGIC FLAG IS OFF, or

 - TAL 2HM $\Sigma \geq$ "1E <site>" BIAS + 200

BACKGROUND

Call indicates when two SSMEs can fail and a TAL abort to the desired site can be performed to the desired MECO range-velocity targets and within crossrange limitations, assuming protection of 2σ MPS FPR, 3σ entry dispersions, abort throttles, and a 15 second abort decision delay. The weather at the site will not be a consideration when assessing this boundary.

For low- and high-inclination missions, this call on the uphill leg is always made to the "inplane" site (Banjul or Zaragoza, respectively) regardless of it's status. For mid-inclination missions, the SE TAL call is always made to the prime TAL site, since all three TAL sites (Ben Guerir, Moron, and Zaragoza) are inplane.

Low energy logic may not disengage until past the SE TAL bias. A loss of 200 fps of margin may be seen at disengage. Therefore, delay the call until it disengages or the summation has 200 fps of margin above the bias.

Rule Reference: A4-56F.1.c

6.1.11 Single-Engine Press

PURPOSE

Documents the procedure used to make this call.

PROCEDURE

- USE 2HM NOMΣ CHANNEL
- SELECT THE "1E Press-to-MECO" BIAS BASED ON SITUATION:
 - "SIMO" BIAS FOR 3-SSME ON
 - "SEQ no dump" FOR 2-SSME ON AND NO ATO SELECTION
 - "SEQ w/dump" FOR 2-SSME ON POST-ATO SELECTION
- WHEN MARGIN \geq BIAS:
CALL: "SINGLE-ENGINE PRESS 104"
- GAP CLOSURE (LAST PRE-MECO TAL TO FIRST SINGLE-ENGINE PRESS):
 - CONFIGURE 2HM FOR ONE SSME AT 109%
 - ACLS DOWN: USE MAXIMUM CAPABILITY BIAS
 - SET ISHALW FLAG = 1
 - WHEN BIAS REACHED → **CALL** "SINGLE-ENGINE PRESS 109"
 - RESET ISHALW FLAG = 0
 - ACLS UP: USE 109% THROTTLE BIAS
 - IF BIAS REACHED PRIOR TO LAST MANUAL TAL VI, **CALL** "SINGLE-ENGINE PRESS 109"
 - OTHERWISE, AT LAST MANUAL TAL VI, THEN
CALL "SINGLE-ENGINE PRESS 109"
 - RECONFIGURE 2HM FOR ONE SSME AT 104%
 - CALL SINGLE-ENGINE PRESS 104 (AS REQUIRED)

BACKGROUND

Call indicates when the critical underspeed can be achieved assuming two engines out, 2σ MPS FPR, and abort throttles.

For gap closure without an acceptable ACLS, the single-engine press call is made at the earliest time possible, assuming all gap closure techniques are employed (max throttle, AOA shallow, nominal (0σ) performance), to maximize avoidance of a downrange ELS landing. Note that only the max throttles decision is made pre-MECO -- the other techniques depend on the actual performance achieved that day. Since the incorporation of the ARD 3 SR, the ISHALW flag must be set to 1 to allow evaluation of AOA shallow (results in the ARD using the shallow underspeed curve for computing XOMS). The flag and power level are reset following the call to allow evaluation of first capability without the need for gap closure techniques. This may or may not be called to the FD and/or crew depending on loop traffic and subsequent failures.

For gap closure with an acceptable ACLS, uphill with maximum throttles is the preferred technique. Next will be a manual TAL (formerly "late" TAL) out to the last manual TAL V_i for the ACLS. Next come the AOA shallow and nominal performance techniques. Thus, the single engine press call will be made when max throttle capability is achieved, or at the last manual TAL V_i . Since there are no other options at this point, this implies that the rest of the gap closure techniques are thrown in.

Note that the flight rule's "first" closure technique for these cases is actually committing the OMS ballast out to the contingency CG limit. This is rarely available as an option, but would be called out on the bias sheet as a separate line item if necessary. It's frequency of use is a factor in not specifically mentioning it in this procedure. Should this change in the future, the procedure will be updated.

Rule Reference: A4-56H, I (gap closure), A4-55 (design and critical underspeed definitions)

6.1.12 23K

PURPOSE

Documents the procedure used to make the 23K call.

PROCEDURE

- USE FDO LAUNCH DIGITALS
- WHEN VI>22,500 FPS:

CALL: "23K"

BACKGROUND

Provides a consistent point of reference for FD and other flight controllers that there is no longer any pre-MECO TAL abort capability and that MECO will occur in less than one minute.

6.1.13 Underspeed Prediction to Booster

PURPOSE

Documents the procedure for passing a predicted underspeed to Booster.

PROCEDURE

- CALL MADE AFTER SINGLE-ENGINE PRESS CALL (OR SINGLE-ENGINE TAL ON A TAL LEG)
- USE ARD AM MPROP CHANNEL FOR THE CURRENTLY SELECTED MODE

FDO/TRAJ: PASS MARGIN VALUE TO BOOSTER ("ZERO UNDERSPEED" IF MARGIN IS POSITIVE)

BACKGROUND

If an underspeed greater than 500 fps is predicted with 3 or 2 engines running or 250 fps with 1 engine running, Booster must call for a manual throttle down to avoid low MPS net positive suction pressure (NPSP) caused by SSMEs running above the maximum allowable shutdown power level when a low-level cutoff occurs. Underspeeds greater than this number will result in this condition because the low-level cutoff occurs prior to guidance fine countdown, at which the engines are automatically commanded to their pre-shutdown power level. Violation of NPSP could possibly result in uncontained engine damage.

When manual throttling is required, the crew will throttle to minimum power level when 2% MPS propellant remains, based on their gauge quantity.

6.1.14 Uphill Capability Assessment

PURPOSE

Documents the procedure used to assess uphill capability for three engines running.

PROCEDURE

- COMPARE AM NOM MPROP WITH THE APPROPRIATE "Uphill Bias"
- IF AM **NOM MPROP** \geq Uphill Bias FOR DESIGN (ETIP) U/S, THEN NO ACTION REQ'D.
- IF AM **ATO SUM** \geq UPHILL BIAS (CRITICAL U/S):
 - UPHILL CAPABILITY MAY EXIST WITH AN BIGGER OMS ASSIST DUMP
 - GO TO SECTION 6.1.16, "Item 9 For Performance Cases", FOR Item 9 DETERMINATION PROCEDURE
- IF ITEM 9 WAS INSUFFICIENT TO REGAIN UPHILL:
 - IF AM **ATO SUM** \geq UPHILL BIAS (CRITICAL U/S):
 - ATO ABORT REQUIRED
 - ABORT ATO AT:
 - EARLIER OF 2-ENG TAL OR 2-ENG NEG RETURN - 10 SEC
AND
 - 1 2/3 NEG RETURN OR 1 2/3 ACLS
 - UPDATE DUMP WITH ITEM 9 IF REQ'D
- IF AM **ATO SUM** $<$ UPHILL BIAS (CRITICAL U/S), THEN:
 - INFORM FD OF PREDICTED UNDERSPEED
 - INFORM FD THAT UPHILL CAPABILITY DOES NOT EXIST
 - RECOMMEND ABORT TAL

BACKGROUND

Uphill capability is defined as being able to achieve the desired underspeed (design or critical) with three engines running and 2σ -low performance. The uphill biases are designed to indicate this when compared to the Actual Mode nominal MPROP channel in the ARD. The uphill biases take into account

differences in FPR (2σ vs. 3σ), the desired underspeed, fuel bias, unusable propellant, and SVDS (6-DOF vs. 3-DOF) calibration.

6.1.15 NAV Call Summary

PURPOSE

Documents the standard FDO/NAV interface during powered flight. Standard powered flight calls are discussed here. Off-nominal procedures are documented in section 6.11, Navigation/Flight Control Problems.

PROCEDURE

- 0:15 FDO MODE SELECTED SOURCE → TM
- ≈0:20 NAV: GOOD FILTER
FDO: SELECTED SOURCE → FLTR
- 1:50 FDO: STATUS NAV PRE-SRB SEP
- 2:10 FDO: STATUS NAV POST-SRB SEP
- ≈3:00 NAV: FILTER GOOD ON THREE SOURCES
- < P.T. ATO FDO: STATUS NAV PRIOR TO PRESS-TO-ATO

BACKGROUND

During powered flight, FDO is dependent on NAV to provide an accurate high-speed tracking filter state vector. At specific times, to confirm vector accuracy, FDO requests a filter vector status from NAV. These times are prior to and post-SRB separation (since in that timeframe several radars are released from Orbiter/ET tracking to track the SRBs during their descent) and prior to the critical Press-to-ATO call.

6.1.16 Item 9 for Performance Cases

PURPOSE

Documents the procedure used to do an Item 9 update of the OMS Assist dump in order to regain uphill capability.

PROCEDURE

- | • FDO:
 - GET INITIAL ITEM 9 QUANTITY (XX%) FROM ABORT SUPPORT
 - CALL: "ITEM 9 + YY"
 - NOTE: MAX QTY \leq ATO DUMP - 3 % IF ATO DUMP IS I/C

- | • TRAJ:
 - CUR Item 9 = XX% on **ARD OUTPUT GUI**

NOTE

DO NOT ENTER A CUR ITEM 9 UPDATE PRIOR TO OMS ASSIST START.

- | • FDO:
 - | • VERIFY THAT AM NOM MPROP IS BETWEEN Uphill Bias FOR DESIGN (ETIP) U/S AND -100
 - | • ITERATE ON ITEM 9 QTY UNTIL ABOVE IS SATISFIED
 - | • CALL: "UPDATE ITEM 9 + YY"
 - | • VERIFY THAT ITEM 9 WAS ENTERED (PROP OR GPO)
- | • TRAJ:
 - ADJUST OMS ASSIST (NOMINAL) DUMP START TIME IF REQUIRED
 - IF THE OMS ASSIST DUMP TERMINATED AND RESTARTED AFTER THE ITEM 9 ENTRY:
 - Δt = OMS ASSIST RESTART TIME MINUS OMS ASSIST 1ST STOP TIME
 - K64 ('N' Dump Type) DUMP IGNITION = ORIGINAL OMS ASSIST START + Δt
 - INFORM FDO WHEN COMPLETE

BACKGROUND

The use of Item 9 to lengthened the OMS Assist burn can be done to regain uphill capability when performance has been lost. This applies to both thrust limiting and stuck in the bucket cases. This is preferred now versus the old procedure of aborting ATO for these cases. This allows the dumping of OMS prop to decrease the predicted underspeed without having to potentially freeze the plane and lose the rendezvous mission.

ABORT SUPPORT will use a pre-flight generated chart to determine the first guess at the Item 9 quantity based on the AM NOM MPROP value. TRAJ can quickly input this value in the ARD OUTPUT GUI, Manual EO/Aborts Update sub-window. This would go in as a CUR Item 9. The value input will show up as the "K64 Quan" on the ARD Maintenance display (lower left corner.). However, the logic will not work correctly if the CUR Item 9 is entered prior to the OMS assist starting. This is because the Current Item 9 is applied to the current dump in progress and the logic gets confused if there's no dump ongoing.

If the OMS Assist finished onboard before the Item 9 was entered, the OMS Assist burn will re-start after a minimum of 30 second has elapsed. The ARD assumes a continuous OMS Assist burn when the Item 9 is entered. In order to sync up the ARD, the OMS Assist start time must be modified. This is done by changing the OMS Assist start time by the duration of the gap between initial termination and re-start. Changing the ARD 's OMS Assist burn start time will then have both the onboard and the ARD's OMS Assist burn completing at the same time.

6.2 *Post-ATO Selection*

6.2.1 Droop TAL/ACLS 109

PURPOSE

Documents the procedure used to make the Droop call, post ATO abort declared.

PROCEDURE

- CONFIGURE THE ARD 2HM FOR ONE ENGINE AT 109%
- WHEN 2HM DROOP ALTITUDE ON ARD OUTPUT REACHES 265 K FT:

CALL ON **MOCR DYN**: "DROOP <site> 109"; WHERE SITE IS:
 - BEN GUERIR, for Low-Inclination
 - ZARAGOZA for High-Inclination
 - <Prime TAL> for Mid-Inclination
- IF ARD 2HM IS CONFIGURED FOR A HIGHER PRIORITY CALL, USE:
 - **INERTIAL VELOCITY** FROM ABORT SUPPORT

6.2.2 Single-Engine TAL/ACLS 104

PURPOSE

Documents the procedure used to make this call for a post ATO selection case.

PROCEDURE

- USE 2HM TAL Σ CHANNEL AND THE "1E - PTA" BIAS FOR THE DESIRED SITE:
 - BEN GUERIR, for Low-Inclination
 - ZARAGOZA for High-Inclination
 - <Prime TAL> for Mid-Inclination

- ✓ PROPER SITE SELECTED IN 2HM

- ✓ 1 ENGINE AT 104% IN 2HM

- **CALL:** "SINGLE-ENGINE <site> 104" when the earlier of following is satisfied:
 - TAL 2HM $\Sigma \geq$ "1E - PTA <site>" BIAS AND LOW ENERGY LOGIC FLAG IS OFF, or

 - TAL 2HM $\Sigma \geq$ "1E <site>" BIAS + 200

BACKGROUND

Call indicates when two SSMEs can fail and a TAL abort to the desired site can be performed to the desired MECO range-velocity targets and within crossrange limitations, assuming protection of 2σ MPS FPR, 3σ entry dispersions, abort throttles, and a 15 second abort decision delay. The weather at the site will not be a consideration when assessing this boundary.

For low- and high-inclination missions, this call on the uphill leg is always made to the "inplane" site (Banjul or Zaragoza, respectively) regardless of it's status. For mid-inclination missions, the SE TAL call is always made to the prime TAL site, since all three TAL sites (Ben Guerir, Moron, and Zaragoza) are inplane.

Low energy logic may not disengage until past the SE TAL bias. A loss of 200 fps of margin may be seen at disengage. Therefore, delay the call until it disengages or the summation has 200 fps of margin above the bias.

Rule Reference: A4-56F.1.c

6.2.3 Single-Engine Press 104

PURPOSE

Documents the procedure used to make this call.

PROCEDURE

- USE 2HM NOMΣ CHANNEL
- SELECT THE "1E Press-to-MECO" BIAS BASED ON SITUATION:
 - "SIMO" BIAS FOR 3-SSME ON
 - "SEQ w/dump" FOR 2-SSME ON POST-ATO SELECTION
- WHEN MARGIN \geq BIAS:
CALL: "SINGLE-ENGINE PRESS 104"
- GAP CLOSURE (LAST PRE-MECO TAL TO FIRST SINGLE-ENGINE PRESS):
 - CONFIGURE 2HM FOR ONE SSME AT 109%
 - ACLS DOWN: USE MAXIMUM CAPABILITY BIAS
 - SET ISHALW FLAG = 1
 - WHEN BIAS REACHED → **CALL** "SINGLE-ENGINE PRESS 109"
 - RESET ISHALW FLAG = 0
 - ACLS UP: USE 109% THROTTLE BIAS
 - IF BIAS REACHED PRIOR TO LAST MANUAL TAL VI, **CALL** "SINGLE-ENGINE PRESS 109"
 - OTHERWISE, AT LAST MANUAL TAL VI, THEN
CALL "SINGLE-ENGINE PRESS 109"
- RECONFIGURE 2HM FOR ONE SSME AT 104%
- CALL SINGLE-ENGINE PRESS 104 (AS REQUIRED)

6.2.4 Press-to-MECO (Three-Engine ATO)

PURPOSE

Documents the procedure used to make the Press-to-MECO call. Note, this call is not made on a 2-engine ATO case.

PROCEDURE

- USE HM NOM MPROP CHANNEL AND THE "Press-to-MECO" BIAS
- WHEN BIAS IS REACHED:

CALL: "PRESS-TO-MECO"
- GAP CLOSURE (LAST RTLS OR LAST PRIME TAL TO FIRST PRESS):
 - USE APPROPRIATE GAP CLOSURE BIAS (FUNCTION OF ACLS STATUS)

ACLS UP

1. ACCEPT CRITICAL UNDERSPEED (**USE BIAS**)
2. COMMIT OMS BALLAST TO CONTINGENCY CG LIMIT
3. ACCEPT ACLS
4. MAX THROTTLES
5. ACCEPT AOA SHALLOW (ISHALW FLAG ON **and USE BIAS**)
6. MAX RANGING USING LOW-ENERGY GUIDANCE (ACLS OR PRIME)
7. NOMINAL PERF. (0σ)

ACLS DOWN

1. ACCEPT CRITICAL UNDERSPEED (**USE BIAS**)
2. COMMIT OMS BALLAST TO CONTINGENCY CG LIMIT
3. MAX THROTTLES
4. ACCEPT AOA SHALLOW (ISHALW FLAG ON, **and USE BIAS**)
5. MAX RANGING USING LOW-ENERGY GUIDANCE TO PRIME SITE
6. NOMINAL PERF. (0σ)

BACKGROUND

Call indicates when the design underspeed can be achieved assuming one engine out, 2σ MPS FPR, and abort throttles.

This call is usually made from the HM NOM MPROP channel.

For this case since the Press-to-ATO call is not made (e.g., OMS engine failure, etc.), this call becomes "critical".

Rule Reference: A4-56E, I (gap closure), A4-55 (design and critical underspeed definitions)

6.3 *Post-TAL Selection*

6.3.1 Call Summary

PURPOSE

Document calls made by the FDO following an TAL abort. Unique calls not covered in section 6.1 are documented in the subsequent sections.

1. LOW-INCLINATION MISSIONS

Prime TAL In-Plane

Droop <prime> 109
Single-Engine Limits (prime)
Single-Engine <prime> 104

Prime TAL Out-of-Plane

Droop <ACLS> 109
Single-Engine Limits (ACLS)
Single-Engine <ACLS> 104
Single-Engine <prime> 109

2. MID- AND HIGH-INCLINATION MISSIONS

Droop <prime> 109
Single-Engine Limits (prime)
Single-Engine <prime> 104

BACKGROUND

For low-inclination missions, the ACLS provides earlier single-engine capability when the prime site is out-of-plane. Calls could be made based on one or both of the two ACLS's if the furthest out-of-plane site is prime.

For low-inclination missions when the prime site is in-plane, all calls are to the prime site. The same is true for mid-inclination missions, where all sites are in-plane, and for high-inclination missions, where all sites are effectively out-of-plane and reselects during powered flight do not significantly improve single-engine capability.

6.3.2 Single-Engine Limits

PURPOSE

Documents the procedure used to make the “single-engine limits” call following an engine-out and a TAL abort. The “limits” call is only required if Booster determines that a sensor on one of the remaining engines is failed, or if a redline on one of the remaining engines is exceeded but the exceedance is stable.

PROCEDURE

FOLLOWING ENGINE-OUT AND TAL ABORT

- ENTRY SUPPORT: PROVIDES “SINGLE-ENGINE LIMITS” VI
- IF BOOSTER REQUIRES A “LIMITS” CALL:
 - VERIFY DAE PREDICTED MECO FOOTPRINT
 - SINGLE ENGINE AT 109 IN 2HM
 - DAE P MECO PBI CONFIGURED FOR 2ND HYP MODE
- CALL “SINGLE-ENGINE LIMITS” WHEN THE FIRST TAL/ACLS SITE IS WITHIN THE STRETCH PREDICTED MECO FOOTPRINT

BACKGROUND

Call indicates the earliest time after which a two-engine out trajectory with a throttle-up to max throttles on the remaining engine will achieve stretch capability to the TAL site (or ACLS). This boundary protects 2 σ MPS FPR.

Rule Reference: A4-56F.1.b

6.3.3 Single-Engine TAL 109

PURPOSE

Documents the procedure used to make this call. The call is required only on low-inclination missions when the prime TAL site is out-of-plane. For other cases, use procedure 6.2.2.

PROCEDURE

- USE 2HM TAL Σ CHANNEL AND THE "1E SEQ 109" BIAS FOR THE DESIRED SITE:
- ✓ PROPER SITE SELECTED IN 2HM.
- CONFIGURE 2HM FOR ONE-ENG @ 109% (OFTEN VERY CLOSE TO "SINGLE-ENGINE ACLS 104" CALL)
- WHEN TAL 2HM $\Sigma \geq$ "1E <site>" BIAS:

 CALL: "SINGLE-ENGINE <site> 109"

BACKGROUND

Call indicates when two SSMEs can fail and a TAL abort to the desired site can be performed to the desired MECO range-velocity targets and within crossrange limitations, assuming protection of 2σ MPS FPR, 3σ entry dispersions, maximum throttles, and a 15 second abort decision delay. Using 109% throttle on the remaining engine is preferable to reselecting to an ACLS.

Rule Reference: A4-56F.2.e

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6.4 Post-RTLS Selection

6.4.1 Manual Pitcharound for Unconverged Guidance

PURPOSE

Document procedure to determine manual PPA time for unconverged guidance.

PROCEDURE

POST-RTLS SELECTION, IF GUIDANCE IS UNCONVERGED (PPA "INH" ON RTLS DIGITALS) OR IF GPO DETERMINES THAT GUIDANCE IS BAD:

- WHEN HM TWO-ENG RTLS $\Sigma = \underline{2000}$

CALL "STAND BY FOR MANUAL POWERED PITCH AROUND"

- WHEN TWO-ENG RTLS $\Sigma = \underline{1000}$

CALL "PITCH AROUND NOW"

BACKGROUND

Powered pitch around timing is critical to ensuring that the ET propellant mass at MECO is not excessive (target is 2% remaining). Should onboard guidance be unconverged or if for any reason its output is erroneous, a manual PPA call can be made using the ARD.

6.4.2 Single-Engine Press

PURPOSE

Documents the procedure used to make this call.

PROCEDURE

POST-POWERED PITCH AROUND

- AT HDOT = 0 AND INCREASING (UPRANGE VELOCITY)
- CALL: "SINGLE-ENGINE PRESS"

BACKGROUND

This call is empirically derived and occurs at $H_{dot} = +100$ fps. The call is made based on $H_{dot}=0$ to account for data lags. Usually, the crew is notified ahead of time that they are go to re-enable limits at the "two-out red" contingency abort region on their TRAJ display. The "single-engine press" call is a heads-up to the Flight Control Team that this boundary has been achieved, and the crew is usually given a reminder call to re-enable limits at this time.

Rule Reference: A4-56C.5

6.5 *Post-Contingency Abort Selection*

6.5.1 2 OUT DROOP

PURPOSE

Documents the procedure used in this scenario.

PROCEDURE

- FDO:
 - VERIFY THAT WE DO NOT HAVE SINGLE ENGINE TAL CAPABILITY
 - SELECT LOW XRNG TAL TARGETS (PER ONBOARD)
 - EVALUATE OTHER SITES IN 2HM/DAE
 - EVALUATE THROTTLE BACK TO 67%

- TRAJ:
 - MODEL THROTTLE UP TO 109%
 - MODEL CONTINGENCY DUMP
 - AM CONT DUMP - **ENABLE**
 - ADJUST "C" DUMP START TIME (OBTAIN TIME FROM DUMP LOG)

BACKGROUND

For this case, GPO should be calling for the 2 OUT DROOP procedure. FDO can verify that we are past the Droop boundary but prior to the Single-engine TAL boundary.

The crew will go to max throttles and then start the contingency OMS dump (Item 6 and 7). TRAJ must then take action to model both of these crew actions.

FDO may find that a different TAL site may provide better post MECO capability or options. Late in powered flight, throttling back to 67% may also provide for better post MECO capability than remaining at 109%. Both of these can be looked at in the second HM and the DAE.

Rule Reference: A4-56F.1 and 4-59I.

6.5.2 2 OUT TAL

PURPOSE

Documents the procedure used in this scenario.

PROCEDURE

- FDO:
 - VERIFY THAT WE DO HAVE SINGLE ENGINE TAL CAPABILITY
 - IF PAST SINGLE-ENGINE TAL 104,
 - **CALL:** MAX THROTTLES NOT REQUIRED
 - CONTINUE TO MONITOR PERFORMANCE UNTIL MECO
 - CALL UP TAL TARGETS
 - MECO: CALL R-V STATUS
- TRAJ:
 - MODEL CONTINGENCY DUMP
 - AM CONT DUMP - **ENABLE**
 - ADJUST "C" DUMP START TIME (OBTAIN TIME FROM DUMP LOG)

6.5.3 East Coast Abort Landing

PURPOSE

Documents the procedure used in this scenario.

PROCEDURE

- FDO:
 - VERIFY THAT WE DON'T HAVE SINGLE ENGINE TAL CAPABILITY
 - MONITOR ECAL SITE SELECTION – HAVE TRAJ K51
 - MONITOR RANGE SAFETY LIMITS
- TRAJ:
 - INFORM FCO THAT WE'RE GOING ECAL
 - STOP THE ARD
 - MECO: **CALL** MECO NAV
GO TO LANDING PHASE
CONFIGURE ENTRY DISPLAYS

BACKGROUND

For this scenario, the ARD cannot accurately modeling the onboard trajectory. Therefore, it is not necessary to chase throttles and the ARD can be stopped. However, the ETIP and filter are still running and can be monitored. Leave the ARD OUTPUT up to easily and quickly till when MECO occurs.

6.5.4 Bermuda Contingency Abort Landing

PURPOSE

Documents the procedure used in this scenario.

PROCEDURE

- FDO:
 - VERIFY THAT WE DON'T HAVE SINGLE ENGINE TAL CAPABILITY
 - MONITOR BDA SITE SELECTION – HAVE TRAJ K51
 - MONITOR RANGE SAFETY LIMITS

- TRAJ:
 - INFORM FCO THAT WE'RE GOING TO BERMUDA
 - STOP THE ARD
 - MECO: **CALL** MECO NAV
GO TO LANDING PHASE
CONFIGURE ENTRY DISPLAYS

BACKGROUND

For this scenario, the ARD cannot accurately modeling the onboard trajectory. Therefore, it is not necessary to chase throttles and the ARD can be stopped. However, the ETIP and filter are still running and can be monitored. Leave the ARD OUTPUT up to easily and quickly till when MECO occurs.

6.5.5 Bailout

PURPOSE

Documents the procedure used in this scenario.

PROCEDURE

- FDO:
 - VERIFY WITH LSO THAT SAR FORCES HAVE BEEN ALERTED
 - VERIFY THAT LSO AND TRAJ HAVE BAILOUT APP UP
 - LISTEN UP FOR CREW BAILOUT CALLS
- TRAJ:
 - INFORM FCO THAT WE'RE GOING TO BAILOUT
 - CALL UP BAILOUT APPLICATION:
 - NOTE: USER CAN CHANGE TACAN FOR DETERMINING BEARING
 - PRESS **CREW BAILOUT** BUTTON AS EACH CREWMEMBER GOES OUT
 - PRESS **RECORD EVENT** PBI TO CAPTURE DATA FOR ANY OTHER EVENT (E.G. HATCH BLOWN)
 - INFORM FCO UPON ORBITER IMPACT

BACKGROUND

In the case that bailout is required, FDO needs to make sure that LSO has informed the Search and Rescue (SAR) forces that a bailout is imminent. Once bailout has begun, the FDO team captures the position of bailout of each crewmember. This information will then be forwarded to the SAR forces.

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6.6 *ARD Maintenance*

6.6.1 Auto-Thrust Update and No-Go Criteria

PURPOSE

Document real-time procedures for evaluating the ARD solution and performing a thrust update using the Thrust Update GUI at the bottom of the FDO Launch Digitals display. These procedures are valid only from three to six minutes MET and if no SSME failure has occurred.

CLUSTER UPDATE PROCEDURE

- 2:30 MET: TRAJ: SELECTED SOURCE → TLM
- 3:00 MET: TRAJ: EVALUATE MARGIN SLOPE WITH ARD SUPPORT
- √ TREND CONSISTENT WITH Δ TMECO (EARLY O/B TMECO, + TREND)
- IF TREND $> \pm 30$ FPS/MIN:
 - ARD NO-GO UNLESS OTHER CONFIRMING INDICATIONS OF OFF-NOMINAL PERFORMANCE ARE PRESENT
 - FDO: INFORM FD & USE NO-COMM MODE BOUNDARY VI's
- IF TREND $> \pm 4$ AND $< \pm 30$ FPS/MIN:
 - CLICK THE FREEZE PBI WHEN YOU GET A "GO" FLAG
 - INFORM FDO OF THE TREND
 - CLICK THE EXECUTE "ALL" PBI
 - VERIFY UPDATE INDICATOR IS "ALL"
 - SELECTED SOURCE → FLTR
- TRAJ: √ WITH BSE: SEEING TREND; SSME PERFORMANCE NOM?
 - IF THRUST LIMITING, REQUEST DATA, GO TO SECTION 6.7
 - FDO: IF UPDATE PERFORMED, INFORM FD
- POST-UPDATE, MAY RESELECT NOM THRUST WITH **RESTORE** PBI
- NOTE: AFTER THRUST UPDATE PERFORMED:
 - IF **THRUST LIMITING** OCCURS, **RESTORE** BEFORE ENTERING THRUST LIMITING DATA
 - IF AN **ENGINE FAILS**, **DO NOT RESTORE**

BACKGROUND

A set of ten smooth entries in the ΔV margin array (about 20 sec) are required for an accurate curve fit. To satisfy this, telemetry vectors (TLM) are much preferred over filter vectors, however, an approximate solution may be obtained using the FLTR. When the array is filled, the algorithm begins to output thrust data. Another ten seconds are required to fill the thrust averaging array (five entries) prior to output of stable thrust errors (averaging the individual thrust errors provides extra smoothing). TLM should remain the selected source until an acceptable thrust solution has been frozen. Note that downlink dropouts result in ARD extrapolation of old vectors. Therefore, since extensive periods of static TLM require selection of FLTR until data is restored, up to 30 seconds may be required after TLM is reselected before a good thrust update is obtained, less if the FLTR vectors are smooth.

At 3:00 MET, the Trajectory Officer and ARD Support determine the health of the ARD solution using several cues. TMECO difference between the vehicle and ARD should generally be less than one second. Differences greater than this indicate presence of anomalies such as: a) significant thrust mismatch (requiring a relatively large thrust update); b) SSME thrust limiting; c) large NAV dispersions or guidance problems; d) non-thrust dispersions beyond flight experience such as a large loading error, inert weight error, or Isp dispersion; or e) a ground configuration problem (database or modeling error). The nominal ΔV margin should trend in a direction consistent with the TMECO discrepancy, i.e., a later O/B TMECO indicates low performance O/B and the ARD should reflect this with a downward trend.

Any margin trend beyond the ΔV margin deadband (3.4 fps/min) is considered to be due to an O/B thrust dispersion (ref. flight rule 4-21), since the delta-V margin is much more sensitive to thrust dispersions than others. However, thrust updates are not performed beyond the SSME system specification limit ($\pm 10,392$ lbs/cluster or $\pm 0.74\%$, with a margin slope of ± 30 fps/m) without a confirming indication. In this case it is assumed that a ground configuration problem is responsible unless secondary cues are present, such as large O/B TMECO difference from pre-flight predict, or a suspected SSME performance case. Cases (b) and (c) above, once declared in the FCR, should not be modeled with a thrust update. A previous cluster thrust update should be taken out with the Restore PBI. No procedures exist for identifying or handling case (d) above other than obtaining SSME data from Booster in real-time if they can support this.

Thrust update output can be examined once the ΔV margin and averaging arrays are filled with telemetry-based data ($\approx 3:00$ MET). Thrust error computations should be checked for agreement with the ΔV margin trend and TMECO difference (i.e., high computed thrust should be accompanied by an early O/B TMECO and upward margin trend). If the standard deviation of thrust error

solutions from the averaging routine is below a certain threshold, then a "GO" flag is set to indicate that solutions are stable. This should occur around 2:50 - 3:10 MET. Prior to this, the flag indicates "NO-GO", but *will not* inhibit execution of a thrust update (updates are inhibited only during first stage, if the ΔV margin array is not filled, if in 3g throttling, or if any engines have failed). The thrust error in lbs per engine will be displayed along with the current standard deviation of the thrust error array.

The Thrust Update Freeze PBI will be depressed when a satisfactory thrust error solution is obtained. ARD Support will call for a freeze based on the "GO" flag. A typical ARD Support call is "We have a "GO" flag, trend of -11, go for Freeze. Note also that margin slope output becomes stable well prior to obtaining a "GO" flag, so stability can be observed prior to achieving a "GO" flag.

Activation of the Freeze PBI records the computed frozen Δ thrust and displays it on FDO Launch Digitals and MSK 600. Then the Thrust Update "**ALL**" PBI under the EXECUTE block of the Thrust Update portion of the FDO Launch Digitals is depressed to apply 1/3 of the Δ thrust to all 3 engines. TRAJ can then reselect FLTR for state vectors if desired. Booster should next be consulted to determine if an SSME performance case is present. If so, then data should be requested and modeled via SSME Thrust Limiting procedures (section 6.7). A discontinuous change in the ΔV margin will occur after a thrust update, along with better agreement of onboard and ARD MECO times. Note that the "GO" flag is also turned off until the ΔV margin array and thrust error averaging array have had time to refill and stabilize; if the FLTR is noisy, the "GO" flag may not reset, however this is not necessary to verify a good update. An "**ALL**" indication on the Update Indicator on the FDO Launch Digitals is the feedback to verify that the thrust update got into the Traj Server.

The thrust update output should not be used outside of the timespan of 3:00 to 6:00 MET. If for some reason it is desired to remove the updated thrust, the **RESTORE** PBI can be depressed to set thrust back to the pre-launch tag value. This will also trigger a mass recycle, reset the delta-V array, and initialize thrust error output to zero pounds.

A thrust update can also be performed on a single engine if Booster believes one engine is behaving anomalously. This is done by depressing the appropriate **L**, **C**, or **R** PBI under the EXECUTE block of the Thrust Update portion of the FDO Launch Digitals. For example, during STS-44, a level 0.5 Pc shift was present of which Booster was aware, but which did not satisfy all requirements for the thrust limiting ARD update. In this case, instead of applying 1/3 of the frozen Δ thrust to all 3 SSMEs the entire frozen Δ thrust is applied to the one engine. Again, a restore can be done later if Booster does call a performance case.

In all cases, any time a thrust update is performed, FDO should inform FD.

6.6.2 Weight Update Procedure

PURPOSE

To define the how and when a weight update will be made to the ARD during powered flight.

PROCEDURE

WARNING

The general policy is to never add fuel to the ARD unless there is specific reason to believe that there is erroneous MPS mass (e.g. suspicious engine out time). Therefore, in general all MPS weight updates will be negative

- Determine sign of update
 - Sign = sign of O/B MECO – ARD MECO
- Determine magnitude
 - MPS Flowrates
 - 675 #/sec/engine at 65%
 - 1040 #/sec/engine at 100%
 - 1085 #/sec/engine at 104.5%
 - 1130 #/sec/engine at 109%
- ARD Support will compute the ΔETP
- Upon FDO's GO, TRAJ has DYN input the ΔETP

BACKGROUND

Should it become necessary to perform a weight update in the ARD, the ARD Support will determine the value for the update. In this case, it will be an update to the ARD's propellant so it goes in as a ΔETP . Note the warning about adding fuel to the ARD. This should not be done without a valid reason otherwise the update is non-conservative.

6.6.3 Error Recognition and Recovery

PURPOSE

To define how to troubleshoot errors in the ARD that occur post-liftoff.

PROCEDURE

The most common ARD problems are covered in this section as well as corrective action.

ERROR	CORRECTIVE ACTION
ADAPTIVE GUIDANCE DELTA WEIGHT INCORRECT	INPUT THE PROPER VALUE INTO THE DELTA WEIGHT OVERRIDE
DISAGREEING GROUND AND O/B MECO TIMES AFTER STAGING (AFTER OA COMPLETE)	<ul style="list-style-type: none"> √ IYs (ARD VS O/B) √ VALID VECTOR SOURCE √ THRUST ERROR (ARD TREND) √ W/BSE ON Δs TO MR OR PL √ MASS HISTORY TABLE (VERIFY NO RESET TO ENGINE START WEIGHT AT L/O) – IF SO, PERFORM ~ -12000 ΔETP
SLOWLY DIVERGING AM NOM SUM	POSSIBLE WEIGHT OR SLIGHT PERFORMANCE ERROR <ul style="list-style-type: none"> √ THRUST ERROR (ARD TREND) √ MECO TIMES √ POSSIBLE EO TIME ERROR √ OMS DUMP MODELLING (ARD VS O/B)
LARGE DIVERGENCE OF AM NOM SUM	<ul style="list-style-type: none"> √ FOR POSSIBLE ENGINE OUT (DV MARGINS) √ IYs (ARD VS O/B)
MOMENT BALANCING TASK MAX ITERATIONS	<ul style="list-style-type: none"> √ MASS HISTORY TABLE (VERIFY NO RESET TO ENGINE START WEIGHT AT L/O) – IF SO, PERFORM -12000 ΔETP
MAX ENTRIES IN ET WEIGHT HISTORY TABLE	PERFORM MASS TRACK RECYCLE
COMPUTED ET PROPELLANT WEIGHT IS NEGATIVE	<ul style="list-style-type: none"> √ ΔETP UPDATES √ 0% THROTTLE UPDATE TIME
MAX TURN RATE – NEW SOLUTION	USER BEWARE – ARDPEG HAS BEEN RESTRICTED TO A MAX THRUST VECTOR TURNING RATE. USE EXTREME CAUTION IN MAKING MODE BOUNDARY CALL FROM THIS CHANNEL. ARD WILL BE OVERLY OPTIMISTIC.
VGO, MX – TURN THRTL ON	VGO > 75000 FPS. USUALLY RESULTS FROM EXTREMELY LOW THRUST/WEIGHT. ARD SOLUTION FROM THAT CHANNEL IS SUSPECT.
MAX ITER – OLD SOLUTION	MESSAGE APPEARS WHEN PEG CYCLES 25 TIMES WITHOUT CONVERGING. MAY APPEAR EARLY IN ASCENT FOR RTLS AND SINGLE ENGINE CONFIGS. NOT AN ISSUE IN THESE CASES. IF APPEARS IN OTHER CASES, THE ARD SOLUTION FROM THAT CHANNEL IS SUSPECT.

THROTTLE BUCKET WIPED OUT	HAVE DYNAMICS REBUILD THROTTLE TABLE AS FOLLOWS: ADJ L,C,R ENG TO NOM BUCKET RPL (E.G. 72%) AT TIME OF THROTTLE DOWN, THEN ADJ L,C,R ENG TO 104.5% AT TIME OF THROTTLE UP.
K64 CUR ITEM 9 INPUT IGNORED	CAUSED BY INPUTTING CUR ITEM 9 DUMP PRIOR TO START OF OA. FIX BY CHANGING CUR ITEM 9 VALUE AFTER START OF OA.

6.7 SSME/MPS Failures

6.7.1 First Engine Out

PURPOSE

Accurately model the first SSME failure in the ARD.

PROCEDURE

- UPON CONFIRMATION OF SSME FAILURE (BSE, CREW, ARD OUTPUT, DELTA-V MARGIN):
 - **FDO:** CLICK TWICE ON <L/C/R> ENGINE-OUT PBI
NOTE: IF EO BEHIND DATA PATH, DELAY THIS UNTIL THE CREW PUSHES THE BUTTON
 - **TRAJ:**
 - ENSURE FDO CLICKED ENGINE-OUT PBI
 - VERIFY CORRECT TME-OUT AND VME-OUT UPDATE ON ARD OUTPUT
 - TME-OUT
 - PASS VALUE - 1 SEC
 - IF PASS NOT AVAILABLE, USE BFS VALUE - 1 SEC
 - IF NEITHER AVAILABLE, USE ARD COMPUTED VALUE (DISPLAYED IN AM THROTTLE BLOCK)
 - IF EO BEHIND DATA PATH:
 - LOCK THROTTLE AT ZERO% AT ACTUAL EO TIME: USE ARD COMPUTED VALUE, ΔV MARG DROP, OR BSE SUPPLIED TIME
 - SET TME-OUT EQUAL TO O/B P/B TIME
 - VME-OUT (CRITICAL FOR ATO)
 - USE PASS VALUE IF AVAIL, OTHERWISE USE BFS VALUE
 - IF NEITHER AVAILABLE, USE ARD COMPUTED VALUE (DISPLAYED IN AM THROTTLE BLOCK)
 - IF O/B ENGINE PB LATER PUSHED (NO VALUES DISPLAYED INITIALLY), UPDATE AGAIN AFTER PB PUSHED
 - IF ENGINE OUT IN FIRST STAGE, USE STAGING VREL
 - USE 3500 AS FIRST GUESS
 - AT STAGING, UPDATE WITH VREL FROM FDO LAUNCH DIGITALS
 - \sqrt INPUTS ON ARD OUTPUT (TME-OUT = INPUT TIME + 2 SEC)

BACKGROUND

The engine-out PBI on the ARD OUTPUT display must be clicked twice for time and velocity of main engine-out to be updated. The ARD uses the input time and adds the delta-time for engine throttle response (DTRSPS) to account for the time from shutdown to zero thrust. This delta-time is approximately two seconds. The input time is the PASS value minus one second, to account for delays due to guidance cycle time and other factors. The BFS value and ARD margin cues can be used as backups. The velocity of engine-out parameter is crucial for ATO modelling, as it is used by guidance to compute the ATO OMS dump quantity. For this reason, if an engine fails without onboard guidance knowing about it, the velocity is updated again after the onboard shutdown PBI is pushed, at which time the appropriate velocity is downlisted.

Delaying the input of the engine out PBI for the engine out behind a data path prevents the ARD's engine out safing task from busting the bucket on the other two engines. Locking the dead engine at zero percent at the actual engine out time and then using a TMEO equal to the time the crew hit the engine out button keeps the ARD in sync with the onboard guidance for this case.

6.7.2 Second Engine Out

PURPOSE

Accurately model a second SSME out in the ARD.

PROCEDURE

- UPON CONFIRMATION OF SECOND SSME FAILURE (BSE, CREW, ARD MARGIN):
 - **FDO:** CLICK TWICE ON <L/C/R> ENGINE-OUT PBI
 - **TRAJ:**
 - ENSURE FDO CLICKED ENGINE-OUT PBI
 - VERIFY CORRECT 2EO TME UPDATE ON ARD OUTPUT
 - PASS VALUE - 1 SEC
 - IF PASS NOT AVAILABLE, USE BFS VALUE - 1 SEC
 - IF NEITHER AVAILABLE, USE ARD COMPUTED VALUE (DISPLAYED IN AM THROTTLE BLOCK)
 - ✓ INPUTS ON ARD OUTPUT (TME-OUT = INPUT TIME + 2 SEC)
 - **K60** - AM CONT DUMP ENABLE - **ON**
 - **K64** (Dump Type 'C'), IGNITION = CONT DUMP START ONBOARD (PROP OR DUMP LOG)
 - NOTE: ARD AUTOMATICALLY MODELS SINGLE-ENGINE ROLL CONTROL -- EXPECT CONTINUOUS ARD OMS USAGE

BACKGROUND

The engine-out PBI must be clicked for the second main engine-out time to be updated. The ARD uses the input time and adds the delta-time for engine throttle response (DTRSPS) to account for the time from shutdown to zero thrust. This delta-time is approximately two seconds. The input time is the PASS value minus one second, to account for delays due to guidance cycle time and other factors. The BFS value and ARD computed value can be used as backups.

6.7.3 SSME Stuck in the Bucket

PURPOSE

Accurately model the case of an SSME stuck in the throttle bucket in the ARD.

PROCEDURE

- IF STUCK IN BUCKET
 - CONFIGURE HM FOR TWO GOOD ENGINES (STUCK ENGINE OUT)
 - CONFIGURE 2HM FOR ONE GOOD ENGINE AND STUCK ENGINE (GOOD ENGINE OUT)

 - **TRAJ:** SHIP THRUST LIMITING CASE
 - <L/C/R> ENGINE
 - HYDRAULIC LOCK-UP
 - STUCK THROTTLE LEVEL (USUALLY ZERO)
 - THROTTLE SETTING (XX%)
 - TIME:
 - IF STUCK IN 1ST STEP OF 2-STEP BUCKET (HOT SRB'S ONLY)
 - Y = LAST FULL-SECOND TIME AT 104.5% BEFORE THROTTLE-DOWN IN PRE-L/O ARD THROTTLE TABLES
 - OTHERWISE, Y = LAST FULL-SECOND TIME BEFORE THROTTLE-UP IN PRE-L/O ARD THROTTLE TABLES

 - CONFIRM WITH BSE
 - EXECUTE

- **FDO:** IF STUCK IN THE BUCKET FOR HYDRAULIC LOCK, CLICK ARD HYD FAIL PBI. [DO NOT CLICK FOR ELEC LOCK-UP OR CMD PATH LOCK-UP]

- **FDO:** CALLS (ALL 1-2/3 TIMES FROM ABORT SUP'T OR STUCK THROTTLE DIGITALS, EXCEPT AS NOTED)
 - EARLIER OF 1-2/3 DROOP OR 1-2/3 RTLS
 - 1-2/3 RTLS (IF NOT CALLED ABOVE)
 - EARLIER OF 1-2/3 NEGATIVE RETURN OR 1-2/3 TAL/ACLS
 - 1-2/3 TAL/ACLS (USING DAE, IF NOT CALLED ABOVE)
 - TWO-ENGINE PRIME TAL
 - TWO-ENGINE NEGATIVE RETURN
 - DROOP TAL/ACLS 109
 - PRESS-TO-ATO (TWO GOOD ENGINES, IF AVAILABLE)
 - PRESS-TO-MECO (TWO GOOD ENGINES, DESIGN U/S)
 - 1-2/3 PRESS-TO-MECO (USING ARD, CRITICAL U/S)

- SINGLE ENGINE TAL/ACLS
- SINGLE ENGINE PRESS (104%)
- 2/3 TAL/ACLS
- SINGLE ENGINE PRESS (lowered PL, e.g. 72%) (USING ARD, CRITICAL U/S)

NOTE: MISSION REQUIREMENTS AND/OR FAILURE SCENARIOS MAY REQUIRE REAL-TIME CHANGES OR ADDITIONS TO THIS LIST

(THIS PROCEDURE IS CONTINUED ON THE NEXT PAGE)

- **FDO: ABORTS**
 - IF NOM AM MPROP \geq UPHILL BIAS (CRITICAL U/S) THEN
 - IF NOM AM MPROP \geq UPHILL BIAS (DESIGN U/S) \rightarrow NO ACTION
 - IF NOM AM MPROP $<$ UPHILL BIAS (DESIGN U/S) \rightarrow ATO REQ'D
 - ABORT ATO AT:
 - EARLIER OF 2-ENG TAL OR 2-ENG NEG RETURN - 10 SEC
AND
 - 1 2/3 NEG RETURN OR 1 2/3 ACLS
 - UPDATE DUMP WITH ITEM 9 IF REQ'D
 - IF NOM AM MPROP $<$ UPHILL BIAS (CRITICAL U/S) THEN TAL REQ'D: ABORT TAL WHEN DOWNRANGE CAPABILITY EXISTS FOR 2-ENG AND 1-2/3 ENG CASES
 - TWO-GOOD-ENGINE PRIME TAL, PLUS EITHER
 - 1-2/3 ACLS, OR
 - 1-2/3 NEGATIVE RETURN
 - IF TWO-GOOD-ENGINE PRIME TAL CAPABILITY DOES NOT EXIST BY TWO-GOOD-ENGINE NEGATIVE RETURN - 10 SEC, ABORT TAL AT THAT TIME
- **FDO: ENGINE OUT PRIOR TO ABORT**
 - IF GOOD ENGINE OUT $<$ TAL ABORT, THEN CONTINGENCY ABORT (GPO)
 - IF STUCK ENGINE OUT $<$ TAL ABORT, THEN ABORT TAL IF PAST TWO-ENGINE PRIME TAL, OTHERWISE, ABORT RTLS
- **FDO: ADVISE FD WHEN MAX THROTTLES NO LONGER REQUIRED**

BACKGROUND

If an engine is stuck in the bucket, all of the nominal calls must be made plus all of the 1 2/3 and 2/3 calls. The Stuck Throttle Chart Digitals data is used to make

the 1 2/3 Droop, 1 2/3 RTLS, and 1 2/3 Negative Return calls. After the 1 2/3 Negative Return call, the ARD can be used to make all remaining calls. The ARD should be configured so that the nominal calls can be made out of the HM and the stuck calls can be made out of the 2HM.

If 1 2/3 RTLS comes before 1 2/3 Droop and there's a gap between 1 2/3 RTLS and 1 2/3 TAL, the 1 2/3 DROOP call is made until 1 2/3 RTLS capability no longer exists at 1 2/3 Negative Return. This is because RTLS provides a chance at making a runway while DROOP may or may not. If the crew must abort RTLS after the 1 2/3 RTLS call, then the STUCK RTLS procedure is entered unless the FDO tell the Flight Director otherwise. The FDO must also advise the crew whether or not max throttles is required for the RTLS. If the DROOP procedure is executed, the crew automatically goes to max throttles. Because of the increased risk of running at max throttles, the FDO should always advise the crew whenever max throttles is no longer required.

If 1 2/3 Droop comes before 1 2/3 RTLS and there's a gap between 1 2/3 RTLS and 1 2/3 TAL, the 1 2/3 DROOP call is made twice. The first 1 2/3 DROOP call is made when 1 2/3 Droop is reached and the second is made when 1 2/3 RTLS capability no longer exists at 1 2/3 Negative Return

6.7.4 Manual Throttle for Low LO2 NPSP

PURPOSE

A low LO2 NPSP problem exists if the SSMEs shut down from too high of a power level. This can occur for high underspeeds, where low-level cutoff occurs prior to fine countdown (when the SSMEs throttle to their shutdown power level).

PROCEDURE

Covered by standard FDO call. Reference section 6.1.14, Underspeed Prediction to Booster.

BACKGROUND

Booster will call for a manual throttle down at 2% propellant remaining in the ET if the predicted underspeed is greater than:

- 2 or 3 engines running: 500 fps
- 1 engine running: 250 fps

The booster flight rule and its rationale can be referenced if desired (rule A5-112)

6.7.5 Two Flow Control Valves Failed Closed (Man Throt for Low LH2 NPSP)

PURPOSE

Accurately model capability for manual throttle back to protect SSME low NPSP. This applies for two GH2 flow control valves failed closed. For two valves failed closed, TAL will not be declared by BSE, but may be required for performance. For three failed closed, a TAL will be declared (follow procedures in SOP 6.7.6).

PROCEDURE

- **TRAJ:** UPON BSE CALL OF MANUAL THROTTLES REQUIRED FOR 2 FCVs FAILED CLOSED, ALERT MPSR OF UPCOMING THROTTLE STEPS (95/80/67)
- **FDO:** AFTER 2 ENG TAL CALL, MODEL THREE AT 95 IN HM. ASSESS UPHILL CAPABILITY FROM HM CONFIGURATION & IF REQ'D PERFORM ITEM 9 DUMP TO PROTECT DES U/S.
- WHEN THROTTLE BACK OCCURS
 - **TRAJ:**
 - 3 @ 95/ IN THE ACTUAL MODE AT O/B MET WHEN PRI THROTTLES REACH 95%
 - NOTE: IF O/B MANUAL ADJUST \neq 95%, ADJUST ACCORDINGLY
 - **FDO:** INFORM FD OF CURRENT & ENG OUT CAPABILITY (INCLUDE POWER LEVEL IN ALL BOUNDARY CALLS)
- REPEAT FOR NEXT THROTTLE STEP → 3 @ 80
- REPEAT FOR FINAL THROTTLE STEP → 3 @ 67

BACKGROUND

The fuel Flow Control Valves (FCVs) divert a small amount of gaseous hydrogen from the SSMEs and return it to the ET to maintain pressure in the ET fuel tank as the propellant is consumed. For two FCV's failed, insufficient ullage pressure is available to run the SSMEs at a nominal power level out to MECO. As pressure in the tank falls, NPSP also falls off, resulting in potentially catastrophic engine shutdown. For this reason. Booster will call for manual throttle steps (95/80/67%) in order to protect 3.5 psi NPSP. Booster will also call for manual SSME shutdown from 67% if necessary to protect NPSP (can go to 3.0 psi at min throttles).

The ARD is used to assess uphill capability with reduced throttles. TRAJ and Dynamics are responsible for modeling the AM throttling as it occurs. FDO and Abort Support are responsible for staying one step ahead by modeling future throttle steps in the HM. Typically FDO asks Dyn to model 3 in the HM at 95% after the initial 2 eng TAL call at 104%. ITEM 9 dump requirements are assessed by comparing the HM MPROP to the uphill biases. Then an engine is killed with the PBI to assess 2 eng capability at 95%. The process is repeated for each throttle step. TAL may be avoided if uphill capability remains after each throttle step. Reference Booster rules A5-155, MANUAL THROTTLING FOR LOW LH2 NPSP; and A5-156, ABORT PREFERENCE FOR SYSTEMS FAILURES.

6.7.6 Ullage Leak or Three FCVs Failed Closed

PURPOSE

Accurately evaluate capability for ET ullage leak and/or 3 fuel Flow Control Valve Failures

PROCEDURE

- UPON BSE CALL OF ULLAGE LEAK or 3 FCV FAILED CLOSED:

NOTE:
TAL DELAY TO INPLANE SITE (ACLS) *WILL BE*
DECLARED FOR THIS FAILURE

- **FDO:**
 - INFORM FD OF TAL CAPABILITY, ESPECIALLY IF NEAR LAST TAL
 - START ITEM 9 CONTINGENCY DUMP
 - BSE PROVIDE PREDICTED TIME FOR 1st ENG SHUTDOWN:
 - IF PRIOR TO 7:00 MET, GPO CALL MANUAL MECO ON BEST ECAL/CANADIAN ELS PROXIMATE TO DAE IP/FOOTPRINT (~19K). DELAY UNTIL 3 OUT BLANK IF POSSIBLE.
 - IF AFTER 7:00 MET, ABORT TAL NLT 21K
 - NOTE: NO SINGLE ENG CALLS
- **TRAJ:** IF PROP CALLS FOR DUMP INTERCONNECT:
 - ABORT ATO IN ARD
 - ENA ATO INTERCONNECT
 - GRAB O/B ly's
- PRIOR TO TAL ABORT, BSE WILL CALL FOR MANUAL THROTTLES. AUTO THROTTLES WILL BE RESELECTED AFTER THE ABORT IS INITIATED
- **FDO:** CLICK "ARD MAN THROT" PBI TO **ON** PRIOR TO ABORT. IF "AUTO MED" IS ON, THEN "ARD MAN THROT" WILL AUTOMATICALLY TURN ON IF THE O/B MAN THROTTLE DDD IS ON.

BACKGROUND

LH2 ullage gas bled off the SSMEs provides the necessary pressure to utilize the fuel in the ET. Booster annunciation of an ullage leak indicates failure to maintain pressure in the fuel tank, a CRIT 1 failure. This could be caused by a

leak in the repress lines or a hole in the ET itself. Failure of 3 fuel Flow Control Valves (FCVs) results in a functionally similar failure, in that the ET ullage pressure will not support 3 SSMEs to MECO. If the ullage pressure drops too low the SSMEs could potentially exceed minimum NPSP limits and experience uncontained damage prior to redline shutdown. Earliest MECO conditions and earliest multiple engine out capability are required since there is no way to predict when all engines will shut down, since this is a function of leak rate. Hence a TAL to the inplane site (GO site or ACLS) will be declared. Reference Booster rule A5-155, MANUAL THROTTLING FOR LOW LH2 NPSP, and A5-156, ABORT PREFERENCE FOR SYSTEMS FAILURES.

After SRB sep and upon Booster's call of an ullage leak, TAL Delay is declared in order to hug the east coast and maximize ECAL capability. An ITEM 9 contingency dump should be started immediately. At the appropriate time, Booster will call for a manual SSME shutdown in order to protect NPSP limits. Expect the left SSME to be shutdown first, as it typically has the lowest NPSP value of the cluster. After shutdown, some NPSP recovery will be gained, which should allow the remaining two SSMEs to run for about 45-60 additional seconds. Based on Booster runtime predictions, PROP will call for to interconnect the ITEM 9 dump if necessary. Since the ARD cannot model an interconnected OMS assist, the proper workaround is to abort ATO in the ARD, interconnect the ATO dump, and grab the onboard PASS IY's (N/A if BFS).

If the first engine-out occurs prior to about 7:00 MET (about 18 kfps Vi), then chances are the remaining runtime will not support crossing the north Atlantic to reach a TAL site (expect MECO Vi ~20.5-21.5 kfps Vi). For some cases, high energy Gander procedures would be required. Rather than risk these contingency procedures, GPO or FDO should call for a manual MECO when the DAE orbiter IP (green triangle) is proximate to the best ECAL or Canadian ELS (about 19 kfps). If Canadian ELS WX is GO, GPO can verbally call "3 out blank" based on onboard telemetry, indicating first capability to perform an OPS-3 entry w/ max Nz < 3.5 G's. This should occur around 18.4 kfps Vi. Then MECO can be called based on the orbiter IP or footprint adjacent to the desired site. For large leak cases, BSE may have to shutdown the remaining SSMEs earlier; here GPO will have to make the MECO call based on ECAL capability. In either case, the actual MECO call should be based on the DAE footprint instead of the DSCT-41 barchart since the chart assumes 3 engines-out. Also, recall that the DAE is not particularly accurate for low MECO velocities; DDS should be run on a post-MECO vector to determine the appropriate entry guidance mode.

If instead the first SSME shutdown occurs after 7:00 MET, then chances are at least a stretch into Shannon can be made, and with any luck a stretch or nominal entry can be achieved to Zaragoza or Istres. In this case, TAL abort should be selected by 21 kfps Vi, and the 3 engine throttle-back allowed. Regardless of the expected runtime, Booster will provide an expected time for the first SSME shutdown as a heads up. FDO and GPO can use this to gauge whether to

request a manual shutdown for Gander, or press across the north Atlantic to attempt a TAL site.

6.7.7 Three Low-Level Sensors Failed Dry

PURPOSE

Identify method of determining abort capability for this failure.

PROCEDURE

- TAL IS REQUIRED ALMOST EXCLUSIVELY BECAUSE DESIGN UNDERSPEED MUST BE PROTECTED
 - MODEL CUTOFF AT ARMING MASS IN ARD
 - $\Delta ETP = -32000 \text{ LBS}$
 - $\Delta ETD = +32000 \text{ LBS}$
 - IF NOM MPROP $> 2\sigma$ DESIGN UNDERSPEED BIAS, THEN CONTINUE UPHILL WITH NO ACTION, OTHERWISE ABORT TAL
 - **NOTE: AN ATO DUMP MAKES THE UNDERSPEED WORSE DUE TO REDUCED VEHICLE MASS AND EARLIER LOW-LEVEL CUTOFF**

- IF TAL ABORT IS REQUIRED, THEN
 - CALL FOR RCS INTERCONNECT TO INHIBIT
 - MODEL CUTOFF AT ARMING MASS FOR A TAL
 - $\Delta ETP = -(32000 \text{ LBS} + \text{TAL OMS DUMP} - \text{OMS ASSIST})$
 - $\Delta ETD = +(32000 \text{ LBS} + \text{TAL OMS DUMP} - \text{OMS ASSIST})$
 - NOTE: IF TAL DUMP IS GOING TO BE CUTOFF BY MECO THEN GET PREDICTED DUMP AMOUNT IN LBS FROM PROP

 - REDES TO THE MOST INPLANE TAL/ACLS UNLESS CAPABILITY STILL EXISTS TO THE PRIME TAL
 - IF NEGATIVE TAL MARGIN, CALL FOR RCS INTERCONNECT TO INHIBIT

BACKGROUND

If three low level sensors are failed dry then MECO will occur at the arming mass. The arming mass is a function of the total vehicle mass. It is roughly computed by taking the expected total vehicle mass at MECO and subtracting 32,000 lbs. This means that MECO will occur with an extra 32,000 lbs of propellant remaining in the ET. This is modeled in the ARD by removing that propellant from the ET (i.e. a negative ΔETP) and converting to dry mass (i.e. a positive ΔETD). The design underspeed must be protected for this case and uphill is almost always lost. Any kind of a dump will cause MECO to occur even earlier because the total vehicle mass is being reduced, therefore ATO is not an option. In the case of a TAL, MECO will occur with an additional amount of

propellant remaining in the ET which is equivalent to the TAL OMS dump. The RCS interconnect should be inhibited to insure that all propellant dumped has a propulsive effect and is not just reducing the weight. After the new TAL Δ ETP and Δ ETD have been entered into the ARD, if the margin shows that at least 2 sigma can be protected to the prime TAL then a rede to the inplane site is not required. If the 2 sigma margin is not met then the most inplane TAL/ACLS site should be selected. Reference ARD Support Informal Memo, "ARD modeling of 3 ET low level sensors failed dry case" (3/31/92 date).

Reference flight rule A5-157.

6.7.8 Loss of Low-Level Cutoff Capability

PURPOSE

Documents procedures used to ensure safe MECO conditions in the event of loss of low level cutoff capability (3 or more low-level sensors failed wet).

PROCEDURE

FDO: ADVISE FD OF TAL/ACLS CAPABILITY

BACKGROUND

While there is no flight rule governing this situation, the BSE hip pocket procedure is to call for a TAL. Since the sensors usually read wet it is very hard for BSE to call this case.

6.7.9 Command Path Failures

PURPOSE

Accurately model Command Path Failures in the ARD.

PROCEDURE

- **TRAJ:** UPON NOTIFICATION OF COMMAND PATH FAILURE, MODEL LOCK-UP
 - CALL UP THRUST LIMITING
 - <L/C/R> ENGINE
 - HYDRAULIC LOCK-UP
 - LEVEL 0
 - POWER LEVEL $X\%$ (FROM ARD PRI THROTTLES)
 - TIME AS APPROPRIATE
 - IN BUCKET OR TRANSIENT, TIME OF:
 - 50 SEC, IF IN BUCKET
 - THROTTLE DOWN OR THROTTLE UP TIME, IF IN TRANSIENT
 - CLICK FPR PBI
- **FDO:** IF STUCK IN BUCKET, EVAL. UPHILL CAPABILITY POST-SRB SEP
 - IF AM NOM MPROP \geq UPHILL BIAS (ETIP (DESIGN) U/S), THEN NO ACTION REQUIRED
 - IF AM **NOM** MPROP \leq UPHILL BIAS (ETIP (DESIGN) U/S) AND AM **NOM** SUM \geq UPHILL BIAS (CRITICAL U/S): INCREASED OMS ASSIST REQUIRED
 - ITERATE ON ITEM 9 QTY (TRAJ AND ABORT SUPPORT)
 - EVAL TO GET AM NOM MPROP BETWEEN UPHILL BIAS (ETIP U/S) AND -100
 - NOTE: MAX QTY \leq ATO DUMP - 3 % IF ATO DUMP IS I/C
 - IF AM **NOM** SUM \leq UPHILL BIAS (CRITICAL U/S) AND AM **ATO** SUM \geq UPHILL BIAS (CRITICAL U/S): ATO ABORT REQUIRED
 - ABORT ATO AT:
 - EARLIER OF 2-ENG TAL OR 2-ENG NEG RETURN - 10 SEC **AND**
 - 1 2/3 NEG RETURN OR 1 2/3 ACLS
 - UPDATE DUMP WITH ITEM 9 IF REQ'D

- IF AM **ATO** SUM < UPHILL BIAS (CRITICAL U/S), THEN EVAL IF RESTRING REQUIRED TO REGAIN UPHILL CAPABILITY
- RESTRING EVALUATION:
 - ABORT SUPPORT SUPPLIES PRELIMINARY LAST TIME FOR RESTRING
 - MODEL THREE GOOD ENGINES IN HM
 - STUCK ENGINE OUT
 - OTHER TWO ENGINES AT 157.5% (EQUIVALENT OF 3 AT 104.5%)
 - MONITOR UPHILL CAPABILITY USING HM PER STEPS ABOVE
- IF RESTRING DONE:
 - **TRAJ:** USE THRUST LIMITING TO TAKE SSME BACK TO “NOMINAL” AT RESTRING TIME.

BACKGROUND

A command path failure means that the GPC is no longer able to command the throttle setting for a SSME. The SSME will remain at the last setting it received from the GPC. The throttle will not drift for a command path failure. The HYD FAIL FLAG is not turned on for this case. Command path failures are modelled as a hydraulic lock-up. It may be possible to restring to get out of this case.

Since the addition of the OMS assist on STS-88, we now have an additional option to regain uphill capability for an engine stuck in the bucket. The OMS assist dump, even if I-loaded to dump zero seconds, can be extended with an Item 9 entry to decrease the predicted MECO underspeed. This option is preferred over aborting ATO since it does not require freezing the plane and preserves the option to perform a rendezvous. However, if the performance hit is severe enough the ATO selection may be required in order to get uphill.

6.7.10 TAL Delay

PURPOSE

To provide procedures for the implementation of TAL Delay.

PROCEDURE

- LOG THE TIME OF 2-ENGINE TAL
- IF ENGINE OUT IS $\geq 2E \text{ TAL} + 10 \text{ SEC}$
 - CALL: IN THE TAL DELAY WINDOW, ITEM 9 + XX where XX is the CONT Qty
- IF ENGINE OUT IS $< 2E \text{ TAL} + 10 \text{ SEC}$
 - CALL: WE'RE NOT IN THE TAL DELAY WINDOW, ABORT TAL NOW

NOTE: For an engine out past the TAL DELAY BIAS, TAL Delay is possible.

- If no abort declared by the TAL DELAY BIAS, CALL "ABORT TAL NOW."

BACKGROUND

TAL boundaries protect for a 15 second decision delay in executing the abort. However, informally in simulations for the past several years, Flight Directors have been inclined to delay the actual abort selection well past 15 seconds when either of the two remaining SSME's were suspect. Flight Design has coordinated a prolonged effort to certify delaying the TAL abort if sufficient performance is available. With STS-108, delaying the TAL abort after an SSME failure may be implemented.

The implementation agreement was that TAL delay could be performed for an engine out between 2-engine TAL plus 10 seconds and Press-to-ATO. The maximum delay on abort selection is constrained by either the 3σ TAL boundary (as protected by the TAL Delay bias) or the Single Engine OPS 3 boundary, whichever comes first. Reference AEFTP #175.

6.8 SSME Thrust Limiting Failures

6.8.1 Thrust Limiting Adjustments

PURPOSE

Accurately model SSME performance adjustments due to specific, Booster-identified thrust limiting failures. These failures include Back-up Electric Lock-ups, Pc Shifts, HPOT Efficiency Loss, Flowmeter GPM Sensor Shifts, LPFT Discharge Temperature Shifts, and Nozzle Leaks. They manifest themselves in such a way that engine throttling is maintained, but performance is biased due to the off-nominal condition. See 6.8.2 for Hydraulic Lock-up procedures and 6.8.3 for Electric Lock-up procedures.

PROCEDURE

- **TRAJ:** UPON BSE CALL OF PERFORMANCE CASE IN PROGRESS:
 - CALL UP THRUST LIMITING GUI
 - HIT **CLEAR**
 - IF THRUST UPDATE PERFORMED EARLIER, HIT **RESTORE**

- **TRAJ:** ENTER BSE DATA INTO GUI AND READ BACK TO BSE:
 - "<L/C/R> ENGINE"
 - "<failure type>"
 - "LEVEL <BSE value>"
 - THROTTLE % (IF REQ'D)
 - "TIME OF <N+NN>"
 - **EXECUTE**

 - CLICK THE "FPR" PBI

 - FOR CASE PRIOR TO 1+07: GET NEW Δ WT OVERRIDE VALUE FROM ARD SUPPORT, AND PASS IT TO DYNAMICS:
 - "K67 Δ WT OVERRIDE <value>"

- **TRAJ:** WHEN CONFIRMED BY ARD SUP'T, NOTIFY FDO: "ARD IS GO"

- **TRAJ:** IF BSE REPORTS RETURN TO NOMINAL:
 - "<L/C/R> ENGINE"
 - "<NOMINAL>"
 - THROTTLE % (IF REQ'D)
 - "TIME OF <N+NN>" (time from BSE)

- EXECUTE
- CLICK THE "FPR" PBI
- WHEN CONFIRMED BY ARD SUP'T, NOTIFY FDO: "ARD IS GO"
- **PC SHIFT CASES ONLY:** FOR PC SHIFT CASES, THE BAD PC CHANNEL CAN SOMETIMES BE TURNED OFF, THEREBY REGAINING NOMINAL PERFORMANCE ON THE AFFECTED ENGINE.

IF BSE REPORTS THAT THE BAD PC SENSOR CHANNEL CAN BE TURNED OFF, AND IF UPHILL CAPABILITY DOES NOT EXIST WITH CURRENT CONDITIONS:

- **TRAJ:** MODEL TWO ENGINES AT 156% IN THE HM (PC SHIFT ENGINE OUT)
- **FDO:** IF UPHILL BIAS IS SATISFIED IN HM, RECOMMEND BAD PC CHANNEL BE TURNED OFF

BACKGROUND

All thrust limiting adjustments are modelled in the same way. Hydraulic lock-ups are covered in the subsequent section. FDO must be notified that an update is pending, so that aborts are not initiated until the ARD configuration is verified. Reference the ARD Support Console Handbook (DM-CH-03) for FPR update computation.

The user should input the actual time that any thrust limiting case occurs. The Thrust Limiting application will automatically delay the throttle input time of all cases, except hydraulic and electric lock-ups, until after the throttle up transient, since an earlier throttle entry would result in a significant error in the thrust bucket. For example, a Pc shift input at 30 sec *with* throttles would completely wipe out the throttle bucket for that engine. For this reason, throttle data is not input earlier than 1+07, and the propellant usage delta is accounted for with a delta-weight override adjustment computed by ARD Support (Reference the ARD Support Console Handbook, DM-CH-03).

Note: All thrust limiting adjustments are modelled as a "lock." This is to prevent an off-nominal performing engine to be returned to the nominal power level by the engine-out safing task should another engine fail. When an engine is returned to "nominal" (as reported by BSE if the failure is cleared by any means), it is modelled as an "adjust" to allow this throttling to once again occur, if required.

By the flight rules, for Pc Shift cases which result in loss of uphill capability, the bad Pc transducer can be turned off. This reduces engine redundancy but will be performed is doing so will avoid a TAL or RTLS. Reference flight rule A5-110, SSME Performance Dispersion, paragraph B.1.c.

NOTE

Always press CLEAR on the Thrust Limiting menu prior to using it for the first time during ascent. Failure to do so may result in stored data from a previous sim being shipped to the ARD. The menu stores thrust limiting data for each engine, and ships this data to the ARD whenever the menu is executed.

6.8.2 Hydraulic Lockup

PURPOSE

Accurately model SSME hydraulic lockup cases, including valve drift.

PROCEDURE

- **TRAJ:** UPON BSE CALL OF HYDRAULIC LOCK-UP IN PROGRESS:
 - CALL UP THRUST LIMITING
 - "<L/C/R> ENGINE" (C if APU 1 ↓, L if APU 2 ↓, R if APU 3 ↓)
 - "<HYDRAULIC LOCK-UP>"
 - "LEVEL <BSE value>"
 - THROTTLE % (IF REQ'D)
 - "TIME OF <N+NN>"
 - APU fail time if pre- or post-bucket
 - If in the bucket:
 - IF STUCK IN 1ST STEP OF 2-STEP BUCKET (HOT SRB'S ONLY)
 - Y = LAST FULL-SECOND TIME AT 104.5% BEFORE THROTTLE-DOWN IN PRE-L/O ARD THROTTLE TABLES
 - OTHERWISE, Y = LAST FULL-SECOND TIME BEFORE THROTTLE-UP IN PRE-L/O ARD THROTTLE TABLES
 - EXECUTE
 - CLICK THE "FPR" PBI
 - WHEN CONFIRMED BY ARD SUP'T, NOTIFY FDO: "ARD IS GO"
- **FDO:** CLICK THE "ARD HYD FAIL" PBI; CONFIRM SSME UNPARALLEL WITH GNC
- **FOR DRIFTING THROTTLE CASES ONLY:** AFTER THE INITIAL LOCK-UP HAS BEEN INPUT:
 - **TRAJ:** CALL THRUST LIMITING
 - "<L/C/R> ENGINE"
 - CLICK "DRIFTER MECO LEVEL"
 - "MECO THROTTLE %"
 - "MECO LEVEL X"
 - "MECO TIME FROM BOOSTER" (USUALLY 15:00 MET)

- EXECUTE
 - CLICK THE "FPR" PBI
 - WHEN CONFIRMED BY ARD SUP'T, TELL FDO: "ARD IS GO"
- GET ADDITIONAL MARGIN DRIFT FROM ARD SUP'T, PASS TO FDO

BACKGROUND

Hydraulic lockups are the most challenging thrust limiting cases to model, due to the fact that the valves may drift without the APU hydraulic system to control them. Each engine's throttling function is controlled by a single APU: APU 1 controls engine #1 (center), APU 2 controls engine #2 (left), and APU 3 controls engine #3 (right). When an APU initially fails, simply lock the engine at the current commanded power level until more information is obtained from Booster. The hypothetical mode is configured to reflect the stuck engine out for two reasons: 1, if valve drift occurs, that engine is the most likely to fail; and 2, the ARD cannot predict future throttle performance, so the hypothetical mode has questionable value when configured with the stuck engine running.

In case of a subsequent valve drift, the affected ARD throttle table is configured to accept the MECO power level which will be supplied by Booster. This is usually supplied as a prediction for 15:00 MET to protect for slips to the MECO time. The ARD will interpolate between the throttle, MR, and ISP values at the time of the lock and the predicted MECO levels. However, the portion of the mass track built prior to modeling the drift is based on the initial lock value. This is corrected by shipping a mass track recycle after the MECO levels are modeled. The mass track recycle will be reflected as a change to the fuel bias. Once again, after a MECO level is input and the mass track recycle is complete, the FPR is recomputed based on the new fuel bias.

NOTE

Always press CLEAR on the Thrust Limiting menu prior to using it for the first time during ascent. Failure to do so may result in stored data from a previous sim being shipped to the ARD. The menu stores thrust limiting data for each engine, and ships this data to the ARD whenever the menu is executed.

6.8.3 Electric Lockup

PURPOSE

Accurately model SSME electric lockup cases.

PROCEDURE

- **TRAJ:** UPON BSE CALL OF ELECTRIC LOCK-UP IN PROGRESS:
 - CALL UP THRUST LIMITING
 - "<L/C/R> ENGINE"
 - "<HYDRAULIC LOCK-UP>"
 - "LEVEL <BSE value>"
 - THROTTLE % (IF REQ'D)
 - "TIME OF <N+NN>"
 - Lock-up time from BSE
 - Throttle down or throttle up time, if in transient)
 - If in the bucket: Use time in the middle of the bucket
 - EXECUTE
 - CLICK THE "FPR" PBI
 - WHEN CONFIRMED BY ARD SUP'T, NOTIFY FDO: "ARD IS GO"

BACKGROUND

The electric lock-up cases are similar to the hydraulic lock-up cases except the potential for drifting levels doesn't exist. Therefore, they are modeled with Hydraulic lock-up option of the Thrust Limiting application. If it is stuck in the bucket, a time from the middle of the bucket can be used for modeling this case.

NOTE

Always press CLEAR on the Thrust Limiting menu prior to using it for the first time during ascent. Failure to do so may result in stored data from a previous sim being shipped to the ARD. The menu stores thrust limiting data for each engine, and ships this data to the ARD whenever the menu is executed.

6.9 OMS Failures

Interconnected Dumps

While the procedures that follow were written based on the documented crew procedures, they may require some changes to the interconnect status depending on the actual crew action.

- TO MODEL A NON I/C DUMP SWITCHED TO I/C MID DUMP;
 - DEPRESS APPROPRIATE I/C DUMP BUTTON ON ARD OMS GUI (e.g. TAL I/C ON)
 - UPDATE THE RCS ON TIME ON ARD OMS GUI (defaults to I1 dump type)
- TO MODEL AN I/C DUMP SWITCHED TO NON I/C MID DUMP;
 - √ APPROPRIATE I/C DUMP BUTTON ON ARD OMS GUI (e.g. TAL I/C ON)
 - INPUT RCS OFF TIME ON ARD OMS GUI (defaults to I1 dump type)

6.9.1 OMS Engine Fail and OMS GN2 Tank Fail

PURPOSE

To accurately model OMS engine fail and OMS GN2 Tank Fail cases in the ARD. This procedure has been optimized for uphill cases in which quick determination of OMS ΔV and vehicle weight is desired without relying solely on the PROP Officer for information.

PROCEDURE

- TRAJ
 - FAILED OMS ENGINES = 1
 - $\Delta OMS = -20 * \Delta t_{fail}$ (Δt_{fail} = time bad eng burned (assist + abort dump))
 - Enable the ATO, TAL, & RTLS interconnects
- FDO
 - If prior to PTA, CALL PTA ON CRITICAL (HM SUM) ATO BIAS WHILE PROTECTING MPROP ≥ -300
 - CALL PTM ON CRITICAL (HM SUM) PTM BIAS WHILE PROTECTING MPROP ≥ -300

BACKGROUND

OMS engine failures are fairly straightforward to model in the ARD. If an OMS engine failure occurs, PROP announces it on the FD loop then informs FDO on MOCR DYN or over the console. TRAJ then uses the ARD OMS GUI to configure the ARD to reflect a single OMS engine down. The ARD assumes the engine failure applies to the whole dump (and OMS assist if applicable), therefore if the engine failed significantly long after dump start, a manual Δ OMS adjustment is required to inform the ARD how much propellant was dumped through the engine prior to its failure.

The result of an OMS GN2 Tank Fail is nearly identical to the classical OMS Engine Failure as far as powered flight procedures go; the engine is considered unusable for uphill aborts. The fact that it is usable for TAL and RTLS results in a small but acceptable error in the TAL and RTLS channels.

Reference AEFTP #175 for details on the change which allows an OMS dump for an uphill abort with an OMS engine failure. For this case, Press-to-ATO is made assuming a 1 + 24 ATO dump, regardless of the ATO interconnect I-load. PTA is called once the critical bias in the ATO SUM channel is reached -AND- an $MPROP \geq -300$ is assured. This prevents an ATO from violating the single OME underspeed limit of 300 fps. Note that the Prop Officer will call for the crew to enable the OMS-to-RCS interconnect as soon as an ATO is declared. Exceptions to using an interconnected dump may be made on a flight-specific basis.

The Press-to-MECO call is made based on the critical underspeed for this failure, while protecting for single OME inefficiencies for OMS-1. Call PTM when the critical bias in the NOM SUM channel is reached -AND- an $MPROP \geq -300$ is assured. This limits the max underspeed in order to avoid growth in OMS-1 ΔV due to extended burn arc on a single OME (ref AEFTP #175 5/18/2001). FR A2-62 allows waiving ETIP protection in the event of SSME failure accompanied by any loss of OMS dump capability.

6.9.2 OMS Propellant Leak / Fail or Helium Tank Fail

PURPOSE

To accurately model OMS propellant leaks, propellant fails, and OMS helium tank fails in the ARD.

PROCEDURE

- **TRAJ:**
 - K64 (Current Dump Type) DUMP CUTOFF = Time good engine off
 - If TAL/RTLS or TAL Delay: Initial Guess = He/Prop Fail Time + 2:00
 - FAILED OMS ENGINES = 1
 - Δ OMS / Δ RCS per failed side total dump duration using Prop Fail / Helium Tank Fail tables: (or expected total dump duration--NLT MECO-10 seconds)
 - Δ OMS = -(LB LOST)
 - Δ RCS = +(LB TRAPPED)
 - Update with corrected values if actual Prop fail / Helium Tank Fail time different than predicted
 - ATO/TAL/RTLS INTERCONNECT = INH
 - After OMS Prop or He TK FAIL: K87 update TAL/RTLS timers to 120 sec (Unless TAL/RTLS already)
- **FDO:**
 - No PTA. Call PTM ON CRITICAL (HM SUM) PTM BIAS WHILE PROTECTING MPROP \geq -300.
 - Evaluate NOM/AOA channels for non-leaker dump/ATO capability, if needed in order to protect design u/s for 3 eng uphill:
 - **TRAJ:** Δ OMS = Δ OMS - good OME dump needed
 - **FDO:** Pass good OME lbs needed to be dumped to Prop Officer
- *If Subsequent ATO*
 - **TRAJ:** K64 ('I1' Dump Type) DUMP CUTOFF = I1 start + 1 sec
- *If Subsequent TAL/RTLS*
 - **TRAJ:** K64 ('I1' Dump Type) DUMP CUTOFF = Time good engine off

BACKGROUND

A common procedure is used to model propellant fails and propellant leaks, as well as helium tank fails and helium tank leaks that are expected to result in helium tank fail pre-MECO.

Propellant leaks and fast helium tank leaks are modeled as expected prop / tank fails at a future time specified by the Prop Officer. This future time is no later than MECO - 10 seconds and may have to be adjusted if the predicted MECO time changes or if the actual time of failure was different than predicted. This procedure was optimized to produce correct results for the ARD actual mode; ARD hypothetical mode computations will not reflect the extra leaking OMS dump time that may be achieved by the later predicted MECO time.

All of these failure cases impose significant impacts to performance. The amount of OMS lost is a function of how much OMS has already been dumped (e.g. during OMS assist) and how much of the non-leaking OMS must be used for ballast to maintain the Y cg in the contingency cg box. The PROP group provides Helium and Propellant dump tables that contain the data for input into the ARD for OMS and RCS deltas as a function of dump time which accounts for the lost propellant on the tank failed side as well as the good propellant required for ballast. Knowing the total time the failed side dumped prior to the failure is required to pull the correct data from the table. This is modeled in the ARD by subtracting the lost and unusable OMS from the OMS and adding the unusable amount to the RCS. This process maintains overall vehicle mass accuracy while accounting for the lost OMS ΔV capability. (Note that for OMS tank leaks, these procedures assume the propellant leaks into the pod.) The ARD does not track the RCS as a propulsive quantity and is used essentially as a "dry" vehicle weight.

The good OMS engine will be turned off immediately for these cases to conserve OMS propellant. However, a dump of the good OMS can be re-started, if needed to protect design underspeed for 3 SSMEs running, as long as post-MECO ΔV requirements are protected. Due to ARD OMS model limitations, the only way to consistently determine the amount of good OMS dump needed is with ΔOMS . The ΔOMS needed is then passed to the Prop Officer, who manages the good OMS on/off time to achieve the desired dump. The minimum good-side dump that the Prop Officer can manage the manual dump on/off times is approximately 750 pounds. Alternately, an ATO abort may be performed if freezing the plane provides uphill capability. This is an advantageous strategy, since for any of these cases, rendezvous is likely NO-GO anyway. Since the good OMS engine is off, no additional dump would be performed for an ATO unless FDO requests one.

For a prop or helium leak, the crew will begin an ITEM 9 dump to dump the leaking propellant to depletion. This is to reduce the amount leaked into the pod and to make use of the leaking propellant while it is still usable. Or for a helium

leak, the goal is to increase the amount of usable propellant in “blowdown” mode by dumping prop and increasing ullage volume in the tank prior to helium tank fail. Although any depletion dump will be cutoff at MECO - 10 seconds, by using this value in the Propellant Fail/He Fail dump tables, the ARD will have the corrected MECO mass. The ARD will incorrectly assume an instant mass loss the moment the case is modeled but this is roughly offset by the fact that the ARD does factor in any thrust capability of the dump. For the purposes of abort boundary calls and uphill capability assessment, it is assumed that the leaking OMS system has no post-MECO ΔV capability regardless of the amount predicted to remain in the tank at MECO. This is because there are significant liens against use of the leaking OMS system, such as the possibility that propellant that has leaked into the pod will sublime and freeze the fuel lines. Post-MECO any useful ΔV from the leaking OMS is on a best effort basis.

In the case of an immediate prop or helium tank failure, no additional dump on the “bad” side can be performed. Here the appropriate line of the Prop Fail / He Fail table to use is the line corresponding to the total dump time of the failed system prior to failure (e.g. the ITEM 9 line if failure occurs after OA).

Crossfeed valves are closed for a propellant fails, propellant leaks, and helium tank failure, so an interconnected dump is not possible.

For a subsequent RTLS or TAL, the good OMS engine is turned back on briefly to attempt to reach TLC while still protecting the Y cg of the vehicle. The prop officer manages the dump time and cg management of the vehicle for these aborts.

6.9.3 OMS Helium Leak

PURPOSE

Accurately model OMS helium leak case (OMS He TK P Low) in the ARD.

PROCEDURE

- If He LEAK & pre-MECO Dump Req'd:
 - Get expected leaking side dump duration from PROP Officer
 - If tank fail expected pre-MECO → GOTO OMS Prop Leak / Fail & Helium Tank Fail proc (SOP 6.9.2)
 - **TRAJ (after 2E TAL):**
 - FAILED OMS ENGINES = 1
 - ITEM 9 per Prop Officer (slip OA start time, if req'd)
 - Use He LEAK level table LB TRAPPED for leaking side expected total dump duration
 - $\Delta OMS = -(LB\ TRAPPED) - 20 * \Delta t_{DUMP}$ $\Delta t_{DUMP} = \text{good eng burn } \Delta t$
 - $\Delta RCS = +(LB\ TRAPPED)$
 - TAL INTERCONNECT = INH
 - **FDO:**
 - No PTA. Call PTM ON CRITICAL (HM SUM) PTM BIAS
 - Evaluate NOM/AOA channels for non-leaker dump/ATO capability, if needed
 - **TRAJ:** $\Delta OMS = \Delta OMS - \text{good OME dump needed}$
 - **FDO:** Pass good OME lbs needed to be dumped to Prop Officer
 - *FOR SUBSEQUENT ATO: If ATO dump less than blowdown dump, Prop Officer will call for ITEM 9 to restore blowdown dump*
 - **TRAJ:** Re-input ITEM 9 blowdown dump per Prop Officer
 - *FOR SUBSEQUENT RTLS or TAL:*
 - **TRAJ:**
 - Unfail OME
 - $\Delta OMS = 20 * \Delta t_{\text{good_OME_off}}$ or RTLS/TAL lbs heavy
 - *FOR SUBSEQUENT He TK FAIL:*
 - **TRAJ:** Update ITEM 9, ΔOMS / ΔRCS to match actual dump cutoff
- IF PRE-MECO Dump not req'd:
 - **TRAJ:** Dial-down OMS Assist to 3σ APM (NOM bias) per Prop Officer request, if applicable
 - **FDO:** All normal abort boundary calls will be made

BACKGROUND

Helium is used as a pressurant to force OMS fuel and oxidizer out of their tanks and into the combustion chamber. When a helium leak is detected, it can be either a fast or slow leak. If the leak is fast enough, helium tank fail can be expected pre-MECO, in which case SOP 6.9.2 "OMS Prop Leak / Fail & Helium Tank Fail" should be used. The Prop Officer can predict if and when helium tank fail is expected to occur as long as the dump is not interconnected. Traj should determine this information first, as it dictates which procedure should be used. Note that once Traj initiates the steps on the helium leak procedure, Traj should stay with this procedure even if the leak rate changes such that the tank is expected to fail prior to MECO. Steps at the bottom of this procedure provide the proper response in the event of a later downmode to "tank fail". This is preferred over attempting to back out of this procedure and then switch over to SOP 6.9.2.

If the helium leak is slow enough to react to and no abort dumps are in progress, a dump to "max blowdown" can be performed. This procedure involves doing a partial OMS dump to the point of maximum ΔV potential. Once the dump has progressed to this predetermined point, the valves between the propellant tanks and the helium pressurant are closed. The helium continues to leak out of the helium leg, but enough pressurized helium is trapped in the propellant tanks to use most of the remaining OMS. The blowdown dump is modeled in the ARD with an ITEM 9 which matches the Prop Officer's ITEM 9 request. There will be a small amount of unusable propellant on the leaking side even if max blowdown is achieved. This is modeled in the ARD using PROP-supplied data. The data includes a column labeled LB TRAPPED and is printed out in ~5-second dump time increments. The dump time that results in maximum ΔV is approximately ITEM 9 + 52. The LB TRAPPED which corresponds to the specified dump time, is added to the RCS and subtracted from the OMS. If the blowdown dump is cutoff by MECO, the LB TRAPPED that corresponds to the total expected dump time on the leaking side should be used.

The good OMS engine will be turned off immediately for an OMS helium tank failure to conserve OMS propellant. This is modeled in the ARD by failing an OME and subtracting the OMS propellant which was already dumped on that side. However, a dump of the good OMS can be re-started, if needed to protect design underspeed. Also, an ATO abort may be performed if freezing the plane provides uphill capability. To avoid a conflicting ITEM 9 with the existing blowdown dump, this additional good OMS dump must be modeled with additional $-\Delta OMS$. This quantity is then passed to the Prop Officer, who manages the good OMS on/off time to achieve the desired dump. The minimum good-side dump that the Prop Officer can manage the manual dump on/off times is approximately 750 pounds.

If an ATO abort is performed after the blowdown dump was started, the ATO timer will override the existing ITEM 9. If the ATO dump is less than the blowdown dump, the Prop Officer will call for another ITEM 9 to reset the dump quantity to achieve max blowdown. This must be modeled in the ARD by re-inputting the ITEM 9.

For either of the above cases no Press-to-ATO will be called. If a downhill abort is subsequently initiated, the good OMS will be turned on to support the abort dump. This is modeled in the ARD by unfailing the OME. It is easiest to model the remaining quantity of OMS using the normal RTLS or TAL timer, plus any residual propellant not dumped (lb heavy from PROP Officer), minus the unusable amount if extreme accuracy is desired (again from PROP Officer; this is not really necessary for downhill aborts). To do this, overwrite Δ OMS with lb heavy minus unusables, and Δ RCS with unusables quantity.

If an RTLS or TAL abort is being performed when the helium leak is detected, continue the ARD dump (which may be slightly out of sync) and simply overwrite Δ OMS with the dump lb heavy from the PROP Officer. This will provide an overall correct account of OMS and RCS weight for the ARD by accounting for the dumped amount, leaked propellant, and dump remaining quantity. If a contingency dump is stopped early, then turn off the contingency dump in the ARD with the K64 MED.

If the leak is small enough to support a dump to TLC at an MET of 20 minutes, no blowdown dump will be performed pre-MECO. Leak rates of this size provide full capability for early OMS-1 TIGs. Since there is no loss of critical OMS capability, the "Press-to-ATO" call will be made and ET footprint criteria must be protected. However, if the leak rate will not support a dump all the way to max blowdown for the earliest TIG, then a real-time OMS Assist reduction will be performed if there is ascent performance margin above 3σ . Performing the blowdown dump prior to the inplane TIG results in a Δ V loss towards achieving the mission. Therefore it is prudent to trade excess ascent performance margin to increase the OMS propellant available post-MECO.

6.9.4 OMS Failure Procedures Summary

OMS ENG FAIL or GN2 TK FAIL (if unusable for uphill aborts)

NON-I/C dump switched to I/C mid-dump:

- I/C DUMP ENA = ON
- UPDATE RCS ON TIME

I/C dump switched to non-I/C mid-dump:

- I/C DUMP ENA = ON
- INPUT RCS OFF TIME

TRAJ

- FAILED OMS ENG = 1
- $\Delta OMS = -20 * \Delta t_{fail}$ ← $\Delta t_{fail} = \text{time bad eng burned}$
- ATO, TAL, RTLS I/C ENA (assist + abort dump)

FDO

- PTA on CRIT (HM ATO Σ)
- IFATO: ENA I/C ASAP, size dump <300 fps u/s
- PTM on CRIT/max u/s 300 fps (NOM MPROP)
- If OME re-strigable, treat as eng fail

OMS He TK LEAK (Pre-MECO Dump Req'd -&- TK Fail NOT expected pre-MECO)

TRAJ

- Expected leaking side dump duration from PROP*
- **After 2E TAL:** FAILED OMS ENG = 1 for good OME off
- Item 9 (slip OA start time if cutout) } Per expected dump duration
- Helium leak table:
 - $\Delta OMS = -(\text{LB TRAPPED}) - 20 * \Delta t_{DUMP}$ ←
 - $\Delta RCS = +(\text{LB TRAPPED})$ $\Delta t_{DUMP} = \text{good eng burn } \Delta t$
 - TAL INTERCONNECT = INH
- Additional - ΔOMS as needed (per FDO)
- **FOR SUBSEQUENT ATO:** Re-input Item 9 blowdown dump per PROP
- **FOR SUBSEQUENT RTLS or TAL:**
 - Unfail OME
 - $\Delta OMS = 20 * \Delta t_{\text{good OME off}}$ or RTLS/TAL lb heavy
- **FOR SUBSEQUENT He TK FAIL:**
 - Update ITEM 9, $\Delta OMS/\Delta RCS$ to match cutoff
 ↑
 incl. good eng burn Δt

FDO

- No PTA (call "unpress" if after PTA)
- PTM on CRIT (HM NOM Σ)
- AM (3 eng) - protect design u/s
 - Evaluate NOM/AOA channels for non-leaker dump/ATO capability, if needed
 - Pass good OME lbs needed to be dumped to Prop Officer
- **FOR SUBSEQUENT ATO:** If ATO dump less than blowdown dump, PROP will call for Item 9 to restore blowdown dump
- Post-MECO: dump prop posi / radial up

***NOTE**

If dump cutoff by MECO:
 Total dump duration = [TMECO - 10 sec - ITEM 9 start time]
 + OA dump duration (if Item 9 post-assist)

Pre-MECO Dump NOT Req'd:

- TRAJ: Adjust OA dump qty to 3σ APM per PROP, if applicable
- FDO: All normal abort boundary calls will be made

OMS PROP LEAK / OMS PROP FAIL / He TK FAIL

TRAJ

- Expected leaking side dump duration from PROP*
- K64 current dump cutoff = time good eng off ←
 - If TAL/RTLS or TAL Delay:
 Initial Guess = He/Prop Fail time + 2:00
- FAILED OMS ENG = 1 For bad OME
- Prop Fail/He TK Fail table for expected dump duration:
 - $\Delta OMS = -(\text{LB LOST})$
 - $\Delta RCS = +(\text{LB TRAPPED})$
 - Post fail, update if Prop fail/He TK fail time different than predicted
- ATO/TAL/RTLS I/C = INH
- **Post-TK fail:** K87 update TAL/RTLS timers to 120 sec (Unless TAL/RTLS already)
- Additional - ΔOMS as needed (per FDO)
- **Subsequent ATO**
 - K64 I1 dump cutoff = I1 start + 1 sec
- **Subsequent TAL/RTLS**
 - K64 I1/ I2 dump cutoff = time good eng off

FDO

- No PTA (call "unpress" if after PTA)
- PTM on CRIT / max u/s 300 fps (HM NOM MPROP)
- AM (3 eng) - protect design u/s
 - Evaluate NOM/AOA channels for non-leaker dump/ATO capability, if needed
 - Pass good OME lbs needed to be dumped to Prop Officer
- Post-MECO: dump prop OOP nose north

***NOTE**

If dump cutoff by MECO:
 Total dump time = [TMECO - 10 sec - ITEM 9 start time]
 + OA dump duration (if Item 9 post-assist)

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6.10 Other Systems Failures

6.10.1 Cabin Leak

PURPOSE

To document FDO's responsibilities in the case of a cabin leak.

PROCEDURE

Once cabin leak detected:

- Keep FD informed of status of abort options
- Give FD a heads up on end of abort windows:
 - Coming up on Negative Return
 - Coming up on Negative TAL/ACLS
- Continue to make all abort boundary calls

BACKGROUND

EECOM will determine if a cabin leak develops, if the leak is isolatable or not, the leak rate and which abort is preferred (if required). If an RTLS is preferred, it is up to FDO to verify that we haven't flown past Negative Return. If the leak occurs late in second stage, FDO must verify that we still have TAL capability if a TAL is preferred. Ref. flight rules A2-54A.3 and A2-54B.5.

6.10.2 Loss of All Cryogenics

PURPOSE

To document FDO's responsibilities in the case of the loss of all cryogenics.

PROCEDURE

Once the loss of all cryo (or impending loss) detected:

- Keep FD informed of status of abort options
- Give FD a heads up on end of abort windows:
 - Coming up on Negative Return
 - Coming up on Negative TAL/ACLS
- Continue to make all abort boundary calls

NOTE: This case calls for the earliest landing time. RTLS has an earlier landing time than TAL.

BACKGROUND

EGIL will determine if the loss or impending loss of all cryo has occurred and will call for an abort if that happens. This case requires an expedited landing which means that RTLS is preferred over TAL. Therefore, FD will ask- to FDO to verify that we haven't flown past Negative Return. If the failures occur late in powered flight, FD may ask FDO to verify that we still have TAL/ACLS capability. Ref. flight rule A2-54A.4.

6.10.3 Multiple APU Failures

PURPOSE

To document FDO's responsibilities in the case of the impending loss of all APU/hydraulic systems.

PROCEDURE

Once the impending loss of all APU/hydraulic systems has been detected:

- Keep FD informed of status of abort options
- Give FD a heads up on end of abort windows:
 - Coming up on Negative Return
 - Coming up on Negative TAL/ACLS
- Continue to make all abort boundary calls

NOTE: This case calls for the earliest landing time. RTLS has an earlier landing time than TAL.

BACKGROUND

MMACS will determine if the loss or impending loss of all APU/hydraulic systems has occurred and will call for an abort if that happens. This case also requires an expedited landing which means that RTLS is preferred over TAL. Therefore, FD will ask- to FDO to verify that we haven't flown past Negative Return. If the failures occur late in powered flight, FD may ask FDO to verify that we still have TAL/ACLS capability. Ref. flight rule A2-54A.1.

6.10.4 Loss of Thermal Windowpane

PURPOSE

To document FDO's responsibilities in the case of the loss of a thermal windowpane.

PROCEDURE

Once the loss of a thermal windowpane has been detected:

- Keep FD informed of status of abort options
- Give FD a heads up on end of abort windows:
 - Coming up on Negative Return
- Continue to make all abort boundary calls

NOTE: This case calls for a RTLS abort.

BACKGROUND

The crew will determine if the loss of a thermal windowpane has occurred and will call for an abort if that happens. This case requires a RTLS in order to minimize the thermal stresses on the remaining windowpanes. Therefore, FD will ask- to FDO to verify that we haven't flown past Negative Return. Ref. flight rule A2-54A.2.

6.11 Navigation/Flight Control Problems

6.11.1 Tracking Problems

PURPOSE

To document possible tracking problems, their impacts and procedural workarounds.

PROCEDURE

- NAV: Report any problems that impact tracking data to FDO. For example:
 - Loss of all tracking data
 - Loss of a radar
 - Loss of a ROCC computer
 - Disagreeing C-bands
 - Loss of S-band ranging
- NAV: Based on the impact of the problem, give FDO a filter GO/NO-GO status
- FDO: IF FILTER IS NO-GO, SELECT TM AS SELECTED SOURCE
 - INFORM FD OF LOSS OF TRACKING DATA
- FDO: IF NO FILTER AND NO TM:
 - INFORM FD
 - USE NO COMM ABORT BOUNDARY VIs FOR ABORT CALLS

BACKGROUND

There are several failures that can happen in the tracking network. Some of the failures are minor and have no impact on the data coming into the MCC. Some may result in loss of a single source that can quickly be replaced by another radar. There are several C-bands in the KSC area to choose from. The loss of a ROCC computer results in the loss of one of two paths of routing the data from the Eastern Range to the MCC. This just results in the loss of redundancy. Flight rule A3-51, Trajectory Processing Requirements, states that high-speed tracking data (both S-band and C-band) are only highly desirable for launch. Therefore, the loss of redundancy or total loss of tracking data is acceptable for launch.

NAV is responsible for determining the impact of the failure on the filter. The filter may be: GO with no impact, temporarily NO-GO followed shortly with being GO, and may be NO-GO indefinitely. If the filter is NO-GO, FDO will select

telemetry as the selected source, if telemetry is available. If telemetry is not available, then FDO will make the abort boundary calls using the No COMM velocities. In either case, FDO must inform FD of the failure and the impact.

6.11.2 Onboard Navigation Problems

PURPOSE

To document possible onboard navigation problems, their impacts and procedural workarounds.

PROCEDURE

- GPO: Monitors the health of the O/B nav. Possible problems include:
 - Bad IMU data taken into nav
 - BFS only impacted by bad IMU
 - PASS nav out of limits and causing the trajectory to deviate

- GPO and GNC:

- Work together to solve nav problem. Options include:
 - Deselect bad IMU(s)
 - Deselect bad IMU in the BFS
 - Perform a delta state update to the PASS
 - Force GPS into the BFS
 - Fly CSS until nav is corrected

- FDO:

- Maintain awareness of traj and range safety limits
- ARD is optimistic while crew is flying CSS
- Performance will degrade until return to AUTO
- AFTER NAV UPDATE, EVAL UPHILL (Possible loss of uphill capability)

- TRAJ:

- Advise FCO of the problem
- Verify K51 runway matches the onboard

BACKGROUND

The impacts of bad onboard nav can be significant. FDO must be aware that the bad nav may cause significant trajectory deviation from the nominal. GPO may instruct the crew to take over CSS using the Powered CSS cue card while the nav update is being worked. Currently, it is not possible to force a GPS vector

into the PASS during OPS 1. This is an option in the BFS. If nav is out of limits in the PASS, a delta state will be required.

While the crew is flying CSS, the ARD will be optimistic in its predictions since it assumes AUTO flying to the same MECO targets. Also, while the vehicle is deviating from the nominal trajectory the ARD's performance predictions will continue to decrease. In some cases, the performance loss may be significant enough to cause the loss of uphill capability.

6.11.3 Flight Control System Problems

PURPOSE

To document possible flight control system problems, their impacts and procedural workarounds.

PROCEDURE

- GNC: Monitors the health of the O/B flight control system. Possible problems include:
 - SRB TVC malfunctions
 - SSME TVC malfunctions
 - Bad control channel outputs
 - Sluggish control due to degraded hydraulic system
 - Potential loss of control
- FDO:
 - Maintain awareness of traj and range safety limits
 - ARD is optimistic while crew is flying CSS
 - Performance will degrade until return to AUTO
 - AFTER FCS CORRECTION, EVAL UPHILL (Possible loss of uphill capability)
 - If SSME manually shutdown, inform FD of the recommended abort.
- TRAJ:
 - Advise FCO of the problem

BACKGROUND

The impacts of flight control system problems can be significant. FDO must be aware that these problems may cause significant trajectory deviation from the nominal. The impacts on the trajectory are similar to the bad nav case. Reference SOP 6.11.2 for more background.

If the problem requires a SSME to be manually shutdown, FDO should inform FD of the recommended abort option.

6.11.4 BFS Engage

PURPOSE

To point out PASS/BFS differences and document console procedures for ascent on the BFS.

PROCEDURE

UPON BFS ENGAGE:

- FDO: CHECK NAV STATE w/GPO
- TRAJ:
 - PUSH V53 (TLM12), V56 (TLM10) STATE VECTOR PBIs
 - CONFIRM IYs FROM MPROP TREND
 - IF ATO:
 - IF BFS VMEO < V_MSSN_CNTN: ✓BFS IYs SELECTED
 - \geq V_MSSN_CNTN: GRAB NOM IYs*
 - AT MECO: VERIFY GND MECO FLAG SET (PUSH PBI IF REQ'D)
NO-GO FOR ET PHOTO PITCH MNVR

<p><u>BFS LIMITATIONS</u> NO CSS DURING PWD FLT NO SE CALLS (NO SERC) CSS POST-MECO, ENTRY</p>
--

*grab IYs after 10 sec delay from BFS engage or abort select

BACKGROUND

Flight rules dictate that the BFS will be engaged during ascent in the event of: loss of the redundant set (all PASS GPCs), loss of PASS capability to control the vehicle due to GPC/MDM failures, divergent trajectory, or no roll maneuver initiated after tower clearance. Additionally, some redundant set split scenarios during powered flight will be cause to engage BFS. For trajectory deviations, CSS may be selected after 1:30 MET prior to engaging BFS, in order to see if this re-gains control. BFS software was designed so that all necessary ascent/orbit/entry functions could be executed from a single GPC, without ever having to access mass memory storage. Due to memory constraints thus imposed, BFS has only minimal capability. Significant drawbacks are: no CSS/man throttle capability during powered flight, no single engine capability since single engine roll control was not implemented, and no contingency abort logic. Post-MECO attitude maneuvers and OMS burn attitude hold must be controlled manually. For a description of BFS limitations for entry, refer to section 4.7.2.6 of the FDO Console Handbook, Vol IV.

The primary console cue to indicate the crew has engaged BFS is a blinking "BFS Engage" DDD on the "FDO Ascent DDD" ROSS alarm panel. DPS will also make a voice call on the Flight loop. Following this, TRAJ should immediately click the V53 and V56 state vector PBIs in order to switch the onboard state vector source from PASS to BFS. This is to assure a valid TLM

state vector for the ARD and the Delta-state Processor. Another check TRAJ and ARD Support should perform is to verify good ly's. A one-to-one comparison on ARD Maintenance is not possible since BFS ly's are not downlinked. Therefore, indirect cues must be used, such as monitoring the nominal MPROP trend, or checking ARD ADI yaw value. If the margin trend is small, and ARD computed yaw angle is not increasing dramatically, then the ARD ly's are in sync with the BFS.

FDO should verify the health of the BFS nav state by checking with GPO and/or scanning FLTR-BFS state vector differences on FDO Launch Digitals. A significantly perturbed nav state could adversely affect ascent performance, requiring GPO to uplink a delta-state. BFS maintains a single nav state by tracking IMU data from PASS. Once PASS fails, or if BFS stops tracking PASS for some reason (BFS goes "stand-alone"), then the BFS continues propagating using the last DV from the IMUs. Therefore, the BFS nav state will degrade rapidly if engagement is delayed past about 10 sec.

Special logic is executed by the ARD Output code following selection of ATO while on the BFS (or engaging BFS following ATO abort). The ARD Output automatically selects the BFS ly's by performing a K84\$, K84B\$. During the next three ARD cycles, the BFS ly's are automatically grabbed and compared to the current BFS ly's in the Traj Server. Note that since the onboard BFS ly's are currently not downlinked, the "BFS ly's" that are grabbed are actually set equal to $-R \times V$ from the onboard BFS state vector. If the comparison shows the "grabbed" ly's are different from what's in the Traj Server, then the "grabbed" ly's are stored as the new BFS ly vector and used by the ARD. The intent of this logic is to enable the ARD to freeze to the same plane as the onboard following ATO selection prior to V_mssn_cntn. Grabbing the ly's multiple times is done to allow for data delays and guidance timing issues shortly after aborting ATO. TRAJ can monitor this action on Advisory Services as long as "Auto-MED" is on.

This logic is not desirable when ATO is performed with VMEO greater than V_mssn_cntn. Here the onboard will continue flying toward the nominal ly's, while the ARD will grab and use BFS ly's based on the current plane ($-R \times V$). This will result in the nominal MPROP margin decreasing slowly at first, with an increasing slope over time. ARD-BFS yaw steering commands will also show a growing difference. To fix this, FDO must manually select the NOM ly's using the ly selection menu at the top of ARD MON (equivalent to K84\$, K84N\$). This step should be delayed until after the ARD performs its automatic ly grab for 3 cycles--about 6-10 sec delay is sufficient. Then ly's can be verified as before, by monitoring nominal MPROP and steering commands.

ARD "Auto-MED" logic normally sets the MECO flag in the Traj Server based on telemetry, even while on BFS. However, some failures such as SSME data path, will inhibit this event from occurring. It is prudent to verify ground MECO for all BFS cases. The MECO light on "FDO Ascent DDD" ROSS alarm panel *does not*

work while on the BFS, since the purple “bad data” indicator from PASS overrides the ground MECO flag. For this reason, a dedicated ground MECO DDD was added to the “FDO Backup Launch PBIs” alarm panel. This indicator is not affected by telemetry, and thus won’t get stuck “purple” while on the BFS. At MECO, TRAJ should check the GND MECO DDD to see if the flag has been set in the Traj Server. If not, press the PBI to ship the MECO MED. Beware that pressing the PBI multiple times toggles the MECO flag on and off. If there is a significant delay in getting the flag set, TRAJ should adjust the MECO time on the AME Primary display back to the actual time of MECO (BFS TMECO on ARD Output).

6.11.5 SSME TVC Stuck Hardover

PURPOSE

To document console procedures for modeling SSME Thrust Vector Control (TVC) actuator stuck in the hardover position.

PROCEDURE

- IF C ENG STUCK HARDOVER IN -pitch (UP) OR L/R ENG STUCK HARDOVER +/- yaw (OUTBOARD):
 - TRAJ: MODEL APPROPRIATE THROTTLE LEVEL & Isp ON STUCK SSME w/ STUCK ACTUATOR ROSS ALARM:
 - SRB IGN \leq TF \leq 2:30: USE 2:30 VALUE
 - 2:30 < TF \leq 3:30: USE 3:30 VALUE
 - 3:30 < TF \leq MECO: USE 5:00 VALUE
 - FDO:
 - STUCK EO IN HM & 2HM
 - EVALUATE UPHILL CAPABILITY W/ ITEM 9 DUMP &/or ATO IF REQ'D
 - S/D STUCK ENG IF HM MPROP > AM MPROP. S/D C ENG NLT 7 MIN MET or L/R ENG AT PTM
 - EXPECT 50 FPS PERFORMANCE HIT DUE TO 6 DOF S/D EFFECTS
 - IF GOOD ENG OUT \rightarrow LOC.

Throttle Settings for ARD Modeling of an Actuator Stuck Hardover

SSME	Direction	Angle (deg)	TVC Failure Time (MET)	ARD UPDATE Throttle Setting
Center	Pitch	-10.5	2:30	100.0%
Center	Pitch	-10.5	3:30	99.9%
Center	Pitch	-10.5	5:00	99.8%
Left	Yaw	8.5	2:30	100.2%
Left	Yaw	8.5	3:30	100.1%
Left	Yaw	8.5	5:00	99.6%
Right	Yaw	-8.5	2:30	100.2%
Right	Yaw	-8.5	3:30	100.1%
Right	Yaw	-8.5	5:00	99.6%

BACKGROUND

It is possible for the actuators that drive the SSME gimbals to become stuck during ascent in either pitch or yaw. There are three possible outcomes: gimbal returns to null (neutral), gimbal locks in current position, or gimbal drifts well beyond the normal operating envelope to one of its extreme hardover conditions. There are four possible outcomes for hardover failures: 1) the failure occurs in first stage and flight with the SRBs is sustainable until SRB tailoff begins, so the stuck SSME is shutdown prior to 1:40 MET; 2) an immediate loss-of-control may occur, resulting in eventual breakup; 3) a bell collision may occur (within ~three seconds), which is also likely to result in vehicle breakup; or 4) the failure occurs in second stage, and the vehicle continues in controlled flight expected to last until 7:00 MET or SEPTM. The stuck SSME must be shut down by 7:00 MET (center SSME -pitch (up)) or single-engine press (left/right SSME +/- yaw (outboard) to ensure that controllability of the vehicle is maintained because the good actuators eventually reach their software control limits and loss of control soon follows (reference flight rule A8-2) if the hardover SSME remains on. For hardover cases with sustained controlled flight, proper execution of these procedures is essential for maintaining a "GO" ARD.

When an SSME actuator becomes stuck hardover, a portion of the thrust will be lost due to the SSME not pointing in the commanded direction. If the nominal thrust level is T , and the angle between the commanded and actual directions at any given time (t) is $\lambda(t)$, then the amount of thrust that is acting perpendicular to the commanded direction is $T\sin(\lambda(t))$. This is the amount of thrust loss as a function of time. This is sometimes called a "cosine loss", because the effective thrust of the engine with the stuck actuator is now $T\cos(\lambda(t))$.

During summer 2005, DM44 / B. Stahl and M. Abadie conducted analysis to understand how best to model this reduced effective thrust in the ARD. The throttle and I_{sp} values determined through this analysis should be used for hardover TVC failures only. The analysis concluded that throttle level and I_{sp} could be reduced on the sick SSME in the ARD in order to accurately model the effective thrust loss present on all three SSMEs. With one SSME stuck hardover, the other two SSMEs are deflected to compensate and maintain vehicle control. Consequently, there is actually an effective thrust loss on all three SSMEs.

Modeling the entire effective thrust loss on the sick SSME in the ARD has two main benefits. For one, the single update is much easier to perform than an I_{sp} and throttle setting update on three different SSMEs. Also, when the sick SSME is failed per procedures, the ARD will reflect the true vehicle configuration without further modeling steps because the ARD modeling is automatically taken out.

As mentioned above, the effective thrust is reduced as a result of a hardover failure. However, after a TVC failure occurs, the effective thrust increases slightly as a function of time (as compared to the effective thrust immediately

following the TVC failure) because the good SSME actuators gimbal to maintain a trimmed vehicle as the center of gravity changes. The single throttle setting required to model the hardover actuator is really an average over the time from TVC failure to failure of the stuck SSME. This approach yields a good estimate of performance and is far easier for the FDO team than making several throttle inputs as a function of time. The procedure states that the throttle value corresponding to the next TVC failure time should be selected from the table above. This is the most conservative approach because the later failure time corresponds to a lower throttle setting or lower effective thrust, and a lower effective thrust results in less performance predicted by the ARD. Note: Ben Stahl determined that three time points (2:30, 3:30 and 5:00) were required to model all cases.

The DM44 analysis derived the reduction in throttle setting both analytically and empirically through simulation runs. Both approaches agreed well with one another. Once the throttle setting is determined, the Isp is chosen to keep the mass flow rate constant. Even though the hardover SSME has a reduced effective thrust, the overall thrust is still the same. Since $Isp = \text{thrust}/\dot{m}$, a constant \dot{m} requires that Isp and thrust are decreased by the same proportion. This explains why $Isp_{NEW} = (TH_{NEW}/TH_{INITIAL}) * Isp_{INITIAL}$.

If no attempt is made to model the hardover SSME in the ARD, the Actual Mode (AM) NOM MPROP can easily trend as much as 50 fps/min while the hardover SSME is burning. But with the above modeling concept in place, the AM NOM MPROP trend is reduced to less than 3 fps/min. Thus, a small trend can be expected with this modeling, but performance predictions are substantially improved. As expected, once the hardover SSME is failed, the ARD remains accurately modeled.

FDO should realize that a bias must be applied to the EO ARD predictions. The DM44 analysis identified a jump in the hypothetical mode (HM) NOM MPROP when the sick engine is failed. The jump occurs for the center SSME stuck hardover in negative pitch, the left SSME stuck hardover in positive yaw, and the right SSME stuck hardover in negative yaw. Several 6 DOF simulation runs indicated that the HM NOM MPROP can jump down by as much as 30 to 50 fps at the engine failure time due to vehicle pitch or yaw transients not modeled in the ARD. While the ARD is accurately modeling the loss in effective thrust, this is achieved by reducing the thrust of one SSME and not by actually gimbaling the sick SSME to hardover and the other two SSMEs to compensate. As the sick engine fails, the thrust directions of the good SSMEs quickly change, which induces vehicle pitch or yaw transients. These transients reduce performance of the vehicle, but the ARD is unaware of these transients. The 30 to 50 fps bias accounts for this discrepancy.

The DM44 analysis was performed using STS-114 OCF Ascent/Entry Trainer runs and STS-114 OCFR2 IPS STAMPS 6 DOF simulation runs. No flight-to-flight sensitivity analysis was performed with other missions; however, the throttle levels required to model the stuck actuator should not substantially change from

one ISS mission to the next. No sensitivity was performed for other inclinations either. It is not known whether due East missions will require different throttle modeling. This should be evaluated if another Hubble repair mission is manifested.

As long as the ARD HM is configured with the sick engine out, the 2-engine abort boundaries will be mostly accurate assuming that only the sick engine fails. If one of the good engines fail after a hardover TVC failure has occurred, loss of control will be imminent, and GNC will call for an immediate shutdown of the hardover SSME. In fact, if the failure of the good SSME was predicted, GNC would have called for the hardover SSME to be shutdown prior to the good engine failure to avoid loss of control.

Flight reconfiguration is required to maintain the Stuck Actuator Ross Alarms application. The throttle levels will not change from flight to flight, but since the Isp is a function of the nominal Isp, these values must be updated for all three engines once the DOLARD file is loaded.

Reference ACME presentation "SSME Stuck Actuator ARD Modeling" presented on August 10, 2005 and DM44 Note of Interest NOI DM44-06-0805.

6.12 Environment Dispersions

6.12.1 DOL Winds Effects (Report to FD)

PURPOSE

To document possible day of launch trajectory dispersions due to winds aloft.

PROCEDURE

- FDO:
 - Note any unexpected trajectory deviations (Alt vs RGO)
 - Verify good selected source
 - Report to FD (e.g. trajectory is lofted/depressed more than expected)
- TRAJ:
 - Advise FCO of the deviation

BACKGROUND

There should be very little deviation due to winds now with the use of DOLILU II. This day of launch (DOL) process recomputes the entire first stage I-loads to compensate for day of launch winds and atmosphere using the close to launch mass properties. The net result is that this re-design effort tries to correct the nominal trajectory back towards the original trajectory. There still may be some offset from the original, but it is usually very small. Any expected deltas can be seen prelaunch in the plots generated by the DOL team.

If any trajectory deviations are noticed that are larger expected, then they should be passed to the Flight Director. This is just an advisory since no action will be taken. There's no way to tell in real-time what environmental factor caused the deviation.

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6.13 Other System Dispersions

6.13.1 Hot/Cold SRBs

PURPOSE

To document the impacts of Hot/Cold SRBs.

PROCEDURE

- FDO:
 - At ~ 22 seconds, check TDEL
 - IF TDEL < -.021 or > +.021, expect two stage bucket

- TRAJ:
 - At ~ 22 seconds, check TDEL
 - IF TDEL < -.21 or > +.21
 - Verify bucket throttle levels
 - Verify DELWT (AGT product)
 - If DELWT is incorrect, have DYN input correct value as DELWT Override
 - Verify FDO copies throttle bucket

BACKGROUND

At around 17 seconds MET, the onboard will compute the difference between the time the vehicle reached an I-loaded relative velocity and the prelaunch computed time. This delta time is referred to as Tdel_adjust or simply Tdel. The value of Tdel is theoretically indicative of SRB performance. The throttle bucket is adjusted based on the value of Tdel if Tdel is outside of the deadband (± 0.21 seconds). A negative value indicates that the Shuttle achieved the I-loaded velocity earlier than expected, and the SRBs are termed "hot". Conversely, a positive Tdel indicates "cold" SRBs.

The ARD computes a value for Tdel based on the PASS if available. If Tdel is outside of the deadband, both TRAJ and ARD SUPPORT look up the expected throttle settings for the computed Tdel on a table generated by flight design (Adaptive Guidance Table or AGT).

The ARD does not adjust its throttle bucket. Instead, the ARD computes a delta weight (DELWT) based on Tdel and applies that delta weight to the ET propellant. TRAJ and ARD SUPPORT use the AGT to verify that the correct value of DELWT is computed. For extremely large values of Tdel, ABORT SUPPORT may recommend a correction to the DELWT. This may happen

because the equations used by the ARD to compute the DELWT may start deviating from the actual correct value for $T_{del} > 2\sigma$. The correct value is input on the K67 MED as a DELWT Override.

One of the other changes introduced by DOLILU II (STS-70 and subs) was the adjustment of the T_REF_Adjust I-load. This is the reference time used in computing Tdel. This parameter is now re-computed on DOL and uplinked with the other DOLILU parameters. This essentially "re-centers" the reference time based on the expected conditions on DOL. Therefore, if the SRBs perform nominally the Tdel will have a value 0.00 seconds.

7 POST-MECO

7.1 Standard Post-MECO Procedures

PURPOSE

This procedure outlines the standard calls and procedures that must be executed in the Post-MECO timeframe. Off nominal procedures are referenced but not contained in this section.

PROCEDURE

IMMEDIATELY POST-MECO:

√ MECO STATE (FDO LAUNCH DIGS)

- U/S
- HA / HP
- TIME OF APOGEE → ~OMS-1/2 TIG = $T_{HA} - 1$ or 2 MIN

IF HA < 95 OMS-1 REQUIRED

- **CALL:** FLT/FDO XX FPS U/S , OMS-1 REQ'D, NO-GO ET PHOTO
- GO TO OMS-1 TARGETING PROCEDURES

IF HA > 95, OMS-1 NOT REQUIRED

- **CALL:** FLT/FDO [NOM MECO OR XX FPS U/S], OMS-1 NOT REQ'D,
- IF U/S ≤ 26 FPS, **CALL:** GO FOR ET PHOTO
- IF U/S > 26 FPS, **CALL:** NO-GO ET PHOTO
- BRING UP AME PRIMARY, DMT1, DMT2, MNVR MON, EPH
PROF STAT

AT FILTER STOP:

- **TRAJ:** GO TO OPS PHASE
 - ANCHOR ON V58
 - INPUT ATO DUMP WGL IF REQ'D
 - EXECUTE AME (SINGLE PASS, PREFERRED TARGET SET)
 - √ AME SOLUTION, MPS AND OMS-2
 - IF AME GOOD, TRANSFER AME → DMT 1 & 2
 - ELSE, RUN AME OMS-1/2 PLANNING
 - VECTORS V58/59
 - GET GOOD MPS AND OMS-2 SOLUTION
 - TRANSFER AME → DMT 2 & 1

POST MPS DUMP SV → V1 → NETWORK

AT ~FILTER STOP + 1:00

- **FDO:** BRING UP VECTOR COMPARE 1
STATUS NAV ON BEST VECTOR SOURCE (V58, V59, V60, V61)
EVALUATE ET LIGHTING (IF REQUIRED FOR PHOTOGRAPHY)

POST MPS DUMP:

- **TRAJ:** RE-ANCHOR EPH-1 IF REQ'D
 - CONFIRM MPS DUMP → DMT2
 - IF ANCHORED ON O/B: GRAB V53 → V1, RE-ANCHOR EPH 1
 - POST MPS DUMP SV → V1 → NETWORK

START OMS-2 PLANNING:

- **FDO:** DISCUSS OMS-2 PLAN WITH **PROP AND TARGETING**
(NOM TARGETS, ATO, MIN HP?)
 - GET TARGET SET# FROM **TARGETING**
 - IF RNDZ: GO TO PROCEDURE 7.1.9
- **TRAJ:** RUN AME
 - DESIRED THRUSTERS (FROM **PROP**)
 - VECTORS: V1/V53
 - DESIRED TARGET SET#
 - REAL-TIME PEG-4 TARGETS REQ'D? → IF YES, Ref. SOP 7.3.4
 - EVALUATE SOLUTION WITH **TARGETING**
 - TRANSFER AME → REPLACE OMS-2 → DMT 1
 - POST OMS-2 VECTOR → V2 → NETWORK
- **FDO:** EVALUATE OMS-2
 - ✓ DMT 1
 - PASS PLAN / TIG TO FD
 - GIVE GPO GO TO BUILD COMMAND LOAD (IF REQUIRED)
- **TRAJ:** RUN AME
 - RUN FD1 PLS ST/SH D/O, ΔV 's → **PROP** (FD2 PLS IF FD1 PLS ↓)

EVALUATE AOA:

GO TO AOA PROCEDURES

BACKGROUND

These steps are the nominal procedures executed by FDO and TRAJ post MECO for an uphill case. They include evaluating MECO conditions (OMS-1 required?), running the AME, evaluating the best state vector source, setting up ephemeris 1, evaluating ET lighting for possible photography and generating deorbit ΔV s for flight day 1. Also, FDO must evaluate the best post MECO option and recommend the appropriate targets for OMS-2.

7.1.1 OMS-1 Targeting

PURPOSE

This procedure outlines the Post-MECO procedures that must be executed in the event of a large underspeed that requires that an OMS-1 burn be executed. An OMS-1 burn is required anytime the post-insertion apogee is less than 95 nmi.

PROCEDURE

This procedure assumes that the underspeed and OMS-1 required calls have already been made the Flight Director. If not, do so now.

- **FDO:** PASS PRELIMINARY OMS-1 TIG AND TGT SET TO **FD**
 - TIG = TIME_{HA} - 2:00 (GET TIG FROM AME OR T_{HA} FROM FDO LAUNCH DIGS)
 - ✓ AME RESULTS
 - ✓ OMS-1/2 TARGETING CARD
 - **TARGETING:** OMS-1 TARGET SET [USUALLY TGT SET 1] →

TGT SET 1 = COMMON TARGET SET. OMS-2 CAN BE UPHILL OR AOA
TGT SET 5 = AOA SHALLOW

AT FILTER STOP:

- **TRAJ:** GO TO OPS PHASE
 - ANCHOR ON V58
 - INPUT ATO DUMP WGL IF REQ'D
 - EXECUTE AME (SINGLE PASS, PREFERRED TARGET SET)
 - IF AME GOOD, TRANSFER AME → OMS-1 TO DMT 1, MPS dump TO DMT 2
 - ELSE, RUN AME OMS-1/2 PLANNING SINGLE PASS
 - VECTORS V58/V59
 - GET GOOD OMS-1 SOLUTION
 - TRANSFER AME → OMS-1 TO DMT 1, MPS dump TO DMT 2
 - POST MPS DUMP → V1 → NETWORK

AT ~FILTER STOP + 1:00

- **FDO:** BRING UP VECTOR COMPARE 1
STATUS NAV ON BEST VECTOR SOURCE (V58, V59, V60, V61)
- **TRAJ:** RE-ANCHOR EPH-1 IF REQ'D

This procedure continued on following page...

POST MPS DUMP:

- **TRAJ:**
 - CONFIRM MPS DUMP → DMT2
 - POST MPS DUMP → V1 → NETWORK

RETARGET OMS-1 USING THE POST MPS VECTOR

- **TRAJ:** RUN AME
 - DESIRED THRUSTERS (FROM **PROP**)
 - GRAB O/B VECTOR (FETCH V53); MOVE TO V1 IF ANCHORED ON O/B
 - VECTORS: V1/V53
 - OMS-1 TARGET SET
 - EVALUATE SOLUTION WITH **TARGETING**
 - TRANSFER AME → REPLACE MANEUVER 2 → DMT 1
 - POST OMS-1 VECTOR → V2 → NETWORK

7.1.2 ET Feedline Disconnect Failure

PURPOSE

This procedure outlines the procedures that must be executed in the event of a ET feedline disconnect failure.

PROCEDURE

This procedure assumes that the crew will follow the checklist procedure for this failure. The checklist calls for the crew to inhibit the ET sep until MECO + 6 minutes or OMS-1 TIG – 1:30, whichever comes first.

The main things here are that the MPS dump will still occur at MECO + 2 and the onboard TIG for OMS-1 and/or OMS-2 will be incorrect due to the delayed ET sep.

- TRAJ
 - IF IN THE AME, TRANSFER AME SOLUTION TO EPH 1
 - DO ΔV OVERRIDE OF **7.5** FPS OF MPS DUMP (DUE TO INCREASED WEIGHT OF ET)
 - MOVE POST DUMP VECTOR TO V1
 - IF OMS-1 REQUIRED, VERIFY TIG IS AT TTA = 2. ADJUST TIG IF REQUIRED.
 - TRANSFER TO EPH 1, REPLACING OLD OMS-1 (IF REQUIRED) AND OMS-2.
- FDO
 - IF OMS-1 REQUIRED, REPORT FINAL TIG TO FD ONCE KNOWN
 - INFORM FD THAT CREW MUST MANUALLY UPDATE OMS-1 TIG

BACKGROUND

The ET feedline disconnect failure requires delaying the ET sep to allow pressures to be reduced in the lines first. The standard procedure has the crew inhibit the auto ET sep and then perform a manual sep at MECO plus 6 minutes. However, if OMS-1 is required and the TIG is before MECO + 6, then the ET sep is performed a TIG minus 1 and ½ minutes. In either case, the OMS-1 and/or OMS-2 TIGs onboard will be incorrect since they are computed by adding a delta time to the time of ET sep. Therefore, the crew will have to manually update the OMS-1 TIG. The OMS-2 TIG will be fixed if OMS-2 targets are uplinked. Otherwise, the crew will also have to manually fix the OMS-2 TIG.

7.1.3 ET Photography Go/No-Go

PURPOSE

To document the proper procedure for determining the Go/No-Go status for performing ET photography post MECO.

PROCEDURE

- GO/NO-GO CALL IS MADE AFTER MECO WITH THE MECO U/S REPORT
 - NO-GO IF U/S>26
 - NO-GO FOR +X IF ET SEP IS IN DARKNESS* **
 - NO-GO FOR PITCH MNVR IF NO LIGHT (MECO + 4 TO OMS-2 TIG – 9 MINUTES) **
 - NO-GO FOR +X IF IMPACTS RENDEZVOUS (LARGE PHASE ANGLES) ***

* RENDEZVOUS FLIGHTS MAY BE AN EXCEPTION FOR CERTAIN PHASE ANGLES (+X MAY BE REQUIRED FOR PHASING).

** REQUIRES PRE-FLIGHT ANALYSIS OF SR/SS DATA.

*** THE +X MANEUVER WILL DECREASE THE MAX ACCEPTABLE PHASE ANGLE, THEREFORE WILL NOT BE DONE AT THE END OF THE PHASE WINDOW.

BACKGROUND

ET photography is performed on most missions when possible to allow post-flight analysis of the tank insulation. There are two methods for performing this photography. One is the use cameras in the ET umbilical well. However, these cameras are not always manifested. A +X translation of 11 seconds is performed immediately after ET sep to do the photography with the umbilical well cameras. The other method is for the crew to take pictures through the overhead window with a handheld camera. This requires a pitch maneuver to be performed are the MPS dump to get the ET in view. The FDM can verify if one or both methods has been approved for the mission.

There are three reasons for FDO to NO-GO the photography of the ET after MECO. If the ET sep occurs in darkness, then the photography with the umbilical well cameras will not work. However, even though the sep may be in

darkness, the +X may be required for rendezvous phasing (opening of the phase window). Similarly, there may be some cases where the +X will impact rendezvous phasing (close of the phase window) and will not be desired. The Lead FDO will be able to determine what phase angles must have the +X for phasing.

Another reason to NO-GO the ET photography is if the entire time from MECO plus 4 minutes (post MPS dump) to OMS-2 TIG minus 9 minutes is in darkness. This timeframe is the window of opportunity to perform the ET photography through the overhead window. This is based on the groundrule that the maneuver to OMS-2 attitude will be done no later than TIG – 8 minutes and that at least 1 minutes between ET sunrise and the maneuver to attitude is required to make the pitch up maneuver worthwhile.

The other reason that FDO would NO-GO the ET photography is based on a MECO underspeed greater than 26 ft/sec. This was based on the resulting underspeed for a 3 sigma nav error.

The analysis of the ET lighting must be done pre-flight. In order to verify the lighting, SR/SS must be executed. The TSA ephemeris may not allow modeling the MPS dump at MECO + 2 minutes. The dump may be delayed slightly to get it to work. The SR/SS processor may require an OMS-2 in the ephemeris in order to run.

There are other systems reasons for NO-Going the ET photography (ref. FR A2-68).

7.1.4 Launch to OPS or Landing Phase Transition

PURPOSE

To document the proper procedure for when to make the transition from Launch to OPS or Landing phase in the Traj Server after MECO.

PROCEDURE

TRAJ

- NOM and ATO:
 - Go to OPS phase
 - Tracking data available: after NAV calls "Filter Stop" (~ MECO + 1:30)
 - No Tracking: ASAP after MECO
- TAL, RTLS and ECAL:
 - Go to LANDING phase ASAP after MECO

BACKGROUND

The time to transition from Launch to OPS phase is dependent on the scenario. On uphill runs, it is desired to allow NAV to continue to process high-speed tracking through post MECO (launch phase is required). It takes approximately 45 seconds for the filter to re-converge after the transition from powered-flight to coasting flight. NAV will continue to run the filter until either the data starts getting noisy due to low elevation or the elevation angle gets below 3 degrees. In either case, NAV will make a "Filter Stop" call to FDO when this has happened.

On a TAL, RTLS or an ECAL, there is no transition from Launch to OPS phase. Instead, the transition is from Launch directly to Landing phase. The MOC restriction that applied to TAL that required going to OPS phase in order to generate an entry set no longer applies.

7.1.5 Anchor Vector Selection

PURPOSE

To document the proper procedure for determining the anchor vector for Ephemeris 1 after MECO.

PROCEDURE

The choices for anchor vector are:

- V58 – Selected source at MECO + 30 and MECO + 60 seconds
- V59 – Telemetry state at MECO + 30 and MECO + 60 seconds
- V60 – Selected source at Filter stop
- V61 – Telemetry state at Filter stop
- V53 – Latest “grabbed” onboard state vector

NOTE: For both V58 and V59, the MECO + 60 state vector over-writes the MECO + 30 state vector.

FDO:

- View Vector Compare 1
- Determine NAV's recommendation
- Choose Anchor Vector and inform TRAJ

TRAJ: Anchor EPH 1 on VXX.

BACKGROUND

Post filter stop, NAV will call FDO and display V58 – V61 in Vector Compare 1. NAV will then make a recommendation for the anchor vector. The filter state vector is preferred. If the filter didn't re-converge post MECO or the tracking data was suspect, then the onboard (usually V59) will be recommended.

7.1.6 Ephemeris Weight Configuration

PURPOSE

To document the proper procedure for configuring the vehicle weight in Ephemeris 1 immediately after MECO.

PROCEDURE

If no off-nominal prop dumps: No Change Required

If prop dumps executed during powered flight (e.g. ATO, OA modified):

- Enter a WGL just after ephemeris start or modify the init weight
 - Obtain Δ WT value from ARD Support, Targeting or PROP

BACKGROUND

The AME will automatically pick up any weights changes due to any pre-MECO dumps that were modeled in the ARD. However, these changes do not automatically get to the ephemeris. Therefore, the weight change must be entered manually. The initial weight may be modified or a Weight/Gain Loss entry may be input just after the ephemeris start time.

7.1.7 State Vectors for Tracking Network

PURPOSE

To document the proper procedure for getting the post MECO state vectors to GSFC's Flight Dynamics Facility (FDF). They are used for computing acquisition data for the tracking network.

PROCEDURE

TRAJ:

Post AME transfer to EPH 1:

- Verify good MNVR 1
- Transfer burnout of planned MNVR 1 to V1 (Before MET 15:00)
- Inform DYN that V1 is GO for the network

Post MNVR 1 confirmation:

- Run AME (OMS-2 plan)
- Transfer AME to EPH 1, replacing MNVR 2
- Verify good MNVR 2
- Transfer burnout of MNVR 2 to V2 (Before MET 25:00)
- Inform DYN that V2 is GO for the network

NOTE: If OMS-1 is required, OMS-2 may be MNVR 3. In this case, the burnout should go to V3 and also be sent out by MET 25:00.

BACKGROUND

The standard agreement between MOD and GSFC's FDF is that we provide our best state vector for initial acquisition planning at an MET of 15 minutes. This is based on either the MPS dump or OMS-1 if an early OMS-1 is required. The post OMS-2 state vector is desired by an MET of 25 minutes. Of course, an earlier delivery of these vectors will be gladly accepted. The 15 minute constraint does not allow waiting until the MPS dump is confirmed, therefore a planned MPS dump burnout vector is used. Similarly for OMS-2. After the maneuvers are transferred to the ephemeris and verified, DYNAMICS will move the burnout vectors to the VAT and on TRAJ's GO, will tell TRACK that the vectors can be sent to the FDF.

7.1.8 PEG-7 Targets

PURPOSE

This procedure is used model an OMS-2 burn with PEG-7 targets when PEG-4 targets cannot be used.

PROCEDURE

FDO:

- Determine desired Hp (Min, 105, nom, etc.). Coordinate with PROP.

TRAJ:

- Determine PEG-7 targets
 - Run AME with appropriate target set (1, 2, 16, 18 or 20)
 - Get PEG-7 targets from AME output
 - Direct input mnvr into ephemeris

BACKGROUND

There may be some rare case where the PEG-4 targets cannot be used for OMS-2. In this case, the PEG-7 targets can be obtained from the AME display once the desired OMS-2 targets are executed in the AME.

7.1.9 Pre-OMS-2 State Vector Update for Ground-Up Rendezvous

PURPOSE

This procedure is used to evaluate the need for an update of the onboard state prior to OMS-2, in order to reduce subsequent out-of-plane rendezvous maneuver costs. It applies to ground-up rendezvous missions only.

PROCEDURE

IF: $ABS(Wdot) < 6$ fps OR a good TRK SV is NOT available (\checkmark with NAV)

THEN: pre-OMS-2 SV update is not required (EXIT procedure)

ELSE:

- Anchor EPH1 on TRK SV (V58 or V60)
- Confirm MPS Dump/OMS-1 in EPH1
- Transfer burnout to V1 or V2
- Run AME: OMS-2 targeting on V1/V1 or V2/V2
- Transfer AME to EPH1; DO NOT FREEZE OMS-2
- If variable-Hp OMS-2:
 - Compute updated Hp: Have FDO SUPPORT run OMP w/OMS-2 plan with post-MPS/OMS-1 TRK SV
 - Update OMS-2 PEG-4 HT in EPH1
- Run OMP w/NPC plan off EPH1 *OMS-2 burnout*.
NPC cost assuming uplink performed = _____ (UPD)
- GRAB O/B VECTOR (FETCH V53)
- Freeze EPH1 OMS-2 on current O/B SV (post-MPS/OMS-1)
- Run OMP w/NPC plan off EPH1 *OMS-2 burnout*.
NPC cost assuming no uplink = _____ (NO UPD)

- IF $ABS(NO\ UPD) - ABS(UPD) \geq 6$ fps THEN

1. Inform FD and GPO: Pre-OMS-2 SV update is required.

NPC Savings of _____ (UPD) fps > update criterion of 6 fps.

2. Inform GPO: EPH1 go for pre-OMS-2 SV update.

3. Once O/B state has been updated, **Unfreeze** EPH1 OMS-2 mnvr

- IF $ABS(NO\ UPD) - ABS(UPD) < 6$ fps THEN

Inform FD and GPO: Pre-OMS-2 SV update is not required.

NPC Savings of _____ (NO UPD) fps < update criterion of 6 fps.

BACKGROUND

This procedure allows the FDO to determine if an out-of-plane ΔV savings can be realized by updating the state vector prior to OMS-2. It requires that the FDO compute two rendezvous profiles to determine the NPC ΔV with and without an update. For this analysis, the OMP plan used must assume that OMS-2 has been executed. Therefore, a post-OMS-2 state vector is used when performing the evaluation. One OMP run assumes that the onboard state is updated, while the other based on the OMS-2 frozen on the onboard assumes that the update is not performed. If the NPC savings is greater than or equal to 6 feet/second and the state vector update is performed, then the OMS-2 should be unfrozen prior to execution.

The three criteria which must be satisfied to perform the update are documented in flight rule A4-57.F. The validity of the filter solution, which requires at least 30 sec of post-MECO tracking, is performed by NAV. The post-MECO Wdot check is performed using the Vector Compare display. If either of these two criteria are not met, then there is no need to perform this procedure, since either the planar accuracy of the onboard state is sufficient or a valid filter solution is not available for comparison. The A/E FTP approved a minimum ΔV savings of 6 ft/sec before allowing an update. The 6 ft/sec is based on the accuracy of the filter state vector at MECO + 30 sec.

7.1.10 DOL Ascent Summary

PURPOSE

Documents the procedure for writing a quick-look ascent summary after OMS-2 has been completed. This is a preliminary Ascent FDO post-launch report compiled primarily for the Flight Director.

PROCEDURE

All steps are completed/coordinated by the FDO.

- At a convenient point post-OMS-2, coordinate a tag-up on MOCR DYN with TRAJ, ARD Support, Abort Support, and Targeting.
- Request from all participants the data required to complete the form (details below).
- When multiple times and velocities are received, “average” them as appropriate to result in the most accurate “actual” value. Remember that these values are preliminary “quick-look” data only.
- Call up the blank form on the PC under \divisions\dm\private\dm46\forms\ASC SUMMARY.doc. Enter “actual” and “predicted” values, with the predicted values (final pre-launch values) in brackets immediately to the right of the actual values.
- After the report has been completed, sign it at the bottom and give copies to FD, MOD, PAO, GPO, and CAPCOM. Put the original in the FDO log.
- Detailed Item Descriptions
 1. FLIGHT NUMBER: Enter the proper flight number in the header section.
 2. LIFTOFF: Actual liftoff time from FDO Launch Digitals.
 3. TDEL: Actual value from ARD Output. Use the PASS value unless BFS engage occurred prior to the throttle bucket. The predicted value is 0:00.
 4. Throttle Bucket: Actual and predicted throttle bucket commands from Abort Support.
 5. Performance: Actual performance call (Nominal or Low).
 6. Abort Mode Boundaries: Actual values from the post-OMS-2 tag-up; predicted values from Abort Support based on the DOL Bench ARD run.
 7. ARD Thrust Update:

- Either Update “WAS” or “WAS NOT” performed: Enter the nominal margin trend rate (from TRAJ or ARD Support).
8. MECO Command time: Actual MECO command time from ARD Output. Use PASS value unless BFS was engaged prior to MECO. Obtain the predicted time from ARD Support or Abort Support.
 9. Zero Thrust Conditions: Use TSA Checkout Monitor of the best post-MECO state vector (from NAV), per the following instructions:
 - A. If no +X photo DTO translation performed, propagate the best post-MECO state vector backwards to MECO command time + 7 sec.
 - B. If +X translation for ET photography performed:
 - i. Propagate the best post-MECO state vector backwards to MECO command time + 26 sec.
 - ii. Anchor an EPH with this state vector using the MECO weight.
 - iii. Model the translation as a BFI maneuver with the following inputs:
 - Pitch/Roll/Yaw = 0 / 180 / 0
 - TIG = MECO command time + 26 sec
 - T = N sec, where N is the actual Δt of the maneuver from PROP
 - Thruster = PX4
 - iv. Replace the maneuver with a PEG-7 maneuver with the opposite signs of the PEG-7 components from the BFI maneuver in step iii. Use the same TIG as in step iii.
 - v. Propagate the burnout state vector backwards to MECO command time + 7 sec. This is the zero thrust state vector.
 10. MPS Dump: Start time is obtained from Booster. The actual ΔV , apogee and perigee are obtained from the DMT of the confirmed dump. Predicted values are obtained from the planned maneuver in EPH 3.
 11. OMS-2: All the actual values are obtained from the DMT after the maneuver has been confirmed. The predicted values are obtained from the planned maneuver in EPH 3.
 12. Notes: Enter any unique notes required based on day-of-launch activities.

BACKGROUND

Self-explanatory.

LIFTOFF AT xxxx/xxx:xx:xx:xx.xx GMT

TDEL: x.xxx sec [x.xxx] **THROTTLE BUCKET:** xxx/xx% [xxx/xx]

PERFORMANCE: NOMINAL

<u>ABORT MODE BOUNDARIES:</u>	<u>MET (mm:ss)</u>		<u>VI (fps)</u>	
TWO-ENGINE <prime>	x:xx	[x:xx]	xxxx	[xxxx]
NEGATIVE RETURN	x:xx	[x:xx]	xxxx	[xxxx]
PRESS-TO-ATO	x:xx	[x:xx]	xxxxx	[xxxxx]
DROOP <prime/acls> 109	x:xx	[x:xx]	xxxxx	[xxxxx]
PRESS-TO-MECO	x:xx	[x:xx]	xxxxx	[xxxxx]
SINGLE-ENGINE <prime/acls> 104	x:xx	[x:xx]	xxxxx	[xxxxx]
SINGLE-ENGINE PRESS 104	x:xx	[x:xx]	xxxxx	[xxxxx]

ARD THRUST UPDATE WAS PERFORMED.

NOMINAL MARGIN TREND RATE: x fps/min;

MECO COMMAND:
 VI (ZERO THRUST): x:xx.x MET [x:xx]
 xxxxx fps [xxxxx]
 H_A x H_p (ZERO THRUST): xxx.x x xx.x nm [xxx.x x xx.x]

MPS DUMP:
 ΔV: xx:xx MET [xx:xx]
 xx.x fps [xx.x]
 H_A x H_p: xxx.x x xx.x nm [xxx.x x xx.x]

OMS-2:
 ΔV: xx:xx.x MET [xx:xx]
 xxx.x fps [xxx.x]
 H_A x H_p: xxx.x x xxx.x nm [xxx.x x xxx.x]

7.1.11 Post-MECO OMS Dump to Max Blowdown for Ground-up Rendezvous missions

PURPOSE

This procedure is a deviation from the standard procedure in the Ascent Checklist, the purpose of which is to dump OMS propellant for an OMS helium leak. The modification to the maneuver is to burn the propellant radially versus out-of-plane. This may result in preserving the option to perform the rendezvous without compromising subsequent deorbit capability and crew safety.

PROCEDURE

Obtain $V_{\max bd}$ (delta V to max blowdown) from PROP. Provide the following PEG-7 targets to the crew (to replace the standard Ascent Checklist out-of-plane targets):

TIG = 000/00:20:00 MET

V_x = $V_{\max bd}$ if resulting $HA \leq HA_{\max}$ ($HA_{\max} = HA_{tgt}-5$, unless otherwise provided by FDO Support), else

= $V_{\max bd} - 2*(HA-HA_{\max})$

V_y = 0

V_z = $SQRT(V_{\max bd}^2 - V_x^2)$

BACKGROUND

The intent of this procedure is to efficiently use as much of the dumped OMS as possible. Therefore, it is desired to raise apogee to just below that of the target spacecraft. Using the standard procedure would certainly cause the loss of the rendezvous, since this significantly large out-of-plane burn would introduce a large planar error without significantly changing orbital energy.

The targets have to be computed on a flight-specific basis since the amount of OMS to dump to reach max blowdown varies.

7.1.12 7.1.12 Nominal Post-OMS-2 Console Reconfiguration

PURPOSE

Provide procedural details for configuring the console for orbit ops during the post insertion timeframe.

PROCEDURE

- FDO, TRAJ: DEACTIVATE ABORT SWITCH SOFTWARE (SOP 9.5.8)
- FDO, TRAJ: LOG OFF OF COMMAND MANAGER
- LENGTHEN EPH 1 TO 48 OR 72 HOURS
- OPS 2: CONFIGURE ROSS STATE VECTOR PBI'S:
 - V54 BFS → TGT
 - UPP PBI → FILT
- DCT COLUMNS 3 AND 6: C1=0, C2=0, RANGE=0 (UNLESS LOW ORBITAL ALTITUDE)
- TRANSFER RENDEZVOUS PLAN TO EPH1 AND 2.

BACKGROUND

Clean-up steps have FDO and TRAJ deactivate the abort switch software and log off of the Command Manager. Increasing the length of ephemeris 1 allows MARS/FDO SUPPORT to transfer an updated and complete rendezvous profile to be transferred. After the transition to OPS2, reconfigure state vector PBIs for orbit ops. The Deorbit Constraints Table is reconfigured back to the standard orbit/entry config with the initial guesses for C1, C2 and Range zeroed out. . The final step is to have MARS/FDO SUPPORT transfer a complete, updated rendezvous maneuver plan into eph 1 and 2. Following this, the console is ready for the orbit team to take over.

7.2 AME Operations

The following sections describe the standard procedures/options for operating the Abort Maneuver Evaluator (AME).

7.2.1 Multi-target mode

This method of executing the AME is used initially after the receipt of the MECO PBI. The multi-target mode executes the AME through an entire list of pre-selected targets sets. All the costs of each option are computed. Those target options that are possible with the propellant available are displayed in cream color, while the ones that are not achievable are displayed in red.

Multi-target mode is the default when executing the AME. The AME is set up to automatically execute (auto-queue) at MECO + 6, 30 and 60 seconds. The MECO + 6 second cycle using only the telemetry state vector while the other two cycles use the selected source vector for the primary state vector for modeling the trajectory up to the first maneuver. The auto-queue's default settings are for the AME execute multi-target mode with ALL targets. This means that the AME will start after the MECO PBI is shipped and will execute all the targets in the AGT. The MECO PBI first stops the ARD, ETIP, and DAE and then the vehicle, OMS and RCS weights are transferred from the ARD to the AME before the first execution of the AME. The recon process may deliver sequence slot 1 to be used in the auto-queue sequence.

Targets used by both the AME and the Flight Software (FSW) for OMS-1 and OMS-2 are stored in targets sets that are I-loads. The target options are usually referred to A/B where A is the OMS-1 target set and B is the OMS-2 target set. For example, the ATO/Min Hp target set has an ATO OMS-1 burn followed by an OMS-2 to raise perigee to the minimum Hp. The target set ID numbers (ITGT) are found in the ASAB30 product.

The typical list of target sets that are in the multi-target sequence 1 (standard downmode) used by the AME are listed below. This list of targets is in order of priority.

- Nominal (ITGT 16)
- ATO/Min HP (ITGT 2)
- ATO/AOA-ST (ITGT 6)
- ATO/AOA-SH (ITGT 7)
- AOA-SH/AOA-SH (ITGT 5)

NOTE: AOA-ST = Steep AOA,
AOA-SH = Shallow AOA

The list of targets can be easily modified on the AME Primary display. The multi-target sequences can be viewed in the upper right corner. Each sequence is shown in a column under the numbers. The targets selected for each sequence each have a "X" in the box in the column. To add another target set to a sequence is easy as clicking the mouse in the appropriate box. This usually should not be required since the target sequences are delivered in the recon process.

7.2.2 Single-pass Mode

The other option for executing the AME is the single-pass mode. This mode allows the AME to be executed for a single target set that is user-specified. For example, if FDO wanted to evaluate the ATO/ATO target set (ITGT 1), then that target set ID number would be selected as well as selecting the single-pass mode before queuing the AME. The desired target set is selected by clicking on the target ID number under the OMS targets column. The AME Primary display allows all these options to easily be selected by the user. After the single-pass execution is complete, the results can be viewed on the bottom of the AME Primary display.

7.2.3 OMS-1/2 Selection

One of the main options for executing the AME is the OMS-1/2 selection. The AME can be executed for evaluate OMS-1 and OMS-2 (or MPS dump plus OMS-2 for no OMS-1 required cases) or OMS-2 only. The choices are **OMS-1 and OMS-2 Planning** and **OMS-2 Planning**. This selection is made on the AME Primary display also. The appropriate state vector and OMS-1/2 planning selection combination must be used for the AME to work properly. This will be expanded on in the next section.

7.2.4 State Vector Selection for AME

The user may select two state vectors for the AME. The first one is used to propagate up to the first maneuver TIG. The second one is used to model the burn similar to "freezing" a maneuver in the ephemeris. Of course, both state vectors could be set to the same VAT slot. The terminology for the two state vectors is just the two VAT slot numbers separated by a slash (e.g. V58/V59). The default for use by the AME during the multi-target mode immediately after MECO is V58/V59. Any valid VAT slot may be used. Four state vectors get saved automatically in the VAT post-MECO. These four are:

- V58 – Selected source at MECO + 30 and MECO + 60 seconds
- V59 – Telemetry state at MECO + 30 and MECO + 60 seconds
- V60 – Selected source at Filter stop
- V61 – Telemetry state at Filter stop

NOTE: For both V58 and V59, the MECO + 60 state vector over-writes the MECO + 30 state vector.

After NAV stops the Filter, TRAJ has DYN mode from LAUNCH phase to OPS phase. The AME can also be executed in OPS phase. However, if the phase is changed back to LAUNCH for some reason, then a Liftoff PBI followed by a MECO PBI must be entered for the correct flags to be set to allow the AME to run.

It is important to use state vectors compatible with the OMS-1/2 selection. All **OMS-1 Planning** executions must use a pre-OMS-1 or pre-MPS dump state vector. Similarly, all **OMS-2 Planning** runs must use a post OMS-1 or post-MPS dump state vector.

The standard procedures include transferring the preferred targets from the AME to EPH 1 after MECO. This requires that TRAJ execute the AME with the preferred targets in single-pass mode first. The transfer of the AME solution to the ephemeris will cause the MPS dump, OMS-1 (if required) and OMS-2 maneuvers to be modeled in the ephemeris using the same TIGs and targets as in the AME. After this initial transfer, the next step is to move the post maneuver 1 state vector to V1. This is then used to send to Goddard's Flight Dynamics Facility (FDF) for use in acquisition data generation.

If OMS-1 is not required, then the post MPS dump state vector (V1) can then be used in the AME for performing **OMS-2 Planning**. In order to use the V1 state vector, the selection is made in the upper left block on the AME Primary display. Usually, V1 is used for both state vectors (SS and TLM).

If an OMS-1 is required and is later than MECO + 4 minutes, it will be modeled in the AME as a separate maneuver. In this case, the post-OMS-1 state vector should be moved to V2. This state vector can then be used in the AME for performing **OMS-2 Planning**. A preliminary post-OMS-1 state vector (V2) should then be sent out to "the network" (GSFC's FDF).

The AME is re-executed after the MPS dump is confirmed. The post dump vector is again moved to V1 and then V1 is used by the AME.

OMS-2 targets may be tweaked from what's in the I-loads. The TIG may be modified, θ_T adjusted, HT changed, etc. Once the FDO is GO with the resulting OMS-2, the AME solution may again be transferred to EPH 1. If an OMS-2 already exists in the ephemeris, the transfer can still be done with a replace maneuver option on the transfer. Just be sure to specify which maneuver to replace (e.g. transfer the AME replacing maneuver 2). Once the plan for OMS-2 is finalized, the post burn vector will be shipped to the network.

7.2.5 AME Error Recognition and Recovery

Errors can occur and will usually result in no AME solution being displayed. This may require Dynamics assistance in troubleshooting. One common error includes using incompatible state vectors and targets.

ERROR	CORRECTIVE ACTION
AME DOES NOT EXECUTE	CHECK "GRND MECO" DDD ON FDO BACKUP LAUNCH PBI PANEL: IF NOT RED, THEN PUSH TO SET MECO EVENT IN TRAJ SERVER. AME MULTI-TARGET WILL AUTOMATICALLY EXECUTE IN 6 SEC. SET MECO TIME ON AME PRIMARY TO CORRECT VALUE.
NO SOLUTION DISPLAYED	CHECK FOR INCOMPATIBLE STATE VECTORS AND/OR TGT SET
NO MPS DUMP IN AME USING OMS-1 PLANNING MODE (N/A IF OMS-1 TIG < MECO+4)	INPUT VECTOR IS PAST TIG OF MPS DUMP. RE-RUN USING EARLIER VECTOR, OR GRAB O/B VECTOR POST-MPS DUMP AND RUN OMS-2 PLANNING.
AME PEG-7s DO NOT MATCH EPH	CHECK AME WT = BURN INIT WT IN EPH CHECK FOR VECTOR MISMATCH MAY BE INDICATION OF O/B VECTOR ERROR
AME SOL'N WILL NOT TRANSFER TO EPH	MAY BE TRYING TO REPLACE EXECUTED MNVR IN EPH. CONFIRM MNVR W/ O/B □Vs AND PROCEED TO OMS-2 PLANNING.

7.3 Nominal/ATO

7.3.1 OMS-1 Evaluation and TIG Recommendation

If an OMS-1 is required (MECO HA < 95 NM), then the FDO must recommend the desired target set to be used for OMS-1 and the TIG. FDO uses the AME and the Ascent Checklist's OMS-1/2 TGTING card to determine the proper target set to use. TARGETING will also use these same tools to independently determine the desired OMS-1 target set. Once the OMS-1 target set is chosen, the recommendation is passed to FD/crew. This is required by MECO + 1 minute.

In the Traj Server, the AME auto-cycles up to four times post-MECO (initiated by the MECO PBI) and provides a detailed, fully-integrated evaluation of performance available. The auto-downmode sequence will cycle down through a pre-defined list of target options until it finds one that can be supported with the available propellant. For most OMS-1 required cases, the AME will compute the TIG based on either TTA = 2 (time to apogee = 2 minutes) or MECO + 2 minutes, whichever is later. The AME computed OMS-1 TIG should be passed to FD as a preliminary value. This can be updated later if required. The AME will compute the ΔV required to execute the OMS-1 at this TIG and the displayed solution will show the first target set that has a positive ΔV margin.

FDO will pick the highest priority abort mode that can be supported with the available propellant. The OMS-1 options are ATO, AOA-Shallow and Optimum AOA. The ATO OMS-1 targets (target set 1) are referred to as "common targets" because they can be used to execute an ATO, Min Hp, AOA-Steep or AOA-Shallow with the OMS-2 burn. Using the ATO OMS-1 targets allows avoiding commitment to an AOA until after OMS-1. That is not true with the AOA-Shallow (target set 5) and Optimum AOA (target set 3 or 4) OMS-1 targets. For this reason, target set 1 will be used for the majority of OMS-1 burns.

The initial AME OMS-1 solution will have a slightly earlier TIG (~45 seconds) than required. This will change after the MPS dump is modeled in the ephemeris since TTA moves out slightly after the dump is done. The MPS dump always happens at MECO + 2 minutes unless the crew is asked to perform a dump inhibit.

Once the final OMS-1 solution is computed, the TIG and ΔV for the maneuver should be reported to FD and PROP.

7.3.2 OMS-2 Evaluation and TIG Recommendation

The OMS-2 target set used will depend on what happened earlier (OMS-1 or no OMS-1), the amount of prop available and the status of the prop system. PROP will inform FDO of any failures in the prop world and some of them require only raising perigee to MIN HP. Some of the OMS-2 targets are designed for use

only when no OMS-1 was required (e.g. target set 16) and some are designed for use post OMS-1 (e.g. target set 1). Here again, FDO and TARGETING use the AME and the Ascent Checklist's OMS-1/2 TGTING card to determine the proper target set. TRAJ will execute the AME in "OMS-2 Planning" mode with the desired target set. The AME is queued using either a post MPS dump state vector if no OMS-1 was performed, or a post OMS-1 state vector if OMS-1 was done.

TRAJ and TARGETING may tweak the values of the PEG 4 targets to optimize the solution. TIG, HT and θ_T may be changed. If anything of the targets are changed, then the new targets will have to be given to the crew. The preferred option is to uplink the new targets. However, a voice read-up followed with crew manual input is an option as well.

7.3.3 Restraining to Regain OMS Engine(s)

There are some failures that will take away an OMS engine that can be recovered with a restraining. For these cases, PROP will need to know the ΔV required for the maneuver assuming that PX4 or PX2 jets are used for OMS-2. In that case, OMS-2 will only raise perigee to MIN HP. TRAJ can easily compute the ΔV by executing the AME with the appropriate thruster selected. TARGETING will confirm the appropriate target set (usually 20 for no OMS-1 required case and target set 2 for an OMS-1 case). Note that since the RCS thrusters are being evaluated for use as a downmode, the planned TIG should be used for PX4 or PX2, not the optimum TIG for that thruster.

7.3.4 Real-Time PEG-4 Targets

PURPOSE

Define the procedures that can be used to compute the PEG-4 targets in real-time. This is done for cases that result in a MECO underspeed that results in the apogee between 95 NM and the nominal apogee.

PROCEDURE

TRAJ:

- PRELAUNCH: Record post MPS dump ω_p (C/O @ 30 min MET) [this is ω_{PNOM}]

PRIME METHOD

- Get $H_{DESIRED}$ from TARGETING or FDO SUPPORT ($H_{DESIRED}$ may be 105, circ at HA or some other alt for rndz)
- Desired $H_T = H_{DESIRED} + \approx 6.2$
- AME GUI: OMS-2 Design option
 - Input Desired H_T
 - $\sqrt{\text{OMS-2 TIG SLIP}} = 0:00$
 - Select proper vectors
 - Execute AME
 - Tweak TIG TTA to optimize the burn (first guess $\approx 1/2 T_{go}$)

NOTE: TIG TTA must be $> 0:00$

BACKUP METHOD

- Post MECO, determine actual ω_p [this is ω_{PACT}]
- Compute new $\theta_T = \theta_{TNOM} - (\omega_{PNOM} - \omega_{PACT})$ where θ_{TNOM} is the theta for the nominal targets
- $H_T = H_{DESIRED} + \approx 6.2$
- TIG = Time $H_{ACT} - 1:00$ (initially)

- Change TGT 16 θ_T and H_T directly thru AME GUI
- Adjust OMS-2 TIG Slip as required

BACKGROUND

The backup procedure was developed to allow the FDO to customize some PEG-4 targets for OMS-2 to either circ at apogee or raise to 105 NM. This procedure uses the nominal targets (θ_T) as a baseline and computes a new θ_T based on how much the line of apsides has rotated due to the MECO underspeed. The underspeed will also result in the time of apogee being earlier and the TIG will be adjusted accordingly to approximately TTA = 1 of the post MPS dump state vector. The H_T has to be biased by 6 to 7 NM to actually achieve the desired height (onboard guidance doesn't account for J2 effects).

Beginning with STS-111, the Traj Server was available for ascent. This gave us a new capability in the AME. The OMS-2 Design (a.k.a Real-time design) option was added to the Traj Server version of the AME. This option will automatically do the computations required to compute the new θ_T and allows for easy input of the desired H_T and TIG TTA (1:00 is the default). Iterating on TTA is done to find the optimum TIG. Once the optimum TIG is determined, the solution can then be transferred to the ephemeris and GPO can then build a PEG-4 command load to uplink the targets.

Although the backup method will probably not be used anymore, it is left in this procedure for possible use in case the auto logic fails for some reason.

7.3.5 OMS-2 Targeting for Rendezvous

PURPOSE

To define the procedure used post-MECO for computing OMS-2 for a rendezvous flight where the OMS-2 is a phasing burn.

PROCEDURE

- ANCHOR EPH1 ON V58
- EXECUTE AME, SINGLE-PASS MODE, TGT 16
- TRANSFER THE AME SOLUTION TO EPH1
- RE-ANCHOR ON O/B (IF REQUIRED)
- CONFIRM THE MPS DUMP
- TRANSFER THE MPS DUMP B/O TO V1
- TRAJ: CONFIGURE AME FOR OMS-2 PLANNING
- FDO: HAVE FDO SUPPORT RUN OMP TO COMPUTE OMS-2 H_A / H_P (Optional: view output on Maneuver Evaluation Table)
- TRAJ: UPDATE TGT 16 OMS-2 H_T (DESIRED $H_A/H_P + J2$ BIAS)
REFERENCE SOP 5.2.6 TO OPTIMIZE OMS-2 TIG
FETCH NEW V53
RE-RUN AME ON V1/V53
IF AME $H_A/H_P = \text{DESIRED } H_A /H_P \pm 0.1$, THEN CONTINUE
ELSE ITERATE ON H_T
- TRANSFER NEW AME SOLUTION REPLACING MNVR 2
- FREEZE MNVR 2
- VERIFY A GOOD OMS-2 SOLUTION IN DMT 1
- IF UPLINKING TARGETS, MODIFY EPH TIG WEIGHT (= O/B WT)
- UPDATE THE OMS-2 TARGETS (IF ONLY H_T CHANGED, THIS CAN BE VOICED UP TO THE CREW)

BACKGROUND

This procedure ensures that the proper OMS-2 is computed based on the actual post-MECO conditions. In order to accomplish this task, the OMP is re-executed using an actual post MPS dump state vector. This will result in a new desired apogee or perigee height being computed. The TGT 16 H_T is then modified until the resultant H_A or H_P is within 0.1 NM of the desired value. TIG may also have to be tweaked. FDO is dependent on FDO SUPPORT to execute OMP to determine the desired H_A or H_P .

7.3.6 Cutoff at Minimum Perigee or 105 NM perigee

PURPOSE

To define the procedure used post-MECO for computing OMS-2 for a cutoff at either MIN H_p or 105 NM.

PROCEDURE

- EXECUTE AME SINGLE-PASS WITH THE APPROPRIATE OMS-2 TARGET SET
 - NO OMS-1 REQUIRED
 - ITGT 18: $H_p = 105$
 - ITGT 20: $H_p = \text{MIN } H_p$
 - OMS-1 REQUIRED
 - ITGT 1: $H_p = 105$
 - ITGT 2: $H_p = \text{MIN } H_p$
- VERIFY GOOD SOLUTION IN AME
- TRANSFER SOLUTION TO EPH
- DISPLAY OMS-1 IN DMT 1

BACKGROUND

In the early days of the Space Shuttle program there were no special targets delivered for cutting off OMS-2 at a lowered than planned altitude. However, these targets for both OMS-1 required and not required cases are now standard options delivered for the AME. The O/B does not have the equivalent of target sets 18 and 20 in the I-loads. However, those two target sets are usually identical to the nominal targets except for the H_i . If these targets are going to be used, they can be uplinked or the new H_i read up to replace the nominal H_i .

7.4 AOA

PURPOSE

The following sections describe the standard procedures/options for operating the Abort Maneuver Evaluator (AME) for AOA cases.

NOTE: The crew will not have the targets available in the software if an alternate AOA site is prime (i.e. they will have either rely on the MCC to uplink the targets or manually key them in).

NOTE

AOA Shallow trajectories for 51.6° missions may have large misses from the target line. This is expected due to the "generic target lines" used. Descent Flight Design has generically cleared these target lines. **For 51.6° missions, disregard the TIG slip computed by the AME for AOA shallow cases.**

PROCEDURE

- GET DATA FROM **PROP**:
 - ΔOMS AVAILABLE FOR AOA (LBS)
 - THRUSTERS (OBP, OR, OL, PX4...)

- SELECT A SET OF AOA OMS TARGETS
 - CHECK OMS TARGET SUMMARY TABLE FOR REGION
 - CHECK APOGEE RANGE OF AOA TARGET SETS
 - ASK **TARGETING** FOR RECOMMENDATION

- **TRAJ**: RUN THE AME , OMS-2 ONLY
 - GRAB O/B VECTOR (FETCH V53)
 - POST MPS DUMP OR OMS-1 (IF REQ'D) VECTORS: SS = V1 OR V2, TLM = V53
 - ORBITER WT = DMT 1 B/O (OMS-1) or DMT 2 B/O (MPS Dump)
 - GET PROP WASTING DIRECTION (+/-) FROM **TARGETING**
 - ENTER AOA PROP (IF NOT SHALLOW)
 - √ ATO MBO (SET EQUAL TO ORB WT)
 - √ THRUSTER(S)
 - TVR = 180 (NOTE: MUST U/L PEG TGT'S TO GET TVR=180 O/B)
 - CLEAR OMS-2 TIG SLIP
 - HAVE **TARGETING** EVALUATE SOLUTION
 - ADJUST **OMS-2 TIG SLIP**, IF REQ'D, TO NULL AOA dRNG
 - IF INSUFFICIENT PROP, USE SHALLOW TARGET SET (DO NOT USE **OMS-2 TIG SLIP**, SEE NOTE IN BOX ABOVE)

This procedure is continued on the next page

- SET UP EPHEMERIS 4 FOR AOA
 - ANCHOR OUT OF EPH 1 POST MPS DUMP OR POST OMS-1 WITH WEIGHT TRANSFER
- BE SURE EPH 1 WGL'D FOR ATO DUMPS IF REQ'D TRANSFER A ME TO EPH 4

PERFORM THE FOLLOWING ADDITIONAL STEPS IF AOA IS IMMINENT OR HAS BEEN DECLARED:

- **TRAJ:**
 - IF DISPERSED O/B VECTOR:
 - GRAB O/B, AND FREEZE AOA OMS-2 BURN IN EPH 4 (ASSUMES NO STATE VECTOR U/L)
 - PUT EI-5 VECTOR FROM EPH4 IN CHECKOUT FOR ENTRY SUPPORT (DDS)
 - UNFREEZE AOA OMS-2 BURN
 - GENERATE ENTRY EPHEMERIS FOR AOA (ASSUMES STATE VECTOR U/L):
 - RUN EDS with XXX AOA selection file where XXX is the prime AOA site (use AOA OMS-2 B/O vector, override weight with burnout weight)
 - ASSESS AOA TIG SLIP:
 - ADJUST **AOA TIG SLIP** UNTIL ΔV IS UNACCEPTABLE (CHECK PROP) OR MAX OF 5 MINUTES OR dRNG IS UNACCEPTABLE
 - NOTE VALUE OF AOA TIG SLIP

FDO:

- QA AOA SOLUTION
 - √ DMT 1
 - √ DRAG VS V_E
 - √ ENTRY ELAPSED TIME
 - √ ENTRY DIGITALS

Compare with DDS results from ENTRY SUPPORT (ASSUMES NO O/B STATE VECTOR UPDATE)

This procedure is continued on the next page

IF AOA IS DECLARED:

- IF DISPERSED O/B VECTOR AND NO STATE VECTOR U/L:
 - RE-FREEZE OMS-2 ON THE O/B
 - RE-RUN EDS ON NEW OMS-2 B/O
- OPTIONAL: TRANSFER AME AOA SOLUTION TO EPH-1 AND VERIFY

- GIVE GPO "GO" TO BUILD PEG4D COMMAND LOAD
 - NOTE: If pressed for time, GPO can build command load without the EDS run having completed (no MM303 attitude)

- PASS FD OMS-2 TIG

- GENERATE AOA DEL PAD

BACKGROUND

7.4.1 DI/Steep and Shallow

These trajectories are used when an AOA is needed following a MECO which does not require an OMS-1. There may be 2 or 3 DI/Steep targets and 2 or 3 DI/Shallow targets for each mission and each AOA site. The targets are designed to cover a range of MECO apogee altitudes. The OMS Target Summary Table lists the MECO apogee design range for each DI/AOA target set. For example, on STS-91 there was a steep and a shallow target set that was good for apogees between 150 and 200 NM (target sets 10 and 11 for steep and shallow respectively). There were 2 other targets sets for apogees between 95 and 150 NM (target sets 8 and 9 for steep and shallow respectively).

NOTE: DI/AOA Shallow TIGs are typically ~30 to 35 minutes MET. Experience has shown that these early TIGs may be tough to support.

Any case where the MECO apogee falls close to the break point between target sets requires both options to be evaluated. The later TIG is preferred and may also be cheaper.

7.4.2 ATO/Steep and Shallow

These targets assume that an ATO OMS-1 was executed earlier and either an AOA steep or AOA shallow will be performed. The AOA steep OMS-2 target for used after an ATO OMS-1 was performed is usually stored in target set 6. The AOA shallow OMS-2 target for used after an ATO OMS-1 was performed is usually stored in target set 7. These targets usually have a TIG after 45 minutes MET, therefore allowing plenty of time to prepare for OMS-2.

7.4.3 Optimum (OPT) Steep and Shallow

These targets are optimized to support a MECO underspeed around the design underspeed. In theory this is good because in some cases (39° inclination missions) this may increase the design underspeed. However, in reality they will probably never be used for two reasons. First, these targets have a unique OMS-1 target set that are designed for used at MECO + 4 minutes. This requires an immediate decision/commitment to an AOA. Secondly, the ATO/Min Hp trajectory could be used in most cases instead of the OPT AOA targets if the FRCS is used for OMS-2. The ATO/Min Hp trajectory is preferred over AOA. Also, the underspeed range covered by OPT AOA that exceeds the capability of ATO/MIN Hp without FRCS is usually fairly small.

If OPT AOA OMS-1 targets are executed, then either the OPT steep or the OPT shallow targets could be performed at OMS-2. These are usually target sets 4 and 3 (steep and shallow respectively).

7.4.4 Shallow/Shallow

These targets are optimized for a shallow AOA. They would be used in the case where the underspeed was larger than the critical underspeed but within the max capability to support the shallow/shallow option. This region where AOA shallow/shallow would be used may be ~ 85 to 150 ft/sec greater underspeed than the critical underspeed.

Just like the optimum AOA, the decision/commitment to go AOA must be made prior to OMS-1. This is because the only option after the AOA shallow OMS-1 is the AOA shallow OMS-2. The shallow/shallow option does provide some flexibility since OMS-1 TIG can be the later of MECO + 2 minutes and time to apogee (TTA) equal to 2 minutes. The AOA shallow/shallow targets are usually in target set 5.

The flight rules do not allow us to consider the FRCS prior to MECO for use in OMS-2. However, the rules do allow the FRCS to be considered post-MECO if the entire OMS-2 can be complete out of the forward. This important because

the OMS 1/2 TGTING card in the Ascent Checklist (page 2-7) does not consider FRCS. So if the underspeed/prop available combination fell just to the left of the ATO/MIN Hp region, FRCS could possibly be used to avoid an AOA. If the ATO/Min Hp option failed by more than the ΔV available in the FRCS, then the shallow/shallow must be done. However, the decision must be made quickly since AOA shallow OMS-1 TIG is typically between MECO + 2 and MECO + 13 minutes, depending on the magnitude of the underspeed.

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7.5 TAL

7.5.1 “Standard Stuff”

PURPOSE

Define “standard” operational procedures for configuring for trajectory monitoring and evaluation post-MECO on a TAL.

PROCEDURE

- POST MECO:
 - **LANDING PHASE**
 - GRAB V53
 - VERIFY VECTOR IS GOOD (TIMETAG, VE, ETC.)
 - IF TLM VECTOR IS BAD, USE FLTR VECTOR
 - **EDS TO BEST/PREFERRED SITE** (ref. 7.5.2)
 - IF AN ELS IS BEST, USE EDS SELECTION FILE FOR CLOSEST TAL SITE W/RWY OVERRIDE
 - VERIFY GOOD ENTRY (Drag vs VE, ENTRY DIGITALS)
 - ENTRY SET → NETWORK
 - ENTRY PLOTS, KILL ASCENT PLOTS
 - GO TO **ENTRY MONITORING**

BACKGROUND

The “standard stuff” listed above are all the steps required to switch over from powered flight to entry monitoring on a TAL. The onboard state vector is preferred for use in generating the entry ephemeris. The ORB will be run to the preferred site, which FDO and ENTRY SUPPORT will choose based on the output of DAE and the applicable flight rule (A2-52). Now with EDS, the entry sim can be run in any phase (not just OPS phase). Therefore, the Traj Server will be taken directly to landing phase at MECO.

TRAJ will work with DYN to complete the above steps. After verification of a good entry profile, TRAJ or DYN tells DFE that the entry set is GO and can be sent to the network via GSFC’s FDF.

7.5.2 TAL Site Selection

PURPOSE

To define the procedure for choosing the highest priority landing site for a TAL post-MECO

PROCEDURE

- USE DAE OUTPUT TO DETERMINE FOOTPRINT REGION
- REFER TO FR A2-52 TO MAKE RECOMMENDATION
- CONSULT ENTRY SUPPORT IN MAKING SELECTION.

7.5.3 TAL Sim Report

PURPOSE

To define the procedure for reporting the results of the TAL EDS sim to the Flight Director.

PROCEDURE

- QA EDS results (Drag vs VE, ENTRY DIGITALS)
- Report the following:
 - GO/NO-GO status based on sim results
 - IF NO-GO, REPORT REASON (e.g.thermal violations) AND RECOMMEND ALTERNATIVE (E.G. ALT ALPHA PROFILE, REDES TO OTHER SITE, ETC.)
 - TAEM conditions (NOM, X NM Short, Etc.)
 - 1st ROLL REVERSAL VELOCITY
 - IF Low Energy logic required, report VE of Low Energy logic disengage

BACKGROUND

Once the EDS run has completed, the results are reported to FLIGHT. If the assumption of alpha profile used in the sim produced a NO-GO profile, then FDO must recommend an acceptable alternative. Otherwise, the keys parameters listed above are voice to FD.

7.5.4 Entry Monitoring

PURPOSE

To define the console procedures for monitoring the entry trajectory on a TAL.

PROCEDURE

- Verify that LSO has informed the proper site of the imminent landing
- Verify the entry ephemeris is configured for the correct runway
- GO TO 4.9.13 - ENTRY PHASE HIGH SPEED CHECKLIST

7.6 RTLS

7.6.1 RTLS Entry Monitoring

PURPOSE

To define the console procedures for monitoring the entry trajectory on a RTLS.

PROCEDURE

TRAJ

HAVE DYN GO TO LANDING PHASE IMMEDIATELY AT MECO

FDO

√ R-V STATUS – EOW; ABORT SUPPORT

REPORT R-V STATUS TO FD

MONITOR THE PULLOUT AND TRANSITION (α RECOVERY, NZ HOLD)

IF S-TURN LINE CROSSED, REPORT TO FD: EXPECT S-TURN

FDO & TRAJ

GO TO 4.9.13 - ENTRY PHASE HIGH SPEED CHECKLIST

BACKGROUND

On a RTLS, the Traj Server is switched from LAUNCH phase directly to LANDING phase. The Energy over Weight display will not plot until the Traj Server is in LANDING phase. This display is needed to evaluate the EOW versus Range by comparing the actual conditions with the target line. The other part of the R-V status comes from comparing the flight-path angle at ET SEP. ABORT SUPPORT does this evaluation and makes a call to FDO. In order to expedite the phase transition, TRAJ usually has DYN primed and ready to go to LANDING phase immediately at MECO. This will allow EOW to begin working as soon as possible.

After the pullout, the EOW display will give a good indication of whether a S-turn will be required. If energy was a little hot, the pullout may result in the EOW versus range plot crossing above the S-turn line. For this case, an advisory call is made to the crew to give them a heads up on the possibility of onboard guidance commanding a S-turn to bleed off the excess energy. NOTE: There is no HAC turn angle constraint for S-turn on a RTLS.

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7.7 Contingency Abort/Bailout

7.7.1 Site Selection and Evaluation

The site selection for a contingency abort is currently based on pre-flight analysis for a first guess at the best site. The analysis shows the best site based on engine-out times and/or velocities. The real-time analysis is done by the standard entry technique of using the output of the High-Speed Entry Processor to evaluate the energy. This requires putting the different landing sites in the prime slot to evaluate both energy and DELAZ. Caution must be used because the energy will oscillate due to any phugoids (if any). ENTRY SUPPORT and GPO may have recommendations on sites to evaluate.

7.7.2 East Coast Abort Landing (ECAL) and Bermuda Contingency Abort Landing

Once the best site has been determined and passed to the crew, the FDO must continue standard entry evaluation. NOTE: A very high energy case that looks impossible may actually be made if the crew flies past the field and the turns around to make a STIN approach. REF 4.5.11 – ENTRY PHASE HIGH SPEED CHECKLIST.

7.7.3 Bailout Recommendation

After all options have been exhausted (STIN, MEP, closest runway, etc.) and it is clear that a bailout will be required, go to 4.5.14 – BAILOUT CHECKLIST. NOTE: For ECAL, it is mandatory that the FDO ensure that the vehicle will not impact land/populated areas. This may require giving the crew a heading parallel to the coast to insure that this occurs. However, if the vehicle is far enough from the coast, a straight ahead heading may be acceptable.

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8 ASCENT MASS PROPERTIES

The purpose of the Ascent Mass Properties function is to provide a means of tracking, computing, and updating MCC knowledge of the Orbiter's weight and center of gravity (CG). The resulting data is used as input to some trajectory processors and by flight controllers to determine the potential for off-nominal vehicle flying characteristics.

8.1 Initialization for Ascent

The Lead FDO is responsible for all pre-mission mass properties set-up. Mass properties data from flight design is saved into Paperless Mass Properties (PMP) files which allow quick input into the Traj Server with reduced chances of introducing an error. For each flight design cycle, ascent, orbit, and entry PMP files are created. For the Close-To-Launch (CTL) cycle, only the ascent and orbit PMP files are created. The ascent PMP files (sim and flight) and CTL Orbit PMP file are discussed in this section.

8.1.1 Ascent PMP file and Traj Server Configuration Verification

PURPOSE

Ensure that the Traj Server Mass Properties data is properly configured for ascent.

PROCEDURE

QA THE ASCENT PMP FILE

LOAD THE ASCENT PMP FILE AND PERFORM QA USING THE FOLLOWING DISPLAYS (COMPARE WITH PROP-31):

- BUILDUP DISPLAYS
 - ORBITER BUILDUP
 - CARGO BUILDUP
 - NON-PROPULSIVE CONSUMABLES BUILDUP
 - CRYOGENICS BUILDUP
- OMS FUEL DEPLETION SEQUENCE
 - OMS WEIGHTS FROM LINES 5-8
 - Δ OMS = SYSTEMS AOA VALUE FROM PROP
 - MIX RATIO = 1.66

- TANKS = BOTH
- IF Δ OMS IS NOT CORRECT, ENTER CORRECT VALUE AND RE-EXECUTE CG SUM TO PROVIDE CORRECT EI, TAEM, AND LANDING WEIGHTS AND CG'S
- TVC WEIGHT TRANSFERRED TO CG SUMM

This procedure is continued on the next page

- ✓ CG SUMMATION (COMPARE WITH PROP-34)
 - L/O WEIGHT
 - L/O TO OMS-2 BIAS: NOMINAL USAGE FROM LIFTOFF TO OMS-2 TIG
 - SYS AOA D2EI: NOMINAL USAGE FROM THE DEORBIT BURN TO ENTRY INTERFACE (EI) ON A SYSTEMS AOA TRAJECTORY
 - SYS AOA FDUMP: NOMINAL FRCS DUMP ON A SYSTEMS AOA
 - AOA EI TO M3: NOMINAL USAGE FROM EI TO MACH 3 (APPROXIMATELY TAEM INTERFACE) ON A SYSTEMS AOA TRAJECTORY
 - PTI'S: PTI USAGE ON A SYSTEMS AOA TRAJECTORY (SHOULD BE ZERO)
 - M3 TO LANDING: NOMINAL USAGE FROM MACH 3 TO LANDING ON A SYSTEMS AOA TRAJECTORY
 - INERT ORB (GDN): ORBITER WITH LANDING GEAR DOWN
 - INERT ORB (CL): ORBITER WITH PAYLOAD BAY DOORS OPEN
 - INERT ORB (OP): ORBITER WITH PAYLOAD BAY DOORS CLOSED
- TRANSFER DATA TO Traj Server (FROM PMP)
 - UNDER THE "DATA" MENU
 - CLICK ON 'SYNC THE MOC'
 - CLICK ON 'SYNC ALL'
 - VERIFY ENGINE CHARACTERISTICS TABLE IS UPDATED
 - VERIFY MASS PROPERTIES TEXT FILE UPDATED

BACKGROUND

The Ascent PMP file is loaded by TRAJ as part of the standard launch initialization procedures (ref. section 4.1, Initialization for Ascent). This file configures the Traj Server Engine Characteristics Table and the mass properties text file for a Systems AOA. This procedure ensures that the Traj Server, DMP and EDS data are set up properly for this case.

8.1.2 Orbit Mass Props Group MED Verification

PURPOSE

Ensure that the Orbit Mass Props group MED is correct for flight use. **NOTE: This procedure is required for flight ONLY.**

PROCEDURE

VERIFY THE FOLLOWING KEY ITEMS BY COMPARING THE ***Orbit Mass Props Group MED HARDCOPY*** TO THE PROP-34 PRODUCT OR THE ORBIT MASS PROPERTIES IN THE FDO DATA BOOK, AS NOTED BELOW. **DO NOT** LOAD THE ORBIT MASS PROPS GROUP MED PRIOR TO LAUNCH.

- MZH THRUST AND FLOWRATE: 1786.1 LBS, 7.78 LBS/SEC
- CORRECT PARALLEL TRIMS

BACKGROUND

The Orbit Mass Props Group MED is set up for flight use to reflect the actual MZH thruster. All other large changes (removal of DMP first guess shallow targets used by the ascent team and fixes the parallel trims in the Engine Characteristics Table) are handled later during the post OMS-2 mass properties update.

8.1.3 Incorporation of Late Mass Properties Updates

PURPOSE

Identify the method of providing updates to mass properties data following a launch attempt.

PROCEDURE

- OBTAIN ALL PREDICTED UPDATES FOR NEW LAUNCH TIME
 - EECOM
 - EGIL
 - MMACS
- IF REQUIRED, DETERMINE BALLAST
 - COMPUTE NEW AOA CG
 - DETERMINE Δ CG FROM PREVIOUS VALUE
 - COMPUTE THE Δ TO OMS BALLAST (REF. FDOCH, VOL. 3, FIGURE 3.6.5.2-2)
 - DETERMINE FROM PROP-34 THE AOA BALLAST CG
 - COMPUTE NEW AOA BALLAST CG (NEW BALLAST CG
 - = OLD BALLAST CG + Δ CG)
 - COMPUTE THE CG VIOLATION
 - IF (NEW BALLAST CG - 1075.2 < 0)
 - THEN A VIOLATION EXISTS AND BALLAST IS REQUIRED

BALLAST = (NEW BALLAST CG - 1075.2) * Δ OMS/INCH

ELSE NO BALLAST REQUIRED
- DOCUMENT THE Δ TO OMS BALLAST IN THE LOG
- PASS UPDATES TO TARGETING AND ABORT SUPPORT

UPDATE ASCENT PMP FILE WITH QUANTITIES THAT HAD A SIGNIFICANT CHANGE

BACKGROUND

Any late changes which occur after the CTL cycle and the publication of the L-7 day TDDP must be coordinated through the Lead FDO and the Flight Design Manager. These changes, which may include cryogenics quantity updates due to usage during a scrubbed or aborted launch attempt, must be reviewed to determine whether the change is significant enough to warrant an update to the CTL Ascent PMP file. If time allows, the Flight Design Prop group may re-deliver the CTL PROP-34 product to reflect the changes. If there are significant changes and time does not allow a re-delivery, the FDO/TRAJ team must update the appropriate quantities and determine the ballast required (if any) for FD1 landings (AOA and PLS).

8.2 *Mass Properties Update Technique References*

Mass properties update techniques and displays used during the ascent phase are identical to those used on-orbit. Since this information is fully documented in the Orbit FDO Console Handbook (DM-CH-07, Volume 3), the pertinent section numbers are simply stated here to facilitate easy cross-reference.

8.2.1 Paperless Mass Properties (PMP) Processor

Reference Orbit FDO Console Handbook section 3.6.

8.2.2 "Back-of-the-Envelope" Technique for Aborts

Reference Orbit FDO Console Handbook section 3.6.5.1.

8.2.3 Generic CG Shift Data

Reference Orbit FDO Console Handbook section 3.6.5.1.

8.3 Mass Properties Console Procedures for Ascent

8.3.1 Nominal Post-OMS-2 Update

PURPOSE

Provide procedural details for standard computation of current Orbiter weight and CG post-OMS-2.

PROCEDURE

NOTE

ENSURE THAT EPH 1 IS ANCHORED AFTER THE MPS DUMP MANEUVER; IF NOT, TUP EPH 1 ON V1 OR V2

- LOAD THE ORBIT MASS PROPS GROUP MED
- PERFORM A CURRENT MASS PROPERTIES UPDATE CYCLE PER ORBIT FDO CONSOLE HANDBOOK SECTION 3.6.7.2
- UPDATE EPH 1 CURRENT WEIGHT TO LINE 25 WEIGHT FROM PMP, PASS CURRENT WEIGHT TO PROP

BACKGROUND

Sets up the mass properties displays for on-orbit use, and provides a current post-OMS-2 vehicle weight. The ephemeris must be anchored past the MPS dump model since the Orbit Mass Props Group MED will reset the MZH thruster characteristics from MEP thruster characteristics back to MZH. Loading the Orbit Mass Props Group MED first will result in an inaccurate weight loss model for the MPS dump upon the next ephemeris TUP, if the anchor vector remains prior to the dump. The current mass properties update procedures are identical to those used on-orbit.

8.3.2 Systems AOA

PURPOSE

Provide procedural details regarding computation of weight and CG data for a systems AOA.

PROCEDURE

- CONFIRM AOA Δ OMS WITH PROP

- IF Δ OMS IN FUEL DEPLETION SEQUENCE IS CORRECT, NO FURTHER ACTION IS REQUIRED -- CG SUMMATION PAGE CONTAINS ACCURATE WEIGHTS AND CGS

- IF Δ OMS IN FUEL DEPLETION SEQUENCE IS INCORRECT:
 - EXECUTE OMS DEPLETION SEQUENCE WITH CORRECT VALUE
 - \checkmark CG SUM - VERIFY TVC WEIGHT AT TOP OF CG SUM

- PROVIDE TAEM CG TO GNC AND FD

BACKGROUND

The PMP ascent mass properties file is already set up for a systems AOA. The only pertinent variable is the fuel to be used for OMS-2. If the amount to be used is different than that already set up, a simple execution of the OMS depletion sequence with the new Δ OMS will provide the correct data.

8.3.3 Performance AOA

PURPOSE

Provide procedural details regarding computation of weight and CG data for a performance AOA.

PROCEDURE

- IF OMS FUEL **ONLY** IS BEING USED: ADD OMS-1 AND OMS-2 FUEL USAGES (ACTUAL AND/OR PREDICTED) AND ENTER SYSTEMS AOA PROCEDURE (8.3.2) WITH THIS VALUE FOR Δ OMS
- IF RCS FUEL IS REQUIRED FOR COMPLETION:
 - OBTAIN POUNDS HEAVY OR LIGHT IN THE OMS, ARCS, AND FRCS SYSTEMS WITH RESPECT TO A PERFORMANCE AOA FROM PROP
 - USE BACK-OF-THE-ENVELOPE CG ESTIMATION METHODS TO COMPUTE THE MACH 3 WEIGHT AND CG, USING THE ABBREVIATED REPORT AOA M3 LINE AS A REFERENCE
 - PROVIDE MACH 3 CG TO GNC AND FD

BACKGROUND

If only OMS fuel is being used, the end result is the same as that for the Systems AOA. Therefore, procedure 8.3.2 should be used with the total OMS-1 plus OMS-2 usage input for Δ OMS.

If any RCS (aft or forward) is used, then deltas should be computed from the performance AOA case. The Abbreviated Report in PROP-34 contains abort mass properties at selected points. The Mach 3 AOA, RTLS, and TAL values are used as the "baseline" for weight and CG computations performed using the "back-of-the-envelope" method. The AOA information contained therein is for the performance AOA case. This method results in CG and weight deltas which are then applied to the "baseline" to arrive at the final values.

8.3.4 TAL

PURPOSE

Provide procedural details regarding computation of weight and CG data for a TAL.

PROCEDURE

- OBTAIN POUNDS HEAVY OR LIGHT IN THE OMS, ARCS, AND FRCS SYSTEMS WITH RESPECT TO A TAL FROM PROP
- USE BACK-OF-THE-ENVELOPE CG ESTIMATION METHODS TO COMPUTE THE MACH 3 WEIGHT AND CG, USING THE ABBREVIATED REPORT TAL M3 LINE AS A REFERENCE
- PROVIDE MACH 3 CG TO GNC AND FD

BACKGROUND

The Abbreviated Report in PROP-34 contains abort mass properties at selected points. The Mach 3 AOA, RTLS, and TAL values are used as the “baseline” for weight and CG computations performed using the “back-of-the-envelope” method. This method results in CG and weight deltas which are then applied to the “baseline” to arrive at the final values.

8.3.5 RTLS

PURPOSE

Provide procedural details regarding computation of weight and CG data for an RTLS.

PROCEDURE

- OBTAIN POUNDS HEAVY OR LIGHT IN THE OMS, ARCS, AND FRCS SYSTEMS WITH RESPECT TO AN RTLS FROM PROP
- USE BACK-OF-THE-ENVELOPE CG ESTIMATION METHODS TO COMPUTE THE MACH 3 WEIGHT AND CG, USING THE ABBREVIATED REPORT RTLS M3 LINE AS A REFERENCE
- PROVIDE MACH 3 CG TO GNC AND FD

BACKGROUND

The Abbreviated Report in PROP-34 contains abort mass properties at selected points. The Mach 3 AOA, RTLS, and TAL values are used as the “baseline” for weight and CG computations performed using the “back-of-the-envelope” method. This method results in CG and weight deltas which are then applied to the “baseline” to arrive at the final values.

8.3.6 Contingency Abort

PURPOSE

Provide procedural details regarding computation of weight and CG data for a contingency abort.

PROCEDURE

- OBTAIN POUNDS HEAVY OR LIGHT IN THE OMS, ARCS, AND FRCS SYSTEMS WITH RESPECT TO A TAL OR RTLS FROM PROP (CHECK WITH PROP TO CONFIRM THE REFERENCE ABORT MODE USED)
- USE BACK-OF-THE-ENVELOPE CG ESTIMATION METHODS TO COMPUTE THE MACH 3 WEIGHT AND CG, USING THE ABBREVIATED REPORT TAL OR RTLS M3 LINE AS A REFERENCE
- PROVIDE MACH 3 CG TO GNC AND FD

BACKGROUND

The Abbreviated Report in PROP-34 contains abort mass properties at selected points. The Mach 3 AOA, RTLS, and TAL values are used as the “baseline” for weight and CG computations performed using the “back-of-the-envelope” method. As there is no “contingency abort” line item, either the RTLS or TAL mode, whichever best represents the dump configuration, must be chosen. This method results in CG and weight deltas which are then applied to the “baseline” to arrive at the final values.

9 RANGE SAFETY

9.1 Range Safety Function and Authority

Space vehicle launches are by nature hazardous operations, involving high-speed vehicles carrying large amounts of highly explosive and/or toxic propellants. In some cases, the payloads themselves may be dangerous if not carefully contained, as is the case for satellites powered by Radioisotope Thermoelectric Generators (RTGs). To ensure that people and property on the ground are protected from the potential hazards of launch operations, constraints on allowable launch trajectories and launch conditions are imposed by the authorities who oversee the use of the Eastern and Western Ranges (ER and WR, respectively). Conversely, Range Safety has the additional objective of protecting vehicles which are operating within allowable constraints from unnecessary or unintentional flight termination. The Air Force's 45th Space Wing (45SPW) provides the range safety control functions for launches from the ER, which includes Space Shuttle operations at KSC.

9.2 Range Safety Facilities and Personnel

Offices and facilities for the ER are located at Patrick Air Force Base under the direction of a USAF commander. Similar functions are carried out at the WR, although this document concerns itself with Shuttle-related ER operations only.

For each operation (or "test" as it is referred to by range personnel) conducted on the range, one or more Flight Control Officers (FCOs) are assigned to implement the controls necessary to fulfill the range safety responsibilities. The FCO may be an Air Force officer or a civilian USAF employee. For Space Shuttle operations, two FCOs are assigned to each flight, with one being designated the Senior FCO (SFCO or "Senior"). The "Senior" is the primary FCO interface with the MCC on flight day. Both work together at a console located in the Range Control Center at the Cape Canaveral Air Force Station (CCAFS), from which the launch is monitored, ground operations are controlled, and flight termination action is initiated, if required.

9.3 *Space Shuttle Range Safety*

9.3.1 Flight Termination Criteria

To ensure adequate protection from the hazards of a malfunctioning vehicle, criteria are established which require that the flight be terminated if they are exceeded. These criteria are flight-phase dependent, but are developed under the groundrule that no appreciable piece of an exploding vehicle will be allowed to fall behind a set of impact limit lines (ILLs) which are drawn around the areas to be protected. This groundrule, along with assumptions made regarding the maximum rate at which the vehicle's velocity vector may be turned by control malfunctions, the characteristics of the debris resulting from breakup or destruct action, and the effects of winds on the debris are used to generate a set of destruct lines beyond which the vehicle is not allowed to fly.

As stated, assumptions are made about how a malfunctioning vehicle will behave. Currently, it is assumed that a worst-case malfunction occurs which turns the vehicle velocity vector in the worst possible direction at the highest possible rate that does not by itself cause structural breakup.

Another assumption is made that for a given trajectory, a fixed relationship exists between slant range from the launch pad and vehicle speed. This assumption is used to form an initial condition for destruct line construction for points in space that are not along the nominal trajectory.

A third assumption is that all the velocity attained for a given slant range lies in a plane which is perpendicular to the limit line of interest. In other words, no component-wise breakdown of velocity is performed to determine the actual speeds relative to the impact limit lines.

An assumption is then made that explosion velocities are imparted to the debris resulting from destruct action, and that the incremental velocity on any given piece is directed toward the impact limit line. Debris velocity is the most sensitive factor in determining destruct lines.

Currently, winds are assumed to blow directly back toward the respective limit lines. The assumed wind is comprised of the mean monthly wind with the 3σ headwind component applied. While this assumption is certainly conservative, winds have a relatively small effect on the final destruct lines since the heavy debris is not seriously affected by winds and the lighter pieces are not normally a safety concern.

These assumptions are applied in the process of destruct line construction using a worst-on-worst method. This technique effectively ensures a zero probability of impact behind a limit line, but can result in overly-restrictive flight limitations which may dictate the destruction of the vehicle when in reality it is performing in

an acceptable manner, from a statistical, casualty-expectation point of view. While NASA provides input to destruct line construction methodology, the ultimate decisions regarding which techniques and assumptions will be used are dictated by the ER.

9.3.2 Collision Avoidance (COLA)

In addition to protection of persons and property on the ground, the Range Safety function includes an effort to ensure that no early on-orbit collision will occur with any human-occupied space vehicle already in orbit. This is independent of the assessment performed by the U.S. Space Command for pre-liftoff conjunction analysis (reference 5.3.8, SPADOC COMBO Notification). The collision avoidance analysis is performed at the ER with a computer program called COLA (for **COL**lision **A**voidance) using anticipated Shuttle state vectors supplied by JSC. Launch window cutouts are imposed by the ER during periods when the Shuttle trajectory would pass too close to the affected orbiting object(s). The approach limits are based on whether the vehicle is occupied (200 km downtrack, 50 km crosstrack/radial) or not (50 km) at the time of the Shuttle launch. The intent is to preclude international incidents where concern may arise within foreign government(s) that the U.S. may be interfering with their spacecraft. It also serves the Range Safety function of protecting good vehicles from inadvertant destruction due to collision. COLA restrictions apply from liftoff through the first orbit.

9.3.3 FCO Range Safety Displays

Flight-specific range safety destruct lines are determined at the ER using trajectory data supplied by JSC. They are plotted on two displays used by the FCO -- the Vertical Plane (VP) and Tangent Plane (TP) displays. The VP plots launch vehicle position and is sometimes referred to as the Present Position display. The TP plots the vehicle's instantaneous vacuum impact point (IIP), and is sometimes called the IP display (for Impact Point). The format and concepts behind these displays are discussed in appendix D, Displays.

9.4 Range Safety Flight Rules

Rules dealing with Range Safety Operations are contained in sections 2, 4 and 8 of NSTS-12820, STS Operational Flight Rules. Section A4.1-6 is primarily a duplication of Range Safety Launch Commit Criteria, but it also dictates specific flight termination criteria, the periods of flight to which they apply, FCO/FDO reporting requirements, and directs MCC to take action in the event the vehicle deviates toward a flight termination line after SRB separation. In addition, criteria for waiving flight termination requirements are laid out in the Controllability Rule. The rules also define use of the Abort Request switch on the FDO console and the MCC actions to be implemented in response to deviations towards a limit line. Section 8 defines controllability for Range Safety purposes and, as a GNC-owned rule, is not discussed here. Reference the Flight Rules document for complete rules and rationale.

9.4.1 Controllability

In first stage, the Space Shuttle must operate in a very narrow aerodynamic corridor in order to maintain structural integrity during the region of high dynamic pressure. To control these loads, load relief logic is provided in the first stage steering task. Additionally, attitude and engine throttling compensation in response to sensed SRB performance dispersions are allowed to feed into the open-loop attitude profile commands. Vehicle response to these and other factors can lead to relatively large departures from the nominal design trajectory, while still remaining inside the acceptable performance envelope. In some cases, such deviations may exceed the 3σ statistical envelope and may even violate a Range Safety destruct line.

To allow for such unpredictable, but safe flight conditions, the Controllability rule was put in place for Shuttle. This rule is intended to preclude unnecessary destruction of the vehicle which is otherwise proceeding in an acceptable manner. Rule A4-256 states that during the SRB thrusting period, the FCO will not take action against a vehicle which is in violation of destruct criteria as long as the Flight Director declares that the vehicle is under control. Note that this rule applies only during first stage. Second stage actions are outlined in rule A4-254, described in section 9.4.2.

Controllability is invoked when the vehicle first exceeds any of the 3σ envelopes on the FCO's displays. At this point, the FCO will call "Amber Zone" to the FD on the FD loop. The call is a cue to GNC and FD that a controllability report must be made. Control status is assessed by GNC, based on criteria specified in section 8 of the Flight Rules. If the vehicle loses control, GNC will annunciate this immediately to the FCO via the controllability warning light on the FCO console. The light serves to minimize the amount of protection which must be built into the destruct lines to allow for FCO decision time. In all cases, the FD

will verbally pass a controllability report to the FCO. If the vehicle is under control, the FCO will allow the flight to continue, even if a destruct line is subsequently violated, provided that vehicle control is maintained. If it is out of control, or subsequently loses control, destruct action will be taken by the FCO per the flight rules or if/when structural breakup occurs.

9.4.2 Flight Termination / Manual MECO Criteria and Actions

Because there is no destruct package on the vehicle after staging, flight termination action is only application in first stage. In second stage the FCOs, MCC, and crew are responsible for taking actions to prevent the IIP from crossing defined limit lines. The FCOs have the final authority on range safety determination. A "Manual MECO" is the final action that can be taken by the crew to avoid a limit line. Flight rule A4-260 defines the actions that will be taken leading up to a manual MECO. The FDO procedures are defined in 9.5.3.

The call for a manual MECO will usually come from the MCC. When the FDO sees that the orbiter impact point is 15 seconds from the line, the CAPCOM will tell the crew to execute a manual MECO. At the same time, the Flight Director sends the abort light. If MECO has not occurred by the time that the impact point crosses the line then the FCO will send the abort light. The main job of the FDO during the execution of limit line avoidance or manual MECO procedures is to keep the team informed of the orbiter's IIP proximity to the MECO line. The FDO may also be required to send the abort light as a back-up to the Flight Director. In this instance the abort light means that a manual MECO is required.

The FCO can request a manual MECO if the IIP contacts the MECO line. This will be done by sending an abort request command (abort light) and verbally transmitting the manual MECO codeword to the MCC.

9.4.3 Range Safety Limit Avoidance Actions

This rule outlines the options available to the crew and MCC to correct an errant trajectory which is in danger of violating a destruct line. They include updating the onboard state vector, manually flying the vehicle away from a line, engaging the BFS, selection of an RTLS, TAL, or ATO abort, or manually shutting down the SSMEs to stop the motion of the IIP.

9.5 Real-Time FDO/FCO Interface Procedures

In real-time, the FCO operates essentially independent from the MCC for the purpose of implementing Range Safety responsibilities, with the exception of the rule governing controllability, which is discussed below. The FCO does, however, remain in communication with the FDO and FD throughout powered flight and includes MCC-supplied data in assessing the trajectory.

9.5.1 Prelaunch Communications and Calls

PURPOSE

Document standard pre-launch FCO/FDO communications.

PROCEDURE

L-2 Wks FCO: Codeword letter to FDO.

L-2 Days ARD Support: Fax Abort Mode Boundaries Bar Chart and Ascent Events Summary to FCO.

L-3h FCO on Console

Comm Checks: FCO Prime, Private Line, FD Loop

Controllability Light Test

L-2h Review Standard Reporting Procedures and Codeword letter date

L-50m FDO: Prime RTLS Runway to FCO

FCO: Confirm receipt of Trajectory Deviations Package (FCO Package, ref. section 5.3.13)

L-30m FDO/FCO L-30m Tag-Up (FDO-initiated)

L-14m Comm Checks: FCO Prime, Private Line

L-4m Final Comm Checks: FCO Prime, Private Line

BACKGROUND

Communications with the FCO are conducted over one of three voice loops. FCO Prime is used for routine communication between the FDO and the FCO. If Flight Director involvement is required, those conversations are carried out on the FD loop. For backup purposes and to provide an "attention-getting" line that cannot be interrupted by other parties, the FCO Private Line is provided. This is a private ring-down loop between the FDO and FCO consoles that the other operator's comm panel to "ring" when the loop is selected.

At about L-2 weeks, the FCO sends the code word letter to the Ascent/Entry FDO Section Head, who forwards it to the Ascent FDO. The letter should be kept sealed until it is opened on launch day at about L-3 hours. Also at this time, the FCO begins COLA runs based on the nominal launch window. Once the L-1 week TDDP data is processed (usually around L-1 or 2 days), ARD Support faxes the FCO office a copy of the updated Abort Mode Boundaries Bar Chart and Ascent Events Summary. This ensures that all parties are working with the same pre-launch data once launch operations begin.

The FCO arrives on console at L-3 hours. An informal tag-up is performed between the FDO, TRAJ, and FCO on FCO Prime to status the countdown, weather, and other issues. COLA launch window cutouts are passed to the FDO at this time. These are forwarded to the Flight Director. Comm checks are conducted several times throughout the count.

At approximately L-2 hrs, the FCO and FDO/TRAJ review "standard reporting procedures." This tag-up, initiated by the FCO, is comprised of a review of the effective date of procedures, flight rules, and the code word letter, to ensure that all parties are working with the same documentation. At about the same time, a test of the GNC "loss-of-control" light is also made. At L-30 min, the FDO initiates a final tag-up regarding MCC issues, I-load selection, etc.

9.5.2 Powered Flight Communications and Calls

PURPOSE

Documents the FDO/FCO standard calls during powered flight.

PROCEDURE

NOTE:

TRAJ MAKES ALL NOMINAL FDO CALLS TO FCO, USING THE "FCO PRIME" LOOP, WITH THE "FCO P/L" (PRIVATE LINE) LOOP AS BACKUP

<u>NOMINAL CALLS</u>	<u>APPROX. MET</u>	<u>INITIATED BY</u>
IP MOVING OUT DOWNRANGE	0:20	FCO
MCC IS GO AFTER THROTTLE UP	1:10	FDO
SRB NLE	1:40	FCO
MCC IS GO AFTER SRB SEP	2:15	FDO
CONFIRM C-BAND LOCKUP	2:15	FCO
<u>OFF-NOMINAL: FCO-INITIATED:</u>	<u>OFF-NOMINAL: FDO-INITIATED:</u>	
DEVIATION TOWARDS LIMIT LINE	SIGNIFICANT PERFORMANCE LOSS	
AMBER ZONE (3 σ LT/RT DEVIATION)	FLIGHT CONTROL PROBLEMS	
ARM/FIRE (CODE WORD)	BFS OR CSS ENGAGE	
MANUAL MECO (CODE WORD)	NAV PROBLEMS THAT NEGATE ONBOARD AS VECTOR SOURCE	
<u>OFF-NOMINAL: FD-INITIATED</u>	ANY ABORT INITIATION	
GOOD CONTROL (AFTER AMBER ZONE)	INITIATION OF FAST SEP	
UNCONTROLLABLE (CODE WORD)		
MANUAL MECO (CODE WORD)		

BACKGROUND

Self-explanatory.

9.5.3 Destruct Line / Manual MECO Avoidance Procedures

PURPOSE

The purpose of this procedure is to document the steps that can be taken to try and prevent an errant trajectory from crossing a destruct line in first stage or a manual MECO line in second stage.

PROCEDURE

Once it has been confirmed that the orbiter is not on its nominal trajectory and is heading toward a range safety line, the following actions should be taken (**listed in priority order**) until the divergence has ceased:

FIRST STAGE:

- **FDO and GPO:** ASSESS THE QUALITY OF THE O/B VECTOR
 - COMPARE THE O/B VECTOR WITH THE FILTER VECTOR IF AVAILABLE
 - STATUS NAV ON THE HEALTH OF THE FILTER
 - IF THE DELTAS ARE LARGE AND THE FILTER IS GOOD, GIVE GPO A GO TO BUILD A DELTA-STATE
- **CREW:** ENGAGE CSS (ONLY APPLICABLE AFTER 90 SECS)
 - MANUALLY FLY AWAY FROM LIMIT LINE
- **CREW:** ENGAGE BFS (ONLY IF KNOWN TO FIX PROBLEM)

SECOND STAGE:

- **FDO and GPO:** ASSESS THE QUALITY OF THE O/B VECTOR
 - COMPARE THE O/B VECTOR WITH THE FILTER VECTOR IF AVAILABLE
 - STATUS NAV ON THE HEALTH OF THE FILTER
 - IF THE DELTAS ARE LARGE AND THE FILTER IS GOOD, GIVE GPO A GO TO BUILD A DELTA-STATE
- **FDO:** ABORT ATO (IF VARIABLE IY ENABLED)
- **CREW:** ENGAGE CSS
 - **FDO:** CALL YAW COMMANDS FROM ARD ADI
 - MONITOR O/B ATTITUDE
- **FDO:** CALL ABORT TAL OR RTLS (HIGHEST PRIORITY)

- **CREW:** ENGAGE BFS (ONLY IF KNOWN TO FIX PROBLEM AND MULTIPLE SSME'S RUNNING)

IF THE ABOVE ACTIONS FAIL TO STOP THE DIVERGENCE, PROCEED TO THE MANUAL MECO PROCEDURES (9.5.4)

BACKGROUND

Self-explanatory

9.5.4 Manual MECO Procedure For Destruct Line Avoidance

PURPOSE

The purpose of this procedure is to document the procedure to have the crew perform a manual MECO for the purpose of avoiding a range safety limit line.

PROCEDURE

Manual MECO action, the associated calls, and the use of the abort light are summarized below:

- ET impact point 30 sec from limit line:
 - FDO: "15 seconds to manual MECO"
 - CAPCOM to CREW: "15 seconds to manual MECO, return to AUTO {if CSS}, prepare for manual MECO"
- When good O/B configuration confirmed and ET impact point 15 sec from limit line:
 - FDO: "Manual MECO now"
 - CAPCOM to CREW: "Manual MECO now"
 - FD transmits ABORT light command
 - If required, FDO transmits ABORT light command as a backup
- ET impact point contacts a limit line:
 - FCO transmits the ABORT light command
 - FCO voices manual MECO codeword to MCC
 - CAPCOM to CREW: "Manual MECO now, manual MECO now"
- Two cues are required for the crew to take manual MECO action
 - "Prepare for manual MECO" call
 - "Manual MECO now" call
 - ABORT light illuminated
 - If ABORT light was already on, 15 sec from the "prepare for manual MECO" call

BACKGROUND

This procedure was developed to satisfy the Range Safety community that the Space Shuttle could safely fly without a range safety destruct package on the External Tank. NASA convinced the Air Force that a manual MECO could be done if required in second stage to prevent the crossing of a range safety destruct line.

A couple of things were added as a result of the negotiations with the Range. The FCO now has two abort light switches on their consoles. The FCO will use the abort light switch if the MCC has not yet requested a manual MECO and the FCO has determined that it is required. Both the FCO and the Senior FCO has one abort light switch on their console. The TRAJ workstation enables one of these switches while one of the FD workstation enables the other.

One of the other things that was added was the manual MECO codeword. This is used by the FCO to request a verbal call to the crew, through CAPCOM, to request a manual MECO. In theory, neither the FCO abort light switch or the FCO verbal request should ever happen. FDO should be requesting the manual MECO per the steps above prior to getting to the destruct line.

The other steps required for fulfilling the requirements are the range safety training. This consists of the crew getting a briefing and tour of the ROCC. Also, the crew and FCT should see at least one range safety case in flight specific training. A short briefing with FD, CAPACOM (if available), FDO, CDR and PLT must also be done prior to each mission. After all of these steps have been done, the Range Safety COFR (certification of flight readiness) statement must be signed. A copy should then be faxed to the FCO. The blank COFR statement is stored in the DM46/FORMS folder on the S drive (RNG_COFR.doc).

9.5.5 ECAL and Bermuda Abort Procedures

PURPOSE

The purpose of this procedure is to document the calls that should be made to the FCO for the case of an ECAL or Bermuda abort.

PROCEDURE

- TRAJ
 - ONCE AN ECAL OR BERMUDA ABORT HAS BEGUN:
 - CALL FCO: We are executing an ECAL or Bermuda abort
 - AFTER ET SEP: CALL "FCO, WE'VE HAD ET SEP"

BACKGROUND

In the case of an ECAL or Bermuda abort, these calls are made to ensure that the FCO is aware of the situation. Some relief may be granted in these contingency cases for proximity to the range safety limit lines compared to the nominal case.

9.5.6 Amber Zone

PURPOSE

Document procedures regarding response to the "Amber Zone" Call. This call is only critical in first stage.

PROCEDURE

UPON "AMBER ZONE"

- ENSURE THAT FD COPIED AMBER ZONE
- CHECK ETIP, OUTPLANE FOR CONFIRMING DEVIATIONS
- FIRST STAGE ONLY: ENSURE THAT FCO COPIES FD CONTROLLABILITY STATUS RESPONSE

BACKGROUND

Reference section A4-256, Range Safety Flight Rules.

9.5.7 Codewords

PURPOSE

Document transmission and use of code words.

PROCEDURE

- L-2 WKS FDO RECEIVES CODE WORD LETTER FROM FCO VIA DM4 BRANCH CHIEF. LETTER STORED UNOPENED UNTIL L-1 HR.
- L-2 HR FDO/FCO STANDARD REPORTING TAG-UP: FCO VERIFIES CODE WORD LETTER DATE WITH FDO
- L-1 HR FDO OPENS CODE WORD LETTER. COPIES ARE GIVEN TO FD AND CAPCOM.

POWERED FLIGHT CODE WORD ACTIONS:

- ARM/FIRE (FCO-INITIATED WITH CODE WORD)
- UNCONTROLLABLE (FD-INITIATED WITH CODE WORD) INDICATES TO FCO THAT VEHICLE HAS LOST CONTROL
- MANUAL MECO (FCO INITIATED) INDICATES THAT A MANUAL MECO IS REQUIRED TO AVOID DESTRUCT/MECO LINES
- FOA BREAKUP (FCO-INITIATED WITH CODE WORD) INDICATES THAT VEHICLE BREAKUP VISUALLY OBSERVED BY PERSONNEL IN THE FORWARD OBSERVER AREA

SCRUB ACTIONS:

- FDO: PICK UP COPIES FROM FD AND CAPCOM. RE-SEAL CODEWORD LETTER FOR USE ON NEXT LAUNCH ATTEMPT

POST LAUNCH:

- FDO: PICK UP COPIES FROM FD AND CAPCOM. DISPOSE OF ALL COPIES IN THE SHREDDER.

BACKGROUND

Reference section A4-255, A4-256, A4-259 , Range Safety Flight Rules.

9.5.8 FDO Abort Switch

PURPOSE

Document FDO activation and use of the abort switch.

PROCEDURE

NOTES

Both FDO and TRAJ must first log into the Command Server (FDO must log in as FDO, **TRAJ must log in as FDO1**). Activate GCS Abort prior to bringing up Monitor S/W. LSO (traj9), ARD (traj1), or GPO consoles may be used in the event of FDO or Traj W/S failure. Abort switch S/W may be run on Traj console in event of failure of FDO W/S.

• **ABORT GRAPHICAL USER INTERFACE (GUI) ACTIVATION**

- CLICK FDO DNAV / APPLICATIONS MENU.
- CLICK "ABORT SWITCH" → "FDO" OR "FCO (WFCR 10 ONLY)" → "ACTIVATE GCS ABORT"
 - IF THE USER SELECTED "FDO":
 - THE ABORT GUI SHOULD APPEAR AND THE ABORT SWITCH SHOULD LIGHT UP AND READ "ABORT" (WFCR29 only)
 - MINIMIZE THE ABORT SWITCH GUI
 - H/W SWITCH WILL DISPLAY "ABORT A/B ON" WHEN ABORTS ENABLED
 - IF THE USER SELECTED "FCO (WFCR 10 ONLY)":
 - THE ABORT GUI WILL NOT APPEAR.
 - THE ADVISORIES PANEL SHOULD SHOW THE STATUS OF THE HARDWARE CONNECTION TO THE FCO's
 - "MONITOR GCS" WILL SHOW GREEN STATUS WHEN FCO ABORT PANEL ACTIVATED
- THE ABORT SWITCH IS NOW CONFIGURED. Abort light test may be monitored w/ "Command Summary" display under Gen Traj \ Command Loads Sub-menu \ Command Server \ Telcom Displays \

• **ABORT SWITCH DEACTIVATION**

- CLICK FDO DNAV / APPLICATIONS MENU.
 - CLICK "ABORT SWITCH" → "FDO" OR "FCO (WFCR 10 ONLY)" → "DEACTIVATE GCS ABORT" → "YES"
- FDO USE ABORT SWITCH UPON FD REQUEST (BACKUP TO FD ABORT SWITCH)

BACKGROUND

The MCC abort switch is used to activate the cockpit abort light in the event the mission must be aborted. This is to provide a confirming cue to the crew per Flight Rule A2-58 (at least two cues are required to abort the mission, including MCC voice call, abort light, SSME status light, etc). The FD is prime for sending the abort light command, using a hardware switch on wfcr9. FDO has a backup hardware switch on wfcr29, which may be used in the event the FD pushbutton is inoperative. Additionally, both FDO and FD may utilize a software abort switch on either their workstations.

Another important function of the abort light is to notify the crew to perform a manual MECO in order to avoid range safety limit lines. In second stage, SOP 9.5.4 specifies that FDO call "manual MECO now" when the 15 sec ETIP predictor bug crosses the destruct line. In order to provide two cues to the crew, FD sends the abort light command concurrent with CAPCOM's call for manual MECO (ref FR A4-259). Again, FDO's switch is a backup to FD. The Flight Control Officer (FCO) also has two abort switches that are activated if the IIP crosses the destruct line in second stage. In this case, FCO calls out the MECO codeword on the FD loop and sends the abort light command simultaneously. This should not occur if MCC is responding in a timely manner.

The two ROCC abort switches are connected to the MCC via independent 9.6 KB data circuits, and interface with the MCC command server via wfcr10 (FC2) and wfcr28 (FC1). For this reason, both Traj and FD must run the FCO GCS abort software on their workstations. FCO should notify FDO in the event of loss of heartbeat on the ROCC abort switches. Troubleshooting steps such as recycling the GCS software should be performed on a time-permitting basis. Note that LCCs do *not* require the ROCC abort switch for commit to launch. LCC 5.1.2.6 and FR A3-3 simply state that *one* abort light command path is mandatory for launch. In the event both FCO switches malfunction, launch may proceed as long as MCC has at least one good path. In this case, FCO will notify FDO of the failures and state that FDO is prime for sending the abort light command for range safety. In other words, approaching the range safety limit line in second stage, FDO will push the abort switch upon hearing FCO's manual MECO codeword. Also in this case, FCO will expect immediate notification if MCC loses abort light command capability prior to T-10 sec, as this will result in a holdfire up to this point.

9.5.9 Controllability Light

PURPOSE

Document the use of the controllability light.

PROCEDURE

- L-2 HRS: TEST LIGHT
 - FDO/TRAJ: COORDINATE WITH GNC, GC -- READY FOR TEST
 - WHEN ALL PARTIES READY, INFORM FCO THAT TEST IS BEGINNING
 - CUE GNC TO SEND LIGHT
 - CONFIRM FCO RECEIPT OF LIGHT AND TONE
 - HAVE GNC CLEAR LIGHT
 - CONFIRM FCO CLEAR
- POWERED FLIGHT: IF GNC DETERMINES LOSS-OF-CONTROL, GNC SENDS LIGHT

BACKGROUND

Reference section 9.4.1, Controllability.

10 CONTINGENCY OPERATIONS

Should a contingency be declared, the team on console should immediately reference SOP 2.8 of the FCOH (Note: The electronic version of the FCOH, available through the DA8 homepage, is currently incomplete and does not contain SOP 2.8). It has the checklist that FD will direct the FCT to follow.

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APPENDIX A: FDO CONSOLE HANDBOOK CHANGE PROCESS

A. FDO CONSOLE HANDBOOK CHANGE PROCESS

- 1) The change initiator fills out a change request (CR) form. The CR form is available on the dm server under S:division/private/dm46/forms/fdochcr. See page A-3 for an example of this form. At a minimum, the initiator supplies the submission date, a short descriptive title, a detailed description of the change, rationale for the change, and the initiator's organization/name.
- 2) The initiator transmits the CR form to the pertinent documentation editor.
- 3) The editor reviews the CR and formulates recommendations for implementation. These include whether or not to implement some or all of the change and a competent technical author designated to draft documentation changes.
- 4) The editor reviews implementation recommendations with the pertinent group lead, who annotates the CR as approved or disapproved for implementation.
- 5) If the CR is disapproved for implementation, the initiator is informed of its disposition. The editor may elect to retain the CR on file for future reference or dispose of the CR completely.
- 6) If the CR is approved for implementation, the editor assigns it a tracking number.
- 7) The author submits draft documentation to the editor.
- 8) The editor reviews and modifies the draft for technical correctness and consistency with related documentation. Additional contributions from the author may be requested by the editor during this process.
- 9) The editor submits the modified draft to selected technical experts for additional peer review.
- 10) Technical experts submit draft feedback to the editor.
- 11) The editor absorbs appropriate peer review feedback into a final draft. Additional contributions from the author may be requested by the editor during this process.
- 12) The editor incorporates the final draft into a page change notice (PCN) original. The PCN may also contain final drafts related to other CRs and appropriate changes to the affected document's table of contents or revision history.
- 13) The editor reviews PCN content with the group lead, mapping changes into CRs authorized for implementation. If a CR is found to be addressed by the PCN such that it has been completely implemented, the lead annotates the CR as closed. Some CRs may be left open because they must be implemented with multiple

PCNs. When satisfied with PCN content, the group lead and Branch Chief approve the document by signing the Signature Page. The editor must fill out both JSC Form 31 and 1410 prior to delivery of the PCN to the Printing Management Branch for formal printing.

- 14) The editor supervises PCN reproduction and distribution. This includes posting the PCN to “general use” console and office copies of the affected document.

FDO Console Handbook Change Request (CR)

Submit Date:	Volume:	CR #
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For Administrative Use Only

Subject:

Description of Change or Addition:

Reason for Change or Addition:

Initiated By:

Assigned To:

For Administrative Use Only

Group Lead Authorization Signatures	
IMPLEMENT	CLOSE (PCN =)

Revised July 1996

APPENDIX B: WORKSTATION PROBLEM REPORTING/RESOLUTION

B. WORKSTATION PROBLEM REPORTING/RESOLUTION

PURPOSE

To describe the generic workstation problem reporting/resolution procedures in the Mission Control Center (MCC).

PROCEDURE

When a workstation problem occurs, perform the following steps:

- 1.) Immediately contact Workstation Software Support (WSS) on WSS CALL. If you are in a time critical situation and your workstation is down, notify Ground Controller (GC) and move to your backup workstation while WSS works the problem.

WSS should take a look at the problem and try to figure out where the problem is. If the problem is with the system, WSS will contact the appropriate United Space Alliance (USA)/Mission Systems Contract (MSC) support personnel to fix the problem. If the problem is with a user application, WSS will contact your Group Administrator (GA).

- 2.) If you believe the problem is with a DM application, call your GA.

WSS should call your GA, however, sometimes it is quicker for you to make this step. The GA on-call list should be on console.

- 3.) Write an Anomaly Report (AR) documenting the problem. Pass the AR number to GC for TRS ARs.

An AR is required on all problems, even if you believe that the problem has already been reported (One AR per SIM/MIS is adequate. If time doesn't permit to write the AR at the time of the event, please write the AR prior to completion of your shift.

Submitting an AR

- 1.) Go to the DRTS webpage and click on the NEW button:
URL: <http://usa10.unitedspacealliance.com/tx/drts/>
- 2.) Blue boxes must be filled in.
- 3.) Fill in the AR Title box with a short description of the problem.
- 4.) AR Originator: Type in last name and then tab off of the field. This will bring up another window with a list of persons with the same last name. If

your name appears in this list, select your name by clicking on the button in the left column on the row with your name. If your name does not appear on the popup window, close that window and hit the Add ORIGINATOR button. Then fill in your last name, mail code and office phone number.

- | 5.) Functional Group: Select the appropriate group. For most of the FDO ARs, it will be FDSW.
- | 6.) Now click on the SUBMIT button.
- | 7.) System: Select the appropriate group. TRAJECTORY for TOCCS applications, TRJ SERVER for Trajectory Server applications. **Do not select USER APPS.**
- | 8.) Application/Subsystem: The pulldown menu varies depending upon the choice selecting for in the System block above.
 - o For TOCCS apps, this would be the appropriate group that you work in (e.g. AEFDO).
 - o For TRJ SERVER, select TS-TRJ - Trajectory server Trajectory applications s/w
- | 9.) Sub-subsystem: This would be the actual application from the list of apps. Select from the popup menu.
- | 10.) Click on SUBMIT button. This will move you to the final page for completing the SR.
- | 11.) Final Page: At a minimum, all blue boxes must be filled in.
 - a) AR Description
 - b) AR Type/Anomaly Type: chose type from the AR Type window that opens up. NOTE: This window must be maximized in order to see/click the SUBMIT button at the bottom. Type "D" is most likely choice here.
 - c) Date and time of failure: Defaults to Local time. Be sure and select UTC (GMT) is applicable.
 - d) Activity: Select the activity type (e.g. mission, sim, comp run, etc.) that was ongoing when the anomaly occurred.
 - e) Problem Impact/AR Priority (Critical, Major, Minor). Critical means that people will work 24 hours a day, 7 days a week, until the

problem is resolved. Be sure the problem is critical before you check this box. GC will ask you to justify this.

- f) Ops Center Level Impact: Chose from options in the popup window. The descriptions help in determining which one applies.
- g) Problem Type/Failure Category: H/W, S/W or Admin
- h) Flight ID Occurrence and Flight ID Fix Required for: self explanatory
- i) Problem Impact to Ops Support: Short description of the impact caused by the problem
- j) Attachments: This is the number of attachments. Put zero if there are none. See note next to the attachments box for instructions on where to send copies of paper attachments.

- | 12.) Once all the mandatory boxes have been filled in, scroll back to the top of the page. It is recommended that you click on SAVE DRAFT now.
- | 13.) Once completed, click on ERROR CHECK AND SUBMIT FOR REVIEW button.
- | 14.) If there were no errors found, the software will now allow you to submit the AR into the system.
- | 15.) **Keep a copy of the AR and attachments for future reference.** Also, for ARs written while on console, give a copy of the AR to GC.
- | 16.) You will receive an e-mail notification once your AR has been accepted by the AR database personnel.

APPENDIX C: DISPLAYS

C. DISPLAYS

The entire set of Ascent FDO displays and Range Safety displays can be viewed by clicking on the appropriate URL below:

TBS

APPENDIX D: PROCESSORS

D. PROCESSORS

D.1 Abort Region Determinator (ARD)

The Abort Region Determinator (ARD) processor is used during powered flight in order to assess the performance and abort capability of the Orbiter. The ARD uses the best available state vector source (Selected Source state vector, SSSV) in its processing. The ARD operates cyclically (2 second cycle) throughout ascent powered flight. The ARD calculates, in terms of velocity margin, the current availability of each of the RTLS ATO, AOA, and TAL abort modes as well as the capability of reaching the MECO targets for the nominal mission. The ARD margins are calculated for three defined input sets: actual mode (AM), hypothetical mode (HM) and second hypothetical mode (2HM or SM). The ARD AM inputs will always reflect the current flight situation and will be used to monitor the current performance capability. The ARD HM inputs are available for evaluation of abort or nominal capability under any conditions desired. Normally the HM is used to hypothesize one SSME out performance capabilities in order to support the FDO MCC abort mode boundary calls. Similarly, the 2HM is used to hypothesize two SSMEs out performance capabilities to support the single engine (remaining) abort mode boundary calls. For the HM and the 2HM cases the SSME(s) is/are considered to have been shutdown at the time of the SSSV being processed but the OMS/RCS dump is considered to have begun a logical number of seconds later (DTBURN - system parameter) to simulate the delay between abort recognition and selection.

For all three modes, the ARD propagates the SSSV conditions to MECO using numerical integration in first stage and analytic projection in second stage. For each abort mode, the applicable OMS/RCS burn (dump) schedule is used in the calculation of the velocity margin. In addition to the abort dumps, the ARD accounts for the OMS Assist burn, SSME 3-g throttling, and, for RTLS, the powered pitch down phase. The propellant remaining at MECO for each abort mode, minus the FPR, is converted to a ΔV margin that is output to the ARD OUTPUT display. It is displayed as MPROP for Main Propulsion system margin (either positive or negative margin). A negative margin is referred to as a predicted underspeed.

The ARD also computes the excess OMS post-MECO delta V available for nominal, ATO, and AOA modes. This excess OMS is converted to the maximum underspeed that can be supported post-MECO with the OMS remaining at MECO. For the abort mode being considered, the answers may vary due to differences in the OMS dumps assumed in each case. For example, NOM and AOA channels assume only an OMS Assist while the ATO channel may assume an additional ATO dump. The excess OMS computations commence at staging

and continue throughout second stage. It is displayed as XOMS on the ARD OUTPUT display.

The ARD function changes after the selection of an abort mode (via PBI). The role of the ARD becomes one of monitoring the progress of the selected abort and investigating further failures.

The ARD is made up of modules (basic fundamental groups of interrelated algorithms required to perform a specific ARD purpose), tasks (algorithms which perform a specific function within an ARD module), and sub-tasks (individual calculations resulting in an overall calculation required by an ARD task). Each ARD module sequences several ARD tasks. ARD tasks may sequence other tasks or sub-tasks as necessary.

The ARD Supervisor (ARDSUP) controls overall ARD processing by executing the ARD executive sequencing module (ARDEXEC) and by scheduling the RTLS event predictor (EP) when an RTLS has been selected. ARDSUP also controls output from the ARD execution.

The ARDEXEC sets event flags and calls the individual modules which comprise the program. It contains the logic to discriminate between the AM and the two HM cycles. ARDEXEC sequencing proceeds as follows:

- o The ARD input task is performed each cycle in order to lock the current values in the ascent constraint table and provide a consistent data set for the other tasks and modules.
- o The vehicle-sensed acceleration calculation task is performed.
- o If there has been a MED input to lock an SSME throttle since the last ARD cycle, then the SSME lock task (ARDLCK) must be performed. The purpose of this task is to set future throttle values of a particular SSME to a constant value.
- o The SS Earth-fixed velocity magnitude task must be performed. The M50 to Earth-fixed (EF) conversion sub-task (ARDCNV) using the SSSV is performed to obtain the EF velocity vector, the EF velocity magnitude can then be computed.
- o If an SSME out PBI has been received, then the SSME out velocity (VMEOUT) and time determination task must be performed. The EF velocity magnitude and the current SSSV time are used as initial interim estimates for the VMEOUT and time. This task is executed only for the first receipt of an SSME out PBI. Updates to these values are made via MED entry once the actual velocity and time are known.
- o If there has been an update to the VMEOUT/time by PBI or MED entry since the last ARD cycle, then the SSME out safing task must be performed. This

task will zero the current and all future throttle settings in the failed SSME table (AM only) for times greater than or equal to the SSME out time. For the remaining SSME's which are not locked, the SSME throttles are adjusted to the maximum or abort throttle setting (KMAX or KABT) for time greater than or equal to the SSME out time in the AM. The throttle setting used by the SSME out safing task depends on the velocity of the engine out. The velocity/time of SSME out is saved.

- o If there has been an update (MED) to an SSME mixture ratio (MR) or Isp (i.e., thrust limiting mode), the SSME lock task must be performed with the MR or Isp history tables for times greater than or equal to the thrust limiting time (MED).
- o The adaptive guidance weight calculation task is performed to compute the adaptive weight adjustment (DELWT) based upon the delta-time (TDEL) from the PASS, BFS, or filter data (when PASS or BFS are not available). DELWT may also be input via MED.
- o ARDEXEC sets the AM/HM/2HM flag.
- o The current mass model is now called in order to provide the current vehicle mass properties (vehicle weight, ET fuel remaining, and OMS/RCS fuel remaining) used in AM/HM/2HM margin predictions.
- o The time for start of active guidance is calculated based upon input start of SRB separation sequence initiation and attitude hold duration as input pre-mission.
- o ARD Main (ARDMNE) sequencing program is now executed. ARDMNE is primarily a task scheduler. It is used for both AM, HM and 2HM margin calculations. It requires from ARDEXEC the AM/HM/2HM flag and current mass properties. Sequencing of the ARDMNE typically proceeds as follows:
 - a. The current SSME throttle setting task is executed. This task ascertains the current SSME throttle (AM/HM/2HM) settings to be used in other tasks.
 - b. The ascent phase determination task is executed in order to determine from the SSSV time if staging has occurred.
 - c. The abort proceed flag determination task is performed in order to set the abort proceed flag. This flag is used throughout the modules and tasks in the ARD to indicate post-abort mode selection. The value for this flag is obtained from the abort PBI, if selected.

The following post-abort mode selection tasks (d, e, f, g, h, i) are now performed if an abort has been selected and the phase indicator flag shows second stage.

These tasks are only performed on the first pass or if an MED update to the abort proceed time or velocity of SSME out has been received.

- d. The 3 SSME RTLS safing task is performed. If all SSME throttles are non-zero then the throttles (only those which are not locked) are set to the 3-engine RTLS fuel dissipation throttle settings.
- e. The post-abort mode selection velocity at engine out initialization task is performed only on the first pass and if all SSME's have non-zero throttle settings. This task sets the velocity of SSME out to the current Earth-fixed velocity magnitude.
- f. The post-abort mode selection OMS/RCS burn table selection task is performed in order to retrieve the appropriate OMS/RCS burn timers. The burn table selection task is executed with inputs of velocity of SSME out and the abort proceed time in order to return the correct OMS/RCS burn times.
- g. For the first pass only, the abort proceed time initialization task is performed. The SSSV time is used as an initial abort proceed time.
- h. If the variable IY execute flag is set and the IY computation completion flag is not set, the post-abort mode selection variable IY calculation task must be performed. If an ATO abort has been selected with the velocity of SSME out set less than the minimum continuation velocity, a new IY target vector is computed based upon the SSSV. If the inclination of the current IY vector is less than the inclination of the Minimum IY, then the current is set to the Minimum IY.
- i. The post-abort mode selection pre-MECO OMS/RCS burn scheduling task is performed with the abort proceed time and OMS/RCS burn timers. Returned are the ignition and termination times for the pre-MECO OMS/RCS burns.
- j. If the ascent phase indicator shows first stage then the ascent numerical integrator (ARDANI) must be executed. The ARDANI performs all tasks and executes all models required to extrapolate SSSV conditions (including vehicle weight and ET propellant remaining) to the start of second stage guidance. The first step is to select the correct table of body axis commands from the ascent guidance table (i.e., SSME out or no SSME out tables). At this point, the loop of calculations used in integrating until the start of second stage is executed. This loop provides the functional evaluations and numerical execution to integrate one complete time step and is repeated until the start of second stage, the following tasks are performed in the loop:

1. Adjustment of the time step to fall exactly on the time of staging.
 2. Obtain the body axis commands and calculate the angle of attack.
 3. Execute the propulsion model to provide thrusts/fuel flow rates of the SSME's and SRB thrust and propellant remaining.
 4. Call the aerodynamic model to provide the aerodynamic forces and pitch moments on the vehicle.
 5. Correct the vacuum thrusts obtained from the propulsion model for atmospheric pressure.
 6. Using the cant angles of the SSME's, calculate the acceleration on the vehicle.
 7. Adjust the cant angles for the SRB's in order to balance the aerodynamic moments and thrust moments of the vehicle. Moments necessary for vehicle attitude control and moments outside the pitch plane are considered negligible. Moment balancing at SRB tail off is ignored as only a few seconds of integration time remains.
 8. For the Runge-Kutta integrator equations, a weights and acceleration calculation task is performed. This task provides the integrator with the mass properties and velocities/accelerations for the beginning, middle, and end of the time step.
 9. Integrate the SSSV over one time step using the Runge-Kutta numerical integrator.
 10. Setup data for the next time step.
- k. The second stage predictor (ARDSSP) must now be executed in order to provide velocity margin predictions for the nominal and all abort modes. The ARDSSP will predict second stage active guidance performance to MECO. Normal pre-abort mode selection and post-abort mode selection predictions are supported by ARDSSP. The following tasks are sequenced by ARDSSP:
- A. Ascertain if pre- or post-abort mode predictor operation is required.
 - B. Initialize PEG inputs (current mass properties and ARDANI output vector (if first stage) or SSSV (if second stage)).

- C. Initialize SSME throttle/lsp settings for PEG input.
- D. Set OMS/RCS ignition/termination times and number/type of thrusters to be used in PEG processing.
- E. Compute the thrust, total flow rate, and exhaust velocity for each thrust phase (constant thrust; up to TFAIL, constant thrust; after TFAIL, constant acceleration; 3-g limiting).
- F. Set velocity of SSME out for post-abort mode selection AOA/ATO prediction requirements (if no SSME has failed this time is set to the SSSV Earth-fixed velocity).
- G. Set PEG mode and abort mode indicator to nominal.
- H. Set OMS/RCS burn execution flag to nominal.
- I. PEG is executed for nominal second stage guidance performance predictions with inputs of nominal IY, FPA, velocity, and radius MECO targets. Note: To insure quick convergence, PEG is initialized with the nominal PEG values from the previous nominal PEG call as initial guesses.
- J. The nominal velocity margin calculation task is now performed.
- K. The nominal post-MECO delta V adjustment task is now performed with the final result being the total nominal velocity margin (total includes any post-MECO OMS delta V margin if in second stage).

The TAL sequencing is the same as the nominal except for the following:

- o Initialize the TAL landing site area targets for the selected TAL site

The ATO sequencing is the same as the nominal except for the following:

- o PEG is executed for ATO second stage guidance performance predictions with inputs of abort IY, FPA, velocity, and radius MECO targets. If the VMEOAT is greater than the ATO target switch velocity (VMEOATO), then the nominal MECO targets are used by PEG for ATO. If variable IY execution has been selected, then the IY vector is calculated as per the task defined in (h) above. Note: To insure quick convergence, PEG is initialized with the ATO PEG values from the previous ATO PEG call as initial guesses.

The AOA sequencing is the same as ATO.

The RTLS sequencing is the same as the nominal except for the following:

- o Initialize the RTLS landing site area targets for the selected RTLS site.
- o PEG is executed for RTLS second stage guidance performance predictions. The PEG radius MECO target is set to the RTLS PPD radius target. Further Peg initialization is also required. The length of turnaround (DTTURN) is initially determined from a system parameter. Otherwise, the following must be done:
 1. If there has been an update to the VMEOOUT by MED or PBI input, then DTTURN is computed.
 2. If current time is greater than the time to turn, then DTTURN is adjusted to the time remaining in the turnaround.
 3. ARDSSP extrapolates the vector through the turn.
 4. The Isp for each SSME is determined from the SSME throttle tables.
 5. The commanded flyback throttle setting, the total SSME flow rate, and total SSME thrust during the flyback are calculated. The acceleration, vehicle mass, weight, and ET propellant remaining are extrapolated to the end of the turn.
 6. The total thrust, total flow rate, and the exhaust velocity are computed for each PEG phase.
- o To insure quick convergence, PEG is initialized with the RTLS PEG values from the previous nominal PEG call as initial guesses. If the previous value of RTLS TGO is less than the TGO to fine countdown then PEG is not called and ARDSSP uses open loop guidance in the VGO computation.
- o The RTLS velocity margin calculation task is now performed with the output of the total SSME RTLS velocity margin. This value is decremented by the delta V required to perform RTLS PPD which is dependant upon the number of SSME's active.

ARDMNE continues after the abort mode delta V margins have been computed.

- o The outputs from ARDMNE (AM) are saved for later execution of the ARD output task.
- o TGO is output to display.
- o ARDMNE is now executed for the HM.

- o The outputs from ARDMNE (HM) are saved for later execution of the ARD output task.

There are several principle modules used in ARDEXEC which are described here.

The ARD output task is used to display all AM/HM/2HM outputs each ARD cycle. Abort mode selected, total Orbiter weight, usable OMS and RCS quantities are passed to the AME processor upon receipt of the MECO PBI. For velocity margin outputs which are not available due to an abort mode selected the outputs to the ARD display are not made.

The current mass model is used to keep track of the vehicle mass properties. The mass properties are based upon fuel usages and expected usages for various abort modes through time.

- a. The initial ET propellant task - The initial ET fuel is updated via MED entry and causes a mass track recycle to zero.
- b. The ET fuel remaining task - This task keeps track of the current ET fuel remaining throughout launch using the throttle history and the propulsion model.
- c. If thrust limiting is enabled, the imbalance task is performed. This task calculates the current mass track LOX/LH2 imbalance which is then adjusted by the input fuel bias and output to display.
- d. Computation of the dry vehicle weight is performed.
- e. The SRB propellant remaining onboard at current time is computed with a call to the propulsion model.
- f. The current OMS/RCS fuels remaining are computed using the OMS/RCS burn schedules for the applicable abort mode.
- g. The vehicle total weight is computed.
- h. Adjustments to the ET (delta ETP and delta weight override), OMS, and RCS fuels are performed as per MED input.
- i. The usable OMS/RCS fuel weights and delta V's are calculated using the total weights from (f) above and the unusable OMS/RCS quantities loaded pre-mission. The delta V's are computed using rocket equations.

The propulsion model is used to evaluate the thrust and mass flow rates of the SSME's.

The following are separate modules which support ARDEXEC:

The aerodynamic model is used to calculate the aerodynamic forces and moments corresponding to inputs from the ARDANI. The 1962 U.S. Standard Atmosphere is used throughout this model.

ARDPEG is the ARD version of the onboard PEG, a general purpose guidance task which computes the reference thrust vector, desired thrust turning rate vector, reference thrust vector time, VGO, and TGO to target conditions for explicitly guided exoatmospheric maneuvers such that propellant usage is minimized. The ARD uses PEG in its predictor mode to analytically predict second stage performance to MECO or to PPD for RTLS. Mode-1 (standard ascent; nominal, ATO, and TAL) and mode-5 (RTLS) are the only PEG modes supported in ARDPEG. Mode-1 MECO target conditions are specified pre-mission and defined by a desired MECO velocity (range-velocity target line for TAL), FPA, radius, IY vector, and TAL crossrange. Mode-5 PPD targets are radius, range-velocity target line, FPA, desired MECO mass, and a bias to move the return flight heading for ET impact considerations. There are some major differences between onboard PEG and ARDPEG. ARDPEG is allowed to iterate to a converged solution or until a maximum number of iterations has occurred, as where the onboard PEG does not iterate as the maximum number of iterations is set (via I-load) to 1. ARDPEG calls the initialization logic at the beginning for each PEG execution, while the onboard is initialized only once on the first PEG call and for an RTLS when an RTLS abort is declared. The PEG three burn phase calculations differ in that the ARDPEG uses phase one to account for any OMS/RCS abort dumps rather than the onboard PEG which assumes dumps are constant through MECO while the dump is taking place (eventually converging to the ARDPEG solution after the dump is complete). ARDPEG does not compute RTLS flyback throttles or output guidance steering commands.

The precise predictor task is used to determine the desired gravity integrals over the powered flight time. An RTLS/TAL approach and landing selection task is performed in order to provide ARDPEG with the RTLS HAC position, distance around the HAC, and a which HAC is selected. For the TAL abort mode the position of the site is all that is required.

The primary outputs computed by ARDPEG and passed back to ARDSSP are VGO, TGO, TAL crossrange, desired out-of-plane thrust turning rate vector, desired turning rate vector, and burn time each for each of the three thrust phases.

ARDPEG is primarily an iteration loop sequencer.

- o The position and velocity magnitude of the current state vector are computed.
- o Initialize the various counters and input data.
- o Determine current thrust phase.

- o Set up iteration loop control and perform loop until either PEG is converged, maximum iterations have been completed, VGO magnitude is less than or equal to zero, or greater than a maximum input value.
 1. Compute the total TGO and the intermediate TGO for each burn phase. TGO is a function of the current VGO, the effective exhaust velocity, and the current estimated acceleration.
 2. Evaluate integrals of thrust over mass summed over all burn phases.
 3. Determine the reference thrust vector for all guidance modes.
 4. Compute the position to be gained, RGO.
 5. Compute the thrust turning rate from RGO and the output from (2) above.
 6. Calculate the integrals due to both thrust and gravity as required in the prediction of the burnout state vector.
 7. Constrain the burnout position vector to be in the desired plane (If plane constraint is active).
 8. Correct the magnitude of the burnout position to be the desired burnout magnitude.
 9. Compute the desired plane (IY) for RTLS based upon the predicted PPD initiation position vector and the position vector of the center of the HAC (offset by the ET IP protection bias). For early RTLS aborts, an interim IY is computed using the current HAC position vector and current vehicle position vector until the guidance time exceeds a pre-mission value. Note: The interim IY vector is used to insure ARDPEG guidance convergence in this early RTLS phase. However, it is not computed onboard and thus there is a time during fuel dissipation during which the onboard guidance may be unconverged.

If the altitude constraint has been released, the out-of-plane thrust vector turning rate is computed to zero the PPD sideslip angle.
 10. The desired velocity vector and, if the plane constraint has been released, the IY vector are computed for all modes other

than RTLS. For TAL calculations, the desired velocity magnitude is a function of the predicted MECO range and crossrange (limited to a pre-mission maximum value) to the selected TAL site.

11. The desired RTLS velocity vector is computed. This vector is a function of the surface range between the predicted PPD position and the runway threshold (including the distance around the HAC).
12. VGO is computed.
13. The VGO vector is now corrected using the calculated miss in velocity and the delta VGO vector (VMISS7 velocity predicted - velocity desired, delta VGO; computed from VMISS and a computed scalar damping factor).
14. Determine if VGO has converged by comparing VMISS to the VGO times a convergence factor.
15. If TGO is less than a pre-mission defined time from MECO, the position and plane constraints are released.

A processor within the ARD code, the RTLS Event Predictor (EP) is activated by the receipt of the RTLS abort PBI and deactivated by the MECO PBI input. The EP is a cyclic abort monitor used during an RTLS abort. The EP computes event times and associated parameters during three operational phases:

- 1 - The turnaround event predictor phase.
- 2 - Turnaround in progress phase.
- 3 - MECO event predictor phase.

In phase 1, the EP computes pitcharound time, pitch attitude change when turnaround is commanded, and the pitch attitude during the fuel dissipation portion of an RTLS abort. The turnaround event predictions are made using an analytical projection of the rate of change of the final mass. Phase 1 is activated by the RTLS PBI and continues until turnaround (phase 2) begins.

During phase 2 the EP provides a prediction for the time to the end of the turn and continues to update this value until the turn is completed.

In phase 3 the EP cyclically computes the MECO time, range, and velocity beginning at turnaround and continuing until the MECO PBI is input. The EP also provides the alpha at PPD and the pitch change during PPD. The EP calculations assume that PEG will hit the PPD target conditions and that the PPD logic will hit the target alpha at MECO. The ARDPEG predictions are then used by the EP to analytically project MECO conditions.

All phases of the EP require cyclic updates of the current SSSV, mass, SSME throttle settings, desired PPD mass, VGO, etc. from the ARD.

D.2 Abort Maneuver Evaluator (AME)

The AME is a processor used in order to plan the highest attainable nominal or abort OMS-1/2 maneuvers based on the actual conditions at MECO. As such, the AME is not designed to support RTLS or TAL aborts. The AME is controlled by MED, PBI, and external processor interfaces (e.g., ARD, Launch Supervisor (LS)). MECO thru OMS-2 TIG is the main time frame of interest in AME processing.

The AME is a state vector/maneuver integration sequencing tool. The state vectors for integration are the current telemetry and the selected source (SS) state vectors. Integration constants, maneuver targets, fuel available, and other processor control parameters are also inputs to the AME. The initial set of control/data parameters are input to the AME pre-mission through the reconfiguration process.

The AME integrates an input state vector to a planned MPS dump TIG, models the MPS dump, integrates to an OMS-1 TIG and models the maneuver (if OMS-1 is required), integrates to an OMS-2 TIG and models the maneuver, totals up the used propellant, accounts for a deorbit on day one if required (analytic deorbit routine or manually input ΔV), and then compares the total propellant required with the total propellant available in compute a ΔV margin for the OMS-1/2 target sets examined. The AME can be used manually to examine target sets individually (single pass), or automatically through examining various sets of targets (Multi-target mode). See Sec. 7.2 for a complete operational description of the AME and its use.

The Executive performs the following tasks:

- o Retrieves the correct targets for OMS-1/2 based upon the desired Multi-target sequence or single pass target request. Calls Main and VER (Verification).
- o Computes ignition times and calls the analytic ephemeris generator (AEG) to propagate the selected source state vector to the initial time of ignition.
- o Determines whether a parallel burn is desired and, if so, the appropriate RCS time.
- o Provides for the functionalization (with respect to inclination) of the OMS-2 AOA target sets when the variable IY option is selected, (example. For input DTIG targets DTIG-1,DTIG-2,DTIG-3; the DTIG target used by the AME is a function of the inclination, (i). $DTIG = DTIG-1 + DTIG-2 * (i) + DTIG-3 * (i**2)$.
NOTE: The DTIG-2 and DTIG-3 coefficients are usually set to zero.
- o Activates the DDD's.

AME Main is called to compute the ΔV margin. When Main is entered, the powered flight numerical integrator (PFNI) is called for a double integration of the initial burn with the ullage timer off. If the TLM and SS vectors are the same or if a NAV update flag (INAV) is set, the powered explicit guidance supervisor (PEGSUP) is called for a single pass integration through the initial burn. INAV is set if the integration of the TLM or SS vector results in failure of the post-OMS-1 altitude (NOM or ATO), gamma (NOM or ATO), or total delta velocity margin test. If the OMS-1 burn was a NOM, ATO, or AOA and did not fail any of the above tests, then an OMS-2 burn is computed. For NOM or ATO, a deorbit ΔV (computed analytically or manually input with the target set) is taken into account in the assessment of the total ΔV margin. In the case of the NOM targets, the deorbit delta V is checked against the nominal EOM delta V (processor input) and the greater of the two is used in the total delta V required computation. VER computes a fully integrated solution for all cases where the total ΔV margin is positive or when no further downmoding is possible. The Free Flight Predictor (FFP) is used for coasting flight integration and the PFNI is used to simulate the maneuvers. The ΔV remaining computation takes into account any OMS ballast required for CG control and extra fuel available from AFT RCS commitment (WCGOMS). For AOA cases, the final post-burn state is propagated to entry interface (EI) in order to compute EI velocity and gamma values.

D.3 Downrange Abort Evaluator (DAE)

The DAE evaluates the orbiter's entry capability by generating a "footprint" that is overlaid on a world map. This footprint represents entry limits both in crosstrack and downtrack capability. Any landing site lying within the footprint can be achieved without violating guidance, thermal, or structural limits. The DAE may be run with any re-entrant state vector. The input vector is propagated to 180 kft with drag, then great-circle range capability from this position is analytically computed for high, low, and nominal drag. A footprint is then generated using generic coefficients that define the size and shape of the footprint based on the three in-plane points. Coefficients are contained in product DATA-22B DAE table, and are input into the Traj Server as part of the recon process via the B73 MED.

The DAE processor executes cyclically in launch phase from liftoff until MECO. It also may be run manually in a single-pass mode in OPS or landing phase using the B70 MED. Different post-MECO dump configurations may be employed in the single-pass mode. For input velocities below 18K ft/sec, DAE output is only an impact point showing in-plane lifting capability. Above 18 kfps, it outputs an Orbiter landing footprint assuming a TAL-type entry trajectory. The B72 MED parameter "mode switching velocity" controls this switchpoint. Between 18 and 25 kfps, the DAE outputs two footprints: one showing landing capability using nominal entry guidance, and another showing capability with low energy "stretch" guidance. Note that the DAE footprint does not show landing capability using "high energy TAL" procedures. See figure 14.3-1 and refer to FR A2-55 for a description of this composite footprint. The B73 MED parameters "xSTR" and "xSTO" control stretch footprint start and stop velocities respectively, where x=1, 2, or 3 for low, mid, or high inclination.

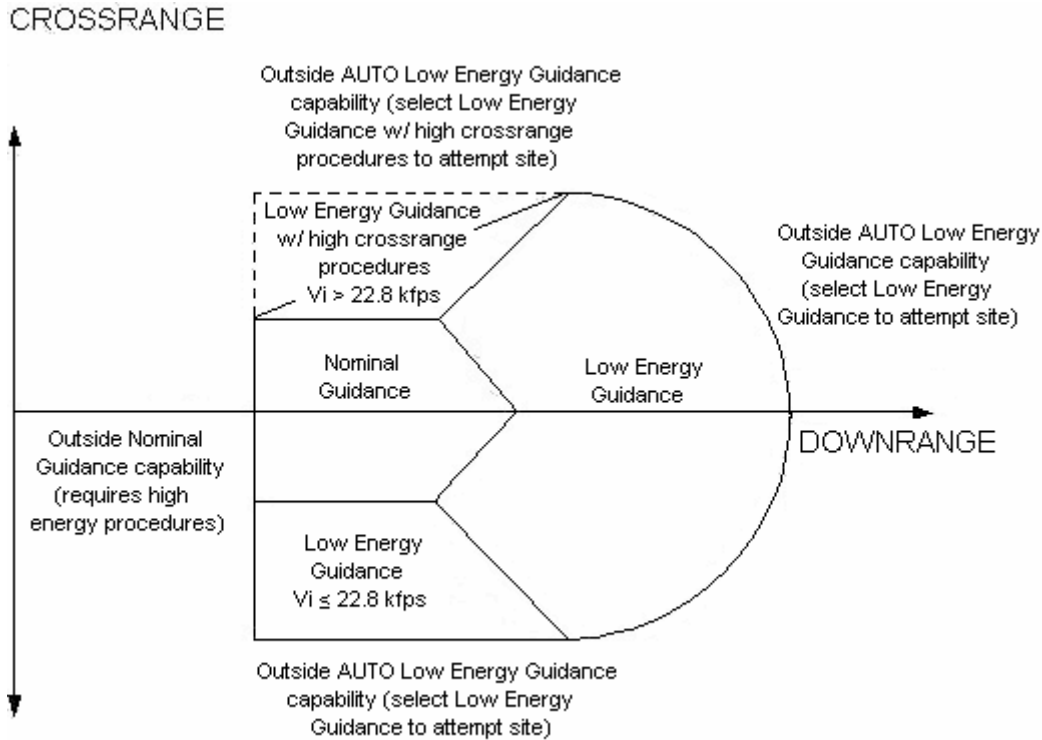


Figure 14.3-1 - DAE Footprint

The default method to execute the DAE is in auto where it uses **predicted** MECO state vectors generated by the ARD. Via PBI, the user can select which channel to use for the predicted vectors. The default is the TAL channel. The user can also change which mode is used. The default is the second hypothetical (2HM) mode. The PBI toggles from 2HM to actual mode (AM) to hypothetical mode (HM) and then repeats. The predicted underspeed for the selected channel is subtracted from the R-V target to obtain a MECO state that's fed to the DAE. The K88 parameter "PROPLVL" is also included in the computation of predicted underspeed in order to protect for powered flight dispersions. Vehicle weight and OMS quantity for the DAE are also handed over from the ARD based on the abort channel and hypothetical mode PBI selections.

In addition to computing a **predicted** footprint each cycle, the DAE also generates a **current** footprint each cycle based on the current SS vector. For each of these two state vectors the DAE actually outputs 3 footprints: no post-MECO OMS dump, OMS only dump, and OMS plus RCS dump. The OUTPLANE display shows the **predicted** footprint and the **current** footprint (see Figure 14.3-2). This display consists of a wide field-of-view of countries bordering the Atlantic Ocean on top, along with 3 zoomed-in views below that follow the current ETIP plus predictor bugs, current DAE IP or footprint, and predicted DAE IP or footprint (left to right on the bottom of Figure 14.3-2). A solid line is used for the no dump footprint, and dashed lines represent the two different dump configurations. In order to reduce clutter, the front screen display

in the FCR only shows the no dump footprint. A post OMS dump vector can be used to manually re-run the DAE for cases where the dump will make a difference in the capability to re-evaluate actual capability after the dump has completed.

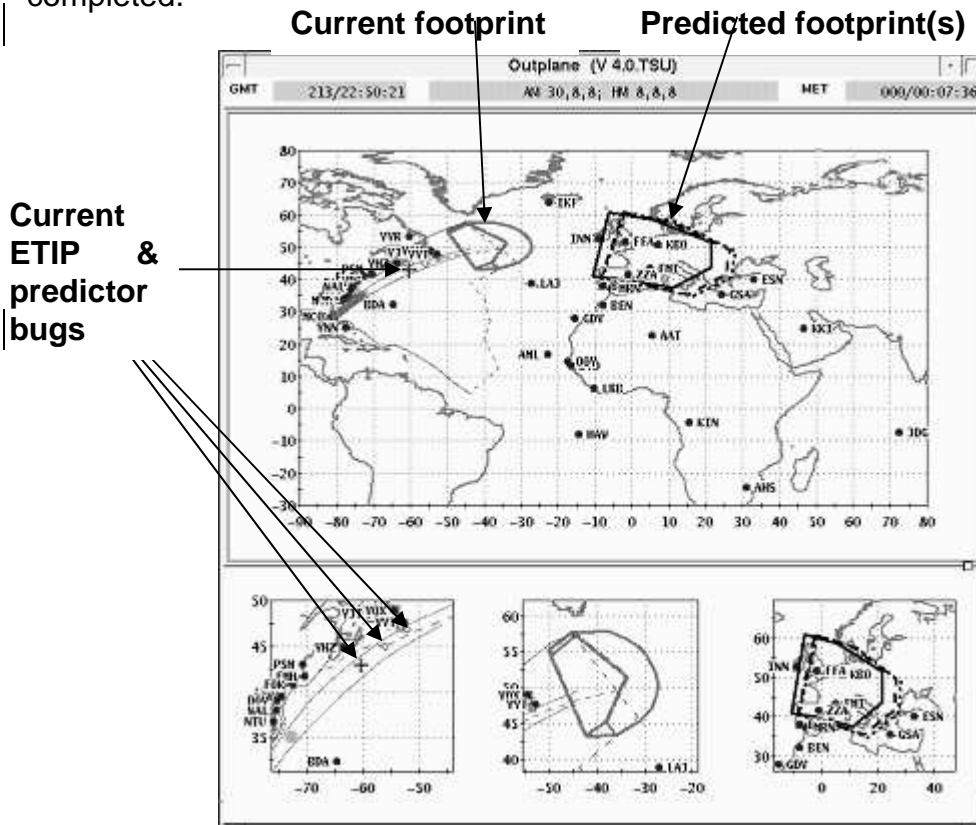


Figure 14.3-2 - OUTPLANE display.

As stated above, standard procedures call for the DAE P MECO CHNL PBI to be set to "TAL" and DAE P MECO MODE PBI to "2nd HYP". Since the 2nd hypothetical mode is set to a single SSME at 109%, its solution is static until well into second stage. For this reason, *an invalid predicted footprint is output prior to 2nd hypothetical mode TAL channel becoming active.* Actually, a nominal footprint hovers over the selected TAL site because 0 fps underspeed (from the unconverged channel) is subtracted from the TAL R-V target. A white stretch footprint replaces this once droop calculations begin updating. The current IP is shown as a green triangle. This is replaced with a composite footprint once xSTR velocity is reached (typically 18 kfps Vi). This shows up on the top wide view as well as the middle zoomed-in view at the bottom. The stretch footprint is deleted once xSTO velocity is reached (typically 22.7 kfps Vi), leaving only the nominal footprint. DAE output is used during powered flight to make the single engine limits call, and post-MECO to assess ability to make TAL or downrange abort sites based on actual MECO conditions. The OUTPLANE display freezes at MECO, preserving this key information for FDO to use if necessary.

To evaluate downrange site capability post-MECO, have DYNAMICS grab an onboard vector (V53) and run the DAE in single pass mode. Experience has shown that this will move the footprint slightly to the right of the “frozen” footprint at MECO, and provide a more accurate picture. Note that a filter vector must be used if the onboard nav state is suspect (V58 provides filter vector 6 sec after MECO). Regardless of which vector source is used, it must be grabbed no later than 72 sec past MECO in order to get unique solutions for the three dump options. For vector time-tags later than this, all three footprints will be equivalent to “no-dump”. This is controlled by the B72 MED, which is shown as the DT parameter on DAE Param 5 display. In the event that the vector is grabbed more than 72 seconds after MECO, the dump start delay can be increased with the B72 MED in order to get the 3 unique footprints. Another workaround is to use V58 or V59. If no MECO PBI has been set (e.g. during powered flight), the DAE assumes the dump start time is 72 seconds after the vector time-tag.

D.4 External Tank Impact Predictor (ETIP)

After STS 51-L, the ETIP processor was added to the FDOs' suite of software. This tool is necessary to allow the FDO to maintain situational awareness of the predicted ET impact point (IP) and the proximity of the IP to the range safety limit lines. The inputs to the processor include the atmosphere, reference area, drag scale factor, ET mass and drag on/off flag. The parameters are delivered in the TBD product and displayed on AME/ETIP AGT MED INPUT display. In cyclic mode the ETIP runs automatically from liftoff to MECO. It uses the current SS vector and assumes all thrusting terminated at the current time. Output consists of predicted ET impact time and location (geodetic latitude and longitude). It also computes two other IPs for predicted times in the future (default to 15 and 30 seconds in second stage). The current IP is depicted as a cross (+) along with two predictor bugs on the OUTPLANE display (see Figure 14.3-2 on previous page). This display shows the range safety limit lines along the East Coast as well as down south protecting the Bahamas. In ops and landing phase, ETIP may be executed in single pass mode using a vector specified by MED input.

Although the ETIP has the capability to generate a better estimate by using drag, the standard practice is to use it with drag turned off. This is done so that the FDO's solution agrees with the FCO's solution which assumes no drag. Drag may be turned on or off via PBI.

D5 Launch Window/Launch Targeting (LW/LT)

The Launch Window/Launch Targeting (LW/LT) processors are used, pre-liftoff, in order to evaluate the targeting effects of an update/change to a rendezvous target state vector and to compute associated targeting parameters for uplink to the Orbiter and use by the ARD and AME. They are actually two separate processors: Launch Window Processor (LWP) and Launch Targeting Processor (LTP) that are used together.

As the name implies, LWP computes the launch window. LWP is used to determine the times that launch can be done to get into the proper orbit to accomplish the rendezvous. It allows the use of inputs to easily determine the planar window open, inplane and close times (longitudes of the descending node) as well as the phase window open and close times using phase angle constraints (if required).

Once the launch window has been determined, the LTP is used to compute the targets to launch at a user-specified time. Output include the MECO, OMS-1 and OMS-2 IYs. Also, MECO, post MPS dump and post OMS-2 state vectors are computed. The solution will also include the phase angle at OMS-2 TIG. LTP has an optional routine that can be executed to predict the performance required to launch at the input time. This option, Launch Targeting Performance Predictor (LTPP), is usually executed when ever LTP is executed. On the MED, the B option for both LT and LTPP computations is used. The LTPP output also includes deltas with respect to the reference data.

The effects are that the liftoff time may be adjusted to satisfy the performance constraints of the flight. OMS-2 targets may be a phasing burn and therefore may be changed based on rendezvous phasing requirements. Once the final launch time and OMS-2 targets are determined, the LTP solution can be transferred over to the AGT so that the ARD, AME and GPO's command applications can use them. The GPO's then build two command loads (Launch Targets and OMS Targets) that are uplinked to the vehicle prior to launch.

D.6 High Speed Trajectory Determination (HSTD)

The High Speed Trajectory Determination (HSTD) processor is used to process high sample rate tracking data to determine current estimates of the Orbiter's state vector for all launch profiles, RTLS abort landings, and EOM landings. It is not used for TAL since there currently are no US tracking stations available for a TAL entry. The HSTD processes up to three ground tracking stations (2 C-band and 1 S-band) simultaneously. The C-band data is in the form of a range, azimuth angle, and elevation angle. S-band data consist of range, azimuth/elevation, and Doppler velocity. C-band data is based upon skin

tracking as where the S-band data is referenced to an S-band beacon onboard the Orbiter.

A High Speed Radar Input processor (HSRIP) presents time homogeneous radar tracking data (time correlated tracking data) to the HSTD based upon a time tag provided by the HSTD. The incoming data stream must include a station ID, station handover flag, time tag, tracking data, data availability flag, vehicle ID (S-band only), and a data good/bad flag associated with each measurement. In each cycle of the HSTD, all measurements must have the same time tag within a tenth of a second.

A Kalman filter algorithm is used to process the incoming tracking data in order to remove noise and provide the current estimate of the Orbiter's state vector (FILTER vector). The algorithm will basically average (using a sophisticated averaging technique) the large volume of incoming tracking data and provide an output state vector. The previous FILTER vector is used to initialize the subsequent cycle resulting in some lag in the acceleration reflected by the FILTER vector. Therefore, large changes in acceleration (SRB Sep. SSME out, or MECO) take some time to be reflected in the output state vector and thus the FILTER has some error around these type of events.

In an HSTD processor cycle, the measurements are sequentially processed by looping through the measurement editing and covariance matrix updating equations for each available and good measurement. The HSTD is initialized at the start of processing or at a restart cue. The initial state vector is constructed from the raw tracking data. For cases where the incoming data becomes temporarily lost or the quality of data is degraded the FILTER is typically restarted in order to start the averaging scheme with a clean source of data. State vector output is in Earth-fixed coordinates. During periods of free or near free flight, an algorithm which includes the effects of gravity in the state and covariance matrix propagation is used. The HSTD will nominally operate at a rate of 5 Hz with vector data output to the displays at .5 Hz. Higher rates are not restricted. The cycle rate is to remain constant throughout a flight phase and this rate is set pre-mission.

D.7 Ascent Data Flow - High Speed Tracking and Telemetry Data

C-Band

During launch and landing the MCC requires both High Sample Rate (10 samples/sec) and Low Sample Rate (1 sample/sec) Data from the supporting C-Band radars. The tracking data for launch/landing is referred to as Launch Landing Trajectory Data (LLTD) which is High Sample Rate (HSR) data. During an east coast launch, the Eastern Range (ER) Range Operations Control Center (ROCC), selects the best and second best source of launch tracking data by

mathematically projecting error ellipses for each east coast source. The source with the smallest error ellipse is selected as the best source and the next smallest is the second best.

The LLTD data flow for a typical ER site is from the radar computer to the ER switch and then to the ETR CCC via teletype lines. The data is converted to 1200 bit Block Data Format (BDF) at the ROCC and put onto the 7.2 kb/s Wideband Data lines as LLTD directly to the MCC.

Acquisition data (acquisition times and antenna pointing data) for ER sites comes from tracking data formatted in a TEFG (Earth Fixed) coordinate system smooth vector. This assumes one site is in track and acquisition data for other sites is generated by transforming that data. This is called Launch Trajectory Acquisition Support (LTAS) and is the source of launch acquisition aiding. This data is generated at the ER ROCC and shared with all sites attempting acquisition.

ER C-Band sites most often used during ascent are:

JSC name, (ER ID); location

ANTC, (91.14); Antigua Island, UK
BDQC, (67.18); Bermuda Island, UK
CNMC, (1.17); Cape Canaveral, FL
CNOC, (none); Cape Canaveral, FL
CNVC, (1.16); Cape Canaveral, FL
JDIC, (none); Jonathan Dickinson, FL
MLAC, (19.14); Merritt Island, FL
MLMC, (19.17); Merritt Island, FL
PATC, (0.14); Patrick AFB, FL
MOTR, (none); Cape Canaveral, FL

S-Band

During launch S-band radars provide the data links to the orbiter, and in addition provide tracking data to the MCC at a high sample rate, 10 samples/sec. The "selected source" in this case would be whatever radar is being used as prime. About three hours prior to liftoff one of the Merritt Island radars (MILS) will lock up on the orbiter. It will be prime throughout launch until hand-over to Wallops (WLP) unless an RTLS abort is declared. In this case MILS would remain prime until near touchdown when the other Merritt Island site (MLXS) might be required.

The S-Band HSR data flow is from the radar computer to the Goddard Spaceflight Center message switch where it is converted to BDF, interleaved with telemetry and site status messages, then sent to the MCC via the direct 2.5 mb/sec line.

ER S-Band sites most often used for launch are:

MILS, Merritt Island, FL
MLXS, Merritt Island, FL
PDLS, Ponce de Leon, FL

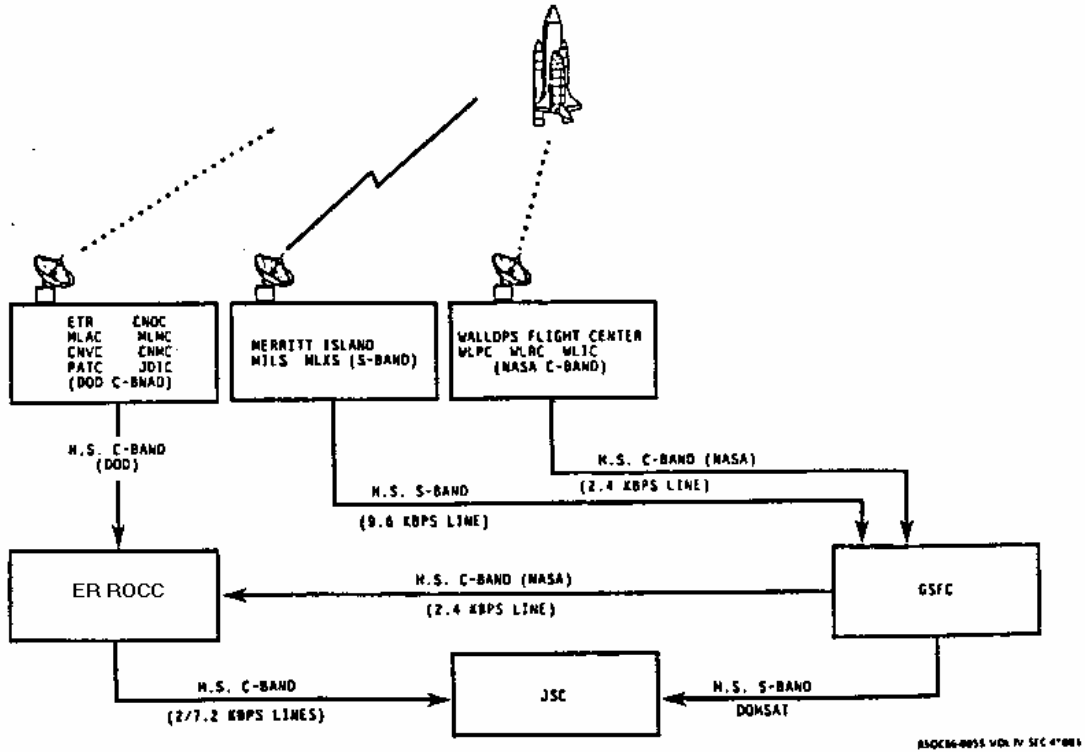
For higher inclination missions (≥ 39 deg), Wallops Island in Virginia has visibility of the Orbiter and is used for the latter part of powered flight. There are three C-bands and one S-band located there.

Telemetry Data

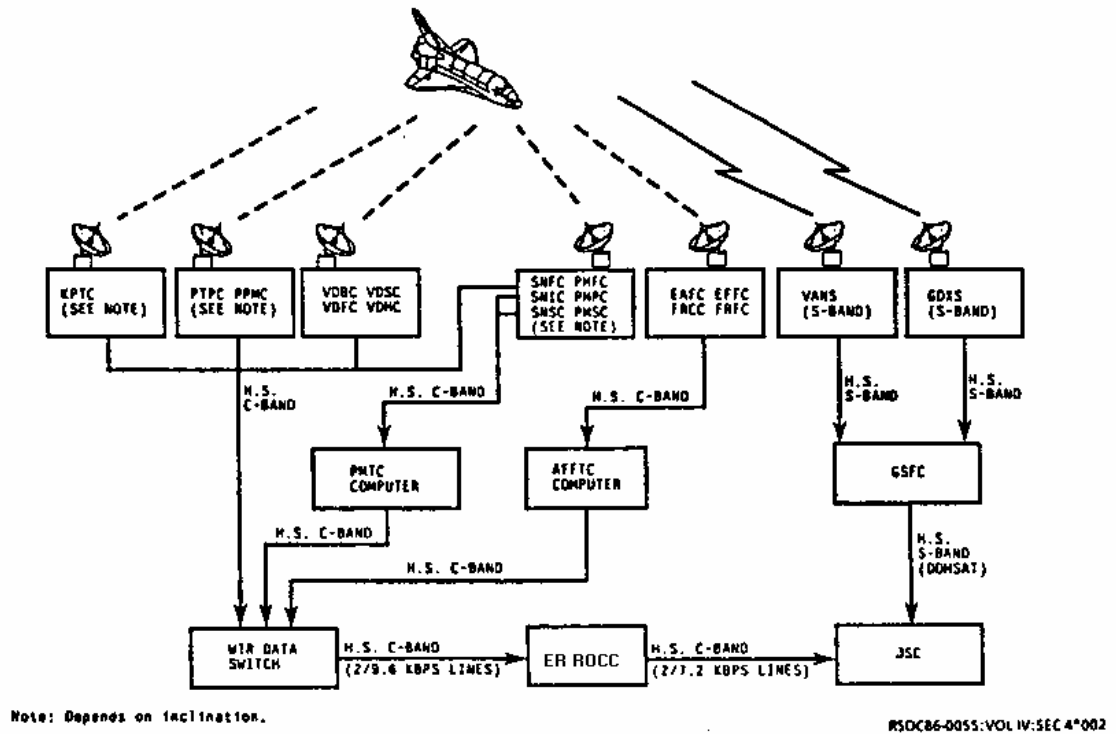
Telemetry data is downlinked from the Orbiter to the ground through the TDRS or S-band ground station data links. Typically, S-band data is routed through the Goddard ground network to MCC the same as the S-band tracking data (interleaved). Once the S-band data reaches the MCC it is sent to the FEP (Front End Processor) and routed to the Trajectory Server. TLM data parameters available for display in the Traj Server are identified by measurement numbers (e.g., V90X7554X, ET Sep control status indicator) or TLM computation numbers (e.g., MOOL0011C). PASS parameters are typically identified by V90's or V70's as their prefixes, BFS parameters are prefixed with a V99.

During ascent, the telemetry data is initially routed via the S-band ground stations. At around 5:45 MET, the vehicle performs a roll-to-heads-up and the S-band is then routed through TDRS-East. The data then gets sent to the TDRS Ground Terminal at White Sands before being routed to Goddard and then JSC.

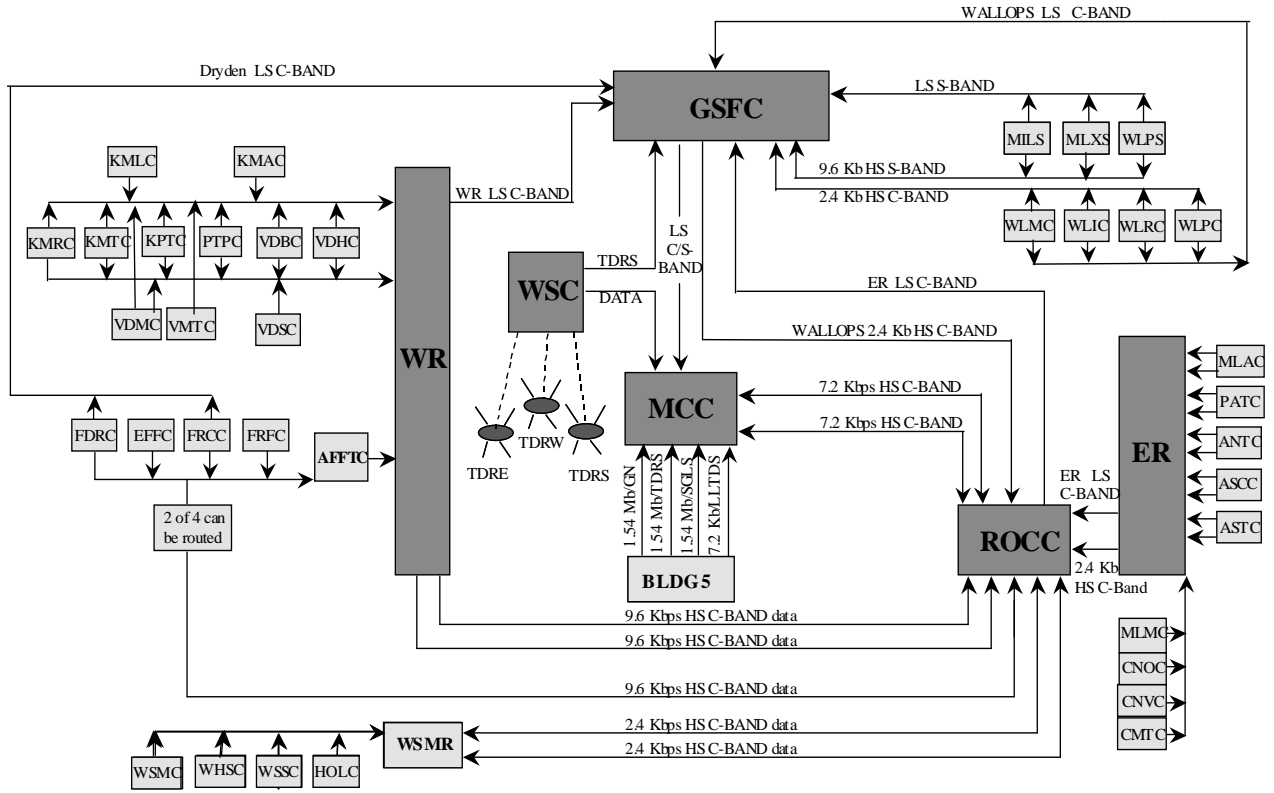
The following figures depict the data flow from the tracking/data sites to the MCC.



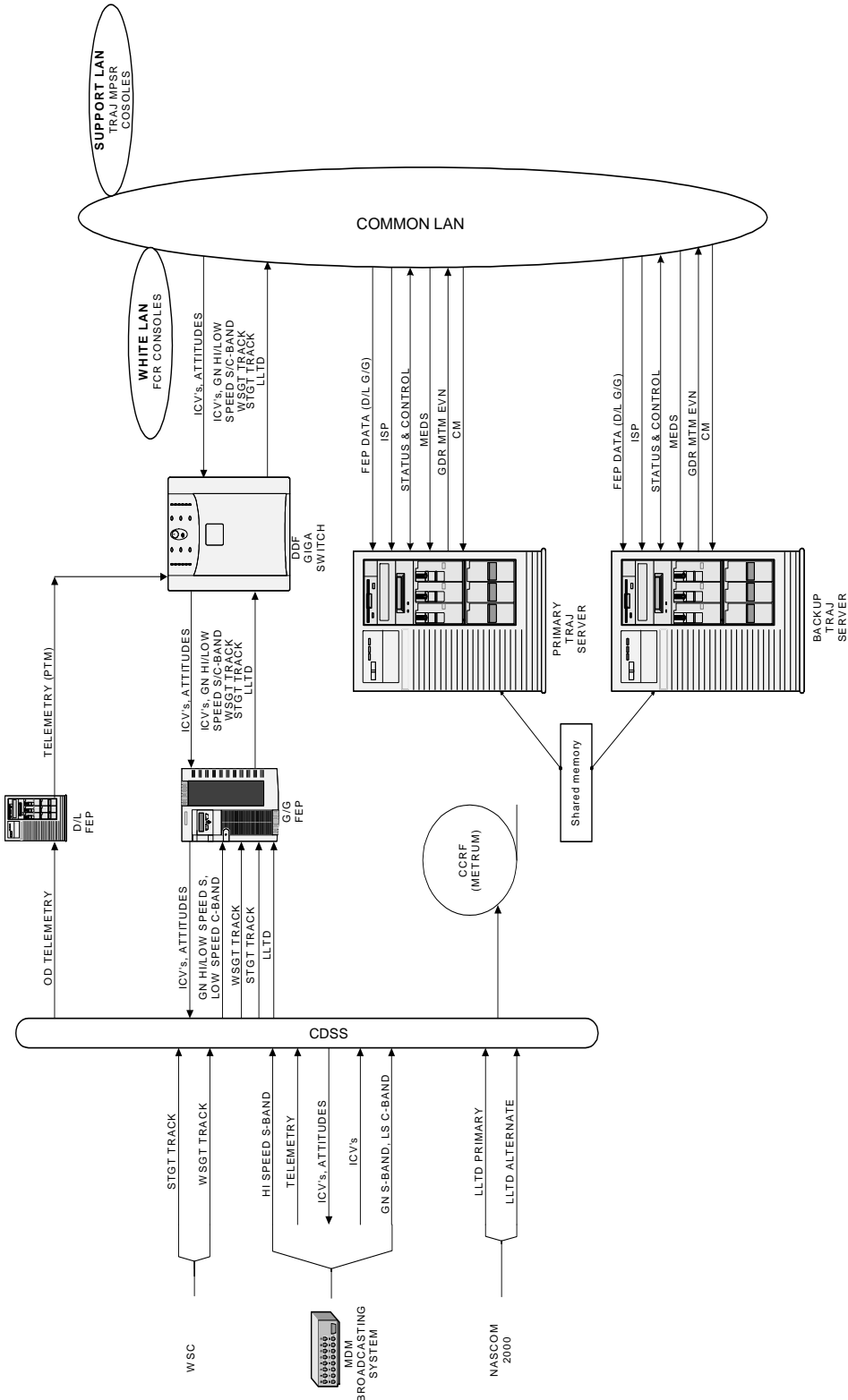
Launch/landing/RTLS/TAL data flow.



EAFB landing data flow.



Tracking Data Flow (both low and high speed)



Tracking/Telemetry data flow within MCC

The diagram above depicts the routing of both the tracking data and telemetry data within the MCC. Basically, the tracking data goes through the ground-to-ground (G/G) FEP while the telemetry (PTM data) gets routed through the downlink (D/L) FEP. This data then goes to the Traj Server through the common LAN.

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